EVALUATION OF ENVIRONMENTAL POLLUTION BY HEAVY METALS IN THE SEDIMENTS OF AL-EZZ RIVER, NORTH OF BASRA

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Abstract
Seasonal sediment samples were collected from the fall of October 12, 2022, until the summer of June 25, 2023, at five stations along the Al-Az River in the Qurna district, north of Basra city. The purpose was to assess the river's pollution with heavy metals, namely 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 sequential extraction phase were as follows (g/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) - values not provided.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 and cobalt exhibited high 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 too 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 cobalt
Key word: pollution, heavy metal, sediment

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, Mauro, Vega-Retter, & Véliz, 2020). Environmental pollutants can be classified into three main types, which (Siddiqua, Hahladakis, & Al-Attiya, 2022) are:

1. Physical pollutants
2. Chemical pollutants
3. Biological pollutants

Materials and methods:
Description of The Study Area:
The Al-Ezz River (also known as Al-Jihad 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(Report Presented by the Directorate of Water Resources).
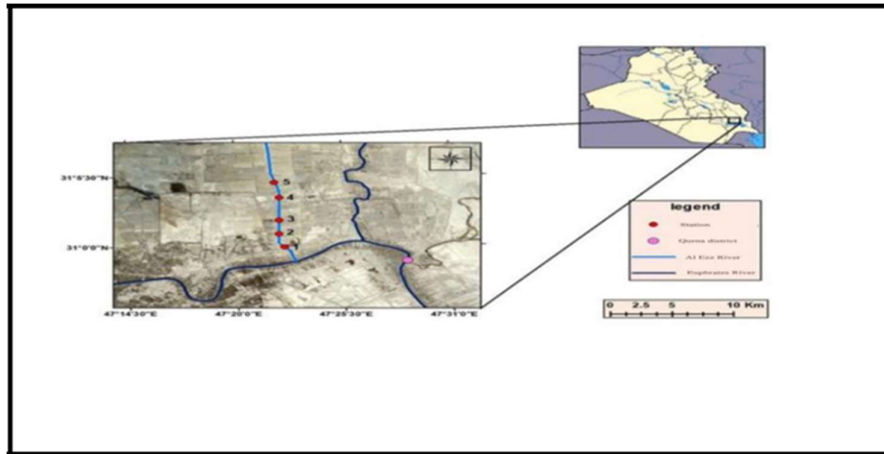
Figure (1) Map of the location of the study area

Material and Methodology

Fieldwork

Five soil sampling sites were chosen to collect samples during four seasons throughout the year. Samples were gathered in the fall, 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.

work and analysis Laboratory

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 and Voutsionu,1981) the analysis was conducted.

PoIIution factor

Pollution factor (I-geo) It was introduced by (Muller, 1969). (EF) is calculated, following the classification by (Huheey, 1983). (CF) the Contamination Factor is calculated, following the classification by (Hakanson ,1980) were calculated to determine the effect of heavy metal contamination of sediment samples (cadmium, lead, copper, iron, manganese, zinc, cobalt, chromium).

Statistical Analysis

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

Results and discussion

Total organic carbon concentration (TOC%) for the four seasons as shown in figure(1-2) The results showed that the highest value of organic carbon concentrations in the first station was (0.188%) during the summer season and the lowest value was (0.114%) in the winter season As for the second station, it recorded the highest value (0.182%) during the summer season and the lowest value (0.077%) in the winter season The third station recorded the highest value (0.1798%) in the summer season and the lowest value (0.085%) during the autumn season. The fourth station recorded the highest value (0.165%) in the spring and the lowest value (0.100%) during the summer. The fifth station recorded the highest value (0.161%) during the spring and the lowest value (0.109%) in the summer. Organic substances are absorbed by the suspended particles in the water. These particles form the sediment and contain the organic material that has been adsorbed. After that, the sediment accumulates on the bottom, where it becomes part of the bottom soil. The bottom can contain different layers of sediment that have accumulated over time and contain different organic matter (Boehm and Quinn, 1973).
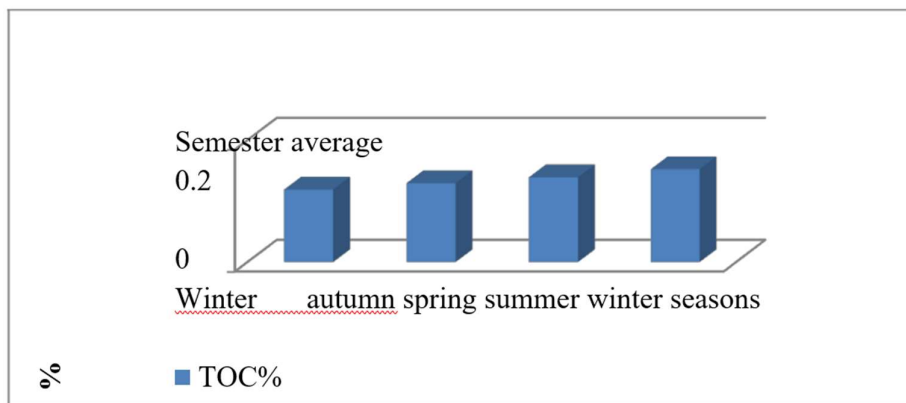
Figure (2) Seasonal changesf of)TOC %)

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 and Jones, 2023). Figure (2)

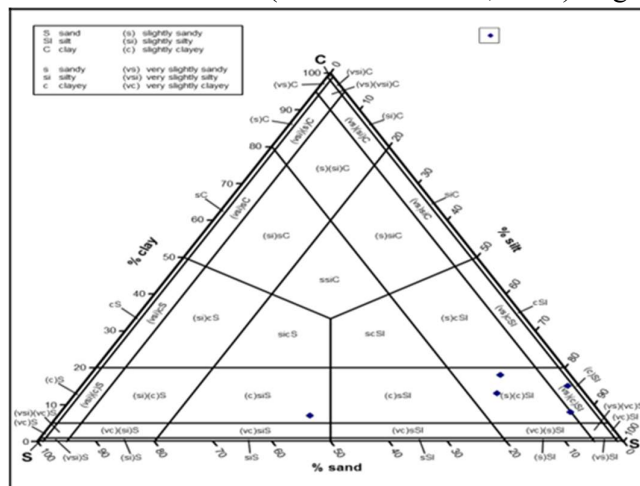Figure (3) Distribution of the particle sizes of clay, silt and sand according to (Blott and Pye, 2012)

Heavy elements

Lead

The concentrations of the residual phase of lead in sediment samples varied across five stations as follows: the first station (193.573-23.076 µg/gm), the second station (168.123-22.027 µg/gm), while in the third station (160.411-45.104 µg/gm), and the fourth station (195.115-19.930 µg/gm), and finally the fifth station (192.030-17.832 µg/gm). The highest average value was (195.115 µg/gm) at the fourth station during the spring season, and the lowest average value was (17.832 µg/gm) at the fifth station during the winter season. The study results revealed the highest concentration of lead in sediments at the fourth station during the spring season, reaching a concentration value of (195.116 µg/gm). This increase can be attributed to the presence of a busy road with vehicular traffic in the area, leading to the dispersion of lead in the environment of the study area. Thus, it can be considered that vehicular movement and emissions associated with passing through this road contribute to the elevated accumulation of lead in sediments near it, in addition to the nearby oil industrial activities, posing an environmental threat. (Bantan et al., 2020). The results of the statistical analysis indicated a correlation between lead and iron (r=0.99) As for the second station, a strong correlation appeared between lead and both iron and manganese (r=0.99).

Table (1) Lead concentrations (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			Location
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	
3.257	155.013	153.075 - 158.774	4.068	193.573	191.153 - 198.269	0.484	23.076	22.787- 23.635	0.617	29.370	29.002- 30.082	1
3.257	155.013	153.075 - 158.774	3.533	168.123	166.021 - 172.202	0.462	22.028	21.752- 22.562	1.080	51.398	50.755- 52.645	2
2.706	128.792	127.182 - 131.917	3.371	160.411	158.405 - 164.303	1.741	82.867	81.831- 84.877	0.947	45.104	44.540- 46.198	3
4.084	194.344	191.914 - 199.059	4.100	195.116	192.677 - 199.850	0.418	19.930	19.680- 20.413	0.749	35.664	35.218- 36.529	4
4.035	192.031	189.630 - 196.690	3.436	163.496	161.452 - 167.463	0.374	17.832	17.609- 18.264	0.881	41.958	41.433- 42.976	5

	165.036			176.144			33.146			40.699		mean

2-Cadmium

he concentrations of the residual phase of cadmium in sediment samples varied across five stations as follows: the first station (2.723-1.290 µg/gm), the second station (4.168-1.720 µg/gm), while in the third station (6.793-2.006 µg/gm), and the fourth station (3.628-1.863 µg/gm), and finally the fifth station (24.704-2.006 µg/gm). The highest average value was (24.704 µg/gm) at the fifth station during the winter season. The lowest average value was (1.290 µg/gm) at the first station during the summer season. The hazard associated with this element lies in its ability to be absorbed by plants from the soil or even bound to their leaves, leading to its transfer to the human body. Consequently, cadmium can accumulate within the food chain, whether in human bodies or in the bodies of livestock that feed on these contaminated plants, The results of the statistical analysis indicated correlations between the residual phase of cadmium and copper (r=0.97), chromium (r=0.97), cobalt (r=0.98), and zinc (r=0.93).

Table (2) Cadmium concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			Location
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	
0.027	1.290	1.273-1.321	0.057	2.723	2.688-2.789	0.056	2.702	2.668-2.767	0.043	2.084	2.057-2.134	1
1.136	1.720	1.698-1.761	0.045	2.150	2.123-2.202	0.048	2.316	2.287-2.372	0.087	4.168	4.115-4.269	2
0.042	2.006	1.980-2.054	0.063	3.010	2.972-3.083	0.142	6.793	6.708-6.957	0.079	3.782	3.734-3.873	3
0.039	1.863	1.839-1.908	0.039	1.863	1.839-1.908	0.047	2.238	2.210-2.292	0.076	3.628	3.582-3.716	4
0.042	2.006	1.980-2.054	0.042	2.006	1.980-2.054	0.519	24.704	24.395-25.303	0.066	3.165	3.125-3.241	5

	1.777			2.350			7.750			3.365		mean

3- Copper

The concentrations of the residual phase of copper in sediment samples varied across five stations as follows: the first station (110.493-4.310 µg/gm), the second station (71.619-0.664 µg/gm), while in the third station (62.535-0.772 µg/gm), the fourth station (84.295-13.793µg/gm), and finally the fifth station (53.028-0.532 µg/gm). The highest average value was (110.493 µg/gm) at the first station during the autumn season. The lowest average value was (0.532µg/gm) at the fifth station during the spring season. A strong correlation was observed between copper and cobalt (r=0.99), chromium (r=0.98), zinc (r=0.98), and cadmium (r=0.97). The presence of copper in the environment is attributed to the use of agricultural pesticides and fertilizers. In some cases, copper is utilized as a fungicide in agriculture (Robert-Sainte et al., 2009), and it can also be found in sewage waters discharged into rivers.

Table (3) Copper concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			Location
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	
0.090	4.310	4.25 - 4.41	0.090	4.310	4.256- 4.414	0.461	21.971	21.696 - 22.504	2.322	110.493	109.111- 113.174	1
0.017	0.827	0.816- 0.847	0.013	0.664	0.655- 0.680	0.439	20.915	20.653 - 21.422	1.505	71.619	70.723- 73.356	2
0.016	0.772	0.762- 0.790	0.543	25.862	25.538- 26.489	0.408	19.436	19.193 - 19.907	1.314	62.535	61.753- 64.052	3
0.289	13.793	13.620- 14.127	0.308	14.655	14.471- 15.010	0.466	22.183	21.905 - 22.721	1.771	84.295	83.241- 86.340	4
0.253	12.069	11.918- 12.361	0.011	0.532	0.525- 0.544	0.652	31.056	30.667 - 31.809	1.114	53.028	82.365- 54.318	5

	6.354			9.204			23.112			76.394		mean

4- Iron

The concentrations of the residual phase of iron in sediment samples from five stations varied as follows: the first station (188.030-87.962 µg/gm), the second station (201.544-92.089 µg/gm), the third station (184.942-96.216 µg/gm), the fourth station (183.397-93.637 µg/gm), and the fifth station (196.139-95.700 µg/gm). The highest average value (201.544 µg/gm) was recorded at the second station during the spring season, while the lowest average value (87.962 µg/gm) was observed at the first station during the winter season. The results of the statistical analysis revealed a strong correlation for the residual phase of iron with lead (r=0.99) and manganese (r=0.90). The expected sources of iron are attributed to the use of fertilizers and pesticides. 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 and Luther III, 1994).

Table (4) Iron concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	Location
3.651	173.745	171.573 - 177.960	3.951	188.030	185.680 - 192.593	1.848	87.962	86.862-90.096	1.978	94.153	92.976-96.437	1
3.854	183.398	181.105 - 187.848	4.235	201.544	199.024 - 206.434	1.935	92.089	90.937-94.323	2.271	108.083	106.732 - 110.705	2
3.886	184.942	182.630 - 189.429	3.830	182.239	179.961 - 186.661	2.022	96.216	95.013-98.550	2.342	111.436	110.043 - 114.140	3
3.805	181.081	178.817 - 185.474	3.854	183.397	181.105 - 187.848	1.967	93.637	92.466-95.909	2.304	109.63	108.259 - 112.290	4
3.951	188.031	185.680 - 192.593	4.122	196.139	193.687 - 200.898	2.011	95.700	94.503-98.022	2.309	109.888	108.514 - 112.554	5
	182.239			190.270			93.121			106.638		mean

5- Manganese

The residual concentration of manganese in the sediment samples from the five stations ranged as follows: the first station (189.949-55.531 µg/gm), the second station (197.110-17.830 µg/gm), the third station (199.371-54.457 µg/gm), the fourth station (245.351-4.296 µg/gm), and finally the fifth station (265.703-1.396 µg/gm). The highest average value was (265.703 µg/gm) in the fifth station during the summer season, and the lowest average value was (1.396 µg/gm) in the fifth station during the winter season. The results of the statistical analysis revealed a strong correlation between the residual phase of manganese and iron (r=0.90)and lead(r=0.99), Manganese is the twelfth most abundant element in the Earth's crust and is a member of the iron family. Both elements are closely linked in geochemical processes (Post, 1999). The highest concentration of manganese (265 µg/gm) was observed in the fifth station, which marks the initial entry of the Ezz River into the Qurna area. This high value suggests that human factors, including waste disposal and industrial growth, contribute to this increase.

Table (5) Manganese element concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	Location
3.992	189.949	187.574 - 194.558	3.730	177.512	175.293 - 181.819	1.167	55.531	54.836- 56.878	1.975	93.985	92.810- 96.265	1
3.334	158.668	156.684 - 162.518	4.142	197.111	194.647 - 201.893	1.663	79.162	78.172- 81.082	0.374	17.830	17.607- 18.262	2
3.485	165.829	163.756 - 169.852	4.190	199.371	196.878 - 204.208	2.119	100.859	99.598- 103.306	1.144	54.457	53.776- 55.778	3
4.103	195.226	192.785 - 199.963	5.156	245.351	242.284 - 251.304	0.090	4.296	4.242- 4.400	1.130	53.813	53.140- 55.118	4
5.584	265.703	262.381 - 272.150	2.637	125.502	123.933 - 128.547	0.029	1.396	1.378- 1.429	1.124	53.490	52.821- 54.787	5
	195.078			188.969			48.249			54.715		mean

6- Zinc

The concentrations of the remaining phase of zinc in the sediment samples varied as follows: the first station (44.985-6.185 µg/gm), the second station (77.936-0.062 µg/gm), the third

station (76.504-2.268 µg/gm), the fourth station (71.346-5.154 µg/gm), and the fifth station (68.481-1.237 µg/gm). The highest average value (77.936 µg/gm) was observed in the second station during the autumn season, while the lowest average value (0.062 µg/gm) was recorded in the second station during the summer season. The statistical analysis results revealed a strong correlation between the residual phase of zinc and cobalt (r=0.99). Due to the extension of agricultural lands along the Ezz River, they usually have higher zinc content compared to natural lands. This disparity in content is largely attributed to the use of agricultural pesticides (Komárek et al., 2010).

Table (6)Zinc concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	Location
0.129	6.185	6.107-6.335	0.234	11.134	10.994-11.404	0.945	44.985	44.422-46.076	0.921	43.839	43.291-44.902	1
0.001	1.857	0.061-0.063	0.060	2.886	2.849-2.951	0.800	38.108	37.631-39.032	1.637	77.936	76.961-79.827	2
0.047	2.268	2.239-2.323	0.164	7.835	7.737-8.025	0.818	38.968	38.480-39.913	1.607	76.504	75.547-78.360	3
0.108	5.154	5.089-5.279	0.281	13.402	13.234-13.727	0.903	42.979	42.441-44.021	1.499	71.346	70.454-73.077	4
0.324	15.463	15.269-15.838	0.025	1.237	1.221-1.267	1.023	48.710	48.101-49.891	1.439	68.481	67.624-70.142	5
5.814			7.298			42.750			67.621			mean

7- Chrome

The concentration of chromium in the sediment samples of the study area ranged as follows: the first station (325.862-53.017 µg/gm), the second station (328.448-71.311 µg/gm), while in the third station (290.948-71.311 µg/gm), the fourth station (226.345-83.606 µg/gm), and finally the fifth station (215.756-54.098 µg/gm). The highest average value was (328.448 µg/gm) at the second station during the autumn season, and the lowest average value was (53.017 µg/gm) at the first station during the winter season. The results of the statistical analysis showed a significant relationship for chromium with copper in the residual phase (r=0.94). The study's findings indicate that the primary source of chromium is attributed to human activities causing pollution, including painting, dyes, chemical manufacturing, and steel production (Jaishankar et al., 2014).

Table (7) Chrome concentration (µg/gm) dry weight of sediment samples in the residual phase

summer	spring	winter	autumn	Location

±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	
1.963	93.442	92.273-95.709	2.118	100.819	99.558-103.265	1.114	53.017	52.354-45.303	6.848	325.862	321.788-333.768	1
1.498	71.311	70.419-73.041	2.222	105.737	104.415-108.302	3.696	175.862	173.663-180.129	6.903	328.448	324.342-336.417	2
1.498	71.311	70.419-73.041	1.705	81.147	80.132-83.116	2.989	142.241	140.462-145.692	6.114	290.948	287.311-298.007	3
1.757	83.606	82.560-85.634	2.067	98.360	97.130-100.746	3.073	146.224	144.396-149.772	4.757	226.345	223.515-231.837	4
2.325	110.655	109.271-113.340	1.136	54.098	35.421-55.410	3.089	147.413	145.570-150.989	4.534	215.756	213.059-220.991	5
	86.065			88.032			136.551			189.051		mean

8- Cobalt

Finally, the residual phase concentrations of cobalt in sediment samples for the five stations were as follows: the first station (24.590-0.021 µg/gm), the second station (50.819-0.109 µg/gm), while in the third station (54.098-0.112 µg/gm) and the fourth station (50.819-0.163 µg/gm), and finally the fifth station (39.344-0.085 µg/gm). The highest average value was (54.098 µg/gm) in the third station during the autumn season, and the lowest average value was (0.021 µg/gm) in the first station during the spring season. The results of the statistical analysis indicated a strong correlation between the residual phase of cobalt and zinc ($r=0.99$). The use of agricultural pesticides and the improper disposal of untreated sewage water into rivers resulted in an increase in the cobalt content in the environment (Defarge et al., 2018) and (Li et al., 2009)

Table (8) Cobalt concentration (µg/gm) dry weight of sediment samples in the residual phase

summer			spring			winter			autumn			
±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	±SD	mean	Range	Location
0.004	0.022	0.021-0.022	0.0004	0.021	0.020-0.021	0.516	24.590	24.282-25.186	0.482	22,950	22.663-23.506	1
0.002	0.109	0.107-0.111	0.005	0.251	0.247-0.257	0.261	12.453	12.297-12.755	1.068	50.819	50.183-52.052	2

0.002	0.112	0.110-0.14	0.012	0.601	0.593-0.615	0.317	15.126	14.936-15.493	1.036	54.098	53.421-55.410	3
0.003	0.163	0.160-0.166	0.006	0.311	0.307-0.318	0.424	20.221	19.968-20.711	1.068	50.819	50.183-52.052	4
0001	0.094	0.092-0.069	0.003	0.151	0.149-0.154	0.472	22.501	22.219-23.047	0.826	39.344	38.852-40.298	5
	0.098			0.267			18.978			43.606		mean

Heavy Elements pllution Indices

1-   Contamination Factor (CF)

In the remaining phase, the value of lead was (13.936) in the fourth station during the spring season and the lowest value (1.273) in the fifth station during the winter season. The CF value of the lead element was (1.273≤CF≤13.936), and this indicates that the environment was highly polluted to very high. As for the cadmium element, the highest value was (164.693) in the fifth station during the winter season and the lowest value (8.6) in the first station during the summer season The CF value of cadmium was (8.6 ≤ CF ≤ 164.693), which indicates that the environment was highly polluted to very high. The highest value of the pollution factor in the residual phase of the copper element was (1.624) in the first station during the autumn season and the lowest value (0.007) in the fifth station during the spring season. The CF value of the copper element ranged between (0.007≤CF≤1.624) and this indicates that the level of pollution in the environment was low. The highest value (0.0040) of the contamination factor in the residual phase of the iron element was in the second station during the spring season, and the lowest value (0.0017) in the first station during the winter season, and the CF value of the iron element was (0.0017≤CF≤0.004), and this indicates that. The environment was low pollution. The highest value of the pollution factor in the remaining phase of the lead element was (5.17) in the fifth station during the winter season and the lowest value (0.0001) in the fourth station during the winter, and the CF value of the manganese element was (0.0001 ≤CF≤5.17) and this indicates that the environment has High pollution. The highest value of the pollution factor in the remaining phase of the zinc element (0.986) was recorded in the third station during the autumn season, and the lowest value (0.015) was recorded in the fifth station during the spring season, and the CF value was (0.015 ≤CF≤ 0.968), which indicates that the environment was low in pollution. The highest value of the pollution factor in the residual phase was (3.284) in the second station during the autumn season and the lowest value (0.53) in the first station during the winter season. The value of CF was (0.53≤CF≤3.284) and this indicates that the environment is highly polluted. The highest value of the pollution factor in the residual phase was (2.163) in the third station during the autumn season, and the lowest value was (0.0008) in the first station during the spring and summer seasons. The value of CF was (0.0008≤CF≤2.163), and this indicates that the environment is moderately polluted. Table (1-9)

Table (9) Contamination factor values for the elements in the residual phase

Station	Season	CF(Pb)	CF(Cd)	CF(Cu)	CF(Fe)	CF(Mn)	CF(Zn)	CF(Cr)	CF(Co)
1	Autumn	2.097	13.896	1.624	0.0018	0.104	0. 554	3.258	0.918
	Winter	1.648	18.013	0.323	0.0017	0.002	0.569	0.530	0.983
	Spring	13.826	18.155	0.063	0.0037	0.197	0.140	1.008	0.0008
	summer	11.072	8.600	0.063	0.0034	0.211	0.078	0.934	0.0008
2	Autumn	3.671	27.792	1.053	0.0021	0.019	0.986	3.284	2.032
	Winter	1.573	15.440	0.307	0.0018	0.002	0.482	1.758	0.498
	Spring	12.008	14.333	0.009	0.0040	0.219	0.063	1.057	0.010
	summer	11.072	11.466	0.012	0.0036	0.176	0.023	0.713	0.004
3	Autumn	3.221	25.218	0.919	0.0022	0.060	0.968	2.909	2.163
	Winter	5.919	45.290	0.285	0.0019	0.003	0.493	1.422	0.605
	Spring	11.457	20.066	0.380	0.0036	0.221	0.099	0.811	0.024
	summer	9.199	13.377	0.011	0.0036	0.184	0.028	0.713	0.004
4	Autumn	2.547	24.189	1.239	0.0021	0.059	0.903	2.263	2.032
	Winter	1.423	14.925	0.326	0.0018	0.0001	0.544	1.642	0.808
	Spring	13.936	12.422	0.215	0.0036	0.272	0.169	0.983	0.012
	summer	13.881	12.422	0.202	0.0036	0.216	0.065	0.836	0.006
5	Autumn	2.997	21.101	0.779	0.0021	0.059	0.866	2.157	1.573
	Winter	1.273	164.693	0.456	0.0019	5.17	0.616	1.474	0.900
	Spring	11.678	13.377	0.007	0.0039	0.139	0.015	0.540	0.006
	summer	13.716	13.377	0.177	0.0037	0.295	0.195	1.106	0.003

2-Enrichment Factor

Table (10) indicates the highest value of the enrichment factor Lead in the residual phase was (3833.01) in the fourth station during the summer season, and the lowest value (665.46) in the fifth station during the winter season. The value of EF was (EF > 50), and this indicates that the environment is extremely rich. The highest value of the enrichment factor in the residual phase was for cadmium (86045.97) in the fifth station during the winter season, and the lowest value (2474.88) in the first station during the summer season. The value of EF was (EF > 50), and this indicates that the environment is extremely enriched. The highest value of the enrichment factor in the remaining phase of copper was (862.90) in the first station during the autumn season, and the lowest value (1.99) in the fifth station during the spring season. The value of EF for the copper element was (EF > 50), and this indicates that the environment is highly enriched. Extremely. The highest value of the enrichment factor in the residual phase of the manganese element was (78.50) in the fifth station during the summer season and the lowest value (0.02) in the fifth station during the winter season. The value of EF for the manganese element was (EF = 1-3), and this indicates that the environment has high Simple enrichment to very intense enrichment. The highest value of the enrichment factor in the remaining phase of

zinc was (456.38) in the second station during the autumn season, and the lowest value (3.99) in the fifth station during the spring season. The value of EF for zinc was (EF > 50) (EF = 3-5), and this It indicates that the environment is of medium to very high enrichment. The highest value of the enrichment factor in the residual phase of the chromium element (456.38) was recorded in the second station during the autumn season and the lowest value (3.99) was recorded in the fifth station during the spring season. The value of EF for the chromium element was (EF = 3-5), and this indicates that. The environment is of moderate enrichment to very high enrichment. Finally, the highest value of the enrichment factor in the residual phase of the cobalt element was (970.93) in the third station during the autumn season and the lowest value (0.22) in the second station during the spring season. The value of EF for the cobalt element was (EF = 3-5), and this indicates that. The environment is very rich to no enrichment.

Table (10) Enrichment coefficient values for the elements in the residual phase

Station	Season	EF(Pb)	EF(Cd)	EF(Cu)	EF(Mn)	EF(Zn)	EF(Cr)	EF(Co)
	Autumn	**1114.06**	7378.05	862.90	55.45	294.69	1730.49	**487.52**
	Winter	**936.92**	10239.25	183.66	1.16	323.68	301.36	**559.10**
1	Spring	**3676.69**	4827.22	16.85	52.44	37.47	268.09	**0.22**
	summer	**3186.37**	2474.88	18.24	60.73	22.53	268.90	**0.25**
	Autumn	**1698.37**	12854.37	487.23	9.16	456.38	1519.43	**940.38**
	Winter	**854.25**	8383.15	167.001	1.59	261.91	954.84	**270.45**
2	Spring	**2979.19**	3555.87	2.42	54.33	9.06	262.31	**2.49**
	summer	**3018.67**	3126.17	3.31	48.06	6.40	194.41	**1.18**
	Autumn	**1445.54**	11312.92	412.62	27.14	434.51	1305.45	**970.93**
3				23533.68	148.53	1.94	256.33	739.17	**314.41**
				5505.57	**104.34**	60.77	27.21	222.63	6.59
				3616.80	**3.06**	49.81	7.76	192.79	1.21
	Winter	**3075.90**		11031.01	**565.37**	27.26	411.89	1032.31	927.11
				7966.92	**174.19**	0.08	290.50	876.91	431.90
4				3386.08	**58.75**	74.32	46.25	268.16	3.39
				3429.40	**65.00**	59.89	18.01	230.85	1.80
				9600.66	**354.82**	27.04	394.42	981.70	716.07

			86045.97	**238.61**	0.02	322.14	770.18	470.23
5								
			3409.14	**1.99**	35.54	3.99	137.90	1.53
			3556.15	**47.19**	78.50	52.05	294.24	0.90

3- Geo Accumulation Index of Heavy Metals

The highest value of the geochemical aggregation factor in the residual phase Lead was (3.215) in the fourth station during the spring season and the lowest value (-0.235) in the fifth station during the winter season. The value of (I-geo) for Pb was (I-geo < 1), and as which indicates that the environment is heavily polluted to non-polluted. The highest value of the geochemical aggregation factor in the residual phase of the cadmium element was (6.778) in the fifth station during the winter season, and the lowest value (2.519) in the first station during the summer season. The value of (I-geo) for the Cd element was (I-geo < 5). This indicates that the environment is extremely polluted to some extent. The highest value of the geochemical agglomeration factor in the residual phase was for copper (0.115) in the first station during the autumn season, and the lowest value (-7.582) in the fifth station during the spring season, and the value of (I-geo) for the element Cu was (I-geo < 1) Which indicates that the environment is not polluted.

The highest value in the residual phase of the iron element was (-8.539) in the second station during the spring season, and the lowest value (-9.735) in the first station during the winter season, and that the value of (I-geo) for the Fe element was (I-geo < 1), and this It indicates that the environment is not polluted. The highest value in the residual phase of the manganese element was (-2.345) in the fifth station during the summer season, and the lowest value (-14.824) in the fifth station during the winter season. The value of (I-geo) for the Mn element was (I-geo < 1), and this It indicates that the environment is not polluted. The highest value in the residual phase was for zinc (-0.604) in the second station during the autumn season and the lowest value (-6.581) in the fifth station during the spring season, so the value of (I-geo) for the element Zn was (I-geo < 1), and this indicates. The environment is not polluted. The highest value of the geochemical agglomeration factor in the residual phase was for chromium (1.130) in the second station during the autumn season, and the lowest value (-1.500) in the first station during the winter season, and the value of (I-geo) for the Cr element was (I-geo < 1) It indicates that the environment is not polluted to moderate pollution. The highest value of the geochemical aggregation factor in the residual phase was for cobalt (0.528) in the third station during the autumn season, and the lowest value (-10.802) in the first station during the spring season, and that the value of (I-geo) for the Co element was (I-geo < 1), and this It indicates that the environment is not polluted. Table (1-11).

Table (11) geochemical aggregation coefficient values for the elements in a residual phase

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	0.483	3.211	0.115	-9.637	-3.844	-1.434	1.119	-0.708
	Winter	0.136	3.586	-2.214	-9.735	-9.510	-1.397	-1.500	-0.608
	Spring	3.204	3.597	-4.564	-8.639	-2.926	-3.411	-0.573	-10.802
	summer	2.883	2.519	-4.564	-8.753	-2.829	-4.259	-0.682	-0.769
2	Autumn	1.291	4.211	-0.510	-9.438	-6.242	-0.604	1.130	0.438
	Winter	0.068	3.363	-2.285	-9.669	-8.998	-1.636	0.229	-1.590
	Spring	3.001	3.256	-7.263	-8.539	-2.775	-5.359	-0.504	-7.223
	summer	2.883	2.934	-6.946	-8.675	-3.088	-5.103	-1.072	-8.426
3	Autumn	1.102	4.071	-0.705	-9.394	-4.631	-0.631	0.955	0.528
	Winter	1.980	4.916	-2.391	-9.606	-8.649	-1.604	-0.076	-1.309
	Spring	2.933	3.741	-1.979	-8.684	-2.759	-3.918	-0.886	-5.963
	summer	2.616	3.156	-7.045	-8.663	-3.025	-5.707	-1.072	-8.387
4	Autumn	0.764	4.011	-0.275	-9.418	-4.648	-0.731	0.593	0.438
	Winter	-0.075	3.314	-2.201	-9.645	-13.202	-1.463	0.130	-0.891
	Spring	3.215	3.049	-2.799	-8.675	-2.460	-3.144	-0.608	-6.913
	summer	3.210	3.049	-2.886	-8.694	-2.789	-4.522	-0.843	-7.845

	Autumn	0.998	3.814	-0.943	-9.414	-4.657	-0.791	0.524	0.069
	Winter	-0.235	6.778	-1.715	-9.614	-14.824	-1.282	-0.025	-0.736
5	Spring	2.960	3.156	-7.582	-8.578	-3.427	-6.581	-1.471	-7.956
	summer	3.192	3.156	-3.079	-8.639	-2.345	-2.937	-0.438	-8.785

Conclusions

1.   The total organic carbon (TOC) values in the sediments recorded the highest value during the summer season and the lowest value during the autumn season.

2.   The sediments in the study area are predominantly clayey-greenish sediments across most of the sampling stations.

3.   The highest values for the heavy elements in the residual phase were (195.116, 24.704, 110.493, 265.703, 77.936, 328.448, 54.098) g/gmμ dry weight, respectively. Meanwhile, the concentrations of the above-mentioned elements in the waters of the study area were (8.015, 0.238, 695.423, 0.323, 1.461, 2.801, 0.095) g/mlμ.

4.   Based on the values of the Geoaccumulation Index (I-geo), the sediments of the Al-Az River can be classified as highly contaminated with lead, heavily to extremely contaminated with cadmium, not contaminated to moderately contaminated with copper, not contaminated with manganese, zinc, and cobalt. Additionally, the environment is moderately polluted with cobalt.

5.   Lead is strongly positively correlated with iron, manganese, and chromium. Cadmium is correlated with both copper and chromium. Copper shows a strong correlation with cobalt, copper, and zinc. Manganese is correlated with lead and iron. Zinc has a strong correlation with copper and cobalt. Chromium is strongly correlated with lead, cadmium, and cobalt. Finally, cobalt is strongly correlated with copper and chromium.

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