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Concentrations of some heavy metals in plants adjacent to the Tigris River, Iraq

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ABSTRACT: The current study was completed in Salah al-Din Governorate for a full year, the period extending from June 2022 until the end of May 2023, to evaluate the concentration of zinc and copper in the plants adjacent to the Tigris River. It included the selection of six sites within the governorate, taking into account the locations close to the sources of pollution with heavy metals and the direct effects of population centers, which are (Al-Boujwari village, Al-Hajjaj village, Wadi Sheshin area, Al-Balaj, Al-Alam district and Al-Mahzam area); plant samples were taken three times for each site, during the four seasons of the year. The results showed that the concentrations of heavy metals varied temporally and spatially, as the values of zinc and copper ranged between (0.62-0.04) (0.52-0.02) mg L^{-1}, respectively. An increase in zinc concentrations was observed compared to copper, and an increase in most concentrations was observed in the summer compared to other seasons.
Keywords: heavy metals; zinc; copper; plants pollution.

Avaliação das concentrações de alguns metais pesados em plantas adjacentes ao rio Tigris, Iraque

RESUMO: O presente estudo foi concluído na província de Salah al-Din, durante um ano inteiro, durante o período que se estende de junho de 2022 até o final de maio de 2023, para avaliar a concentração de alguns metais pesados, zinco e cobre nas usinas adjacentes ao rio Tigre. Incluiu a seleção de seis locais dentro da província, tendo em conta os locais próximos das fontes de poluição com metais pesados e os efeitos diretos dos centros populacionais, que são (aldeia Al-Boujwari, aldeia Al-Hajjaj, área de Wadi Sheshin, Al-Balaj, distrito de Al-Alam e área de Al-Mahzam), foram colhidas amostras de plantas três vezes para cada local, durante as quatro estações do ano. Os resultados do estudo mostraram que as concentrações de metais pesados variaram temporal e espacialmente, já que os valores de zinco e cobre variaram entre (0,62-0,04) (0,52-0,02) mg L^{-1}, respectivamente. Foi observada uma taxa de aumento das concentrações de zinco em comparação com o cobre e aumento na maioria das concentrações no verão em comparação com outras estações.
Palavras-chave: Metais pesados; zinco; cobre; poluição de plantas.

1. INTRODUCTION

Pollution with heavy metals is one of the most dangerous inorganic pollutants due to their accumulation, persistence in the environment, and lack of biological decomposition. Environmental pollution with heavy metals has become a global problem that affects crop productivity and soil fertility (Briffa et al., 2020). It is also transmitted to living organisms.

Heavy elements are usually found in the soil at low levels, either through water or through the food chain, such as crops and plants used as food. Still, due to pollution resulting from industry, agriculture, and other wastes such as urban waste, it is better to measure the plant content of these toxic and dangerous elements, zinc and copper, due to their accumulation and toxicity, which leads to a serious impact not only on the plant but also on human health (Satarug et al., 2023), as the concentration level of element absorption in plants depends on the levels and concentrations of the elements in the soil and the nature of the plant.

Some plants can accumulate elements to a greater extent. Otherwise, as the increased accumulation of these elements can be toxic to most plants, the presence of elements in plants environments is a type of stress that will lead to physiological changes and reduce the vital capabilities of several plants (AL-DOURY, 2020).

Phytoremediation is a form of biological treatment concerned with using specific plants to reduce pollution levels through specific metabolic mechanisms carried out by the plant that lead to the removal, retention, or decomposition of various pollutants (AL-SAFAWI, 2018). Aquatic plants are of great importance in treating household toxic waste due to their ease of setting up and operating treatment systems and their low cost.

Plants that grow along rivers are among the most prominent plants that play a major role in treating wastewater. In Iraq, among the studies conducted on plants adjacent to water, where is Al-Bayati's (2022) study on reed and castor plants; Al-Hamdani (2011) conducted a field survey of aquatic plants growing in sewage and their use in treating pollution; while Al-Fahdawi (2015) mentioned the anatomical characteristics of some plant species growing in

Euphrates River, Al-Safawi; Al-Sanjare (2019) and Younis; Saeed (2023) noted the bioaccumulation of the elements lead and zinc in the vegetative system of reed plants. Hmmod, *et al.* (2018) studied the estimation of heavy metal pollution of water and cultivated plants near the Diyala River and the implications for human health.

Given the danger of heavy metal accumulation in plants and the implications for human health and the ecosystem, the current study aimed to estimate the concentration of heavy metals, such as zinc and copper, in plants adjacent to the Tigris River in Salah al-Din Governorate.

2. MATERIAL AND METHODS

2.1. Study Locations

The study period lasted one year and four seasons, during which plant samples were collected from six locations chosen based on the field survey conducted during that period. These locations were chosen to be close to the sources of heavy metal pollution and to account for the direct effects of population centers in these locations within Salah al-Din Governorate, as shown in the map (Figure 1).

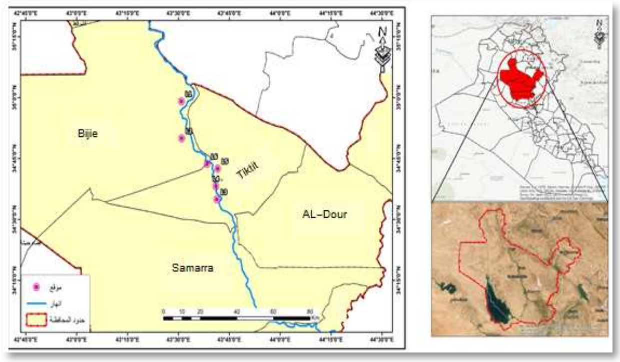

Figure 1. Study locations. Where: L1: Bijie District, Albujwari Village, L2: Al-Hajjaj Village, L3: Tikrit District, Wadi Sheshin area, L4: Al-Balaj, L5: Al-Alam District, L6: Al-Mahzam.
Figura 1. Locais dos estudos. Onde: L1: distrito de Bijie, vila de Albujwari, L2: vila de Al-Hajjaj, L3: distrito de Tikrit, área de Wadi Sheshin, L4: Al-Balaj, L5: distrito de Al-Alam, L6: Al-Mahzam.

2.2. Collecting plant samples

Plant samples were collected in three replicates from different areas of one site from the six mentioned sites. After washing, the samples were placed in polyethylene bags. The shoots were cut from the roots, and the wet weight of each was taken. After drying, they were weighed again and prepared to determine heavy metals.

2.3. Estimation of heavy metals in plants

Heavy metals were estimated in the plant samples that were collected, dried, and ground. The plant powder was digested using the acid digestion method, according to the method of Al-Janabi and his group (1992), where 3 grams of the powder of the plant sample was placed inside a Griffin beaker cup. Added to it were 3 mL of concentrated perchloric acid solution ($HClO_4$), which was heated quietly on an electric hot plate, and the temperature was gradually raised to complete the digestion process.

Leave the solution to cool, and add 3 mL of concentrated nitric acid solution again while continuing to heat until the digestion process is completed and a mixture is obtained that is clear and colored with a light color called light-colored digestate while beginning the evaporation process until the dryness stage approaches. Add 5 mL of diluted hydrochloric acid solution with water at a ratio of 1:1, then heat it to dissolve the remaining sample after digestion and then add distilled water.

The nomination process was completed and the volume of the solution was adjusted until the sample was ready for analysis using an atomic absorption spectrometer.

3. RESULTS

3.1. Zinc (Zn)

The highest concentration in the roots in Table 1 and Figure 1 reached 13.51 mg kg^{-1} in the spring at the fifth site (Al-Alam District), and the lowest concentration was 3.09 mg kg^{-1} in the fall at the same site.

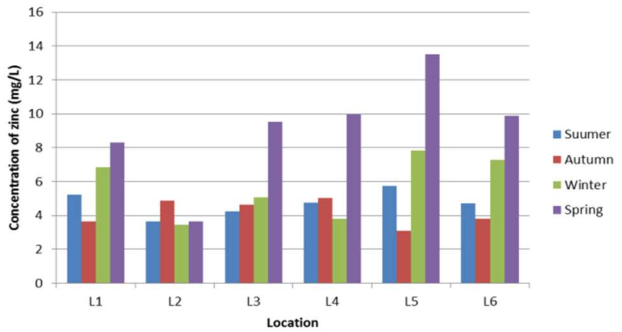

Figure 2. Zinc concentration in plant roots samples (mg L^{-1}).
Figura 2. Concentração de zinco em amostras de raízes de plantas (mg L^{-1}).

3.2. Copper (Cu)

The highest concentration in the roots in Table 3 and Figure 1 was 3.50 mg kg^{-1} in the winter at the fourth site (Al-Balaj), and the lowest concentration was 1.48 mg kg^{-1} in the spring at the fifth site (Al-Alam District).

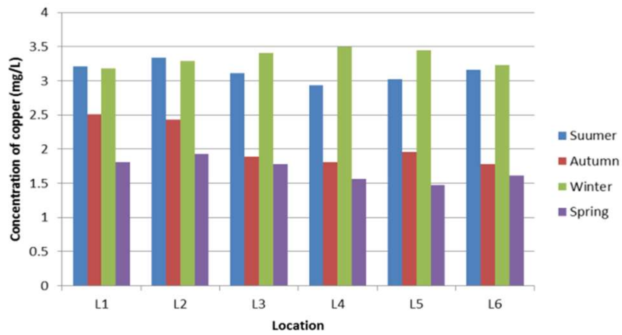

Figure 3. Copper concentration in plant root samples (mg L^{-1}).
Figura 3. Concentração de cobre em amostras de raízes de plantas (mg L^{-1}).

4. DISCUSSION

The variation in zinc values is due to the type of plant, as some of them can absorb zinc. It is collected in its tissues, so it is used to treat pollution, such as cane and castor. As for others, their ability to accumulate zinc in their tissues is less. The other reason is the difference in the percentage of zinc concentrations in the seasons. For example, zinc values increase in the dry season in the summer with high temperatures and low levels. It was watering the soil and relying on irrigation with water contaminated with heavy metals by farmers, which increased its concentration in the soil and plants. However, in the rainy season in winter and spring, its percentage decreases because the rain works to dilute and wash away the soil water, as well as not relying on irrigation during the winter season, and this is what many studies support (SAFFARI; SAFFARI, 2013; WANG et al., 2015; ALMUKTAR et al., 2018). In general, the amount of zinc decreases in the rainy season, while its concentration increases in the summer with high temperatures and evaporation, thus increasing its accumulation in the soil and then accumulating in the plant.

Table 1. Zinc concentration in plant root samples during the study period (mg L^{-1}).
Tabela 1. Concentração de zinco em amostras de raízes de plantas durante o período de estudo (mg L^{-1}).

Location / Season	L1	L2	L3	L4	L5	L6	Mean of location
Summer	5.25	3.65	4.25	4.75	5.74	4.74	4.73 BC
Autumn	3.65	4.88	4.65	5.03	3.09	3.82	3.68 C
Winter	6.85	3.46	5.09	3.80	7.83	7.27	5.71 B
Spring	8.32	3.66	9.54	9.97	13.51	9.88	9.15 A
Mean of season	6.01 a	4.16 a	5.88 a	5.89 a	7.54 a	6.43 a	

The letter a represents the highest value that appears in the results
Values bearing the same letter are not significantly different from each other.

Table 2. Concentration of copper in plant roots during the study period (mg L^{-1}).
Tabela 2. Concentração de cobre nas raízes das plantas durante o período de estudo (mg L^{-1}).

Location / Season	L1	L2	L3	L4	L5	L6	Mean of location
Summer	3.21	3.34	3.11	2.94	3.02	3.16	3.13 B
Autumn	2.51	2.43	1.89	1.81	1.96	1.78	2.06 C
Winter	3.18	3.29	3.41	3.50	3.45	3.23	3.34 A
Spring	1.81	1.93	1.78	1.56	1.48	1.61	1.69 D
Mean of season	2.62 a	2.74 a	2.54 a	2.45 a	2.47 a	2.44 a	

The letter a represents the highest value that appears in the results
Values bearing the same letter are not significantly different from each other.

The decrease in copper in the plant is due to the plant's weak leaf and root growth. In addition to the increase in the pH of the soil, copper deficiency is also due to the weakness of the enzymes that transfer copper from the root to the stem and leaves, where the plant absorbs the element in its ionic form (Cu) and increases the plant’s resistance to fungi. The increase in the element in the plant is due to the lack of acid function in the winter, which leads to an increase in the element's availability in the soil and plants (TAHER; SAEED, 2021; AL-BAYATI, 2022).

5. CONCLUSIONS

The study indicated a clear difference in the concentrations of heavy metals during the different seasons. The concentrations were highest in summer and lowest in winter in general, and zinc recorded the highest concentrations compared to copper. Population and industrial activity clearly impacted increasing heavy metal concentrations, as locations near pollution towards the city have the highest concentrations.

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