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Investigate the Effectiveness of Plants Grown Alongside the Roads of Baqubah City for Phytoremediation of Nickel

Sura Shakir Mahmood and Munther Hamza Rathi*

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

*muntherh7@ gmail.com

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Abstract

Heavy metals are classified as non-degradable contaminants, which are considered to be among the most harmful to the environment. Samples for the research were obtained in September (2022). In this research, the ability of five species of plants grown on roadsides in the city of Baqubah - Diyala province to remove nickel from the environment (soil, air and water) was tested. The study aimed to evaluate the responsibility of various plants grown along The roadside in nickel bioremediation by estimating the concentration of nickel in the plants' leaves and soil, as well as computing the Bioaccumulation Factor (BAF).The plants used in the study were: *Nerium oleander*, *Eucalyptus camalduulensis*, *Albizia lebbeck*, *Ficus nitida*, and *Callistemon viminalis* species from three different locations in Baqubah city were: the industrial area, Hospital street and Al-Mustafa neighborhood. The results indicated substantial variances across the different plant types. It also showed that the soil is not polluted with nickel, compared with the natural abundance of the element in the Baqubah city, and the global average for uncontaminated soil. The *C. viminalis* plant was better for phytoremediation in all regions than other plants, while the other plants varied in their ability to phytoremediation of nickel. All study areas were uncontaminated to moderately contaminate with nickel and located in Class1 of Igeo classification.

Keywords: Heavy Metals, Nickel, Phytoremediation, pollution

Introduction

Many chemicals have caused air, water and soil pollution, which has increased at present as a result of weak control over the use of these materials in various industries, to the point where environmental contamination has become a global concern. The environment receives nickel through some natural sources as well as industries used by humans [1]. Agricultural soil receives airborne nickel particles, which constitutes a source of concern for those concerned. The main sources of nickel in the atmosphere are the increasing combustion of coal and oil for power generation, as well as nickel metallurgy and other unspecified sources such as cement factories. Nickel is one of the micronutrients required for plant growth. It is involved in the synthesis of the urease enzyme in plants. Nickel is very toxic to plants (it affects plant growth, photosynthesis, seed germination, and sugar transport and leads to necrosis and plant wilting, which are considered the most common signs of nickel poisoning), In 1975, nickel was identified as one of the elements involved in the formation of the enzyme urease, which is found in a wide range of plants [2].

Nickel is a trace metal found in soil, water, and air samples across the biosphere that is discharged into the environment from both natural and anthropogenic sources. Nickel compounds (carbonate, acetate, hydroxide and oxide) are all used in different industrial processes, Plants easily absorb these compounds from the soil and surrounding areas. As a result, they can infiltrate the food chain and harm animals and humans [3]. According to research, acute toxicity of nickel in humans is caused by nickel element absorption through the digestive system or inhalation.

Nickel carbonyl inhalation generates two forms of acute toxic effects: immediate and delayed. Vomiting, irritability, nausea, disorientation as other symptoms of acute poisoning can occur. These symptoms can last anywhere from a few hours to two days، delayed symptoms include chest tightness, cough, shortness of breath, palpitations, tachycardia, sweating, cyanosis, and visual abnormalities [4]. The death of a two-year-old girl from cardiac arrest caused by inadvertent consumption of nickel sulfate has been reported [5]. There have also been cases of electroplating workers experiencing shortness of breath and dizziness after drinking water tainted with nickel chloride (1.63 gm/l) [6]. Pollution is monitored using a variety of approaches because certain methods may not give thorough information regarding the impact of these pollutants on ecosystem living components [7]. The use of organisms, particularly plants, has become increasingly significant in indirectly monitoring and assessing pollution concerns, a process called biomonitoring. Vegetation is an important component of ecosystems because it allows for easy sampling and availability [8]. Heavy metal pollution and its removal are considered one of the major challenges facing those interested in ecology and environmental pollution [9]. [10] Found that Nickel levels were within internationally permissible limits when they studied the concentration of this metal on roadside plant leaves in Baghdad city .The current study aims to help those interested in determining which cultivated plants are best for phytoremediation of nickel.

Collecting samples (soil of the study area, plant leaves and the soil on which it grows):

Three areas were selected in the city of Baqubah, representing industrial, commercial and residential areas (table). In September 2022, the plant leaves (bottom, middle and top of the plant) were collected, as well as the soil on which it grows, to a depth of 10-15 cm. The samples were placed in special containers and preserved by refrigeration at a temperature of 4 degrees Celsius until the required chemical analysis. [11] [12]. The plants were classified by taxonomy expert Prof.Dr. Khazal D. Wadi in the Department of Biology Science /College of Science, University of Diyala.

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

Sites	Samples collection Coordinates °N	°E	Study area
The industrial area (A1)	33°43'35.9"N	44°36'49.7"E	Industrial area
Baqubah General Hospital street (A2)	33°44'48.7"N	44°37'16.3"E	Commercial area
Al-Mustafa neighborhood (A3)	33°44'33.5"N	44°37'27.6"E	Residential area

Determination of Nickel concentration

Take just one gram of dry soil or dried plant leaves and put it in a 50 ml beaker, with a 1:5 ratio of HNO_3: $HCIO_4$. Add 10 ml to the beaker above. The digestion was carried out for 1.5 hours at a temperature of around 190°C. The solution was chilled and finished with distilled water to the desired volume. The concentration of Ni was determined using a Flame Absorption Atomic Spectrometer at the Ibn Sina Center, Ministry of Industry and Minerals (MIM) [13]. The nickel concentration was expressed in ppm.

Calculate the Bioaccumulation Factor (BAF):

The potential of plants to bio accumulate nickel in soil can be calculated according to the equation below [16]:

$$BAF\ (mg\ /l) = Con.(Ni)\ in\ Plant\ /\ Con.(Ni)\ in\ soil\ on\ which\ grows$$

Calculate the Geoaccumulation Index (Igeo)

It was calculated according to the equation below [16]:

$$\mathbf{Igeo = \log 2\ (\ Cn\ /1.5\ Bn\ )}$$

Where Cn, the concentration of the nickel in the sample, and Bn, the concentration of the nickel in the earth's crust (75.77 mg/kg) [18], is fixed at 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 [17].

Table 2: Classification of soil

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

Results and Discussion

Concentration of Nickel in soil and leaves of plants in Baqubah city and BAF:

The Industrial area (A1): The results of the current study recorded that the highest concentration of nickel in the soil of plants in the industrial area was in the ***F. nitida*** plant (table 3), where its concentration was **3.6727** ppm then ***A. lebbeck*** 3.5673 ppm, while the soil of the ***C. viminalis*** plant recorded the lowest concentration as it reached 0.7540 ppm. The natural abundance of nickel in soil is 75.77 mg/kg of soil, and the soil is considered polluted if it exceeds that [15]. Significant differences ($P < 0.05$) were found between the concentrations of nickel in the soil of ***F. nitida*** plants and other soil plants , while there were no significant differences between the soil of other plants.

Table 3 showed the highest concentration of nickel in the leaves of plants was 1.5293 ppm in *N. oleander* leaves then ***F. nitida* (1.4297 ppm)**, and the lowest concentration was 0.4413ppm in *E.Camalduulensis* leaves. When compared with the standard value (0.05 – 5 ppm) nickle in the leaves, it is noted that leaves samples are contaminated with this element [15]. Significant differences were observed at the level ($P < 0.05$) between the *F.nitida* and *A. lebbeck* with other plants, while there were no significant differences among the concentration of other plants. [17] Showed in a study conducted in the city of Muqdadiya, Diyala Governorate 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. Study that the *N.oleander* plant can be used in the biological monitoring, of contamination with elements, also it can be used in the phytoremediation of elements depending on the type and concentration of the element in the soil [17]. These results are consistent with the study of [15] nickel concentrations in the environment (air, water, soil, food) do not exceed regulatory limitations in many countries, including Poland, and are not considered harmful to the public. However, it's important to note that nickel, while not widely discharged into the environment, may pose a health risk. The results in table 4 showed that the *C. viminalis* had the highest bioaccumulation factor (BAF) in A1 region (0. 7427), exceeding all other species significantly. The lowest value was in *A. lebbeck* (0. 3087). The best plant for phytoremediation of nickel in industrial area is *C. viminalis* then *E.camalduulensis* (0.3925) then *F. nitida* (0.3892) then *N. oleander* (0.3527) and finally *A. lebbeck.*

General Hospital Street (A_2): As well as the highest concentration of nickel in the soil of this area was 4.6217ppm in soil of *F. nitida* plant then *E. amalduulensis, N. oleander , C.viminalis and finally A.lebbeck (*4.3273 , 4.2240 , 4.0520 and 3.5673) respectively (Table 3) When compared to the value of the element's natural abundance, it is clear that the soil (75.77 $mg.kg^{-1}$) is not contaminated with nickel. And, when the sample concentrations were compared to the global average of uncontaminated soils, which is 34 mg/kg, it was found that the soils are nickel-free approximately[15].

The information that was collected found that there are Significant differences between *F. nitida* with other plants ($P < 0.05$), whereas there is no difference between the other species. Nickel concentrations in leaves ranged from 0.6677 ppm in *E.Camalduulensis* to 1.3440 ppm in *C.viminalis* (Table 3). Significant difference were observed between *E.camalduulensis* and other plants. The difference between plants in their ability to undergo bioremediation may be due to several reasons, including the difference in the age of the plants and their anatomical characteristics, such as the width and thickness of the leaves, in addition to some physiological characteristics and the ability to tolerate stress in different conditions [10]. As well as table 4 showed the *C. viminalis* had the highest bioaccumulation factor (BAF) in A1 region (0. 3316), exceeding all other species significantly, followed by *N. oleander, F. nitida, A. lebbeck and E.camalduulensis (*0. 2983, 0. 2262, 0.2220 and 0. 1542) respectively. The efficiency of the plant in phytoremediation increases when the BAF increases.

Al-Mustafa neighborhood (A_3): The data of the current study recorded that the highest concentration of nickel in the soil of plants in Al-Mustafa neighborhood was in the *N.oleander* plant, where its concentration was 5.0973 ppm then *A. lebbeck* was 5.0720 ppm, while the soil of the *F. nitida* plant recorded the lowest concentration as it reached 4.5337 ppm. The natural abundance of nickel in soil is 75.77 mg/kg of soil, and the soil is considered polluted if it exceeds that [15].

No Significant differences(P < 0.05) between the concentrations of nickel in the soil of all plants used in this study (Table 3). The highest concentration of nickel in the leaves of plants was 2.0190 ppm in *C. viminalis* leaves then *F. nitida* (1.5360 ppm), and the lowest concentration was 0.9890 ppm in *N.oleander* leaves, when compared with the standard value (0.05 – 5 ppm) nickle in the leaves, it is noted that leaves samples are contaminated with this element [15].

Significant differences were observed at the level (P < 0.05) between the *N.oleander* and *A. lebbeck* leaves with other plants, while there were no significant differences among the concentrations of other plants. The current results of the study illustrate the importance of the plants used in the study in reducing nickel pollution in the air and soil, as it is absorbed through the roots of the plant, which ultimately leads to its accumulation in the leaves. The difference in nickel concentrations in the leaves according to the study areas may be due to differences in the age of the plants, as well as the level of pollution in the air and soil as a result of the nature of the studied area and the industrial and domestic waste in that area. [17]. The BAF value of the *C. viminalis* plant (0.4135) was higher than that of all other plants, so it is considered the best in phytoremediation, followed by the Eucalyptus plant (0.2414) followed by *F. nitida* (0.2262) then *A. lebbeck* (0.2064) and finally oleander plant (0.1940). It is clear from the results above that the *C. viminalis* plant was best for phytoremediation in all regions than other plants, while the other plants varied in their ability to phytoremediation of nickel (table 4).

Table 3: Mean ± S.E of Ni concentration of soil and leaves for plants in Baqubah city.

Plants(ppm) areas	*N. oleander*		*E.camalduulensis*		*A. lebbeck*		*F. nitida*		*C. viminalis*	
	Soil	leaves	soil	leaves	soil	leaves	soil	leaves	soil	leaves
A	2.0637± 0.01007 c	1.5293± 0.00751 c	1.1243± 0.00569 c	0.4413± 0.00862 c	3.5673± 0.00709 c	1.1013± 0.00929 a	3.6727± 0.01150 b	1.4297± 0.00709 a	0.7540 ± 0.58371 c	0.5600± 0.00755 c
A 2	4.2240± 0.01171 b	1.2603± 0.00802 b	4.3273± 0.00850 b	0.6677± 0.00808 a	3.5673± 0.00709 b	1.1013± 0.00929 b	4.6217± 0.00971 a	1.0457± 0.01150 b	4.0520± 0.00755 b	1.3440± 0.01000 b
A3	5.0973± 0.01201	0.9890± 0.00700	4.9913± 0.01563	1.2053± 0.01159	5.0720± 0.01054	1.0470± 0.01153	4.5337± 0.05096	1.5360± 0.00755	4.8260± 0.01670	2.0190 ± 0.01249
	a	b	a	a	a	b	a	a	a	a

*Different letters mean there is a significant difference under the probability of (P < 0.05).

Table 4: Bioaccumulation factor (BAF) of plants in Baqubah city

Plants area	*N. oleander*	*E.camalduulensis*	*A. lebbeck*	*F. nitida*	*C. viminalis*
The Industrial District (A_1)	**0. 3527**	**0. 3925**	**0. 3087**	**0. 3892**	**0. 7427**
General Hospital Street (A_2)	**0. 2983**	**0. 1542**	**0. 2220**	**0. 2262**	**0. 3316**
Al-Mustafa neighborhood	**0. 1940**	**0. 2414**	**0. 2064**	**0. 2262**	**0. 4183**
Average	**0.2816**	**0.2627**	**0.2457**	**0.3276**	**0.4975**

Geo accumulation index (Igeo)

The results of the Geo accumulation index of nickel in the study area (A_1, A_2 and A_3), according to the Mueller classification, Table 6 illustrated 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, as shown in Table (2). All areas were uncontaminated to moderately contaminated with nickel and located into Class1($0 < Igeo < 1$).

Table 5: IGeo of study areas

Area	**The industrial area**	**Baqubah General Hospital street**	**Haay Al-Mustafa**
Ni con. in the soil **(ppm)**	**1.1243**	**4.3273**	**4.9913**
IGeo	**0.003**	**0.0114**	**0.0132**

Table 6: I Geo class

The industrial area	Baqubah General Hospital street	Haay almustafa
1	1	1

Conclusion

The results showed that the *C.viminalis* plant was the best in the phytoremediation of nickel, with an average of bioaccumulation rate for the three regions was 0.4975, followed by the *F. nitida* plant (0.3276). Every research region fell into class 1 of I Geo classification and ranged from being totally nickel-free to moderately nickel-contaminated.

Source of funding: Researchers

Conflict of interest: Nothings

Ethical clearance: The research does not deal with animals or human.

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