MARSH BULLETIN
EISSN 2957-9848
Marsh Bulletin Volume 21 Issue 2 (September 2026): 232-246

Assessment Of Heavy Elements in Exchangeable Sediments from Al-Ezz River North of Basrah

Shatha A. Shnaishe[1], Hamzah A.Kadhim[2] and Bassam A. Al Abdul Aziz[3]

[1]Department of Geology. Collage of Science, University of Basrah, IRAQ
[2]Department of Geology. Faculty of Science, University of Basrah, IRAQ
[3] Marine Science Centre, University of Basrah, IRAQ
[*] E-mail: alisabah767@gmail.com

Abstract
Seasonal sediment samples were collected from autumn (October 12, 2022) until summer (June 25, 2023) at five stations along the Al-Ezz River in the Qurna district, north of Basra city. The purpose was to assess the river's pollution with heavy metals: lead (Pb), cadmium (Cd), copper (Cu), manganese (Mn), zinc (Zn), chromium (Cr), cobalt (Co), and iron (Fe), using the sequential extraction phase. Additionally, pollution factors (CF), enrichment factors (EF), and the geochemical accumulation index (I-geo) were calculated to evaluate the degree of heavy metal contamination in the study area's sediments. The study results revealed that the annual average concentrations of the aforementioned heavy metals in the exchangeable phase were as follows (µg/g dry weight): lead (Pb) - 95.842, cadmium (Cd) - 8.549, copper (Cu) - 21.918, manganese (Mn) - 111.016, zinc (Zn) - 23.175, chromium (Cr) - 61.749, cobalt (Co) - 10.826, and iron (Fe) - 122.18. The pollution factor (CF) values indicated that the soil was highly contaminated with lead and cadmium, while copper, iron, and manganese showed low contamination. Chromium exhibited considerable contamination, while cobalt showed moderate contamination. According to the geochemical accumulation index (I-geo) values, the sediments of the Al-Ezz River were classified as heavily polluted with lead and extremely heavily polluted with cadmium. They ranged from not polluted to moderately polluted with copper, and were not polluted with manganese, zinc, and cobalt. The environment exhibited moderate pollution with chromium.
Keywords: sedimentary pollution, heavy elements, Al-Ezz River, Pollution Indices.

Received 28 /8 / 2023 Accepted 22/6/2023 Published 1/ 9 /2026

Introduction

Pollution is one of the significant challenges facing both humans and the environment, particularly due to the industrial advancements accompanying modern life. Pollution occurs in various forms, whether in the air, water, or soil, resulting from the presence of harmful substances or imbalances in essential environmental components compared to their natural levels. This occurs through both human interventions and natural phenomena (Aiello *et al.*, 2021). The development of human capabilities and mismanagement of water resources, especially in recent decades, have contributed to the escalating problem of pollution. This issue has evolved alongside population growth and increased water demand, to the extent that water pollution now casts a shadow over public health (Kılıç, 2020). Statistics indicate that over half of the world's population currently suffers from environmental pollution. However, given the high population density and the ongoing impacts of the oil industry, this issue is soon to be classified among the most pressing environmental concerns (El Jadry *et al.*, 2009). Industrial development has generated a diverse range of hazardous waste, including heavy metals and certain organic pollutants that have severely harmed the ecosystem. These pollutants are now reaching levels that are detrimental to all forms of life (Mitra *et al.*, 2022). Sediments serve as valuable indicators of environmental contamination by many of these toxic elements. Over the past

decades, numerous studies have demonstrated that sediment surfaces provide an excellent tool for assessing the impacts of natural and human processes on depositional environments. The study of sediment surfaces is considered an important tool for understanding changes in depositional environments and the environmental effects resulting from natural and human activities (Copaja *et al.*, 2020). Environmental pollutants can be classified into three main types, which are physical, chemical, and biological pollutants (Siddiqua *et al.*, 2022).

Material and Methods

Study Area

The Al-Ezz River originates from the Maysan Governorate in southern Iraq and is formed by the Al-Bateera River, a tributary of the Tigris River. The Al-Ezz River receives water from several tributaries, including the Umm Al-Fajjil, Al-Jandalah, Al-Adil, and Al-Wadiyah Rivers. It joins the Euphrates River before merging with the Tigris River in the Al-Qurna district, approximately 7 km downstream. Originally created for the purpose of draining marshlands, the river is currently utilized as a flood outlet during periods of heavy rain and floods. The total length of the Al-Ezz River is approximately 75 km, with a length of 40 km in the Basra region and 35 km in the Maysan Governorate. It has an average width of about 2 km, and its deepest point reaches up to 1.5 meters below sea level. The highest recorded discharge of the Al-Ezz River in 2019 was around 135 m³/sec. There are several structures that intersect the Al-Ezz River in the Maysan Governorate, including bridges in places like Al-Azir and Al-Jawabr, as well as dams for water flow control. The water of the Al-Ezz River is utilized by surrounding villages for various human uses, animal husbandry, and irrigation of agricultural lands. The concentration of total dissolved salts in its water varies, ranging from 900 to 2500 ppm (Directorate of Water Resources, 2022).

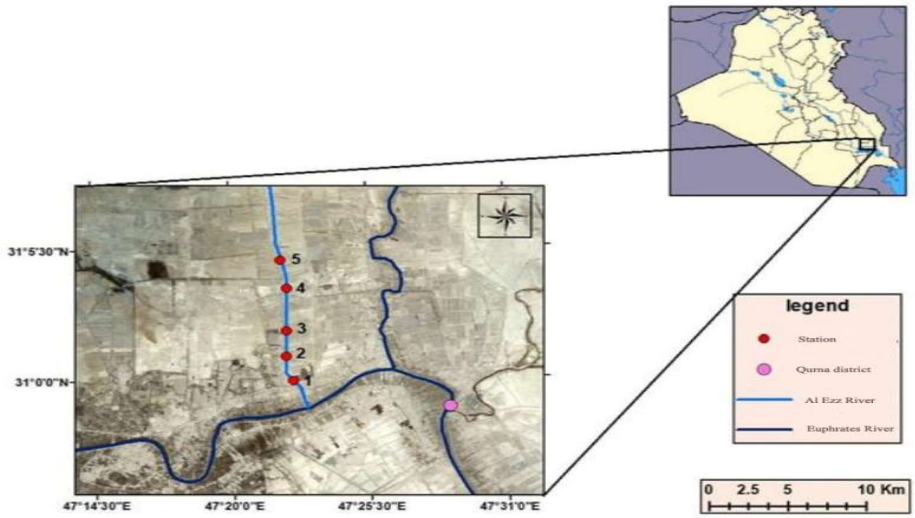

Figure (1) illustrates a map depicting the locations within the study area.

Fieldwork

Five soil sampling sites were chosen to collect samples during four seasons throughout the year. Samples were gathered in the autumn, winter, spring, and summer, spanning from October 2022 to June 2023. Soil samples were preserved in plastic bags and transported to the laboratory for preparation prior to the digestion process to measure heavy element concentrations. All field-specific information for each station, including station number, sample collection date, longitude, and latitude determined using a GPS device, was recorded.

Laboratory Work and Analysis

After collecting the samples during the fieldwork phase, they were transported to the laboratory and dried to obtain completely dry

samples. Subsequently, the drying process was completed using an electric oven. In the following stage, the sample was ground using a ceramic mortar, and then the samples were sieved through a specified diameter metal sieve (63 µm). This rendered the sample ready for atomic absorption analysis using the flame atomic absorption spectrophotometer after performing the sample digestion process. Following the method outlined by (Chester & Voutsinou, 1981), the analysis was conducted.

1.Extraction of exchangeable heavy elements

2.Pollution Indices

Indices of pollution were calculated, including the geoaccumulation index (I-geo), the enrichment factor (EF), and the contamination factor (CF), to determine the impact of heavy metal pollution in sediment samples (cadmium, lead, copper, iron, manganese, zinc, cobalt, chromium).

Contamination Factor and Enrichment Factor

To estimate the degree of contamination in sediments, the Contamination Factor is calculated, following the classification by (Håkanson, 1980). Table (1). To assess the enrichment in sediments, the Enrichment Factor is calculated, following the classification by (Huheey, 1983). Table (2).

Table (1). Contamination Factor

CF	Contamination Factor
CF<1	Low pollution
≤ CF ≤ 3	Moderate pollution
3≤CF≤6	High pollution
CF>6	Very high pollution

Table (2). Enrichment Factor

EF	Enrich Factor
EF<1	No enrichment
EF=1-3	Slight enrichment
EF=3-5	Moderate enrichment
EF=5-10	Moderate to strong enrichment
EF=10-25	Strong enrichment
EF=25-50	Very strong enrichment
EF>50	Extremely strong enrichment

Geoaccumulation Index

The I-geo (Geoaccumulation Index) is a function representing the impact of heavy metal contamination in sediments. It was introduced by (Müller, 1969). Table (3)

Table (3). Geoaccumulation Index

I-geo	**Geoaccumulation Index**
≤ 0	Practically uncontaminated
0 – 1	Uncontaminated to moderately polluted
1 – 2	Moderately polluted
2 – 3	Moderately to heavily polluted
3 – 4	Heavily polluted
4 – 5	Heavily to extremely polluted
> 5	Extremely polluted

Statistical Analysis

Statistical analysis of the study area's results was conducted using the XLSTAT software, 2016 edition.

Result and Discussion

Total organic carbon

The total organic carbon (TOC%) concentrations for the four seasons revealed that the highest TOC value was observed in the first station (0.188%) during the summer, while the lowest value (0.114%) was recorded in the winter. The second station registered the highest value (0.182%) during the summer and the lowest value (0.077%) in the winter. The third station exhibited the highest value (0.1798%) in the summer and the lowest value (0.085%) in the autumn. The fourth station recorded the highest value (0.165%) in the spring and the lowest value (0.100%) in the summer. The fifth station showed the highest value (0.161%) during the spring and the lowest value (0.109%) in the summer.

Organic materials are absorbed by suspended particles in the water. These particles form sediments and contain absorbed organic materials. Subsequently, sediments accumulate at the bottom, becoming part of the bottom soil. The bottom can contain different layers of sediments that have accumulated over time and contain different organic materials (Boehm & Quinn, 1973). Table (4)

Table (4). Total organic carbon

Station Number	Autumn	Winter	Spring	Summer
1	0.157	0.1141	0.1399	0.1886
2	0.085	0.077	0.111	0.1823
3	0.085	0.1667	0.1164	0.1798
4	0.13	0.1431	0.1654	0.1008
5	0.136	0.1452	0.161	0.1092
Mean	0.1186	0.14922	0.13874	0.15214

Grain size Analysis of Sediments

Grain size analysis can be employed to differentiate between various environments and surface sediments, providing insights into sedimentation processes and flow conditions in these environments. Through the utilization of particle size analysis, it becomes possible to ascertain the size and distribution of particles composing sediment deposits, which contributes to identifying the nature of the environment (Tucker & Jones, 2023). Figure (2)

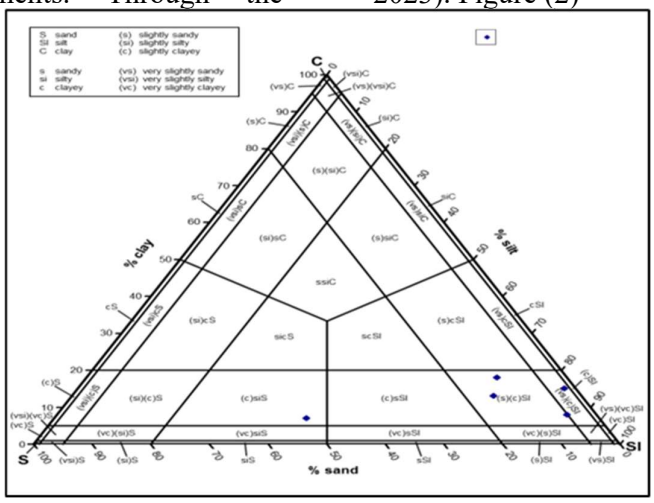

Figure (2) Grain size distribution of each of clay, silt, and sand according to (Blott & Pye, 2012)

Heavy elements

Lead

The obtained results revealed that the concentration of lead in its exchangeable phase for sediment samples from the study area at five stations ranged as follows: the first station (161.953-32.517 µg/g), while at the second station (195.115-16.783 µg/g), and the

third station (160.411-16.783 µg/g). As for the fourth station, it ranged from (174.293-27.272 µg/g), and finally the fifth station (182.005-29.370 µg/g) during the autumn season. The highest average value (195.115 µg/g) was observed at the second station during the summer, while the lowest average value (16.783 µg/g) was recorded at the second and third stations during the winter (Figure 3). The statistical analysis of the correlation coefficients for the exchangeable phase of lead indicated a strong relationship with chromium (r=0.99) and iron (r=0.91), and in the second station, there was a strong correlation of lead with iron (r=0.97) and manganese (r=0.90). The concentration value was recorded as (195.115 µg/g). This increase can be attributed to the presence of a busy road with vehicle movement in the area, leading to the dispersion of lead in the environment of the study area. Consequently, it can be considered that vehicle movement and emissions associated with traffic through this road contribute to the increased accumulation of lead in nearby sediments, in addition to the nearby oil industrial activities, posing an environmental threat (Bantan *et al.*, 2020). This increase is also related to the proximity of the Al-Ezz River to an oil industrial activity, the West Qurna 2 field. The characteristics of the winds carrying pollutants that may accumulate on the surface due to the low mobility of lead can be another reason. The source of lead could also be from continuous vehicle movement, with exhaust emissions from car engines, as well as waste burning, contributing to the lead concentrations in the air and subsequently leading to soil contamination.

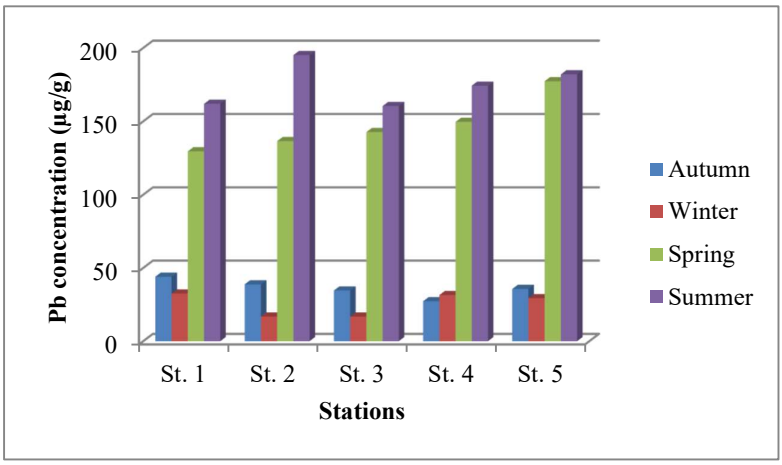

Figure (3) Lead concentration (µg/g) at locations in the study area

Cadmium

The study results revealed cadmium concentrations in the exchangeable phase of sediment samples at five stations, ranging as follows (Figure 4): the first station (5.790-1.146 µg/g), the second station (5.249-0.860 µg/g), while at the third station (4.940-1.720 µg/g). As for the fourth station, it ranged from (54.040-2.150 µg/g), and finally the fifth station (55.584-2.293 µg/g). The highest average value (55.584 µg/g) was observed at the fifth station during the autumn season, while the lowest average value (0.860 µg/g) was recorded at the second station during the summer. In the fourth station, cadmium is correlated with chromium (r=0.99), and there is a strong relationship between cadmium and chromium in the fifth station (r=0.99). Cadmium is released into the environment through various sources, which may be natural or human-induced. Volcanic eruptions and weathering of rocks are among the natural sources of cadmium, where it is released into the environment due to volcanic activity and rock reactions. Human sources include mining and manufacturing processes, in addition to the use of agricultural fertilizers and discharge of untreated sewage (Alloway, 2012).

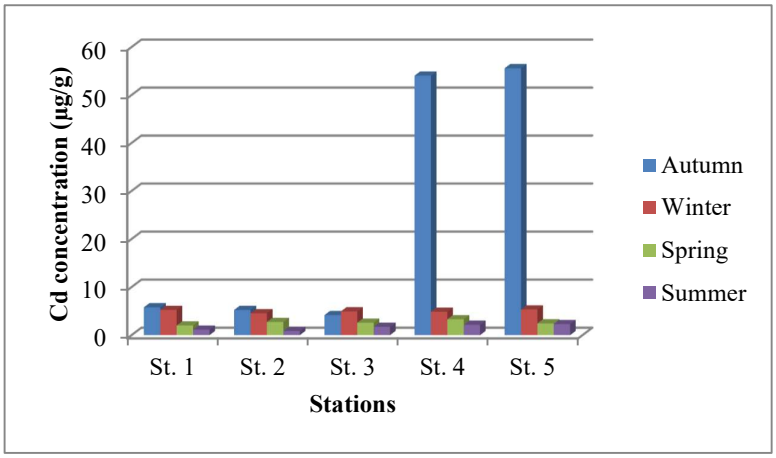

Figure (4) Cadmium concentration (µg/g) at locations in the study area

Copper

The study results indicated that copper concentrations in the exchangeable phase of sediment samples at five stations varied as follows (Figure 5): the first station (42.253-0.134 µg/g), the second station (29.577-1.045 µg/g), while at the third station (209.154-0.286 µg/g). As for the fourth station, it ranged from (31.690-1.621 µg/g), and finally the fifth station (46.478-0.786 µg/g). The highest average value (209.154 µg/g) was observed at the third station during the winter season, while the lowest average value (0.134 µg/g) was recorded at the first station during the spring. The statistical analysis results revealed a significant relationship between copper in the exchangeable phase and zinc in the fourth station (r=0.99). The presence of copper in the environment is attributed to the use of agricultural pesticides and fertilizers. In some cases, copper is used as a fungicide in agriculture (Robert-Sainte *et al.*, 2009), and it can also be found in sewage water discharged into rivers.

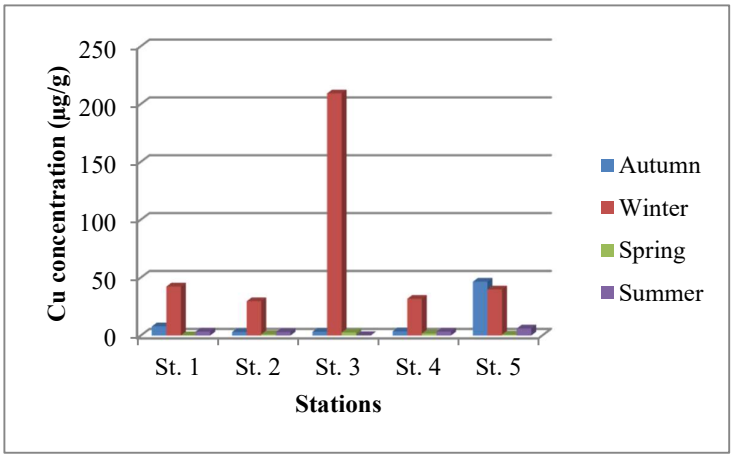

Figure (5) Copper concentration (µg/g) at locations in the study area

Iron

The study results revealed that iron concentrations in the exchangeable phase of sediment samples at five stations varied as follows: the first station (173.359-49.785 µg/g), the second station (177.992-76.612 µg/g), while at the third station (196.139-10.060 µg/g). As for the fourth station, it ranged from (180.695-13.155 µg/g), and finally the fifth station (191.505-70.163 µg/g). The highest average value (196.139 µg/g) was observed at the third station during the spring season, while the lowest average value (10.060 µg/g) was recorded at the third station during the autumn (Figure 6). The statistical analysis results indicated a significant

relationship between iron in the exchangeable phase and chromium (r=0.95) and lead (r=0.91). Iron behaves similarly geochemically to many heavy elements and exhibits a positive correlation with the clay and silt content in the soil, and an inverse relationship with the sand content. This phenomenon suggests iron's ability to adsorb onto the surface of clay minerals, with iron absorption on the surface increasing with higher clay and organic matter content in the soil (Kostka & Luther III, 1994). This explains the variation in iron concentrations among the stations. The expected sources of iron are fertilizer and pesticide use.

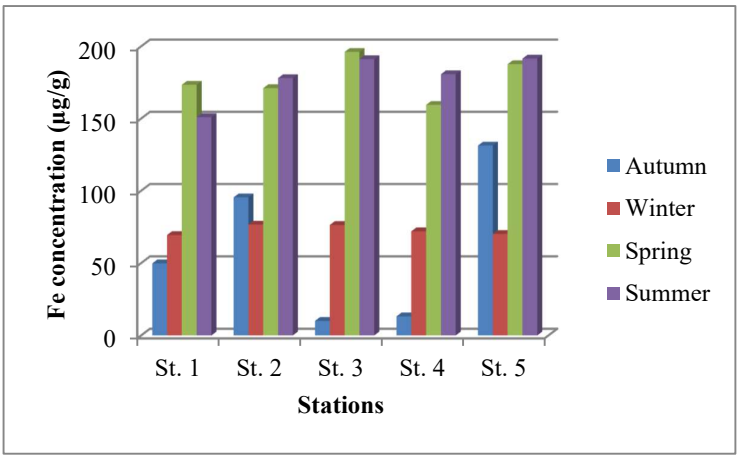

Figure (6) Iron concentration (µg/g) at locations in the study area

Manganese

From the study results, it is evident that manganese concentrations in the exchangeable phase of sediment samples at five stations varied as follows: the first station (140.201-4.296 µg/g), the second station (166.206-53.920 µg/g), while at the third station (221.231-50.375 µg/g). As for the fourth station, it ranged from (198.995-34.479 µg/g), and finally, the fifth station (251.381-53.168 µg/g). The highest average value (251.381 µg/g) was observed at the fifth station during the summer season, while the lowest average value (4.296 µg/g) was recorded at the first station during the winter (Figure 7). The statistical analysis results indicated a significant relationship between manganese in the exchangeable phase and lead (r=0.94), iron (r=0.94), and chromium. The reason for this increase is attributed to human factors, including waste disposal and the growth of industrial activities.

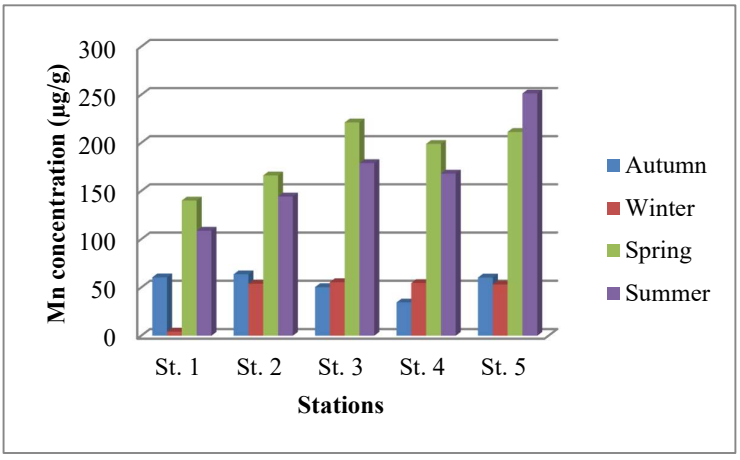

Figure (7) Manganese concentration (µg/g) at locations in the study area

Zinc

The study results revealed that zinc concentrations in the exchangeable phase of sediment samples at five stations varied as follows: the first station (38.350-3.345 µg/g), the second station (40.974-1.432 µg/g), while at the third station (26.647-0.286 µg/g). As for the fourth station, it ranged from (188.252-2.865 µg/g), and finally, the fifth station (86.532-2.680 µg/g). The highest average value (188.252 µg/g) was observed at the fourth station during the winter season (Figure 8). The statistical analysis results indicated a significant relationship between zinc in the exchangeable phase and copper (r=0.99).

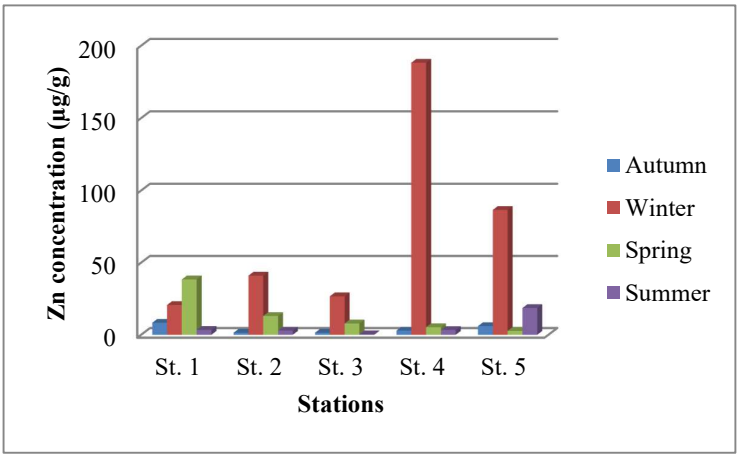

Figure (8) Zinc concentration (µg/g) at locations in the study area

Chromium

The study results demonstrated that chromium concentrations in the exchangeable phase of sediment samples at five stations varied as follows: the first station (61.475-0.872 µg/g), the second station (54.098-1.293 µg/g), while at the third station (98.360-2.586 µg/g). As for the fourth station, it ranged from (181.034-34.426 µg/g), and finally, the fifth station (315.517-42.672 µg/g). The highest average value (315.517 µg/g) was observed at the fifth station during the autumn season. The lowest average value (0.872 µg/g) was found at the first station during the autumn season (Figure 9). Statistical analysis revealed significant relationships between chromium in the exchangeable phase and lead (r=0.99) and iron (r=0.95) at the first station. Furthermore, at the fifth station, chromium was strongly correlated with cadmium (r=0.99). The study indicated that the primary source of chromium is attributed to human activities causing pollution, including activities such as painting, dyeing, chemical manufacturing, and steel production (Jaishankar *et al.*, 2014).

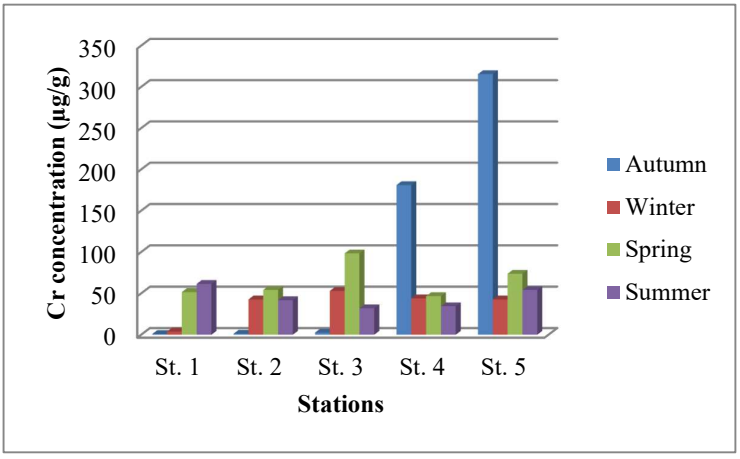

Figure (9) Chromium concentration (µg/g) at locations in the study area

Cobalt

The study results revealed that cobalt concentrations in the exchangeable phase of sediment samples at five stations varied as follows: the first station (22.950-0.11 µg/g), the second station (24.950-0.030 µg/g), while at the third station (22.950-0.078 µg/g). As for the fourth station, it ranged from (22.950-0.210 µg/g), and finally, the fifth station (26.229-0.123 µg/g). The highest average value (26.229 µg/g) was observed at the fifth station during the winter season. The lowest average value (0.030 µg/g) was found at the second station during the spring season (Figure 10). Statistical analysis demonstrated significant correlations between cobalt in the exchangeable phase and cadmium (r=0.98). Additionally, there was a relationship between cobalt at the fifth station and copper (r=0.97). The use of agricultural pesticides and improper disposal of untreated sewage water into rivers have led to an increase in cobalt content in the environment (Defarge *et al.*, 2018; Li *et al.*, 2009).

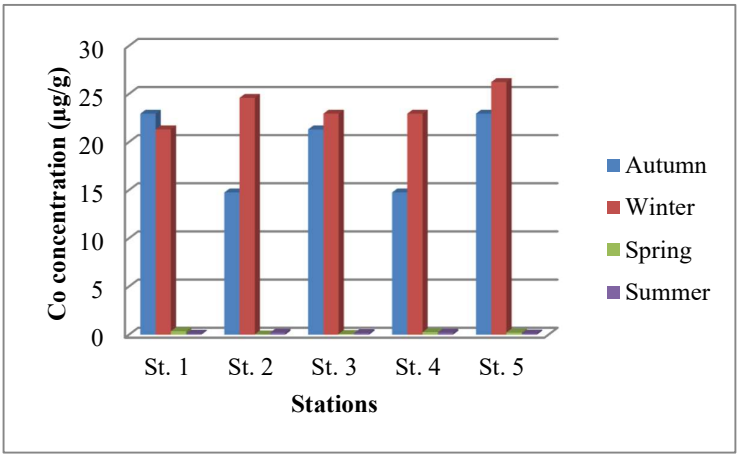

Figure (10) Cobalt concentration (µg/g) at locations in the study area

Heavy Elements pollution Indices

Contamination Factor (CF):

Lead

Table (5) The highest contamination factor (CF) value in the exchangeable phase for lead was recorded as (13.936) at the second station during the summer season. The lowest value (1.170) was observed at the third station during the winter season. The contamination factor (CF) value for lead ranged from (1.17≤CF≤13.936), indicating that the environment experienced a high to very high level of contamination (Table 1). The highest contamination factor (CF) value in the exchangeable phase for cadmium was recorded as (370.561) at the fifth station during the autumn season. The lowest value (5.733) was observed at the second station during the summer season. The contamination factor (CF) value for cadmium ranged from (5.733≤CF≤370.561), indicating that the environment experienced a high to very high level of contamination. The highest contamination factor (CF) value in the exchangeable phase for copper was recorded as (3.075) at the third station during the winter season. The lowest value (0.001) was observed at the first station during the spring season. The contamination factor (CF) value for copper ranged from (0.001≤CF≤3.075), indicating that the environment experienced low to considerable levels of contamination.

Iron

The results indicated that the highest contamination factor (CF) value in the exchangeable phase for iron was recorded at the first station during the autumn season (0.009), while the lowest value was observed at the third station (0.0002) during the autumn season as well. The contamination factor (CF) value for iron ranged from (0.0002≤CF≤0.009), suggesting that the environment experienced a low level of contamination. Table (5)

Manganese

Table (5) The results revealed that the highest contamination factor (CF) value in the exchangeable phase for manganese was recorded at the fifth station during the summer season (0.279), while the lowest value was observed at the first station during the winter season (0.004). The contamination factor (CF) value for manganese ranged from (0.004≤CF≤0.279), indicating that the environment experienced a low level of contamination.

Zinc

The highest contamination factor (CF) value in the exchangeable phase for zinc was observed at the fourth station during the winter season (2.382), while the lowest value was recorded at the second station during the autumn season (0.018). The contamination factor (CF) value for zinc ranged from (0.018≤CF≤2.382), indicating that the environment experienced a moderate level of contamination. Table (5)

Chromium

Table (5) The highest contamination factor (CF) value in the exchangeable phase for chromium was observed at the fifth station during the autumn season (3.155), while the lowest value was recorded at the first station during the autumn season (0.008). The contamination factor (CF) value for chromium ranged from (0.008≤CF≤3.155), indicating that the environment experienced a high level of contamination.

Cobalt

Additionally, the highest contamination factor (CF) value in the exchangeable phase for cobalt was observed at the fifth station during the winter season (1.049), while the lowest value was recorded at the second station during the spring season (0.001). The contamination factor (CF) value for cobalt ranged from (0.001≤CF≤1.049), indicating that the environment experienced a moderate level of contamination. Consequently, the contamination factor results were ranked as follows:

$$CF^{cd} > CF^{pb} > CF^{Mn} > CF^{cr} > CF^{zn} > CF^{cu} > CF^{co} > CF^{Fe}$$

Table (5) Contamination Factor (CF)

Several factors contributed to the increase in heavy metal concentrations in the sediments, including the presence of the West Qurna 2 oil field, vehicular traffic, waste disposal, as well as the use of fertilizers, pesticides, and agricultural enhancers, along with animal grazing. Station	Season	CF(Pb)	CF(Cd)	CF(Cu)	CF(Fe)	CF(Mn)	CF(Zn)	CF(Cr)	CF(Co)
1	Autumn	3.146	38.600	0.114	0.009	0.067	0.105	0.008	0.918
	Winter	2.322	34.997	0.621	0.0013	0.004	0.261	0.038	0.852
	Spring	9.254	13.377	0.001	0.0034	0.155	0.485	0.516	0.014
	summer	11.568	7.644	0.049	0.0030	0.121	0.033	0.614	0.004
2	Autumn	2.772	34.997	0.043	0.001	0.070	0.018	0.012	0.590
	Winter	1.198	30.365	0.434	0.0015	0.059	0.518	0.426	0.983
	Spring	9.750	18.155	0.015	0.0034	0.184	0.144	0.540	0.001
	summer	13.936	5.733	0.042	0.0035	0.160	0.038	0.418	0.008
3	Autumn	2.472	27.792	0.046	0.0002	0.055	0.018	0.025	0.852
	Winter	1.170	32.938	3.075	0.0015	0.061	0.337	0.530	0.918
	Spring	10.190	17.200	0.037	0.0039	0.245	0.099	0.983	0.003
	summer	11.457	11.466	0.004	0.0038	0.198	0.064	0.319	0.006
4	Autumn	1.948	360.267	0.052	0.0002	0.063	0.036	1.810	0.590
	Winter	2.247	32.424	0.466	0.0014	0.060	2.382	0.439	0.918
	Spring	10.686	21.978	0.023	0.0031	0.221	0.066	0.467	0.010

	summer	12.449	14.333	0.048	0.0036	0.186	0.066	0.344	0.008
5	Autumn	2.547	370.561	0.683	0.002	0.067	0.076	3.155	0.918
	Winter	2.097	35.512	0.584	0.0014	0.059	1.095	0.426	1.049
	Spring	12.669	16.244	0.011	0.0037	0.234	0.033	0.737	0.008
	summer	13.000	15.289	0.088	0.0038	0.279	0.234	0.540	0.004

Enrichment Factor

Lead

The study recorded the highest enrichment factor (EF) value in the exchangeable phase for lead, which was (12288.7) at the third station during the autumn season.

The lowest value was observed at the third station during the winter season (766.25). The EF value for lead was (EF>50), indicating that the environment is highly enriched. Table (6)

Cadmium

Table (6) The study recorded the highest enrichment factor (EF) value in the exchangeable phase for cadmium, which was (1369248.80) at the fourth station during the autumn season. The lowest value was observed at the second station during the summer season (1610.55). The EF value for cadmium was (EF>50), indicating that the environment is highly enriched.

Copper

The highest enrichment factor (EF) value in the exchangeable phase for copper was recorded at the third station during the winter season, which was (2014.16). The lowest value was observed at the first station during the spring season (0.56). The EF value for copper ranged from 0.56 to 2014.16, indicating conditions ranging from no enrichment to extremely strong enrichment. Table (6)

Manganese

Table (6), the study revealed that the highest enrichment factor (EF) value in the exchangeable phase for manganese was recorded at the third station during the autumn season, reaching 278.19. The lowest value was observed at the first station during the winter season, measuring 3.43. The EF value for manganese ranged from 3.43 to 278.19, indicating a level of enrichment ranging from moderate to extremely strong.

Zinc

It is evident that the highest enrichment factor (EF) value in the exchangeable phase for zinc was recorded at the fourth station during the winter season, reaching 1655.53. The lowest value was observed at the fifth station during the spring season, measuring 9.04. The EF value for zinc ranged from 9.04 to 1655.53, indicating a level of enrichment ranging from moderate-to-strong to extremely strong. Table (6)

Chromium

Table (6), the highest value for the enrichment factor (EF) in the exchangeable phase for chromium was recorded at the fourth station during the autumn season, reaching 6880.49. The lowest value was observed at the second station during the same season, measuring 6.77. The EF value for chromium ranged from 6.77 to 6880.49, indicating a level of enrichment ranging from moderate-to-strong to extremely strong.

Cobalt

Lastly, the highest value for the enrichment factor (EF) in the exchangeable phase for cobalt was recorded at the third station during the autumn season, reaching 4236.79. The lowest value was observed at the second station during the spring season, measuring 0.35. The EF value for cobalt ranged from 0.35 to 4236.79, indicating conditions ranging from no enrichment to extremely strong enrichment. The sediment in the study area ranges from moderate to extremely high enrichment. Based on the mean EF values in Table (6), the elements are ordered as follows: EF(Cd) > EF(Pb) > EF(Co) > EF(Cr) > EF(Cu) > EF(Zn) > EF(Mn).

$$EF^{cu} > EF^{pb} > EF^{cd} > EF^{zn} > EF^{cr} > EF^{mn} > EF^{co} > EF^{fe}$$

Table (6) Enrichment Factor

Station	Season	EF(Pb)	EF(Cd)	EF(Cu)	EF(Mn)	EF(Zn)	EF(Cr)	EF(Co)
1	Autumn	3160.44	38766.66	115.45	67.50	105.63	8.75	921.99

	Winter	1673.62	25215.14	447.74	3.43	188.17	27.95	614.25
	Spring	2669.17	3857.11	0.56	44.92	140.01	148.93	4.16
	summer	3831.38	2530.38	16.29	40.08	11.06	203.60	1.45
2	Autumn	1452.29	18332.09	22.78	37.07	9.500	6.77	309.17
	Winter	782.37	19814.07	283.87	39.10	338.49	27.496	641.93
	Spring	2850.24	5306.67	4.49	53.98	48.06	158.14	0.35
	summer	3915.01	1610.55	11.92	45.05	10.88	117.43	2.36
3	Autumn	12288.67	138102.10	231.62	278.19	90.13	128.53	4236.79
	Winter	766.25	21566.14	2014.16	40.40	220.88	347.17	601.16
	Spring	2597.89	4384.64	9.56	62.66	25.28	250.74	0.79
	summer	2997.58	2999.86	1.10	52.03	16.86	83.63	1.69
4	Autumn	7403.87	1369248.80	200.73	145.60	137.84	6880.49	2243.00
	Winter	1561.58	22523.57	323.77	42.20	1655.53	305.44	637.79
	Spring	3350.92	6889.94	7.47	69.32	20.84	164.49	3.24
	summer	3444.89	3966.16	13.33	51.68	18.51	95.26	2.32
5	Autumn	970.10	141113.71	260.28	25.54	29.00	1201.52	349.09
	Winter	1494.98	25302.85	416.23	42.09	780.57	304.09	747.66
	Spring	3376.01	4327.32	3.07	62.59	9.04	196.56	2.37
	summer	3394.24	3991.17	23.16	72.92	61.32	141.24	1.28

The geochemical accumulation Index for heavy elements

Lead

Table (7), the highest value of the geoaccumulation index in the exchangeable phase was (3.215) in station two during the summer season, and the lowest value (-0.358) was recorded in station three during the winter season. The value of the geoaccumulation index (I-geo) for the element Pb ranged from -0.358 to 3.215, indicating that the environment ranged from practically uncontaminated to heavily polluted.

Cadmium

The highest value of the geoaccumulation index in the exchangeable phase was (7.948) in station five during the autumn season, and the lowest value (1.934) was recorded in station two during the summer season. The value of the geoaccumulation index (I-geo) for cadmium ranged from 1.934 to 7.948, exceeding 5 at some stations, indicating moderately to extremely polluted conditions. Table (7)

Copper

Table (7) for copper, the highest value of the geoaccumulation index in the exchangeable phase was (1.036) in station three during the winter season, and the lowest value (-9.572) was recorded in station one during the spring season. The value of the geoaccumulation index (I-geo) for copper ranged from -9.572 to 1.036, indicating that the environment ranged from practically uncontaminated to moderately polluted.

Iron

Additionally, the highest value of the geoaccumulation index in the exchangeable phase was (-8.578) in station three during the spring season, and the lowest value (-12.864) was recorded in station three during the autumn season. The value of the geoaccumulation index (I-geo) for iron was (I-geo $\leq$ 0), indicating that the environment is practically uncontaminated. Table (7)

Manganese

Table (7), the highest value of the geoaccumulation index in the exchangeable phase was (-2.425) in station five during the summer season, and the lowest value (-8.295) was recorded in station one during the winter season. The value of the geoaccumulation index (I-geo) for manganese was (I-geo $\leq$ 0), indicating that the environment is practically uncontaminated.

Zinc

The highest value of the geoaccumulation index in the exchangeable phase was (0.667) in station four during the winter season, and the lowest value (-8.694) was recorded in station three during the summer season. The value of the geoaccumulation index (I-geo) for zinc was (I-geo < 1), indicating that the environment ranged from practically uncontaminated to uncontaminated to moderately polluted. Table (7)

Chromium

Table (7), the highest value of the geoaccumulation index for chromium in the exchangeable

phase was (1.072) in station five during the autumn season, and the lowest value (-7.426) was recorded in station one during the autumn season. The value of the geoaccumulation index (I-geo) for chromium ranged from -7.426 to 1.072, indicating that the environment ranged from practically uncontaminated to moderately polluted.

Cobalt

The results indicated that the highest value of the geoaccumulation index in the exchangeable phase was (-0.515) in station five during the winter season, and the lowest value (-10.285) was recorded in station two during the spring season. The value of the geoaccumulation index (I-geo) for cobalt was (I-geo ≤ 0), suggesting that the environment is practically uncontaminated.

From this, we deduce that the geochemical accumulation index for heavy elements in the study area, according to the classification by (Müller, 1969), showed that the sediments of the Al-Ezz River were polluted to severely polluted with cadmium, as it exceeded the maximum threshold of pollution degrees (I-geo > 5), indicating a highly polluted condition in the exchangeable phase. Table (7)

Table (7) The geochemical accumulation Index for heavy elements

Station	Season	I-geo (Pb)	I-geo (Cd)	I-geo (Cu)	I-geo (Fe)	I-geo (Mn)	I-geo (Zn)	I-geo (Cr)	I-geo (Co)
1	Autumn	1.068	4.685	-3.705	-10.557	-4.479	-3.833	-7.426	-0.708
	Winter	0.630	4.544	-1.271	-10.078	-8.295	-2.522	-5.273	-0.815
	Spring	2.625	3.156	-9.572	-8.756	-3.267	-1.627	-1.538	-6.700
	summer	2.947	2.349	-4.930	-8.956	-3.631	-5.146	-1.286	-8.413
2	Autumn	0.886	4.544	-5.107	-9.618	-4.4056	-6.370	-6.857	-1.345
	Winter	-0.323	4.339	-1.786	-9.935	-4.645	-1.532	-1.813	-0.608
	Spring	2.700	3.597	-6.608	-8.776	-3.021	-3.189	-1.471	-10.285
	summer	3.215	1.934	-5.143	-8.718	-3.225	-5.359	-1.843	-7.477
3	Autumn	0.721	4.211	-5.008	-12.864	-4.7440	-6.370	-5.857	-0.815
	Winter	-0.358	4.456	1.036	-9.939	-4.603	-2.152	-1.500	-0.708
	Spring	2.764	3.519	-5.321	-8.578	-2.609	-3.918	-0.608	-8.909
	summer	2.933	2.934	-8.478	-8.616	-2.914	-8.694	-2.230	-7.854
4	Autumn	0.377	7.907	-4.827	-12.477	-5.291	-5.370	0.271	-1.345
	Winter	0.583	4.434	-1.686	-10.025	-4.626	0.667	-1.770	-0.708
	Spring	2.832	3.873	-5.975	-8.877	-2.762	-4.495	-1.682	-7.177
	summer	3.053	3.256	-4.960	-8.697	-3.005	-5.176	-2.123	-7.477
5	Autumn	0.764	7.948	-1.133	-9.157	-4.4830	-4.299	1.072	-0.708

	Winter	0.483	4.565	-1.360	-10.062	-4.662	-0.453	-1.813	-0.515
	Spring	3.078	3.436	-7.019	-8.642	-2.674	-5.466	-1.023	-7.393
	summer	3.115	3.349	-4.079	-8.613	-2.425	-2.674	-1.471	-8.252

Conclusions

In this study of the Al-Ezz River, notable seasonal variations were observed in total organic carbon (TOC) values, with the highest levels occurring during the summer and the lowest during the autumn. The predominant sediment composition across sampling stations was identified as clay-greenish. Importantly, the sediments exhibited elevated concentrations of heavy elements, particularly lead and cadmium, posing significant pollution concerns. Assessment using the Geoaccumulation Index classified the sediments as highly contaminated with lead and heavily to extremely contaminated with cadmium, emphasizing the urgency of addressing these environmental issues. Additionally, strong correlations among various heavy elements highlight complex interactions that warrant further investigation for effective environmental management strategies.

References

Aiello, E., Donovan, C., Duque, E., Fabrizio, S., Flecha, R., Holm, P., . . . Reale, E. (2021). Effective strategies that enhance the social impact of social sciences and humanities research. *Evidence & Policy, 17*(1), 131–146.

Alloway, B. J. (2012). *Heavy metals in soils: trace metals and metalloids in soils and their bioavailability* (Vol. 22). Springer Science & Business Media.

Bantan, R. A., Al-Dubai, T. A., & Al-Zubieri, A. G. (2020). Geo-environmental assessment of heavy metals in the bottom sediments of the Southern Corniche of Jeddah, Saudi Arabia. *Marine Pollution Bulletin, 161*, 111721.

Blott, S. J., & Pye, K. (2012). Particle size scales and classification of sediment types based on particle size distributions: Review and recommended procedures. *Sedimentology, 59*(7), 2071–2096.

Boehm, P. D., & Quinn, J. G. (1973). Solubilization of hydrocarbons by the dissolved organic matter in sea water. *Geochimica et Cosmochimica Acta, 37*(11), 2459–2477.

Chester, R., & Voutsinou, F. G. (1981). The initial assessment of trace metal pollution in coastal sediments. *Marine Pollution Bulletin, 12*(3), 84–91.

Copaja, S. V., Mauro, L., Vega-Retter, C., & Véliz, D. (2020). Adsorption-desorption of trace elements in sediments of the Maipo River basin. *Journal of the Chilean Chemical Society, 65*(2), 4778–4783.

Defarge, N., De Vendômois, J. S., & Séralini, G. (2018). Toxicity of formulants and heavy metals in glyphosate-based herbicides and other pesticides. *Toxicology Reports, 5*, 156–163.

Directorate of Water Resources. (2022). *Report of the Directorate of Water Resources in Basra Governorate*.

Håkanson, L. (1980). An ecological risk index for aquatic pollution control: A sedimentological approach. *Water Research, 14*(8), 975–1001.

Huheey, J. E. (1983). *Inorganic chemistry: Principles of structure and reactivity* (3rd ed.). Harper & Row.

Jader V., Mohammed Jaafar S., and Abdulhameed B., aha Abduljabbar, and Al-Bakri S., Abdul-Ridha Saleh (2009). Efficiency of Rhizophobia in Fuel Oil Degradation and its Impact on Soil Biological Properties. *Iraqi Journal of Agricultural Sciences, 40*(5), 55–69.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, 7*(2), 60–72.

Kılıç, Z. (2020). The importance of water and conscious use of water. *International Journal of Hydrology, 4*(5).

Kostka, J. E., & Luther III, G. W. (1994). Partitioning and speciation of solid phase iron in saltmarsh sediments. *Geochimica et Cosmochimica Acta, 58*(7), 1701–1710.

Li, J., Liang, X., Xu, S., & Hao, J. (2009). Catalytic performance of manganese cobalt oxides on methane combustion at low temperature. *Applied Catalysis B: Environmental, 90*(1-2), 307–312.

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. B., Nainu, F., Khusro, A., . . . Alhumaydhi, F. A. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science, 34*(3), 101865.

Müller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. *GeoJournal, 2*, 108–118.

Robert-Sainte, P., Gromaire, M.-C., de Gouvello, B., Saad, M., & Chebbo, G. (2009). Annual metallic flows in roof runoff from different materials: test-bed scale in Paris conurbation. *Environmental Science & Technology, 43*(15), 5612–5618.

Siddiqua, A., Hahladakis, J. N., & Al-Attiya, W. A. K. (2022). An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. *Environmental Science and Pollution Research, 29*(39), 58514–58536.

Tucker, M. E., & Jones, S. J. (2023). *Sedimentary petrology*. John Wiley & Sons.

تقييم التلوث بالعناصر الثقيلة في الطور المتبادل في رواسب نهر العز شمال مدينة البصرة

شذى عبد الحسن شنيشل، حمزة عبد الحسن كاظم، بسام عاشور العبد العزيز
كلية العلوم، كلية العلوم، مركز علوم البحار، جامعة البصرة، العراق

المستخلص
جُمعت عينات الرسوبيات فصلياً ابتداءً من الخريف 2022/10/12 ولغاية الصيف 2023/6/25 ولخمس محطات ممتدة على طول نهر العز في قضاء القرنة شمال مدينة البصرة لغرض تقييم تلوث النهر بالعناصر الثقيلة بالطور المتبادل (الرصاص Pb , الكادميوم Cd , النحاس Cu , المنغنيز Mn , الزنك Zn , الكروم Cr , الكوبالت Co, الحديد Fe) , وأيضاً تم حساب عامل التلوث (CF) , وحساب عامل الإغناء (EF) ودليل التراكم الجيوكيميائي (I-geo) لغرض تقييم درجة تلوث رواسب منطقة الدراسة بالعناصر الثقيلة .أظهرت نتائج الدراسة بأن المعدل السنوي لتراكيز العناصر الثقيلة بالطور المتبادل (الرصاص Pb , الكادميوم Cd , النحاس Cu , المنغنيز Mn , الزنك Zn , الكروم Cr , الكوبالت Co, الحديد Fe) µg/g (23.175 , 111.016 , 21.918 , 8.549 , 95.842 , 122.18 , 10.826 , 61.749 ,) وزن جاف على التوالي.
أظهرت قيم (CF) بأن التربة ذات تلوث عالٍ جداً بالرصاص والكادميوم وذات تلوث مُنخفض بعنصر النحاس والحديد والمنغنيز وتلوث عالٍ بالكروم والكوبالت. وحسب قيم عامل التراكم الجيوكيميائي (I-geo) فإن رواسب نهر العز يمكن تصنيفُها على أنها مُلوثة بشدة بعنصر الرصاص وملوثة للغاية إلى مُلوثة بشدة بعنصر الكادميوم وغير مُلوثة إلى مُتوسطة التلوث بعنصر النحاس وغير مُلوثة بعنصر المنغنيز والزنك والكوبالت، والبيئة ذات تلوث مُتوسط بعنصر الكوبالت.