Comparative Assessment of Heavy Metals Content in Soil and Irrigation Water Between Two Sites in Bani Saad, Diyala Governorate

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Abstract
The assay was carried out to evaluate the comparison between sampling locations and sampling types in terms of heavy metal content, viz., Cd, Ni, Cu, and Pb, which included a factorial experiment according to the CRD design, as it involved studying two factors: the first factor was the sampling location, which included Al-Hawli and Al-Damanah, belonging to the Bani Saad region, Diyala Governorate, Iraq; the second factor was the sampling type, which included soil and irrigation water. The Al-Damanah location was significantly superior in the heavy metal content, viz., Cd, Ni, Cu, and Pb, which recorded the highest rate, reaching 0.67, 14.46, 40.49, and 9.37 ppm, respectively, compared to the Al-Hawli location, which recorded the lowest rate of 0.48, 12.09, 30.43, and 7.72 ppm, respectively. Also, the soil sample was significantly superior in the heavy metal content, which recorded the highest rate, reaching 0.81, 15.52, 46.63, and 14.88 ppm, respectively, compared to the irrigation water, which recorded the lowest rate of 0.34, 11.03, 24.29, and 2.21 ppm, respectively.

Keywords. Heavy metal, Al-Damanah location, and Al-Hawli location

Introduction

Heavy metal contamination of the soil, atmosphere, and overall environment is a major problem, primarily caused by atmospheric deposition, industrial effluents, the application of artificial fertilizers, and the inappropriate disposal of waste from plants and animals, where higher concentrations of these metals tend to accumulate in various environmental components due to both natural and man-made activities, particularly in regions with intensive industries and agriculture. Additionally, the total heavy metal content of the soil is commonly used to indicate the degree of contamination [19]. The main factor contributing to pollution buildup is industrialization. The fertility of soil is directly impacted by the use of both treated and untreated waste water in agriculture, and contaminated soil poses a threat to the food chain and groundwater quality [13]. Environmental pollution from heavy metals has spread rapidly worldwide over the past decades due to their non-biodegradability and, often, their toxicity even at low concentrations [9]. These metals can enter the human body through various routes, such as inhaling dust, skin contact with contaminated soil, and consuming food products grown in polluted soil [21]. The concentration of heavy metals in irrigation water, soil, and vegetables in agricultural fields has increased as a result of human, natural, agricultural, and industrial activities (such as the use of pesticides and fertilizers, mining, and sewage discharge) [2,17]. One cause of soil and agricultural product contamination with heavy metals is the use of irrigation water contaminated with industrial wastewater. If soil is irrigated with sewage water, the concentration of heavy metals in the edible parts of plants will increase [5]. In other words, the transfer of heavy metals from soil to plants, and their subsequent consumption by humans, is the primary pathway for human exposure to heavy metals, furthermore, excessive exposure to manganese and nickel, in addition to increasing the incidence of atopic dermatitis and eczema, may be associated with reduced IQ in children [7]. The World Health Organization (WHO), Food and Agricultural Organization (FAO), and Ewers U, have established the maximum allowable limits of heavy metals in soils and irrigation water, according to standard guidelines in Europe, where the maximum permissible level in soil (µg/g) of Cd, Ni, Cu, and Pb were (3, 50, 100, and 100 µg/g), respectively, while the maximum permissible level in irrigation water (µg/ml) was (0.01, 1.40, 0.017, and 0.065 µg/ml), respectively [8]. The Bani Saad region, located in Diyala governorate, south of Baghdad, in Iraq, faces the potential for heavy metal contamination of surrounding agricultural lands. To date, no studies have been conducted to assess heavy metal concentrations in the soil and water. Therefore, the primary objective of this study is to compare the heavy metal content between the soil and irrigation water at two sites in the Bani Saad district.

Materials and methods

The study was conducted at the private laboratory of Diyala green gold, on May 11, 2026, to evaluate the comparison between sampling locations and sampling types in terms of heavy metal content, viz., Cd, Ni, Cu, and Pb, which included a factorial experiment according to the CRD design, as it involved studying two factors: the first factor was the sampling location, which included Al-Hawli and Al-Damanah; the second factor was the sampling type, which included soil and irrigation water.

Sampling Collection

Samples were collected from two locations in the Bani Saad area of Diyala Governorate, Iraq: Al-Hawli and Al-Damanah. Two fields were selected for sampling at each location. Samples were taken from five different areas of each field: four from the edges and one from the center. Each sample contained between 250 and 300 grams. These samples were then mixed together to create a single sample of two fields for each location. The samples were taken from the root zone of the plants, while the water samples were collected from irrigation water in the fields of Al-Hawli and Al-Damanah. Each sample contained one liter of water and was collected using plastic containers. Details of the sampling collection locations in the fields and the plants grown there, as well as the GPS positions, are shown in Table 1.

Table 1. The sampling collection locations from the fields with the plants grown in these fields, and their GPS positions

Fields	Location (GPS positions)			
	Al-Hawli	Plant	Al-Damanah	Plant
Field 1	33°35'30.1"N 44°34'29.5"E	Tomato	33°36'20.3"N 44°30'44.7"E	Squash
Field 2	33°34'41.1"N 44°34'44.2"E	Okra	33°36'38.3"N 44°31'33.2"E	Tomato & pepper

Soil samples preparation

The preparation of soil samples included steps according to [12].

Drying: Place soil samples in paper trays to air dry at room temperature.
Grinding and Sieving: Grind the dried soil using a mortar and pestle and pass it through a 2 mm sieve.
Weighing and Digestion:
Accurately weigh 1 g of the finely ground sample and place it in a digester beaker, then add 15 mL of aqua regia.
Heating: Place the beaker on a hot plate at approximately 70–85°C and allow it to boil slowly until the brown smoke disappears and the solution becomes almost transparent.
Filtration and Dilution: Allow the solution to cool, then add a small amount of the double-distilled water and pass it through filter paper (Whatman No. 42), then rinse the beaker and paper with distilled water and transfer the entire filtrate to a 50 mL volumetric flask and complete the volume to the mark.

Water samples preparation

The preparation of water samples included steps according to [12].
The sample is stored in clean plastic (polyethylene) or glass containers and acidified by adding a few drops of concentrated nitric acid until the pH reaches < 2, the sample is then refrigerated.
Shaking and Filtration: The sample is shaken well and then passed through 0.45 µm filter paper to remove suspended solids before digestion begins.
Digestion: A known volume of the sample (50 mL) is taken into a glass flask, 5 mL of concentrated nitric acid is added, and the flask is heated on a heating plate until the solution slowly evaporates to a small volume of 20 mL without allowing the sample to dry out completely.
Cooling and Dilution: The flask is allowed to cool, then an additional 2 mL of concentrated nitric acid is added. The solution is reheated briefly to ensure complete digestion of the organic matter. Afterward, the solution is cooled and transferred to a 50 mL or 100 mL measuring flask, and the volume is topped up with distilled water. Then the complete readings are taken.

Method of heavy metal testing

Cadmium, nickel, copper, and lead were measured using a spectrophotometer on May 17, 2026, by treating soil and water samples as described in [18,6].

Statistical analysis

The statistical data were analyzed using the statistical program SPSS at a probability level of 0.05 [3].

Results and discussion

Cadmium (Cd)

The results in Table 2 indicate that there were significant differences in cadmium content between the sampling location and sampling type. The Al-Damanah location achieved the highest content of cadmium, reaching 0.67 ppm compared with Al-Hawli location, which recorded 0.48 ppm; significant differences were also observed between sample types, as the soil sample achieved the highest content of cadmium, reaching 0.81 ppm compared with the irrigation water sample, 0.34 ppm. For the interaction between the sampling location and sampling type, the combination of Al-Damanah location with the soil sample recorded the highest value (0.92 ppm), while the combination of Al-Hawli location with the irrigation water sample recorded the lowest value (0.26 ppm).

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Table 2. Comparative assessment between sampling location and sampling type in cadmium content

Cadmium (Cd)			
Location (A)	**Sample type (B)**		
	Soil b1	Irrigation water b2	Mean
Al-Hawli a1	0.7 b	0.26 d	0.48 b
Al-Damanah a2	0.92 a	0.43 c	0.67 a
Mean	0.81 a	0.34 b	

Nickel (Ni)

The results in Table 3 show that the Al-Damanah location outperformed the Al-Hawli location in nickel content, which recorded the highest mean, reaching 14.46 ppm, compared to the Al-Hawli location, which recorded the lowest mean of 12.09 ppm. Furthermore, the soil sample outperformed the irrigation water sample in nickel content, which recorded the highest mean, reaching 15.52 ppm, compared to the irrigation water, which recorded the lowest mean of 11.03 ppm. Regarding the interaction between the sampling location and sampling type, the combination of Al-Damanah location with the soil sample recorded the highest mean (17.07 ppm), while the combination of Al-Hawli location with the irrigation water sample recorded the lowest mean (10.22 ppm).

Table 3. Comparative assessment between sampling location and sampling type in nickel content

Nickel (Ni)			
Location (A)	**Sample type (B)**		
	Soil b1	Irrigation water b2	Mean
Al-Hawli a1	13.97 b	10.22 d	12.09 b
Al-Damanah a2	17.07 a	11.85 c	14.46 a
Mean	15.52 a	11.03 b	

Copper (Cu)

The results in Table 4 reveal that the Al-Damanah location was significantly superior in the copper content, which recorded the highest rate, reaching 40.49 ppm, compared to the Al-Hawli location, which recorded the lowest rate of 30.43 ppm. Also, the soil sample was significantly superior in the copper content, which recorded the highest rate, reaching 46.63 ppm, compared to the irrigation water, which recorded the lowest rate of 24.29 ppm. As for the interaction between the sampling location and sampling type, the Al-Damanah location and the soil sample achieved the highest rate (52.92 ppm), while the Al-Hawli location and the irrigation water sample achieved the lowest rate (20.52 ppm).

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Table 4. Comparative assessment between sampling location and sampling type in copper content

Copper (Cu)			
Location (A)	**Sample type (B)**		
	Soil b1	Irrigation water b2	Mean
Al-Hawli a1	40.35 b	20.52 d	30.43 b
Al-Damanah a2	52.92 a	28.07 c	40.49 a
Mean	46.63 a	24.29 b	

Lead (Pb)

The results in Table 5 indicate that the Al-Damanah location had a significantly superior lead content, reaching 9.37 ppm, compared to the Al-Hawli location, 7.72 ppm. The soil sample had a significant superiority in the copper content, reaching 14.88 ppm, compared to the irrigation water, 2.21 ppm. When the interaction between the treatments, the combination between the Al-Damanah location and the soil sample achieved the highest rate (16.17 ppm), while the Al-Hawli location and the irrigation water sample achieved the lowest rate (1.85 ppm).

Table 5. Comparative assessment between sampling location and sampling type in lead content

Lead (Pb)			
Location (A)	**Sample type (B)**		
	Soil b1	Irrigation water b2	Mean
Al-Hawli a1	13.60 b	1.85 d	7.72 b
Al-Damanah a2	16.17 a	2.57 c	9.37 a
Mean	14.88 a	2.21 b	

Through the study results, the Al-Damanah location had a significantly superior heavy metal content compared to the Al-Hawli location. The difference might be attributed to farmers in the Al-Damanah location who use animal fertilizers extensively for agriculture, especially poultry manure, and there are also some industrial factories in that region. This agrees with [16], who reported that natural and anthropogenic factors cause soil pollution, which affects the environment. Furthermore, the soil sample had a significant superiority in heavy metal content compared to the irrigation water. The increased concentration of heavy elements in soil samples, compared to water samples, is due to the high cation exchange capacity of soil particles and their ability to adsorb cationic ions of elements. This is further influenced by the long-term cumulative effect of repeated irrigation processes and the precipitation of elements in a soil environment with an acidic (pH) value that tends toward alkalinity, which reduces the solubility and mobility of these elements in the aqueous solution [2]. The growing industrial and agricultural sectors are causing heavy metal concentrations in soil to rise above average [14]. Heavy metals are considered especially hazardous and deadly pollutants in the environment since they are not biodegradable [15]. The problem with heavy metal contamination of soil is the possibility for heavy metals to be transported to

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other locations by wind and runoff water, resulting in an accumulation of these elements [4]. Plants in agricultural areas have the potential to introduce heavy metals into the human food chain. Furthermore, crop productivity is limited and decreased by heavy metal accumulation in agricultural soil [10]. The growing use of pesticides and fertilizers in agricultural areas, as well as the rapid expansion of industry, has resulted in the accumulation of heavy metal in the environment [22]. Heavy metals extracted from air deposits in surface soil can accumulate through precipitation, trapping and interception [1]. Heavy metals from the soil may be released into the nearby water due to both natural and man-made mechanisms [11]. The natural sources such as dust storms and airborne deposition contribute to soil contamination through an increase of heavy metals [20].

Conclusion

The results of the current study reveal a clear spatial and environmental variation in the distribution and concentration of the studied heavy metals. The highest levels of contamination and accumulation of these metals were recorded in samples of the Al-Damanah location compared to the Al-Hawli location, with a significant difference. Furthermore, the environmental comparison revealed that the soil environment contained significantly higher concentrations of heavy metals compared to the irrigation water, confirming the role of soil as a permanent accumulation reservoir for pollutants due to its adsorption properties and high cation exchange capacity. As for the interaction, the soil composition of the Al-Damanah location constituted the epicenter of maximum accumulation of heavy elements in the study area, necessitating continuous environmental monitoring and urgent management to mitigate the risk of these pollutants entering the food chain.

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