EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(11), 168–178
https://doi.org/10.12912/27197050/192588
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.08.18
Accepted: 2024.09.15
Published: 2024.10.01

Biological Reclamation of Agricultural Soils Contaminated with Some Heavy Metals by Using the Currant Plant *Hibiscus sabdariffa* L.

Mohammed Malik Hamid[1*], Mohammad Tarkhan Abo Almaeakh[2]

[1] Technical Collage of Al-Mussaib, Al-Furat Al-Awsat Technical University, Iraq

* Corresponding author's e-mail: mohammed.hamid@atu.edu.iq

ABSTRACT

Bioremediation is used to reduce the effect of industrial and agricultural pollutants in contaminated soil, which in turn leads to removing and reducing the toxicity of heavy metals polluting the soil. This study evaluates the possibility of using the currant plant to reduce the concentration of heavy metals in some polluted soils within different locations in Babil Governorate. Soil samples were taken from four sites, representing agricultural soil irrigated with wastewater, soil adjacent to a brick factory, and soil adjacent to a sterile drinking water factory, in addition to a control sample, which is agricultural soil irrigated with river water. The soil samples were analyzed Soil to determine the general characteristics and concentration of the total heavy elements represented by lead (Pb), cobalt (Co), nickel (Ni) and zinc (Zn). Then the pollution standards for the soil and plants were calculated and the averages were compared using the least significant difference test at the 5% level. The results showed that nickel and Zinc were significantly superior to the total content of elements in the soil, and the lowest values were for Cobalt. The values of the contamination factor for the soil showed that nickel was in first place, followed by Cobalt, then Lead and Zinc. As for the pollution load index (PLI), its value was highest in the agricultural soils adjacent to the bricks factory, while the values of the accumulation index (I_{geo}) indicated that the Nickel element had surpassed on Cobalt, Zinc and lead. The concentration of elements in the plant shoots indicated a superiority in Zinc and Cobalt, while Nickel and Lead were superior in the root system. The BCF index was less than one for all sites except agricultural soils irrigated with river water, and the site transfer factor TF values were greater than 1 In the elements Cobalt and Zinc. The results also showed that the currant plant is one of the plants that accumulates the heavy metals because it does not show negative symptoms during its growth and thus the possibility of using it to reduce the risk of heavy elements in the soil.

Keywords: heavy metals, soil pollution, bioaccumulation coefficient, plant pollution, currant plant.

INTRODUCTION

The total content of heavy elements in the soil expresses the total concentrations of elements derived from minerals and geological origin materials in developed soils as well as raindrops containing heavy elements or in the form of gases of heavy elements and direct additions of agricultural fertilizers, whether mineral or organic (Saed and Hamid, 2024). Heavy water, food waste, and industrial material residues such as ashes, mine and mining waste, and military projectiles can all be contaminated in the soil. Therefore, the total concentration of heavy elements in the soil is the sum of all those various inputs minus the losses through pasture plants or harvested plants and erosion of soil particles. Through wind or water and infiltration to the bottom of the soil and what is lost through evaporation in the form of gases elements (Nortje and Laker, 2021).

The term environmental pollution is defined as the physical, chemical and biological changes that occur under the influence of a factor such as in factories. Soils differ in their mineral content and these minerals are present in different forms. In a study conducted by Hikon and Yebpella,2024 on the availability of minerals, it was found that the availability of biological minerals can change over time. Yerim and Atoshi, 2023 also indicated that one of the sources of adding heavy elements to the soil is the pharmaceutical industry, as pharmaceutical industries, in addition to other industries, contribute to adding heavy elements to the soil and also affect the necessary minerals in the soil such as magnesium and calcium. In a study also conducted by Gharbi et al., 2024 on areas affected by dust emissions from cement factories, it was found that the concentrations of cadmium, cobalt, nickel and lead are high compared to standard levels. also Dyguś, 2018 conducted an experiment in the bioremediation of coal-fired power waste, and emphasized the importance of plants in the biological reclamation of furnace waste deposits, which contributes to increasing the active area and improving the natural environment. Siuta and Dyguś, 2015 also found that when reclamation of compost resulting from a mixture of municipal waste, urban green waste compost and sewage sludge, it was found that biological reclamation has a significant effect in reducing soil pollution and various types of pollution.

The phytoremediation technique can be classified on the basis of the treatment mechanisms, which is the withdrawal of pollutants from the soil and their concentration in plant tissues or the breakdown of pollutants by various biotic and abiotic processes in plants such as volatilization or restriction and paralysis of the movement of pollutants in the root zone (Gavrilescu, 2022).

Bioremediation is a low-cost and high-efficiency method compared to using other chemical methods, as plants that accumulate heavy elements and have a high ability to collect in plant tissues are used in this process (Mahmood, 2016)

The phytoremediation process is based on the use of plants to restrict the movement and readiness of pollutants in the soil by roots (Rai et al., 2021). It is possible to use this method in treating polluted soils and sewage waste, but it has not been tested with organic pollutants. An example of this case is the ability of the Indian mustard plant, Brassica. juncea was able to reduce hexavalent chromium to trivalent chromium, and some weeds growing in mining areas were able to fix lead, copper and zinc (Amare and Workagegn, 2022). As indicated by Yaashikaa et al. (2022) and that the technique of using plants is useful in restricting and reducing the movement of pollutants and heavy elements in the environment by absorbing them by the roots of plants and not transferring them to other parts of plants or restricting them within the roots of plants by secreting chelating compounds or organic substances or Transforming the image of the element into a form that is less ready for the plant or reduces the movement of pollutants and heavy elements in the soil Phytoextraction also includes the process of absorbing pollutants in the soil and concentrating them in the tissues of plants that accumulate pollutants, and this process is the most widely used, and this process is also called Phytoaccumulaation, and it is called Plants with hyperaccumulators, which are plants that have the ability to absorb relatively high concentrations of heavy elements and transfer them to the branches or to the different plant parts to collect in them. Such plants can be used to remove heavy elements from contaminated soil, and then these plants are disposed of (Pietrelli et al., 2022), an example of this is the plant hibiscus sabdariffa, which can accumulate lead and copper (Wuana et al., 2013). The study aims at the possibility of using the pomegranate plant to reduce pollution with some heavy elements present in agricultural soils that are irrigated with sewage water and those that are located near factories in Babil Governorate.

MATERIALS AND METHODS

Study area

A field experiment was carried out in the year 2023 to study the possibility of using the currant plant in reducing the concentration of heavy elements in some polluted soils in different locations in Babil Governorate. A control representing agricultural soil irrigated with river water, and soil samples were taken that represent the surface layer and a depth (0–50 cm) for those sites. The soil was collected and soil samples were analyzed to find out the general characteristics and the concentration of the total heavy elements represented by lead, cobalt, nickel and zinc. The soil sites subject to the test process represented: Agricultural soil irrigated with river water (control soil P1), agricultural soil irrigated with sewage water (P2), agricultural soil adjacent to the Mahaweel brick factory (P3), and agricultural soil adjacent to the Aafiyat water factory (P4). Table 1 represents the general characteristics of the soils used in the study.

Table 1. The coordinates, texture and some chemical properties of the soils of the studied sites

SOM $gm \cdot kg^{-1}$	$CaCO_3$ $gm \cdot kg^{-1}$	CEC Cmol + kg^{-1}	pH	ECe dS m^{-1}	Text.	Clay $gm \cdot kg^{-1}$ soil	Silt $gm \cdot kg^{-1}$ soil	Sand $gm \cdot kg^{-1}$ soil	Coordinates of locations		S
									E	N	
11.6	26.7	22.4	7.2	6.3	SiCL	366.0	488.0	146.0	32.545	44.205	P1
10.6	26.8	20.1	7.5	4.4	CL	322.4	357.6	320.0	32.348	44.176	P2
12.4	21.9	24.2	7.7	3.8	C	436.0	342.0	222.0	32.713	44.381	P3
9.1	24.6	20.3	7.8	3.6	SiCL	330.4	489.2	180.4	32.388	44.767	P4

Laboratory analysis

The samples were placed in plastic bags, dried, ground and then sieved for the purpose of conducting chemical analyzes (pH, electrical conductivity, cation exchange capacity, organic matter and calcium carbonate) according to the methods mentioned in (Page et al., 1982). As for the total heavy elements, which represent (lead, cobalt, nickel and zinc) were estimated by extraction using a mixture of (Diethylene-Triamine-Penta-Acetic Acid (DTPA)) concentration of 0.005 M with 0.01 M of Calcium Chloride and 0.1 M of Tri Ethanol amine solution at a reaction rate of 7.3 with a ratio of 1 soil: 2 extraction solution According to the method described by (Norvell and Lindsay, 1978), then the heavy metals in the digestion solution were estimated using an atomic absorption spectrophotometer and according to the wavelength of each element.

Experiment

A potted experiment was carried out in a wooden canopy in Babil Governorate, where the seeds of the currant plant directly in plastic pots (with a capacity of 25 kg) by 3 seeds each on 10/3/2023, then the plants were reduced to one for each pot when the number of leaves reached 6 in each plant. Nitrogen fertilizers were added at the rate of 180 kg H^{-1} in the form of urea (46% nitrogen) in two batches, the first two weeks after planting and the second one month after planting, while phosphate fertilizer was added at the rate of 80 kg H^{-1} in the form of calcium phosphate (16% phosphorus) mixed with The soil before planting, while potassium fertilizer was added in the form of potassium sulfate (45% potassium) at a rate of 120 kg H^{-1} after 45 days of planting. The experiment continued for 180 days, after which the plants were extracted, and the length of the main root and the number of leaves for each plant were measured in the experimental units. The elements of lead, cobalt, nickel and zinc were estimated after drying, digestion and extraction for each of the shoot (stem and leaves) and the root system according to the methods presented by Al-Naimi 1999. The following pollution standards were used for soils affected by heavy metals according to the following equations (Hakanson, 1980):

1. Contamination factor:

$$CF = C_{m\ sample}/C_{m\ control} \quad (1)$$

where: CF – the pollution coefficient, $C_{m\ soil}$ – the concentration of the element in the sample soil, $C_{m\ controls}$ – the concentration of the element in the control soil.

2. Pollution load index (Hakanson, 1980) (Table 2):

$$PLI = (CF_1 \times CF_2 \times \ldots\ldots \times CF_n)1/n \quad (2)$$

where: CF_1 is the pollution factor of the first element, CF_2 is the pollution factor of the second element, CFn is the pollution factor of the last element.

3. Geoaccumlation index (Table 3):

$$Igeo = log\ 2\frac{C\ sam.}{1.5\ C\ con.} \quad (3)$$

where: C_{sam} – the concentration of the pollutant in the soil (mg kg^{-1}), C_{con} – the concentration of the pollutant in the control soil sample (mg kg^{-1}) (Table 4).

As for the pollution criteria for plants, they are:

1. Bio contamination factor (BCF1) (Yoon et al. 2006):

Table 2. The values of the pollution factor index

Classification	CF value
Low contamination	CF < 1
Moderate contamination	≥1CF 3<
Considerable contamination	≥ 3 CF 6 <
Very high contamination	CF ≥ 6

Table 3. The values of the pollution factor index based on the classification of Hakanson, (1980)

Classification	PLI value
Nil to very low contamination	< 1.5
Low degree contamination	1.5 > PLI 2 <
Moderate contamination	2 > PLI 4 <
High contamination	4 > PLI <8
Very high contamination	8 > PLI <16
Extremly contamination	16> PLI <32
Ultra high contamination	<32

Table 4. Index of geoaccumulation (I geo) for contamination levels in the soils

Igeo class	Igeo value	Contamination level
0	Igeo ≤ 0	Uncontaminated
1	0 < Igeo < 1	Uncontaminated
2	1 < Igeo < 2	Uncontaminated/moderately contaminated
3	2 < Igeo < 3	Moderately contaminated
4	3 < Igeo < 4	Moderately/strongly contaminated
5	4 < Igeo < 5	Strongly contaminated
6	5< Igeo	Strongly/extremely contaminated

$$BCF1 = (Metal)Root/(Metal)Soil \quad (4)$$

where: *BCF* – the biological concentration factor, *Metal Root* – the concentration of the element in the root system (mg kg $^{-1}$ dry matter), *Metal Soil* – the total concentration of the element in the soil (mg kg $^{-1}$).

If the BCF value is greater than one, this indicates the high ability of the plant to absorb and accumulate the heavy element in its tissues, but if the value is less than one, this indicates the inability of the plant to absorb the heavy element from the soil in sufficient quantity**.**

2. Bioconcentration factor in plants (root system + shoot system (BCF2))

$$BCF2 = (Metal)plant/(Metal)Soil \quad (5)$$

where: *BCF*2: biological concentration factor, metal plant: concentration of the element in the whole plant (mg kg^{-1} dry matter), (*Metal*) *Soil*: the total concentration of the element in the soil (mg kg^{-1}).

3. Bio accumulation coefficient (BAC).

$$BAC = (Metal)Shoot/(Metal)Soil \quad (6)$$

where: *BAC* – bioaccumulation coefficient, *Metal Shoot* – the concentration of the element in the vegetative part (mg kg^{-1} dry matter), *Metal Soil* – the total concentration of the element in the soil (mg kg^{-1}).

4. Translocation factor (TF)

$$TF = (Metal)shoot/(Metal)Root \quad (7)$$

where: *TF* – transfer factor, (*Metal*) *shoot* – the concentration of the element in the vegetative part (mg kg^{-1}dry matter), (*Metal*) *Root* – the concentration of the element in the root system (mg kg^{-1} dry matter).

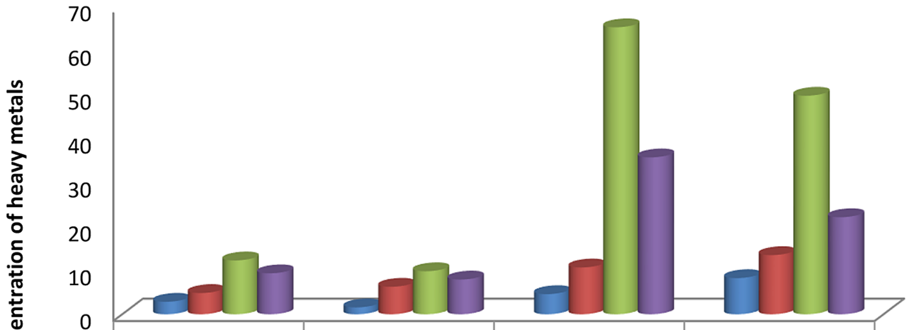
RESULTS AND DISCUSSION

The concentration of heavy metals in the soil of the studied sites

The results of Figure 1 indicate that there are significant differences in the soil content of the studied heavy elements in the research soil sites. Followed by the agricultural soils in the Afiat factory site, while the lowest values were in the agricultural soil site that was irrigated with river water. As for the cobalt element, it appeared with values that ranged between (1.56–9.78) with an average of 6.37 mg kg^{-1}. The highest values were in the agricultural soils adjacent to the Mahaweel Bricks Factory site. Followed by the agricultural soils in the site of the Afiat factory, while the lowest values were in the agricultural soil site that was irrigated with river water, while the nickel element appeared with values that ranged between (4.58–65.25) with an average of 29.04 mg kg^{-1}, and the highest values were in the agricultural soils adjacent to the Mahawil brick factory site Followed by the agricultural soils in the Afiat factory site, while the lowest values were in the agricultural soil site that was irrigated with river water. Finally, the zinc element appeared with values that ranged between (8.22–49.69) with an average of 23.36 mg kg^{-1}, and the highest values were in the agricultural soils adjacent to the site. Mahaweel brick factory, followed by the agricultural soils at the Afiat factory site, while the lowest values were in the agricultural soil site that was irrigated with river water. The increase in the concentrations of the elements for the different treatments and the difference in the concentration in their different locations may be due to the increase in the variability of the sites, how they are used and the sources of pollution in them, which is in line with what Odeh (2018) found, who noticed an increase in the concentration of the elements nickel and zinc in the soil with the proximity of agricultural soil sites to industrial sites. This may be due to the increased precipitation of lead in the calcareous soil in the form of carbonates. We showed that the high degree of soil interaction leads to the precipitation of heavy elements in the form of carbonates, as it is consistent with the findings of Al-Halfi (2012), which showed that soils with a high content of carbonate minerals have a great ability to adsorb or precipitate heavy elements in the soil in the form of carbonates. It also falls within the range of the total cu concentration in the calcareous soil (10–70 mg kg^{-1}), which is below the range of the critical limits that range from 60–150 mg cu kg^{-1} soil. The total cobalt element in the soil is the critical limits of 20–50 mg Co kg^{-1} soil according to Pendias-Kabata, (2011).

Contamination factor (CF) values

The results of Figure 2 indicate that there are significant differences between the soil sites in the values of the pollution factor index. very closely



	Pb	Co	Ni	Zn
P1	2,83	1,56	4,58	8,22
P2	4,82	6,25	10,64	13,45
P3	12,24	9,78	65,25	49,69
P4	9,31	7,89	35,67	22,07

Figure 1. Concentration of heavy metals in the soil of the studied sites (mg kg^{-1} soil)

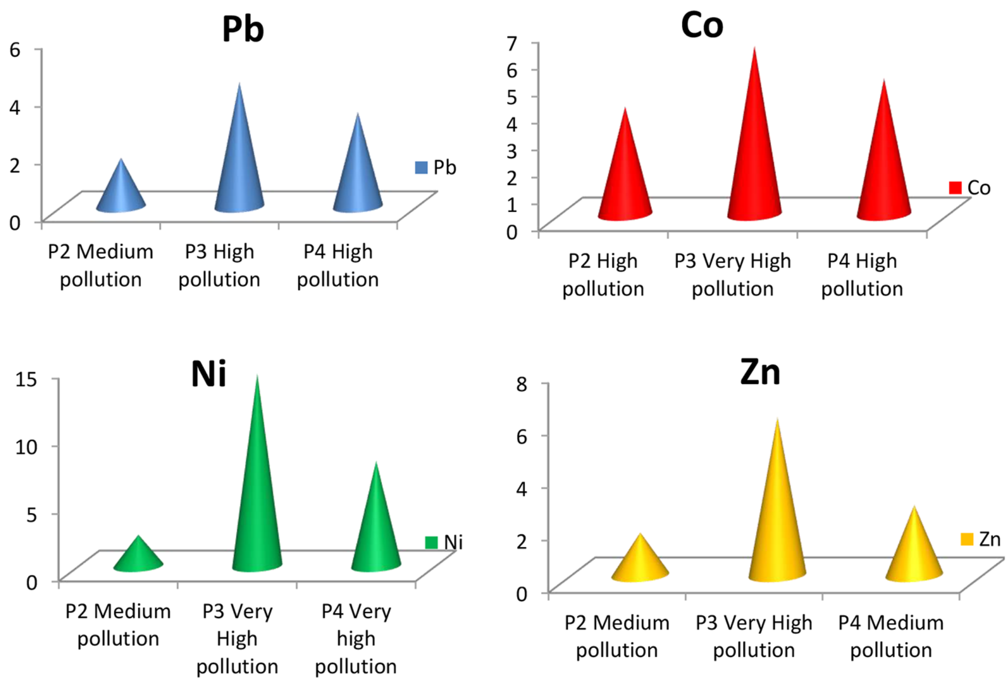


Figure 2. CF values for heavy metals in the soils of the studied sites

followed by the location of the agricultural soils adjacent to the Afiat factory with a high pollution classification, while the lowest values were in the agricultural soil site that was irrigated with sewage water and with a average pollution classification. as for the cobalt element, the values of the pollution factor index ranged between (4.006–6.269) with an average of 5.111, and the highest values were in agricultural soils. adjacent to the site of the Mahaweel Bricks Factory, with a very high pollution rating, followed by the agricultural soils adjacent to the Afiat Factory site, with a high pollution rating, while the lowest values were in the agricultural soil site that was irrigated with sewage water and with a high pollution rating. As for the nickel element, the values of the pollution factor index ranged between (2.323–14.247). With an average of 8.119, the highest values were in the agricultural soils adjacent to the Al-Mahaweel Bricks Factory site, with a very high pollution rating, followed by the agricultural soils adjacent to the Afiat Factory site, with a very high pollution rating, while it was the lowest. It was evaluated in the site of agricultural soil irrigated with sewage water with a average pollution classification. As for the zinc element, the values of the pollution factor index ranged between (1.636–6.045) with an average of 3.455. Afiat factory with a average pollution classification, while the lowest values were in the agricultural soil irrigated with sewage water and with a average pollution classification. The CF pollution factor is used to evaluate soil pollution for one element, (Asrari, 2015). To obtain the results of the pollution factor by measuring the concentrations of total elements in the soil on the concentration of the pollutant in the control sample. The high pollution of agricultural soils adjacent to factories and those that use sewage water in agriculture may be due to the wastes of those factories that are deposited on these soils Kebir and Bouhadjera (2011).

Polluted load index (PLI) values

The results of Figure 3 indicate that there are significant differences between the soil sites in the values of the pollution load index, and the general average for this index was 4.319. The agricultural soils adjacent to the Afiat factory site, with a value of 4.319, with a high pollution rating, while the lowest value for the pollution load index in agricultural soils irrigated with sewage water was 2.257, with a average pollution rating. The high values of the index may be due to the increase in the concentration of elements in soils adjacent to factories and those irrigated with sewage water (Table 5) compared to the amounts of the element in the control soil (those that use river water for irrigation). Mafuai et al. (2015).

Geoaccumulation index (Igeo) values

The results of Figure 4 indicate that there are significant differences between the agricultural soils adjacent to the studied sites in the values of the index of geological accumulation (Igeo). The crops were classified as average pollution, followed by the location of the agricultural soils adjacent to the Afiat plant, and the average pollution was classified, while the lowest values were in the location of the agricultural soil that was irrigated with sewage water, and the classification

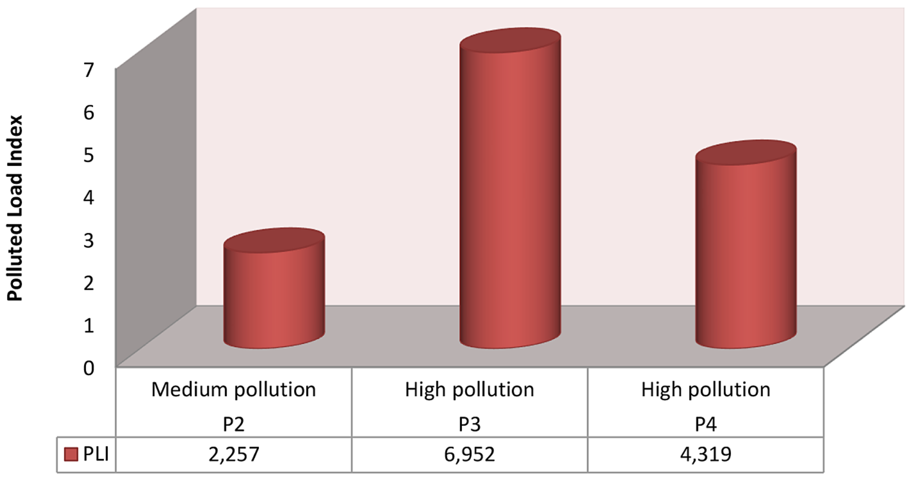


Figure 3. PLI values and their classification in the soils of the studied sites

Table 5. Indicators of vegetative and root growth of pomegranate

Root volume cm³	Root length cm	Leaf area cm²	Number of leaves	Sample location
54	43	2712	87	P1
47	39	2382	56	P2
33	28	1678	42	P3
36	32	1815	48	P4
42.5	35.5	2146.8	58.3	Average
2.68	3.45	167.5	4.82	LSD*0.05*

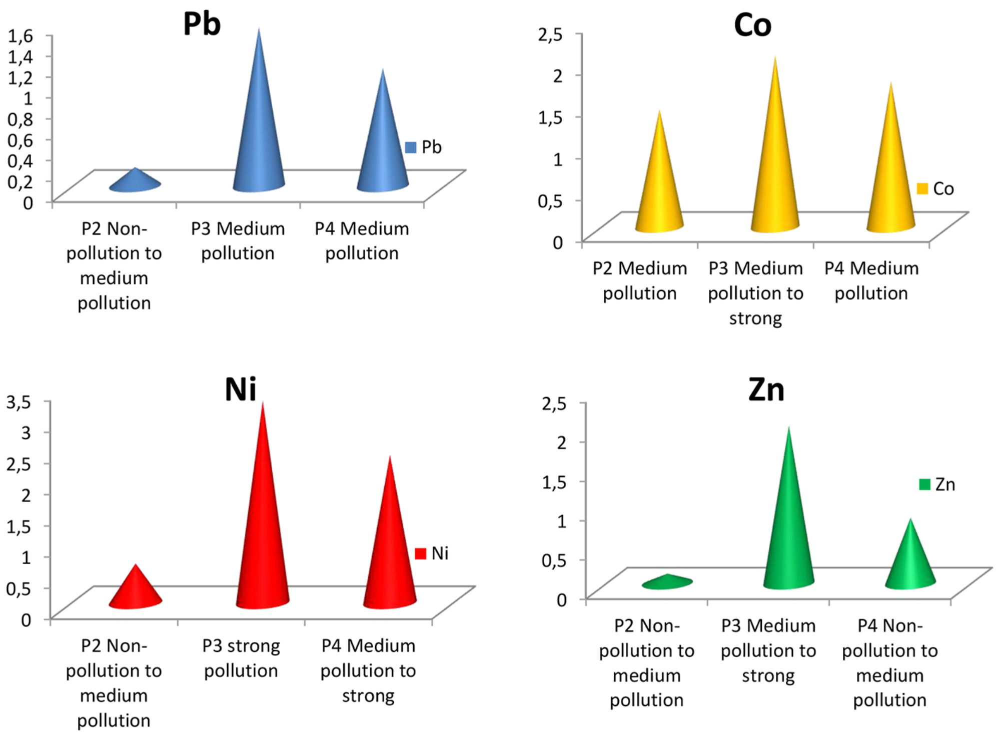


Figure 4. Igeo accumulation index values for lead and cobalt in the soils of the studied sites

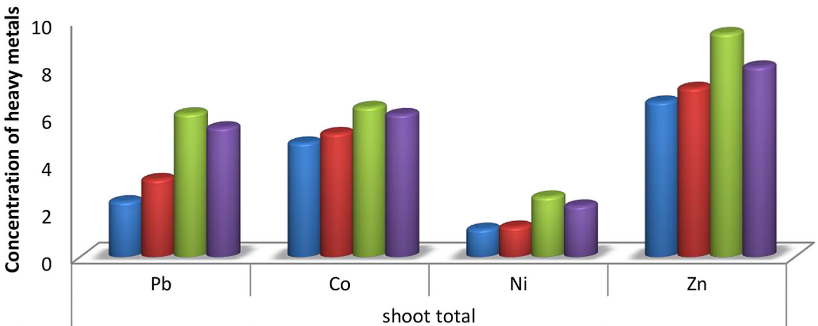
of non-pollution into average pollution. As for the cobalt element, the values of the pollution factor index ranged between (1.417–2.063) with an average of 1.745. The highest values were in the agricultural soils adjacent to the site of the Al-Mahaweel bricks factory, with a average to strong pollution classification, followed by the agricultural soils adjacent to the Afiat factory site, with a average pollution classification, while the lowest values were in the agricultural soil site that was irrigated with sewage water, and with a average pollution classification. As for the nickel element, the values of the index ranged The pollution factor ranged between (0.631–3.248) with an average of 2.085. The highest values were in the agricultural soils adjacent to the Mahaweel Bricks Factory site, with a strong pollution classification, followed by agricultural soils. Adjacent to the site of the Afiat plant, and with a average to strong pollution classification, while the lowest values were in the agricultural soil site that was irrigated with sewage water, and with a average pollution classification. As for the zinc element, the values of the pollution factor index ranged between (0.125–2.011), with an average of 0.992, and the highest values were in the neighboring agricultural soils. The location of the Mahaweel Bricks Factory, with a average to strong pollution classification, followed by the agricultural soils adjacent to the Afiat Factory site, with a non-pollution classification to average pollution, while the lowest values were in the agricultural soil site that was irrigated with sewage water, and with a non-pollution classification of average pollution. The high values of the index may be due to the increase in the concentration of elements in soils adjacent to factories and those irrigated with sewage water compared to the amounts of the element in the control soil (those that use river water for irrigation). Mafuai et al. (2015) found.

Indicators of vegetative and root growth

Table 5 shows some indicators of the vegetative and root growth of the currant plant after the end of the experiment. The results indicate that there are significant differences between the site soils in the characteristics of plant height, whose values ranged between (42–87 cm) with an average of 58.3 cm. The highest values were in agricultural soils irrigated with water. Rivers, followed by agricultural soils irrigated with sewage water, with an average of 56 cm, then the agricultural soils adjacent to the Afiat Water Factory, with a value of 48 cm, and finally the agricultural soils adjacent to the Mahawil Bricks Factory, with a value of 42 cm. Between (1678–2712 cm^2) with an average of 2146.75 cm^2, and the highest values were in the agricultural soils irrigated with river water, followed by the agricultural soils irrigated with sewage water, with an average of 2382 cm^2, then the agricultural soils adjacent to the Afiat Water Factory, with a value of 1815 cm^2, and finally the agricultural soils adjacent to the Mahaweel Bricks Factory, with a value of amounting to 1678 cm^2, and there are significant differences between the soils of the sites in the characteristic of root length, whose values ranged between (28–43 cm) with an average of 35.5 cm. The highest values were in the agricultural soils that It is irrigated with river water, followed by agricultural soils irrigated with sewage water, with an average of 39 cm, then the agricultural soils adjacent to the Afiat Water Factory, with a value of 32 cm, and finally the agricultural soils adjacent to the Mahaweel Bricks Factory, with a value of 28 cm. Its value ranged between (33–54 cm^3) with an average of 42.5 cm^3. The highest values were in the agricultural soils irrigated with river water, followed by the agricultural soils irrigated with sewage water with an average of 47 cm^3, then the agricultural soils adjacent to Afiat Water Factory with a value of 36 cm^3, then the agricultural soils adjacent to the brick factory. containers with a value of 33 cm^3.

Concentration of heavy metals in shoots and roots

Figures 5 and 6 illustrate significant differences in the content of heavy elements within the vegetative and root systems of currant plants across various agricultural soil sites. The root system showed the highest concentrations of heavy elements in soils near the Mahaweel Bricks Factory, while the lowest concentrations were found in soils irrigated with river water. Notably, the cobalt content varied significantly across sites, ranging from 4.82 to 6.32 mg kg^{-1} in the vegetative parts and from 3.07 to 4.19 mg kg^{-1} in the roots. Similarly, nickel concentrations ranged from 1.18 to 2.54 mg kg^{-1} in the vegetative system and from 7.24 to 10.11 mg kg^{-1} in the root system. Zinc content also showed variability, with values between 6.55 and 9.44 mg kg^{-1} in the vegetative system and between 4.25 and 6.14 mg kg^{-1} in the roots. The increased concentration of certain heavy elements in the vegetative system compared to the roots may be attributed to their higher availability in the soil, leading to greater absorption and accumulation in the leaves. The concentrations of



	Pb	Co	Ni	Zn
P1	2,34	4,82	1,18	6,55
P2	3,28	5,22	1,27	7,13
P3	6,05	6,32	2,54	9,44
P4	5,46	6,02	2,16	8,03

Figure 5. Concentration of heavy metals in shoots of plants after the end of the experiment

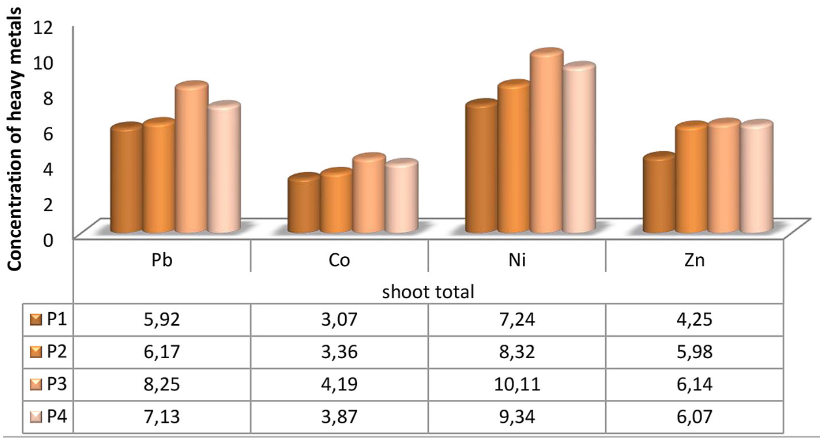


Figure 6. Concentration of heavy metals in roots of plants after the end of the experiment

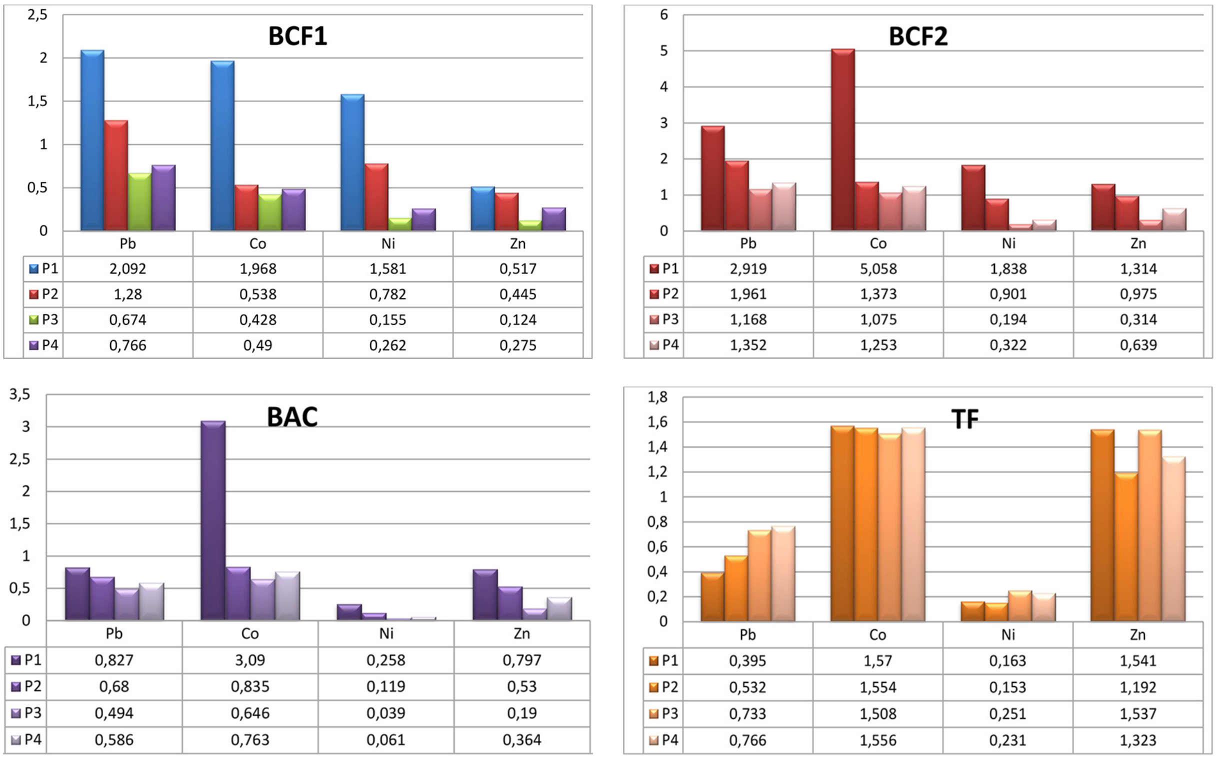


Figure 7. Indicators of contamination factor for marigolds at the end of the experiment

cobalt and zinc in the leaves correspond to their total amounts in the soil. However, the lead levels in the leaves remained below the critical threshold of 5 mg kg^{-1} dry matter. Additionally, cobalt levels did not exceed the permissible limit of 15 mg kg^{-1} dry matter in the mature leaf tissues.

Indicators of plant contamination factor

Figure 7 shows that there are significant differences between the agricultural soils of the studied sites in the characteristics of plant pollution factors. In the BCF1 bioconcentration factor, the values for lead ranged between (0.674–2.092), for cobalt (0.428–1.968), for nickel (0.155–1.581) and for zinc. (0.124–0.517) As for the values of the BCF2 coefficient, the values ranged between (1.168–2.919) and (1.075–5.058) and (0.194–1.838) and (0.314–1.314) for the above elements, respectively, while the values of the bioaccumulation coefficient ranged between (0.494–0.827), (0.646–3.090), 0.039–0.258) and (0.190 –0.797) for the elements, respectively. The values of the TF for the elements ranged between

(0.395–0.733), (1.508–1.570) and (0.153–0.213) and (1.092–1.541), respectively.

CONCLUSION

The study concludes that the current plant exhibits varying degrees of effectiveness in reducing the concentration of heavy elements in polluted soils, with a particular affinity for accumulating zinc and cobalt in its shoot system, while nickel and lead are more concentrated in the root system. The bioconcentration and transmission factors indicate that while the plant may not be universally effective across all elements, it shows potential for remediating soils with certain types of heavy metal contamination. These findings suggest that the current plant could be a viable option for phytoremediation in specific agricultural contexts within the Babil Governorate. Thus, the results indicated that the pollution parameters such as the concentrations of heavy elements such as Pb, Co, Ni and Zn decreased when treated with bioremediation. These results confirmed the pollution parameters that were measured, which are CF, PLI, BCF1, BCF2, BAC and TF. Thus, bioremediation is important in reducing the concentrations of heavy elements and preventing pollution, and thus, the possibility of reclaiming soils near industrial facilities with bioremediation.

REFERENCES

1. Al-Halfi, S.F., 2012. Measuring lead contamination in air, soil, and plants, Al-Taqni Journal, 25(2), 1–11.
2. Al-Nuaimi, S.N.A., 1999. Principles of Plant Nutrition. Dar Al-Kutub for Publishing, University of Mosul, Ministry of Higher Education, Iraq.
3. Amare, T.A., Workagegn, K.B. 2022. Phytoremediation: A novel strategy for the removal of heavy metals from the offshore of lake Hawassa using *Typha Latifolia* L. Soil and Sediment Contamination: An International Journal, 31(2), 240–252.
4. Asrari, E. 2015. Heavy metal contamination of water and soil analysis, Assessment, and Remedation Strategies Apple Academic Press, Canada CRC Press Tayler & Francis Group.
5. Dyguś, K.H. 2018. Vegetation of a multivariant model experiment on coal combustion waste deposits in the years 2005–2017. Ecological Engineering & Environmental Technology, 19(5), 26–35. https://doi.org/10.12912/23920629/94371
6. Gharbi, M.A., Abdulateef, A.A., Alalwany, A.A., Alenzy, A.F.M., Shafeeq, A.F. 2024. Pollution of some agricultural soils by heavy metals in Kubaisa Iraqi Western Desert – A case study. Ecological Engineering & Environmental Technology, 25(4), 215–226. https://doi.org/10.12912/27197050/183723
7. Hakanson, L. 1980. Ecological risks index for aquatic pollution control sediment logical approaches. Water Res. 14, 975–1001.
8. Hikon, B.N., Yebpella, G.G. 2024. Bioavailability of metals in the biosphere. Trends in Ecological and Indoor Environmental Engineering, 2(1), 41–49. https://doi.org/10.62622/TEIEE.024.2.1.41-49
9. Hossain, M.B., Masum, Z., Rahman, M.S., Yu J., Noman, Md A., Jolly, Y.N., Begum, B.A., Paray, B.A., and Arai, T. 2022. Heavy metal accumulation and phytoremediation potentiality of some selected mangrove species from the world's largest mangrove forest. Biology 11(8), 1144.
10. Kabata – Pendias, A. 2011. Trace elements in soils and plants. CRC. Press, Taylor and Francis Group. 253–268.
11. Kanwar, V.S., Sharma, A., Srivastav, A.L., Rani, L. 2020. Phytoremediation of toxic metals present in soil and water environment: a critical review. Environmental Science and Pollution Research, 27, 44835–44860.
12. Gavrilescu, M. 2022. Enhancing phytoremediation of soils polluted with heavy metals. Current Opinion in Biotechnology, 74, 21–31.
13. Kebir, T. and Bouhadjera, K. 2011. Heavy metals concentration in agricultural soils and accumulation in plants growing near of dumpsite of Ghazaouet (west of Al- Geria). International Journal of current research. 2(2), 42 – 49.
14. Mahmood, B.M., 2016. Estimation the levels of some heavy metals in the soil and vegetables irrigated with wells water in some agriculture fields at Al- Dora district – Baghdad. Iraqi J. of SCI., 57(3b), 1918–1925.
15. Nortjé, G.P., Laker, M.C. 2021. Factors that determine the sorption of mineral elements in soils and their impact on soil and water pollution. Minerals, 11(8), 821.
16. Norvall, W.A. and Lindsay, W.L. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Soc. Amer. J., 42, 121–428.
17. Odeh, M.M., 2018. The use of white radish and carrot plants in the central biochemistry of contaminated soil. Master Thesis, College of Agriculture, University of Baghdad.
18. Page, A.L, Miller, R.H. and Keeney, D.R., 1982. Method of soil analysis, part 2, 2nd Agron. Madison Wisconsin, U.S.A.
19. Pietrelli, L., Menegoni, P., Papetti, P. 2022. Bioaccumulation of heavy metals by herbaceous species

grown in urban and rural sites. Water, Air, & Soil Pollution, 233(4), 1–19.

20. Rai, G.K., Bhat, B.A., Mushtaq, M., Tariq, L., Rai, P.K., Basu, U., Dar, A.A., Islam, S.T., Dar T.U.H., Bhat, J.A. 2021. Insights into decontamination of soils by phytoremediation: A detailed account on heavy metal toxicity and mitigation strategies. Physiologia Plantarum, 173(1), 287–304.
21. Saed, M.K., Hamid, M.M. 2024. Studying the Seasonal Changes of some Heavy Metals and Chemical Properties in Main Outfall Water and Evaluating Their Suitability for Irrigation Purposes. In IOP Conference Series: Earth and Environmental Science 1371(8), 082030. IOP Publishing.
22. Siuta, J., Dyguś, K.H. 2015. Crops and Chemism of Plants of a Multivariant Model Experiment on Coal Combustion Waste Deposits. Part II (2012–2013). Ecological Engineering & Environmental Technology, (42), 47–62. https://doi.org/10.12912/23920629/1977
23. WHO, World Health Organization. 2007. Guideline for safe recreational water environments. 1: coastal and fresh waters.
24. Wuana, R.A., Mbasugh, P.A. 2013. Response of roselle (*Hibiscus sabdariffa*) to heavy metals contamination in soils with different organic fertilisations. Chemistry and Ecology, 29(5), 437–447.
25. Yaashikaa, P.R., Kumar, P.S., Jeevanantham, S., Saravanan, R. 2022. A review on bioremediation approach for heavy metal detoxification and accumulation in plants. Environmental Pollution, 119035.
26. Yerima, E.A., Atoshi, M.A. 2023. Assessment of drugs production operations impact on minerals and heavy metals levels of soils around the facilities. Trends in Ecological and Indoor Environmental Engineering, 1(1), 1–6. https://doi.org/10.62622/TEIEE.023.1.1.01-06
27. Yoon, J., Cao, X., Zhou, Q. and Ma, L.Q. 2006. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment, 368, 456–464.