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Research Article

The Potential of Native Plants for Phytoextraction in Phytoremediation of Lead and Nickel from the Soil of Mohammadabad Qazvin Landfill

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Abstract

Background: Heavy metals are dangerous environmental pollutants that cause health hazards to humans, plants, and other living organisms by entering the food chain.

Objectives: This research was carried out around Mohammadabad Qazvin landfill with the aim of measuring the concentration of lead and nickel metals in three plant species, including *Artemisia sieberi*, *Salsola orientalis*, and *Halimocnemis pilifera*, as well as the soil of the region.

Methods: In order to study three plots of 50 × 50 meters with distances of 500 meters from each other in the direction of the prevailing wind in the area, sampling of soil, roots, and aerial organs of plant species was performed. After preparing the samples, the concentrations of lead and nickel metals were measured using an atomic absorption spectrometer.

Results: The results showed that the soil of the three plots did not differ significantly in terms of the concentrations of lead and nickel. Also, there was no significant difference between the aerial organs and roots of the studied species in terms of the concentration of these elements. This difference was statistically significant only in *H. pilifera* in terms of nickel concentration at the level of 5%.

Conclusions: Considering the factors of accumulation and transportation of lead and nickel metals in the studied plants, it can be suggested that *H. pilifera* and *A. sieberi* species are suitable for remediation of lead metal from contaminated soils, while none of these species are suitable for nickel phytoremediation.

Keywords: Heavy Metals, Phytoremediation, Ghazvin Mohammadabad, Landfill, Phytoextraction

1. Background

Currently, one of the major challenges in the field of environment is the gradual increase in the concentration of heavy metals in the soil due to their non-decomposition by microorganisms. Owing to their potential cytotoxic, carcinogenic, and mutagenic properties and effects, these metals pose serious risks to human and other living organisms' health. Heavy metal pollution is not only caused by human activity but also occurs naturally in varying amounts in the environment, especially in the soil (1-5). Meanwhile, landfills are considered one of the centers of production and accumulation of heavy metals. The main problems of landfill for municipal solid waste, leachate, and gas were produced by the decomposition of waste with organic compounds. Special features of municipal waste composition in Iran, such as high percentage of perishable materials and moisture, as well as special climatic conditions such as low rainfall and high evaporation, have caused the leachate to have a high load of heavy metal pollution compared to industrialized countries (6-8). Because these heavy metals are not destroyed and do not decompose, they accumulate in soils and sediments, and due to the bioaccumulative ability of such substances, endanger the health of living organisms, especially humans, by entering the food chains (9-11). Some plant species have the ability to absorb and accumulate large amounts of heavy elements without causing obvious toxic effects. Therefore, this feature of plants can be used to clean soils contaminated with heavy metals, especially in pastures. Some heavy metals such as copper, zinc, and nickel are needed in small amounts as microelements for plant growth and are absorbed by the roots from the soil. The study of natural vegetation in pastures contaminated with heavy metals and determining the concentration of metallic el-

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ements in plant species is of great scientific and practical aspects (12). Steliga and Kluk (13) studied the application of *Festuca arundinacea* in phytoremediation of soils contaminated with lead, nickel, cadmium, and petroleum hydrocarbons. The results show a reduction in soil toxicity during phytotherapy by fertilization process using *Festuca arundinacea*, which is associated with a reduction in the amount of harmful impurities in soils under phytoremediation. Eid et al. (14) performed a comparative evaluation of phytoremediation of heavy metals by four aquatic macrophytes. The results of bioaccumulation factor and displacement factor showed that the studied species, except Ni in *E. stagnina* and Cd in *L. stolonifera*, are suitable for phytostat stabilization of the studied heavy metals. A significant positive correlation was found between the studied heavy metals in water or sediment and plant tissues. Their high bioaccumulation factors, with significant correlations, support the potential of these species to serve as biomarkers and biomonitors of heavy metals in the studied metals.

2. Objectives

This research was carried out around Mohammadabad Qazvin landfill with the aim of measuring the concentration of lead and nickel metals in three plant species, including *Artemisia sieberi*, *Salsola orientalis*, and *Halimocnemis pilifera*, as well as the soil of the region.

3. Methods

3.1. Case Study

Mohammadabad waste landfill is located 20 km away Qazvin to Buin Zahra road, with an area of 110 hectares. Due to the low rainfall (200 - 300 mm) and the long dry season, the vegetation at the site is not significant and includes plants such as *A. sieberi*, *S. orientalis*, and *H. pilifera*. The slope of this region is 6% - 20% and has a cold and semi-arid climate, and the prevailing wind direction is west-east (15).

3.2. Chemical Sampling and Measurements

For sampling of soil and desired plants, three plots with dimensions of 50 $\times$ 50 meters were selected. Because it was not possible to study the concentrations of lead and nickel in four directions due to financial burden, and on the other hand, the effect of wind on the movement of heavy metals has been proven in many studies (16, 17), the selected plots were considered for sampling in the wind direction at intervals of 500 meters. Ten samples of plants were randomly harvested inside each plot. The preparation method of plant samples was dry ash method. In order to analyze and measure the concentration of lead and nickel, after separating the aerial organs and roots, 1 to 2 grams of the samples were placed in an Erlenmeyer flask, and Erlenmeyers were placed in an oven at 80 °C for 48 hours to allow the samples to dry. The dry weight of the samples was then obtained, and the Erlenmeyers were placed in an oven at 500°C for 24 - 48 hours to ash. In the next step, 4 M nitric acid was used for acidic digestion of the samples, and they were volumized with 1% deionized acid, and the concentration of the samples was read by atomic absorption spectrometer (Varian (FS) USA AA 240, Company). After determining the amount of heavy metals in the collected plant samples, BCF (Bio Concentration Factor) and TF (Translocation Factor) indices were measured using the following formulas to evaluate the efficiency of identified plants for pollution control:

BCF = Concentration of heavy metal in harvested plant material (mg/kg)/Concentration of heavy metal in soil solution (mg/kg)

TF = Heavy metal concentration in the aerial parts of the plant (mg/kg)/ Heavy metal concentration in the roots (mg/kg)

Soil texture, organic carbon, lime content, soil salinity, and soil pH were determined by hydrometric (18), Walkley and Black (19), calcimeter, electrical conductivity, and pH meter methods, respectively. Soil samples were passed through a 150-micron sieve to determine the concentrations of lead and nickel heavy metals. In the next step, 4 M nitric acid (volume ratio of 1:8 soil to final composition) was used for extraction (20), and the concentration of samples was read using an atomic absorption spectrometer (21).

3.3. Data Analysis

After obtaining the normality of the data and the homogeneity of the variances, two-way analysis of variance test was performed on the data to investigate the difference in the concentrations of lead and nickel in the plant organs (roots and leaves) in the three sampling plots. Data were analyzed using one-way analysis of variance to determine significant differences in the concentrations of metals mentioned in the soil samples of the studied plots. Pearson correlation was also used to evaluate the significant relationship between lead and nickel in root and leaf organs of plants and soil, as well as the relationship between chemical factors and the concentration of lead and nickel in roots and aerial organs.

4. Results

4.1. Results of Variance Analysis of Plant Data

The results of measuring the concentration of lead and nickel in the roots and aerial organs of each species using independent *t*-test and also between the aerial organs and roots of three plant species using the analysis of variance are summarized in Tables 1 and 2.

Table 1. Mean Concentration of Lead (mg.kg^{-1}) in Aerial Organs and Roots[a]

Species	Aerial Organs	Roots
H. pilifera	3.65^A	3.17^A
S. orientalis	1.51^B	1.70^B
A. sieberi	2.35^B	3.19^A

[a] *In each row shows a significant difference at the level of 5% in the concentration of elements between roots and aerial organs. Common letters in each column indicated no significant difference at the level of 5% in the concentration of elements in the roots and aerial organs of the three plants. Mean comparisons were made by Duncan test at the level of 5% (n = 10).

Table 2. Mean Concentration of Nickel (mg.kg^{-1}) in Aerial Organs and Roots[a]

Species	Aerial Organs	Roots
H. pilifera	2.05^{*A}	2.7^{*A}
S. orientalis	2.3^A	2.66^A
A. sieberi	2.44^A	2.99^A

[a] *In each row shows a significant difference at the level of 5% in the concentration of elements between roots and aerial organs. Common letters in each column indicated no significant difference at the level of 5% in the concentration of elements in the roots and aerial organs of the three plants. Mean comparisons were made by Duncan test at the level of 5% (n = 10).

Among the roots of the three studied plant species, the highest average concentration of lead was related to *A. sieberi* with 3.19 mg, and in the aerial organs, the highest average was related to *H. pilifera* with 3.65. The highest average concentrations of nickel in roots and aerial organs of *A. sieberi* were 2.99 and 2.44 mg, respectively. The results of independent *t*-test to determine the significant difference between the roots and aerial organs of the studied species in terms of lead and nickel concentrations were as follows:

In *H. pilifera*, there was no significant difference between root and aerial organs in terms of lead metal concentration, but there was a significant difference between root and aerial organs in terms of nickel concentration. In *S. orientalis*, there was no significant difference between root and aerial organs in terms of lead and nickel concentrations. In *A. sieberi*, there was no significant difference between root and aerial organs in terms of lead and nickel concentrations. Also, the results of analysis of variance of lead concentration in the roots of different species and aerial organs of different species separately indicated that there was a significant difference between the roots of the studied species in terms of lead concentration at the level of 5%. In this regard, the comparison of the means of the groups with Duncan test showed that the concentration of lead in the roots of *H. pilifera* and *A. sieberi* was not significantly different and had the highest value compared to *S. orientalis*. Also, there was a significant difference between the aerial organs of the studied species in terms of lead concentration at the level of 5%. The results of Duncan test showed that *H. pilifera* species has the highest concentration of lead in its aerial parts, and in this regard, it is significantly different from the other two species at the level of 5%. The results of Duncan test showed that *H. pilifera* has the highest concentration of lead in its aerial organs, and in this regard, it was significantly different from the other two species at the level of 5%. But in the case of nickel, the results were the opposite. Thus, there was no significant difference between the roots of the three studied species as well as the aerial organs of the three species in terms of the concentration of this metal at the level of 5%. Two-way analysis of variance was performed to investigate the effect of plots on the concentrations of lead and nickel in the roots and aerial organs of different species.

In terms of lead and nickel concentrations in the root and aerial organ of *H. pilifera*, there was a significant difference between different plots at 5% level. Regarding lead metal, a comparison of means using Duncan test showed that there was no significant difference between the means of the first and second plots, and they were in the same group, but the third plot had the highest mean value. It has a significant difference from the means of the other two plots. In the case of nickel, the results of Duncan's test showed that the first and third plots were not significantly different at the 5% level, and the highest average value was related to the second plot. In *S. orientalis*, the results showed that the concentrations of lead and nickel in the root and aerial organ between the first, second, and third plots did not have any significant differences at the level of 5%. In *A. sieberi*, there was no difference between different plots in terms of lead concentration in root and aerial organ. But there was a significant difference between different plots in terms of nickel concentration in root and aerial organ at the level of 5%. The results of comparing the means using Duncan test showed that the treatments (different plots) were classified into three groups, the second plot had the highest average value. The first plot also showed more value than the third plot. Among the mentioned results, the comparison of means was done based on Duncan test where there was a significant difference between the different plots in terms of lead and nickel concentrations in the root and aerial organ of the species.

4.2. Correlation Results Between Lead and Nickel in Plant Data

The correlation results of the studied metals showed that except for *S. orientalis*, there was no correlation between lead and nickel in the root and aerial organ of the studied species. Only in the root of *S. orientalis*, this correlation was significant at 95% level. The value of the correlation coefficient between lead and nickel in the root of the mentioned specie was 41%, which according to the value of P-value, this correlation was positive and significant.

5. Discussion

Physicochemical properties of soil affect the rate of absorption of heavy metals from the soil, which can be referred to pH and salinity of the soil. Fertility and improvement of soil conditions in terms of increasing solubility and availability of heavy metals in the soil and absorption in plants are important to optimize the process of clearing soils contaminated with the desired metals, in addition to selecting suitable plant species with better accumulation properties.

Plants can play a special role in improving these metals by absorbing heavy metals from the soil around the root. The ability of the studied plant species to absorb heavy metals from the soil and their accumulation in their tissues was dissimilar, so that lead in *A. sieberi* and *S. orientalis* species is mostly stored in the root, and this metal is stored in larger amounts in the aerial organ of *H. pilifera*. In the case of nickel, it is mostly stored in the roots of the studied plants. According to BCF and TF factors, it can be concluded that *H. pilifera* can be used for lead phytoabsorption and *A. sieberi* for lead phytostabilization. However, none of the plant species are suitable for nickel phytoremediation.

Hibben et al. (16) worked on some heavy metals, including lead, they concluded that atmospheric adsorption could play an important role in the transfer of heavy metals. But regarding the higher concentration of nickel in the second plot, in addition to the above reasons, we can point to the positive correlation of nickel absorption in the roots of *H. pilifera* and *A. sieberi* and the salinity (22) in the second plot ($r = 0.375$). According to the data on physicochemical properties of soil, the highest amount of salinity is related to the second plot, which has caused the root and aerial organ of mentioned plants in the second plot to absorb the highest concentration of nickel.

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Footnotes

Authors' Contribution: Sanaz Khoramipour is the only author of this manuscript.

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