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Efficiency of Some Plants Grown on Roadsides of Baqubah City in the Phytoremediation of Lead and Cadmium

Sura Shakir Mahmood, Munther Hamza Rathi*

Department of Biology, College of Science, University of Diyala, Iraq

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Abstract The study aims to test the ability of some plants grown on roadsides (*Nerium oleander, Eucalyptus camaldulensis, Albizia lebbeck*, *Ficus nitida* and *Callistemon viminalis*) to remove lead and cadmium from the soil and air in the Baqubah city. Species were collected from three different sites in Baqubah city (Diyala Electrical Industries, a commercial area represented by Khurasan Street and a residential area represented by Al- Tahrir area). In the current study, leaves and soil samples were collected from each plant species used in the study during the months of September to December 2023 to evaluate metal accumulation. The recorded data showed that the concentration trend of heavy metals in soil and leaves was lead > cadmium except soil of *C. viminalis* in Al-Tahrir area. Moreover, the results of the accumulation index of heavy metals in the study areas according to Muller's classification showed that the soil of the studied areas in Baqubah city is divided into two categories: unpolluted to moderately polluted areas and areas containing a moderate amount of pollutants. All areas were uncontaminated to moderately contaminated with lead and fell into Class I. As for cadmium, Diyala Company for Electric Industries area (A1) and Khurasan street (A2) were moderately polluted and fell within class II, while Al-Tahrir area (A3) appeared to contain unpolluted and fell in class I. These results suggest the idea that soil and tree leaves can be used as a good in phytoremediation of cadmium and lead. In the case of lead and cadmium, a highly statistically significant relationship ($P < 0.05$) was found between lead and cadmium concentration in soil and plant leaves. The bioaccumulation factor for lead in all plants used in this study was *E. Camaldulensis* > *C. viminalis* > *A. lebbeck* > *F. nitida* > *N. oleander*, and for cadmium it was *E. Camaldulensis* > *C. viminalis* > *F. nitida* > *A. lebbeck*. >*N. oleander* respectively which has proven to be a bioindicator and bioaccumulator of heavy metals, so planting these trees in industrial, commercial and residential areas containing such atmospheric pollutants would be beneficial.

Keywords Pollution, Lead, Cadmium, Phytoremediation

1. Introduction

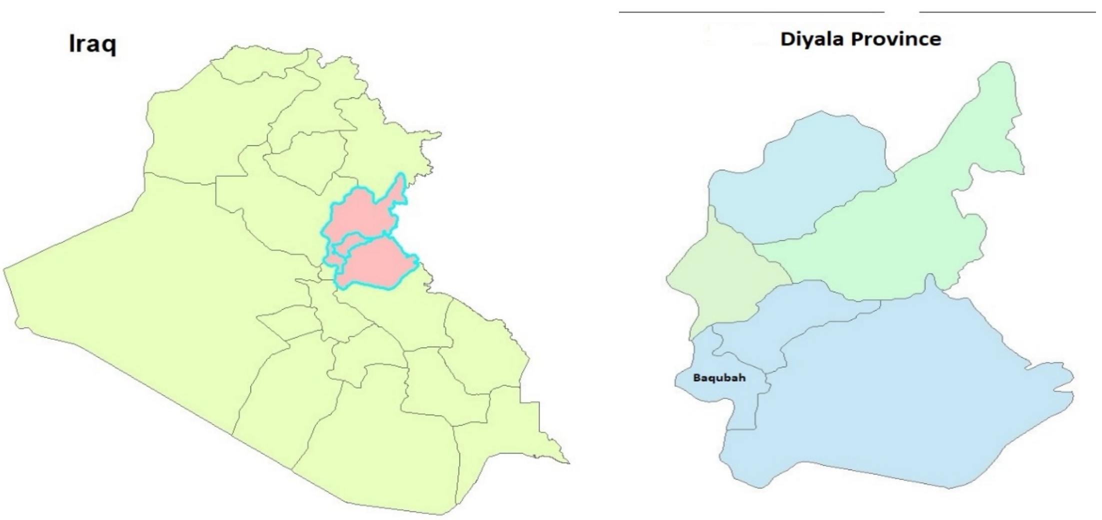
Potentially toxic elements (PTEs) pose a great threat to ecosystems, and long-term exposure causes adverse effects on wildlife and humans. Lead and cadmium are among the most common environmental pollutants in the air, soil and water [1]. In soil contaminated with heavy metals, phytoremediation methods are considered green and environmentally friendly as they rely on using plants. Regarding the results of this study, distinct behaviors have been observed for different plant species that absorb heavy metals from leaves and soil. The basic elements of life are constantly polluted with various pollutants, including heavy metals, which can accumulate in soil, plants, animals, as well as various organisms, and may reach toxic levels [2]. Biomagnification of heavy metals in the environment is a serious threat to human health [3]. Lead and cadmium affect cells and cause damage to their membranes; they also affect enzymes, and can lead to carcinogenesis if they accumulate in sufficient quantities in various tissues [4, 5]. Chronic cadmium toxicity can lead to emphysema, while acute toxicity can lead to headache, nausea, and diarrhea. Lead toxicity causes various symptoms in the cells that make up the blood, the liver, the kidneys, and the nervous system. Chronic toxicity in the blood at concentrations of about 400-600 mg/l leads to continuous vomiting, lethargy, delirium, convulsions, and coma [6].

Many physical and chemical methods exist for removing heavy metals from the environment. Still, they require a high cost, use toxic materials, and produce secondary materials that need additional operations to eliminate them. Therefore, the phytoremediation method is considered a green, environmentally friendly method [7]. The main advantage of the phytoremediation technique is that it is an aesthetically pleasing solar-powered cleaning that can simultaneously treat various environmental toxins. It is a cost-effective technology as phytoremediation costs 60-80% less than standard physical, chemical or mechanical systems [8]. In this technique, plants absorb pollutants and decompose or detoxify them through several methods. This is a practical, plant-based, environmentally friendly, long-term method of reducing air pollutants in indoor and outdoor environments [9]. Plant parts have become increasingly crucial for indirect monitoring and assessment of pollution concerns, a process called biological monitoring. Since vegetation has a role in improving air quality, it is an essential component of ecosystems and is helpful for easy sampling and availability. Leaves are among the plant parts approved for use as bioindicators and bioaccumulators, in addition to biochemical components as viable bioindicators for pollution monitoring and assessment [10].

The current study is an attempt to highlight the varying capacities of plant species from trees, and vegetation in Baqubah city to uptake and accumulate lead, and cadmium and work to increase the density of the best of them within the program to reduce pollution levels within the city environment. In this study, plants *N. oleander, E. camaldulensis, A. lebbeck*, *C. viminalis* and *F. nitida* were chosen due to its distinct properties in ability to withstand and absorb high concentrations of heavy materials minerals. Selected plants can be a good choice to reduce heavy metal contamination as the soil contains high levels of cadmium and lead [3]. Also this study provides some information about the danger and spread of the lead and cadmium in the environment of Baqubah city.

2. Materials and Methods

Baqubah is an Iraqi city located northeast of Baghdad city (the capital of Iraq) and is the administrative headquarter of Diyala Province (Figure 1). It contains residential, industrial and commercial areas. The current study included three areas, as shown in Table 1.



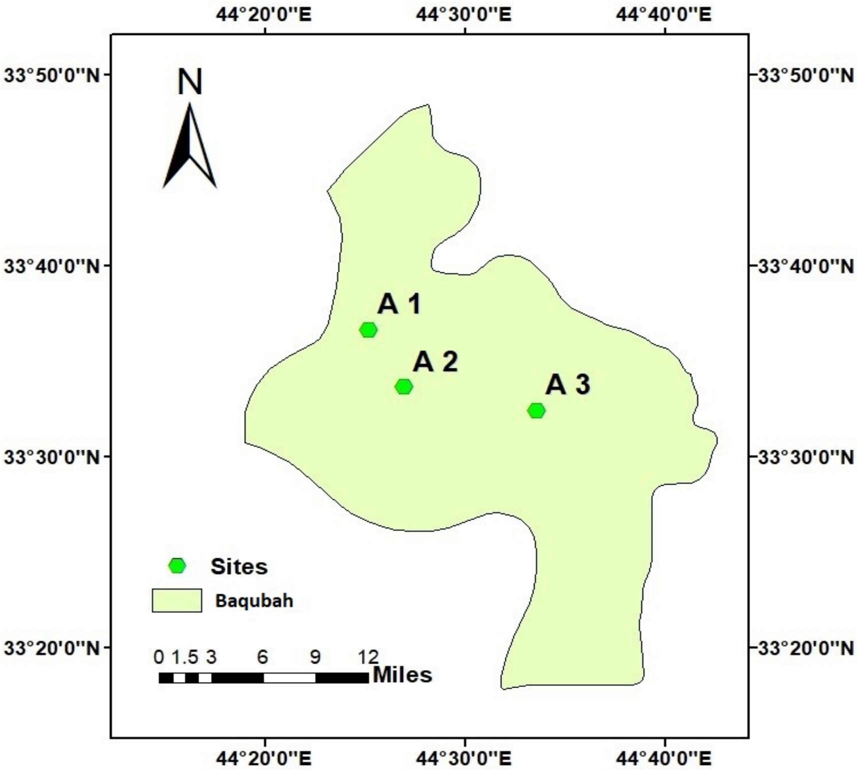


Figure 1. Baqubah city location study samples

Table 1. The coordinates sampling collection from three regions of Baqubah city

Sites	Sites (three replicates for each site)	Samples collection Coordinates °N °E		Study area
Diyala company for electric industries	A1	33.36626088928214,	44.24751984995018	Industrial area
Khurasan street	A2	33.3329381215455,	44.278674251919296	Commercial area
Al-Tahrir	A3	33.32632352867712,	44.33844541108747	Residential area

Samples collection: The study samples were collected from September to December 2023. Five plants (*N. oleander, E. camaldulensis, A. lebbeck*, *C. viminalis* and *F. nitida*) were selected to be planted on roadsides in three areas of Baqubah city (Diyala company for electric Industries, Khurasan street and Al-Tahrir), shown in Table 1. Plants were classified by Prof. Dr. Khazail D. Wadi (specialist in plant taxonomy at the College of Science - University of Diyala). The study samples included obtaining plant leaves from different areas of the plant (bottom, middle and top) As well as, a sample of the soil on which the plant grows was obtained at a depth of approximately 10-15 cm from the surface. To compare the results, other samples were collected from uncultivated soil in the same area and at the same depth mentioned previously. Samples were placed in a marked container, and the information of each sample was recorded. After that, the samples are taken to the laboratory to make the required measurements [11].

Estimating the Level of Lead and Cadmium in Samples

The level of lead and cadmium in the soil and leaves samples were measured at the Ibn Sina Center \ Ministry of Industry and Minerals using a flame atomic absorption spectrophotometer (Varian Specter. AA20) [12,13].

The Calculation of Bioaccumulation Factor

The Bioaccumulation factor is used to determine the amount of heavy elements absorbed by plants from the soil. It is the ratio of the element concentration in the shoots to the element concentration in the soil and is calculated using the following equation [14]:

$$BAF = C \text{ in Plant} / C \text{ in Soil}$$

where: BAF: Bioaccumulation factor

C: Metal concentration (mg/kg)

The Calculation of Geoaccumulation Index (Igeo)

It was calculated according to the following equation:

$$Igeo = \log2 \left(Cn / 1.5\ Bn \right)$$

where Cn, the concentration of the element in the sample, and Bn, the concentration of the element in the earth's crust (lead = 1.08 mg / kg, cadmium = 0.25 mg/kg) [15], the fixed number is 1.5 to reduce the effects of possible differences that can be attributed to lithological differences in the soil as the soil is classified according to a pollution index in Table 2 [16, 17].

Table 2. Classification of soil according to Geoaccumulation index(Igeo)

Igeo value	Igeo Category	quality of the soil
Igeo ≤ 0	0	Unblemished
0 < Igeo < 1	1	Unpolluted to moderately polluted
1 < Igeo < 2	2	Moderate polluted
2 < Igeo < 3	3	Moderate to severe polluted
3 < Igeo < 4	4	Highly polluted
4 < Igeo < 5	5	Heavily to very heavily polluted
Igeo ≥ 5	6	Excessively polluted

Statistical Analysis

All data were statistically analyzed using a computer and using the Statistical Package for the Social Sciences program (SSP) version (22.0), and using Microsoft Excel. The numerical data were described as Mean± SD according to a completely randomized design (CRD).

3. Results and Discussion

1- Concentration of lead and cadmium in soil and leaves of plants in electric industries (A1)

The results of Table 3 showed that the concentration of lead in area A1 ranged between 3.57 ppm, the lowest concentration in the soil of *N. oleander*, and the highest concentration in the soil of *F. nitida,* 4.81 ppm. In comparison with the natural abundance (1.08 mg/kg) [15], researchers found in a study on some soils in Diyala province that all soils in all areas studied were contaminated with lead. Significant differences were found $p < 0.05$ between *C. viminalis* and *N. oleander* plants when compared with other plants. As for the leaves, the highest concentration was in the *A. lebbeck* plant (3.42 ppm), followed by the *C. viminalis, E. camaldulensis*, *F. nitida* (3.33, 2.52, 2.34) ppm finally *N. oleander* plant. It was the lowest concentration (1.94 ppm). Significant differences $p < 0.005$ appeared between the *E. camaldulensis* plant with all the studied plants. There were no significant differences between the *A. lebbeck* and *C. viminalis*, as well as between the *N.oleander* and *F. nitida* plants, while significant differences appeared between the previous two plants on the one hand and the other plants. [18] showed in a study conducted in the city of Muqdadiya, Diyala Province in 2022, that the leaves of the oleander plant played a major role in absorbing quantities of heavy elements (lead, cadmium, arsenic, and selenium). The study also showed that the oleander plant can be used in biological monitoring of elemental contamination. Heavy metals can also be used in biological treatment, which depends on the concentration of these elements in the soil. When compared with the standard values of lead in the leaves (0.3) it is noted that the concentrations highly exceeded the normal limits. The high content of soils for the current study may be due to the proximity of these areas to the highways, and therefore the cars may contribute to the accumulation of lead in these soils. The source to the sink point and this is what was indicated by [19].

As for cadmium, it reached its highest concentration in the soil of the *E. camaldulensis* with a concentration 3.97 ppm and *A. lebbeck* 2.57 ppm. When comparing the obtained concentrations with the natural abundance of the element (0.25mg/kg) [15], it was found that all plant soils are contaminated with cadmium. Significant differences were found between *A. lebbeck* and *C. viminalis* with other plants. High levels of cadmium have been recorded in soils irrigated with sewage water or in which located in areas with high traffic density, excessive use of agrochemicals or located near industrial areas [20, 21].

The results of the values of the bioaccumulation factor for the A1 region (Table 4) showed that the highest value for the lead accumulation factor was *A. lebbeck* > *C. viminalis* > *E. Camaldulensis* > *N. oleander* > *F. nitida*. The highest value of the cadmium accumulation factor in this region was *F. nitida* > *A. lebbeck* > *E. Camaldulensis* > *C. viminalis* > *N. oleander.*

The results obtained for the bioaccumulation factor showed that *A. lebbeck* was the most efficient in the phytoremediation of lead. *F. nitida* was the most efficient in the phytoremediation of cadmium. The results of the Table above indicate that *A. lebeck* was the best in phytoremediation and removing lead, but *F. nitida* was the best for cadmium in A1 areas, which is consistent with the study of [16].

2- Concentration of lead and cadmium in soil and leaves of plants in khurasan street (A2)

The results of Table 5 showed that the highest concentration of lead was in the soil of *C. viminalis* 4.34 ppm, *F. nitida* 2.90 ppm when comparing the concentrations with the natural abundance of the element in the soil (1.08 $mg.kg^{-1}$), it is noted that the soil of all plants is contaminated with lead, with a concentration approximately twice higher than the natural abundance. *E. Camaldulensis* showed a significant difference with all plants, and there is a significant difference between *N.oleander* and *A. lebbeck*, as well as *F. nitida* and *C.*

viminalis, as shown in Table 5.

While the highest concentration of lead was found in the leaves of *C. viminalis* 3.02 ppm, and the lowest concentration was in the leaves of the *N. oleander* 2.15 ppm plant. When comparing the concentrations in the standard ratio of lead for leaves, it was found that all plants were contaminated with lead and exceeded the normal and permissible levels. These results agreed with what was obtained by [22].

The results showed that the highest concentration of cadmium was in the soil of the *C. viminalis* plant 3.86 ppm, *E. Camaldulensis* 2.52 ppm. When comparing to the concentrations with the natural abundance of cadmium (0.25 mg/kg), it was found that all soils are contaminated with cadmium. While in the leaves, the highest concentration of cadmium was found in *C. viminalis* 2.33 ppm, *and A. lebbeck* 0.98 ppm. The results showed that there is a significant difference between *F. nitida* and other plants. Plants differ in their ability to remove heavy elements from the soil due to several reasons, including differences in phenotypic and anatomical characteristics of the plants [13].

When comparing the obtained concentrations to the standard value of cadmium in the leaves (0.2 mg/kg), it was found that all plant leaves have a high content of cadmium. It could be the reason for the high concentrations of cadmium in these plants because they are planted beside the khurasan river, which is considered a branch of the Diyala river, which contains high pollution with cadmium, according to the results study of the [18].

Table 3. Mean ±S.E of Pb and Cd, concentration of soil and for plants in A1

Plants / Conc.(ppm)		*N. oleander*	*E. camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	Soil	3.57 ± 0.00569 b	4.12 ± 0.00764 A	3.92 ± 0.5378 A	4.81 ± 0.00808 a	4.06 ± 0.00400 b
	leaves	1.94 ±0.00757 c	2.52 ± 0.0070 B	3.42 ± 0.00513 A	2.34 ± 0.00907 c	3.33 ± 0.00757 a
Cd	soil	2.99 ± 0.00800 a	3.97 ± 0.00839 A	2.57 ± 0.00889 C	2.86 ± 0.00700 a	2.67 ± 0.01015 c
	leaves	1.37 ± 0.00651 b	2.46 ± 0.01007 A	1.62 ± 0.22867 A	1.80 ± 0.00603 a	1.28 ± 0.00850 b

Table 4. BAF of plants in A1

Plants / Conc.(ppm)	*N. oleander*	*E. camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	0.54	0.61	0.87	0.48	0.82
Cd	0.45	0.62	0.62	0.63	0.48

Table 5. Mean ± S.E of Pb, and Cd, concentration of soil and for plants in A2

Plants / Conc.(ppm)		*N. oleander*	*E. camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	Soil	3.83 ± 0.00600 a	3.66 ± 0.00400 B	3.47 ± 0.01007 C	2.90 ± 0.00503 c	4.34 ± 0.00500 a
	leaves	2.15 ± 0.00700 a	2.36 ± 0.0917 A	2.64 ± 0.00757 B	2.53 ± 0.0057 b	3.02 ± 0.00700 b
Cd	soil	2.78 ± 0.00917 b	2.52 ± 0.01301 B	2.96 ± 0.00808 A	2.83 ± 0.00700 b	3.86 ± 0.00513 a
	leaves	1.64 ± 0.00473 a	1.41 ± 0.1159 B	0.98 ± 0.00900 b	1.15 ± 0.01102 c	2.33 ± 0.00945 a

Table 6 shows the results of the bioaccumulation factor for the A2 region of lead and cadmium, the following values for the accumulation of elements from the highest value to the lowest. Lead recorded its accumulation in *F. nitida* > *A. lebbeck* > *C. viminalis* > *E. Camaldulensis* > *N.oleander*.

Cadmium recorded accumulation in *C. viminalis* > *N. oleander* > *E. Camaldulensis* > *F. nitida* > *A. lebbeck*. The accumulation factor for this area was highest in the *F. nitida* in lead metal (Table 6).

3- Concentration of lead and cadmium in soil and leaves of plants in AL-Tahrir (A3)

The results of Table 7 showed that the highest concentration of lead was in the soil of the *A. lebbeck* 3.67 ppm., and the lowest concentration was in the soil of *N. oleander* 2.02 ppm. When compared to the natural abundance of lead in the soil (1,08 $mg.kg^{-1}$) it was found that all soils are contaminated with lead. Significant differences were observed at the level $P < 0.05$ between the *N. oleander* and *C. viminalis* with other plants. Lead concentrations above the permitted standard limits (0.3 mg/kg) in all of the leaves of the plants in the AL-Tahrir, with the highest concentration 2.76 ppm and the lowest concentration 2.01 ppm. in *E. Camaldulensis*. There was a significant difference between *F. nitida* with other plants.

Cadmium concentration in the soil of A3 region was higher than the standard levels for natural abundance (0.25 $mg.kg^{-1}$), with a *C. viminalis* having the highest concentration 2.92 ppm, and *N. oleander* 2.01 ppm. The use of fertilizers (phosphate fertilizers enriched with cadmium), pesticides and irrigation water contaminated with waste may be among the reasons that raised the level of cadmium pollution in soils. This is consistent with what was mentioned by [23]. The results showed a significant difference among *N. oleander* and other plants, and it was noted that there were no significant differences in other plants.

The highest concentration of cadmium was found in the leaves of *C. viminalis* 1.85 ppm., and the lowest concentration was in the leaves of the *E. Camaldulensis* 0.9830 ppm. When compared to the standard ratio (0.2), it was found that the leaves of all plants were contaminated with cadmium. The results showed a significant difference between *N. oleander* and *A. lebbeck* with other plants, and it was noted that there were no significant differences in other plants.

The results of the bioaccumulation factor for the A3 region (Table 8) showed the following values for the accumulation of elements from the highest value to the lowest: Lead recorded accumulation in *N. oleander* > *F. nitida* > *C. viminalis* > *E. Camaldulensis* > *A. lebbeck*. Cadmium recorded its accumulation in *C. viminalis* > *A. lebbeck* > *F. nitida* > *N. oleander* > *E. Camaldulensis.*

Pollution Indices

To assess the level of pollution in the soils of some areas in Diyala province, pollution indicators were used to serve this purpose:

Geoaccumulation Index (Igeo)

The results of the index of the Geoaccumulation of heavy metals are shown in the study area, according to the Mueller classification [17]. Obtained concentrations with the natural abundance of the elements (1.08 $mg.kg^{-1}$ for lead and 0.25 $mg.kg^{-1}$ for cadmium) [15] are presented. Tables 9 and 10, showed that the soil of the areas studied in the city of Baqubah fell into two categories: unpolluted to moderately polluted areas and areas containing a moderate amount of pollutants.

Table 10 shows that all the studied areas were uncontaminated to moderately contaminated with lead and fell into class I, while for cadmium areas A1 and A2 containing a moderate amount of pollution and fell within class II (Table 2), area A3 was the lowest polluted with cadmium and fell within class I (it was uncontaminated to moderately contaminated with cadmium).

Table 6. BAF of plants in A2

Plants / Conc.(ppm)	*N. oleander*	*E. Camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	0.56	0.64	0.75	0.87	0.69
Cd	0.58	0.56	0.33	0.40	0.60

Table 7. Mean ± S.D of Pb, and Cd concentration of soil and for plants in AL-Tahrir (A3)

Plants / Conc.(ppm)		*N. oleander*	*E. Camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	Soil	2.02 ± 0.00666 c	3.42 ± 0.00700 B	3.67 ± 0.00600 b	3.17 ± 0.00493 b	2.74 ± 0.00950 c
	leaves	2.01 ± 0.00404 c	2.01 ± 0.00611 C	2.04 ± 0.00603 c	2.76 ± 0.00569 a	2.24 ± 0.00500 c
Cd	soil	2.01 ± 0.00802 c	2.58 ± 0.00603 B	2.69 ± 0.00624 b	2.22 ± 0.01510 b	2.92 ± 0.00503 b
	leaves	1.04 ± 0.00400 c	0.98 ± 0.01442 C	1.61 ± 0.00907 a	1.21 ± 0.01002 c	1.85 ± 0.00854 a

Table 8. BAF of plants in A3

Plants / Conc.(ppm)	*N. oleander*	*E. camaldulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
Pb	**0.99**	**0.58**	**0.55**	**0.87**	**0.81**
Cd	**0.51**	**0.38**	**0.60**	**0.54**	**0.63**

Table 9. Concentration of metals in the uncultivated land and Igeo in the study area

Sites / Con.(ppm)*	A1 Diyala Company for Electric Industries	A2 Baqubah khurasan street	A3: Al- Tahrir
Con. of Pb in the uncultivated land	**4.65**	**4.73**	**0.29**
Igeo	**0.86**	**0.88**	**0.55**
Con. of Cd in the uncultivated land	**1.95**	**1.95**	**0.93**
Igeo	**1.56**	**1.56**	**0.79**

*Obtained concentrations with the natural abundance of the elements (1.08 $mg.kg^{-1}$ for lead and 0.25 $mg.kg^{-1}$ for cadmium)

Table 10. I geo class of the study area

Sites / Conc.(ppm)	A1: Diyala Company for Electric Industries	A2: Baqubah khurasan street	A3: Al- Tahrir
Pb	**1**	**1**	**1**
Cd	**2**	**2**	**1**

4. Conclusions

The results showed that the *C. viminalis* plant was the best in the phytoremediation of lead, with an average bioaccumulation rate for the three regions was 0.77, followed by the *F. nitida* plant (0.74). The results were similar for cadmium, as the bioaccumulation rate of *C. viminalis* reached 0.57 followed by the *F. nitida* plant with an average of 0.52 for the three regions. The present study indicates all areas were uncontaminated to moderately contaminated with lead and fell into class I. As for cadmium, areas A1, and A2 were moderately polluted and within class II, while area A3 fell within class I. All plants used in the study and planted on the roadsides of Baqubah city showed good ability to remove heavy metals lead and cadmium from the soil.

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REFERENCES

[1] Hussien S. A., Rathi M.H., Kadhim T.J. "Determination of the levels of lead and cadmium in canned fish and meat, imported to the local markets of Diyala province-Iraq", IOP Conf. Series: Earth and Environmental Science (Vol.790), IOP Publishing Ltd., 2021. DOI: 10.1088/1755-1315/790/1/012043.

[2] Abdollahi S., Golchin A., Shahryari F. "Lead and Cadmium-resistant bacterial species isolated from heavy metal-contaminated soils show plant growth-promoting traits". International. Microbiology, vol. 23, pp. 625-640, 2020. DOI: 10.1007/s10123-020-00133-1.

[3] Ali H., Khan E. "Trophic transfer, bioaccumulation, and biomagnification of non-essential hazardous heavy metals and metalloids in food chains/webs — Concepts and implications for wildlife and human health." Human and Ecological Risk Assessment: An International Journal, vol. 25, no. 6, pp.1353-1373, 2019. DOI: 10.1080/10807039.2018.1469398.

[4] Liu J., Cao L., Dou S. "Trophic transfer, biomagnification and risk assessments of four common heavy metals in the food web of Laizhou Bay, the Bohai Sea." Science Total Environment, vol. 670, pp. 508-522, 2019. DOI: 10.1016/j.scitotenv.2019.03.140.

[5] Saidon N.B., Szabo R., Budai P., Lehel J. "Trophic transfer and biomagnification potential of environmental contaminants (heavy metals) in aquatic ecosystems." Environmental Pollution, vol. 340, pp. 1-11, 2024. DOI: 10.1016/j.envpol.2023.122815.

[6] Liu B., Lv L., An M., Wang T., Li M., Yu Y. "Heavy metals in marine food web from Laizhou Bay, China: Levels, trophic magnification, and health risk assessment." Science Total Environment, vol. 841:156818. 2022. DOI: 10.1016/j.scitotenv.2022.156818

[7] Al-Zubaidi N.A. and Al-Jourani A.H., "A Study of environmental pollution with lead and cadmium in the city of Baquba and its suburbs." Academic Science Journal, vol. 10, no. 4, pp. 82-94, 2014.

[8] Misra S., Misra K.G. "Phytoremediation: an alternative tool towards clean and green environment," Sustainable green technologies for environmental management, 2019, pp. 87-109. DOI: 10.1007/978-981-13-2772-8_5.

[9] Farraji H., Robinson B., Mohajeri P., Abedi T. "Phytoremediation: Green technology for improving aquatic and terrestrial environments." Nippon. Journal of Environmental Science, vol. 1, no. 1, pp. 1-30, 2020. DOI: 10.46266/njes.1002.

[10] Grifoni M., Pedron F., Barbafieri M., Rosellini I., Petruzzelli G., Franchi E. "Sustainable valorization of biomass," From assisted phytoremediation to green energy production, Handbook of Assisted and Amendment: Enhanced Sustainable Remediation Technology 1st ed., 2021. pp. 29-51. DOI: 10.1002/9781119670391.ch2

[11] Diaconu D., Nastase V., Nănău M.M., Nechifor O., Nechifor E. "Assessment of some heavy metals in soils, drinking water, medicinal plants and their liquid extracts." Environmental Engineering and Management Journal, vol. 8, no. 3, pp. 569-573, 2009. DOI: 10.30638/eemj.2009.078.

[12] Abdulla E.K., Rathi M.H. "Occuopational exposure to Lead, Nickel and Copper among workers in Diyala state company /Ministry of industry and minerals-Iraq." HIV Nursing, vol. 22, no. 2, pp. 1478-1482, 2022. DOI: 10.31838/hiv22.02.282.

[13] Abdulhay H.S., Rathi, M.H. "Lead, Cadmium and Nickel contamination of roadside soils and plant leaves in Baghdad city." Journal of Chemical and Pharmaceutical Research, vol. 9, no. 8, pp. 47-51, 2017.

[14] Pachura P**.**, Ociepa-Kubicka A., Skowron-Grabowska B. "Assessment of the availability of heavy metals to plants based on the translocation index and the bioaccumulation factor, Desalination and Water Treatment. vol. 57, no. 3, pp. 1469-1477, 2015. DOI: 10.1080/19443994.2015.1017330

[15] Abd - alwahab S.K. "The investigation of some heavy metals in the agricultural soil of Diyala province and treating them with different types of plants. Thesis Coll. Educ. sci. – Diyala univ. pp.107. 2022.

[16] Luo Z.B., He J., Polle A., Rennenberg H. "Heavy metal accumulation and signal transduction in herbaceous and woody plants: paving the way for enhancing phytoremediation efficiency, Biotechnology Advanced, vol. 34, no. 6, pp. 1131-1148, 2016. DOI: 10.1016/j.biotechadv.2016.07.003.

[17] Wang L., Yu R., Hu G., Tu X. "Speciation and assessment of heavy metals in surface sediments of Jinjiang River tidal reach, southeast of China." Environmental Monitoring Assessment, vol. 165, pp. 491-499, 2010. DOI: 10.1007/s10661-009-0961-2.

[18] Abed S.H., Rathi M.H., Khalil G. I., Taha M.E., "*Nerium oleander* L. as a phytoremediation of heavy metals in Diyala Governorate – Iraq." Journal of Environment and Earth Science, vol. 12, no. 9, pp. 32-39, 2022. DOI: 10.7176/JEES/12-9-04.

[19] Bikash D., Smaraj S.W., Kuntal M. "Sources and toxicological effects of lead on human health." Indian Journal of Medical Specialities, vol. 10, no. 2, pp. 66-71, 2019. DOI: 10.4103/INJMS.INJMS_30_18

[20] Ebong G.A., Exong C.I.. "Pollution status of trace metals in waste impacted soils within Borokiri town, Port Harcourt metropolis, Rivers State, Nigeria." Int J Sci Res Environ Sci. vol. 3, no. 2, pp. 436-444, 2015. DOI: 10.12983/ijsres-2015-p0436-0444.

[21] Bhatti S.S., Bhat S.A., Kumar V., Kaur M., Minakshi, S. V. "Ecological risk assessment of metals in roadside agricultural soils: A modified approach." Human and Ecological Risk Assessment: An International Journal, vol. 24, no. 1, pp. 186-201, 2018. DOI: 10.1080/10807039.2017.1373328.

[22] Zarak A, Castillo A, Kichler K, de la Cruz L, Tamariz L, Kaza S. "Robotic versus laparoscopic surgery for colonic disease: a meta-analysis of postoperative variables." Surgical Endoscopy, vol. 29, no. 6, pp. 1341-1347, 2015. DOI: 10.1007/s00464-015-4197-7.

[23] Al-Anbari R., Al-Obaidy A.M., Al-Imari T. J. "Phytoremediation of Cr and Pb from soil irrigated by wastewater." Engineering and Technology Journal, vol. 34, no. 13, pp. 2380-2386, 2016. DOI: 10.30684/etj.34.13A.1.