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Soil Heavy Metals Pollution and Phytoremediation Potential of *Hordeum bulbosum* L. Around Bituminous Mine, Ilam Province, Iran

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Authors
Afshari F.[1] *MSc,*
Akhzari D.*[1] *PhD,*
Kargar M.[2] *PhD*

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[1]Department of Nature Engineering, Faculty of Natural Resources and Environmental Science, Malayer University, Malayer, Iran
[2]Natural resources administration of Alborz province, Karaj, Iran

***Correspondence**
Address: Malayer University, Malayer, Iran, Postal Code: 6571995863.
Phone: +98 (81) 32355330
Fax: +98 (81) 33339840
d_akhzari@yahoo.com

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ABSTRACT

Aim The fast-growing rangeland plant species, which could be grown in many different climatic conditions, are the best plants for remediation agents of heavy metals from contaminated soils.
Materials & Methods The soil and plant sampling was performed based on the systematic randomized design in four different geographical directions around the Humalan Bitumin mine. The concentration of the elements was measured using the inductive plasma spectroscopy (ICP-OES) spectroscopic analytical method. The quantities values of contaminants were analyzed statistically by SPSS 22 software. Also, the dominant plant species, *H. bulbosum,* was selected to evaluate heavy metal uptake in plant species.
Findings The highest Mn level in shoots parts of *H. bulbosum* (155.34mg/kg) was seen in 100 m distance of the mine. According to biogeochemical indices, the highest amount of heavy metals was observed in the plants grown at a 100-meter distance from the mine. The highest accumulation factor was observed in the cadmium (as 1.15mg/kg), and the maximum enrichment factor was seen in the Mn element as 0.82mg/kg in 100m distance of the mine.
Conclusion *H. bulbosum* represents an important interest in their potential use to remediate toxic metals of soils. *H. bulbosum* enables an important substance for explore the tolerance strategies of heavy metals accumulation in plant cells and has high application value in remediation of heavy metal-contaminated sites. Our results also indicate that TF values of *H. bulbosum* were more than 1 for the Cd metal. So, these species potentially could be used for phytoremediation and phytostabilization application in Cd-contaminated areas.

Keywords Accumulation; Heavy Metals; Biogeochemical; Mine; Enrichment Factor

CITATION LINKS

[1] Distibution and risk asseement of heavy metals in soils from a typical ... [2] Soil heavy metals pollution and phytoremediation potential of native plants on a ... [3] Assessment of soil heavy pollution in a former mining area-before and ... [4] Phytoremediation of heavy metals-concepts ... [5] Efficiency of flax (Linum usitatissimum L.) as a phytoremediator plant for the contaminated ... [6] Heavy metal accumulation in micropropagated plants of kenaf ... [7] Phytoextraction: the use of plants to ... [8] Heavy metal removal in Phytofi ltration and phycoremediation: the need to differentiate between bioadsorption ... [9] Bioaccumulation and photosynthetic activity response of kenaf (Hibicus cannabinus L.) ... [10] Phytoremediation of some heavy metals ... [11] How do the plants used in phytoremediation in constructed wetlands, a sustainable remediation strategy, perform in heavy-metal ... [12] Effect of converting forest to rainfed lands on spatial variability of soil chemical properties in the Zagros ... [13] Soil contamination pattern affected by coal mining activities in a deciduous ... [14] Impact of coal power generation on the characteristics and risk of heavy ... [15] Investigation of phytoremediation ability of rangeland species in soils contaminated ... [16] Remediation of Petroleum-Contaminated Soils using Stipagrostis plumosa, Calotropis procera L., and Medicago sativa under Different ... [17] Hyperaccumulation of lead, zinc, and cadmium in plants growing on a lead/ zinc ... [18] Assessing some shrub species for phytoremediation of soils ... [19] Assessment of TPH and nickel contents associated with tolerant native plants in petroleum-polluted ... [20] Metal hyperaccumulation in plants-Boidiversity prospecting for ... [21] Distribution of arsenic and heavy metals from mine tailings dams at ...

Introduction

Heavy metals are released into the environment due to natural processes such as rock weather and volcanic eruptions, but human activities such as mining, plating, textile industry, battery production, etc. [1]. Unlike organic matter, heavy metals are not fundamentally degradable, so they tended to accumulate in the environment and tissues of living organisms. The concentration of heavy metals may be known as a biochemical action by passing from the roots to the shoots of plants [2]. The total concentration of heavy metals in the soil is used to assess soil contamination [3-4]. The bioavailability of heavy metals in soil depends on many factors, including pH, organic matter content, cation exchange capacity, and metal properties. Heavy metal pollution is one of the most significant non-living stresses that have affected the environment in recent decades [5]. Although heavy metals may be produced naturally in the soil, geological and anthropological activities increase their concentration to levels that may be harmful to plants and animals due to potential poisoning, disrupting their physiology and development [6].

The potential for heavy metal uptake and accumulation varies among different plant species, and the success of the phytoremediation process depends on the correct selection of the plant species [7]. Only a limited number of plants could be growing in heavy metal polluted sites. In several studies, these plants have physiological adaptability, including metal tolerance strategies different from non-tolerant plants [2, 8]. Rehabilitation of contaminated sites by native plants aimed at stabilizing the soil, immobilizing toxic elements in the rhizosphere zone, reducing the risks of metal dust emissions by wind and water erosion from the root zone. The increase in heavy metals content in the soil also inhibits the activity of the beneficial microbes, reducing the diversity of flora and fauna populations and leading to infertility and increased erosion. The transfer of nutrient minerals to humans can occur through the land, food, water, air, and skin [9]. The heavy-metal leachates of mine sites generate a continuous stream of metalliferous and soil salinization over the long term [11]. The toxicological effects of some heavy metals on humans, especially Cd, Zn, Hg, and Pb, which represent a dangerous effect on biological systems, have been well documented [10-11]. Therefore, to assess the severity of the contamination and develop a strategy for soil rehabilitation, including the suitable plant species, information on the concentration metal is required. Based on a literature review, land-use change in natural resources [12] and mining had a significant negative impact on soil physicochemical properties [13]. Heavy metal pollution may be caused by mining activities [14]. Phytoremediation by native rangeland plants [15] has been indicated as an effective policy for soil remediation [16].

This study aimed to investigate the effect of *H. bulbosum* L. as a native rangeland plant around bituminous mines on phytoremediation and phytostabilization of heavy metals.

Materials and Methods

Study area and Data collection

The study area was located in western parts of Ivan city, Ilam Province, Iran (33° 54' 56" N, 46° 04' 30" E). Sampling was performed in late June of 2017. The soil and plant sampling was performed based on a systematic randomized design in four different geographical directions around the Humalan Bitumin mine. Soil samples were taken from 0 to 15cm depth. Vegetation samples were gathered by $2m^2$ plots. Soil and vegetation samples were taken from various distances (100, 200,300, 400, and 500 meters) of the Bituminous mine. Based on the systematic randomized design, soil and plant samples were selected in five distances of four directions in the mine site, and 20 samples of plants and soil were collected at each distance. In order to perform statistical comparisons, soil and vegetation samples were collected outside the area around the mine in similar edaphic and topographic conditions (As control treatment). The concentration of the elements was measured using the inductive plasma spectroscopy (ICP-OES) spectroscopic analytical method. The quantities values of contaminants were analyzed statistically by SPSS software. Also, the dominant plant species, *H. bulbosum,* was selected to evaluate heavy metal uptake in plant species.

Enrichment Factor (EF): is described as the ratio of the concentration of metal in the plant shoots to that in the soil where it grows. This is a measure of the ability of plants to absorb, transport, and accumulate metal (seams) in shoots [17].

Enrichment Factor (EF) = C shoots/C soil (Equation 1)

Which C shoots indicate the concentration of heavy metal in shoots (mg/kg), and C soil refers to the concentration of heavy metal in soil (mg/kg)

Transfer Factor: The transfer factor of elements from root to shoot is a suitable method to determine the amount of element absorption by the plant and assess the plant's ability to transfer metal from root to stem. Values less than 1 for the transfer factor indicate a greater tendency of the plant to accumulate the element in the underground organs than in the aerial parts and the low mobility of the element in the aerial parts of the plant. The solubility of the element in tissue and the metabolism of the plant species are among the main factors in determining the values of this parameter. In this study, the transfer factor was used to calculate the relationships of heavy elements in the root and shoot system. The concentration of heavy elements in root and shoot extracts is calculated in dry weight:

Transfer Factor = C shoots/C roots (Equation 2)

Plant C: The concentration of the element in the shoots (mg/kg) of dry shoot weight

Soil C: The total concentration of the element in the roots (mg/kg) of dry root weight

After harvest, the plant and soil samples were placed in special envelopes and transferred to the laboratory. Elements concentrations were measured by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) analytical technique.

Soil Sampling and Analysis

Soil pH was determined in a soil/water solution with a volume ratio of 1:1. Organic matter (%) and soil texture measured by Walkley-Black and hydrometer methods. Soil bulk density of samples was determined using following [10]:

Bulk density (g/cm^3) = Dry weight/Volume (Equation 3)

The pH and EC of the soil were also measured in a 1:5 solution (soil-to-solution ratio), respectively, using pH and EC meter.

Data Analysis

The collected data were analyzed using SPSS 22 software and variance analysis method to perform statistical analysis and evaluate important differences. Data were analyzed using the statistical significance of Duncan's test at a significance level of $p<0.05$ analysis of variance (ANOVA). The meaning of having the same alphabet in the same column is not significant in terms of value ($p<0.05$).

Findings

Soil Properties

Organic matter, soil texture, electrical conductivity, acidity, and bulk density in the soil around the bituminous mine were measured, and the results were presented in Table 1.

The concentration of metals in the soil of various distances from the mine

Based on the results of the present research, there is a significant difference ($p<0.05$) between the content of Pb and Cd at various distances from the bituminous mine (Table 2). The maximum and minimum amount of Pb and Cd were seen 100 and 500 meters from the mine, respectively (Table 2). Based on ANOVA results ($p<0.05$), there were no significant differences seen in the contents of Ni, Mn, and Zn at various distances from the mine (Table 2).

Concentrations of Pb, Mo, Cd, Ni, Zn, and Mn in the plants' biomass at different distances from the mine Site

The result showed that among the elements measured in plant biomass, the highest mean is related to the Mn element 148.37 mg/kg. It was also observed that the Pb element did not differ significantly between 100 and 200 m. Based on ANOVA results ($p<0.05$), there were no significant differences seen in the contents of Cd, Ni, Mn, and Zn in the plants' biomass of various distances from the mine (Table 3).

Table 1) Soil physicochemical properties around the bituminous mine in different distance

Soil variables	Distance from the mine (meter)					
	Control	100	200	300	400	500
OC	0.011	0.013	0.012	0.013	0.011	0.012
Silt	32.15	37.11	34.02	30.18	29.13	30.16
EC	0.44	0.41	0.39	0.43	0.40	0.39
pH	7.29	6.83	7.02	6.92	7.11	7.07
Bulk density	1.23	1.04	1.56	1.38	1.29	1.33

Table 2) Contaminants of Pb, Mo, Cd, Ni, Zn, and Mn in soil

Elements	Distance from the mine (meter)					
	100	200	300	400	500	Mean
Pb (µg/kg)	12.00±0.02a	11.93±0.07a	10.05±0.04b	9.77±0.06b	8.37±0.01c	10.42±0.03
Mo (µg/kg)	32.92±0.04a	32.81±0.06a	32.23±0.07a	29.65±0.05b	28.28±0.23b	31.18±0.07
Cd (µg/kg)	15.21±0.05a	15.80±0.07a	15.99±0.06a	15.20±0.03a	15.86±0.08a	15.61±0.01
Ni (mg/kg)	0.69±0.07a	0.59±0.06a	0.65±0.04a	0.64±0.08a	0.68±0.02a	0.65±0.002
Zn (mg/kg)	19.72±0.02a	20.03±0.06a	19.17±0.07a	19.51±0.01a	19.99±0.09a	19.68±0.09
Mn (mg/kg)	72.67±0.04a	72.34±0.05a	72.09±0.08a	71.98±0.03a	72.81±0.06a	72.38±0.08

Numbers followed by different letters in each column are significantly ($p<0.05$) different.

Table 3) Concentrations of Pb, Mo, Cd, Ni, Zn, and Mn in biomass *Hordeum bulbosum* L.

Elements	Distance from the mine (meter)					
	100	200	300	400	500	Mean
Pb (µg/kg)	15.72±0.03a	14.70±0.02a	13.66±0.07b	13.37±0.02b	11.90±0.04c	13.87±0.03
Mo (µg/kg)	46.33±0.08a	44.86±0.02a	44.09±0.07a	42.00±0.09b	40.19±0.03b	43.49±0.06
Cd (µg/kg)	23.12±0.01a	22.63±0.01a	22.86±0.02a	23.11±0.03a	21.52±0.04a	26.04±0.05
Ni (mg/kg)	1.620±0.002a	1.520±0.003a	1.720±0.001a	1.660±0.006a	1.420±0.001a	1.580±0.004
Zn (mg/kg)	27.34±0.01a	30.64±0.07a	26.32±0.05a	29.22±0.02a	28.58±0.01a	28.42±0.02
Mn (mg/kg)	152.26±4.72a	155.34±7.31a	149.32±6.13a	141.72±4.63a	143.25±8.23a	148.37±7.11

Numbers followed by different letters in each column are significantly ($p<0.05$) different.

The rate of enrichment and Transfer factors of *H. bulbosum*

The results showed that the highest amount of enrichment factor is related to Ni and Cd elements and the lowest amounts related to Pb (Figure 1).

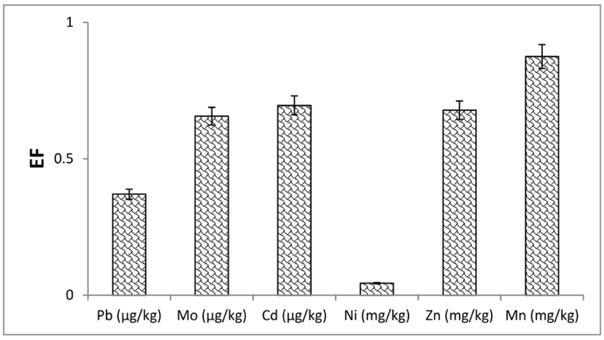

Figure 1) The rate of enrichment factor of heavy metals of *H. bulbosum*

The maximum and minimum values of transfer factor were seen in Cd and Zn (Figure 2).

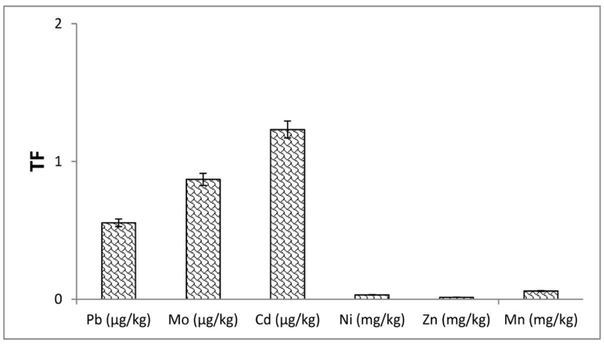

Figure 2) The amount of transfer factor of *H. bulbosum*

Discussion

Phytoremediation is a technology that uses plants to prevent the migration and movement of metals in the soil [18]. This technology aims to reduce pollution and leach soil contaminants by limiting or minimizing the movement and access to the bioavailability of soil elements. This technology uses plants with the highest absorption and accumulation of pollutants in their roots [19].

The phytoremediation potential of *Hordeum bulbosum* L. of various heavy metal uptake around bituminous mine was tested in this research. During plant extraction, the roots of the plants located in the contaminated area absorb the metal elements from the soil and then transfer them to their biomass, which are the places where these metals accumulate. Heavy metals are purified from filth [20]. Some researchers have found pH values of 7.6 to 7.85 on abandoned roofs in the Ubazi Gold Mine, similar to our study findings [21].

Compared with other elements, the higher concentrations of Cd, Mo and Pb are found in the aerial parts of H. bulbosum (as dominant plant species in the study area) (Figure 2), indicating the potential ability of phytoremediation. In the suitable plants for phytoremediation, the concentration of elements in the aerial parts is higher than those of soil [7, 9]. The mean of EF values for Pb, Mo, Mn, Zn, Ni, and Cd is less than one, which indicated the effect of anthropogenic activity on heavy metals contamination in the mine sites [3].

Conclusion

Based on the present study results, *H. bulbosum* represents an important interest in their potential use to remediate toxic metals of soils. The studied plant enables an important substance for explore the tolerance strategies of heavy metals accumulation in plant cells and has high application value in remediation of heavy metal-contaminated sites. Our results also indicate that TF values of *H. bulbosum* were more than 1 for the Cd metal. So, these species potentially could be used for phytoremediation and phytostabilization application in Cd-contaminated areas. Research shows that native rangeland plants are the potential environmentally friendly, cost-effective, and cost-effective solution for extracting or removing metal contaminants from contaminated soil.

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