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# Sequestration of Heavy Metals in Soil and the Leaf of Different Forest Stands around Cement Factory

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ABSTRACT

**Aims** Cement industry is considered as one of the major consuming energies, producing large amounts of environmental contaminants. The aim of this study was to examine the extent of metals Cadmium (Cd), Zinc (Zn), Lead (Pb), and Manganese (Mn) in the soil and leaves of planted around the cement factory in Pinus eldarica, *Ulmus umbraculifera*, and *Quercus brantii* naturally grown there.
**Materials & Methods** In the present experimental study, to perform this, the level of elements was examined in the leaves as well as depths of 0-10 and 10-20cm of soil across the three studied species using atomic absorption device. The extent of elements sequestrated in the factory's electro filter was also measured. One-way ANOVA test, Duncan's test, and SPSS 20 software were used for Statistical analysis.
**Findings** Cadmium was sequestrated in the electro filter was almost close to the level of cadmium in the leaf and soil samples. The level of lead, zinc, and manganese in the electro filter of the factory were higher than the extent of sequestration of these three elements in the leaf of three tree species and the soil below them. Across the three species, with increased depth of soil, the extent of lead sequestration declined. *Pinus eldarica* had the minimum extent of sequestration for the four studied elements both in the soil and leaf across the three studied species.
**Conclusion** *Quercus brantii* and *Ulmus umbraculifera* have a greater potential in sequestration of heavy metals in comparison with *Pinus eldarica*.

**Keywords** Ulmus; Mn; Heavy Metals; Soil

CITATION LINKS

[1] Uses of alternative fuels and raw materials in the cement industry as sustainable ... [2] Effects of chromium exposure from a cement ... [3] Pollution of Street Margin Soil to Pb ... [4] Effects of sulphur, fluoride and heavy metal ... [5] Efficiency of carbuncular mycorrhizal fungi and ethylene demine ... [6] A plant genetically modified that accumulates Pb is especially promising ... [7] Concurrent plant uptake of heavy metal and persistent organic pollutants ... [8] The interactive effects of chelator, fertilizer, and rhizobacteria ... [9] Effects of heavy metals on growth and arsenic accumulation ... [10] Phytoremediation of heavy metal contaminated soils: Natural ... [11] Uptake, Distribution, and Effects of Metal Compounds ... [12] Managing the nutrition of plants and ... [13] Effect of cadmium on some physiological characteristics of Eucalyptus ... [14] Plant contamination by vehicle lead in some of the highways ... [15] Sequestration of heavy metals in the soil and leaves ... [16] Magnetic susceptibility and heavy metal content in ... [17] Influence of cement industry on accumulation of heavy metals in ... [18] Development of a DTPA soil test for zinc, iron, manganese, and ... [19] An investigation into pollution of selected heavy metals of surface soils in Hamadan province using ... [20] Evaluation of heavy metal contamination ecological risk in a food-producing ... [21] Phytoforensics, dendrochemistry, and phytoscreening: New green tools for delineating contaminants ... [22] Ecophysiological and seasonal variations in Cd, Pb, Zn, and Ni concentrations in the leaves of urban deciduous trees in ... [23] Study of the chemistry of an acid soil column and of the corresponding leachates after the addition of an ... [24] Uptake and accumulation of lead by plants from the Bo Ngam lead mine ... [25] Cadmium availability in soil and retention in oak roots: Potential ... [26] Comparison of phytoremediation of heavy metals by woody species used in urban forestry ... [27] The effect of afforestation in reduction oil ... [28] Comparison of lead absorption in organisms (root, stem and leaf) of Oak ... [29] Lead Distribution in Plant and soil of different Lahijan tea gardens Relative to the arbor of ...

## Introduction

The cement industry is considered one of the major energy consuming energies, producing large amounts of environmental contaminants [1]. The most important adverse effect of cement factories on the environment is the emission of debris as well as contaminating gases. Indeed, cement factories first pollute the air, and this pollution is then precipitated and transferred to the soil through the air. In subsequent stages, it can even enter the body of plants, animals, and eventually human [2].

Overall, the pollutants resulting from cement factory include emitted debris and released heavy metals [3]. The amount of metal concentration in the roots of the plants is approximately the same as in soil [4]. Considering their cytotoxic, carcinogenic, and mutagenic effects on humans and other living creatures, heavy metals have jeopardized their life [5]. Indeed, the threats developed by heavy metals for the human and animal's health are augmented with their long stability in the environment [6].

Various techniques have been developed to clear regions contaminated with heavy metals [7-9]. Among these techniques, phytoremediation has been offered as an effective clearing method, in which the absorption and contaminants are considered in plant harvestable tissues. Indeed, Phytoremediation is a technique for removing heavy metals from contaminated regions, and it is an economical, environmentally friendly, and developing method [10]. Absorption of heavy metals from the soil by plants depends on the type and concentration of the metals present in the soil, bioavailability of elements, and the type of plant species [11]. Overall, to select a plant for phytoremediation of soil, the following factors should be taken into account: High absorptivity, production of high biomass, the high transference of elements from the root to the stalk. Therefore, in contaminated industrial regions, in choosing vegetation for removing or mitigating contamination and applying phytoremediation technique, maximum care should be taken Bioavailability of mineral elements such as zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) and their uptake by plants is essential for crop production [12].

Some researchers have investigated the impact of cement dust from the cement industry on soil properties and plant growth. Shariat *et al.* concluded that eucalyptus had the ability to accumulate cadmium without causing any disturbance in its growth [13]. Rahmani *et al.* in their research, stated that the rate of lead absorption by plants is proportional to its concentration in the environment [14]. Panah *et al* investigated the sequestration of Cd, Zn, Pb and Mn in the leaf and soil of *Eucalyptus microtheca, Cupressus arizonica* and *Robinia pseudoacacia*, which have been planted around the cement factory of Ilam. They found *Eucalyptus microtheca* and *Robinia pseudoacacia* demonstrated the most sequestration of heavy metals, and these are suitable species for planting and green space development around the factory [15]. Gołuchowska and Strzyszcz revealed that cement dust contains high amounts of Zn, Cd, Mo, Cu, Pb and Hg [16]. Also, Jozviak studying the influence of cement industry on accumulation of heavy metals showed that the highest average concentrations of Zn, Cd, Cu and Pb were observed during cold period whereas in warm period the concentration of metals was less [17].

Cement industry is one of the most important production industries in Ilam province. In spite of the economy of this factory, unfortunately, it produces a great deal of environmental contamination, which adversely affects vegetation, trees coverage, animal life, and people's health around the factory. Among these contaminants are heavy metals.

The aim of this study was to examine the extent of metals Cadmium (Cd), Zn, Lead (Pb), and Mn in the soil and leaves of planted around the cement factory in *Pinus eldarica, Ulmus umbraculifera*, and *Quercus brantii* naturally grown there.

## Materials and Methods

The present study is experimental.

**Study Area:** The cement factory is located 12km away from Ilam, in Sirvan town. The factory has been constructed within the geographical longitudes 46° 29' 51″ to 46° 30' 52″ western and latitude 33° 42' 55″ to 33° 43' 40″ northern and altitude 1310m above sea level in the marching of the conservation area of Manesht-Ghalarang, which is a forest area [15].

Samples were taken from the soil and the leaves of the *Pinus eldarica* (≈0.5ha), *Ulmus umbraculifera* (≈2ha) *and Quercus brantii* (≈3ha) with an electro filter of the factory. For this purpose, in each stand six soil samples were taken systematically from the depths of 0-10 and 10-20cm. In the next stage, same-horizon samples of each species were mixed and the prepared samples were transferred to laboratory for experimentation. As with soil sampling, for the leaf samples, the samples of each species were mixed and the prepared samples were transferred to the laboratory for experimentation.

**Experimental measurement:** After spreading the samples in the open air and drying them, the soil samples were beaten in the mortar and then passed through a 2-mm sieve for removal of wastes and separation of larger particles. Next, the level of heavy metals in the soil was measured. For measurement of heavy metals, first an extract was taken from the soil samples, for which 10g of the soil sample was poured into a flask, to which 20ml ditetra phosphoric acid was added to the samples. The flasks were shaken by a shaker device at 120rpm for 2h. Eventually, the contents were passed through a filter paper, and the level of heavy metals of the samples was read using atomic absorption device model novAA-P400. Measurement of heavy metals of the factory's electro filter was performed by method Lindsay and Norvell [18].

For measurement of leaf elements, 0.2g of a plant dry compound (leaf) was weighed. For each sample, 4ml of nitric acid 65% was added and then placed at room temperature for 24h. Next, it was placed inside an oven at 90°C for 5-6h so that no would evaporate. Once cooled down, the samples were filtered using filter paper and then brought to 10ml using distilled water. Thereafter, the level of the elements of the studied samples was read by atomic absorption device novAA-P400. The maximum allowable concentration of heavy metals in surface soil for countries is different [19, 20] (Table 1).

**Table 1)** The maximum authorized concentration of heavy elements

| **countries** | **Zn** (mg/kg) | **Pb** (mg/kg) | **Cd** (mg/kg) |
|---|---|---|---|
| Iran | 500 | 75 | 1 |
| China | 200-300 | 80 | 0.6 |
| USA | 1100 | 200 | 0.48 |

One-way ANOVA analysis test was employed before comparing the measured values. In addition, Duncan's test was also employed to compare and the means. Statistical analysis of the data was performed by SPSS 20 software.

## Findings

There was a significant difference between the studied species (*Pinus eldarica, Ulmus umbraculifera* and *Quercus brantii)* (p=0.0001; Table 2).

**Table 2)** One-Way ANOVA results for Cadmium, Zinc, Lead and Manganese among tree species

| Heavy Metals | Mean Square | F |
|---|---|---|
| **Cadmium** | | |
| Soil=0-10cm | 0.004 | 180.403 |
| Soil=10-20cm | 0.007 | 580.667 |
| Leaf | 0.002 | 118.628 |
| **Zinc** | | |
| Soil=0-10cm | 0.327 | 139.026 |
| Soil=10-20cm | 0.201 | 211.425 |
| Leaf | 0.621 | 188.389 |
| **Lead** | | |
| Soil=0-10cm | 0.580 | 157.996 |
| Soil=10-20cm | 0.260 | 235.726 |
| Leaf | 0.436 | 109.253 |
| **Manganese** | | |
| Soil=0-10cm | 0.322 | 191.201 |
| Soil=10-20cm | 0.040 | 23.031 |
| Leaf | 0.203 | 241.867 |

The results of sequestration of elements in the electro filter, soil, and leaves of the studied tree species have been shown in diagram 1 (a, b, c and d).

The level of cadmium (0.553mgkg$^{-1}$) in the electro filter of the factory was almost close to the level of cadmium sequestrated in the leaves and soil of the species. However, the level of lead (40.25mgkg$^{-1}$), zinc (3.92mgkg$^{-1}$) and manganese (3.74mgkg$^{-1}$) in the factory electro filter was far higher than the extent of sequestration of these three elements in the leaves and soil of the samples (Diagram 1).

Across the three studied species, there was a special order, where with increased depth of soil, the extent of lead sequestration diminishes. Furthermore, sequestration of cadmium in oak and pine, sequestration of zinc in oak, sequestration of manganese in oak and elm diminishes with the elevation of soil depth.

In terms of comparison of sequestration of heavy metals in soil with leaves in the studied species, the extent of sequestration of cadmium, lead, and manganese in soil across the three species was higher than the extent of sequestration of these metals in the leaves of the species. However, in contrast to these results, the extent of sequestration of lead was larger in the leaves of all of the three species than in soil.

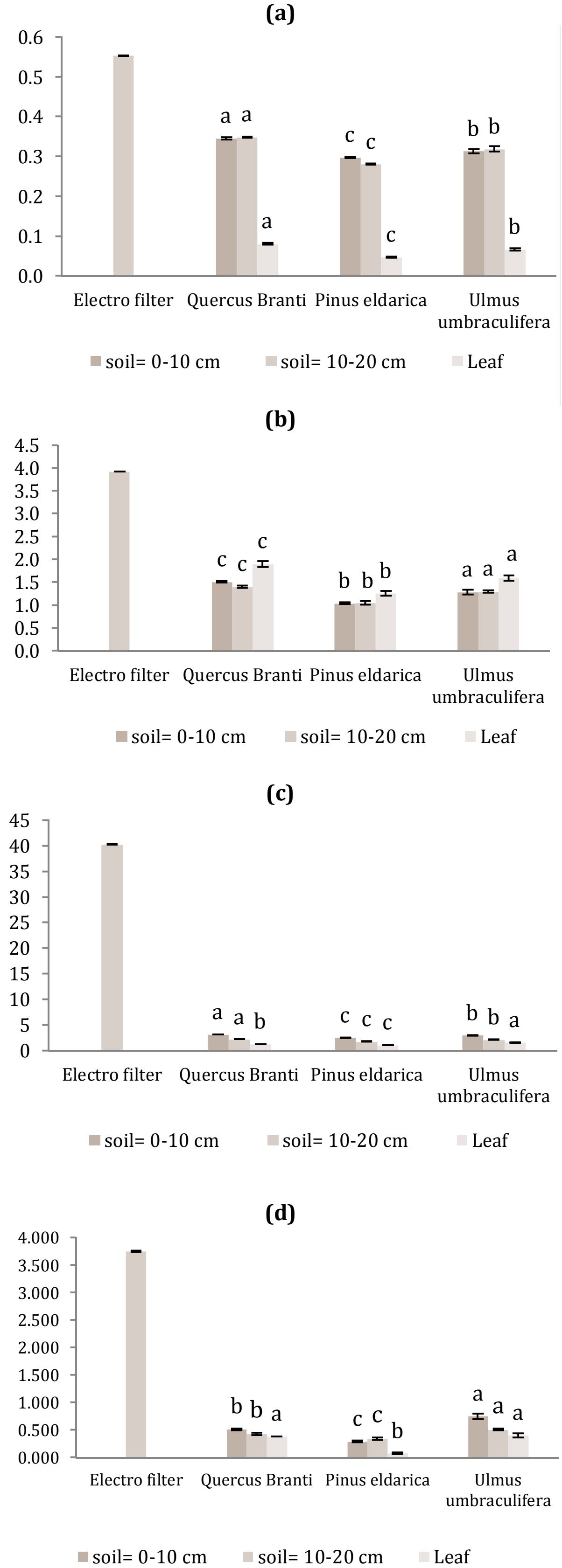


**Diagram 1)** Sequestration of cadmium (a), zinc (b), lead (c) and manganese (d) in the soil and leaves of the species along with electro filter

The minimum extent of cadmium sequestration showed in the soil and leaf. With cadmium sequestration, the maximum extent of sequestration of zinc, both in the leaf and soil was observed in oak.

On the other hand, the extent of zinc sequestrated in the soil and leaf of the pine was lower than that of other species.

As with sequestration of cadmium and zinc, the maximum lead sequestration, both in the leaf and soil was observed in oak. In addition, the extent of lead sequestrated in the soil and leaf of the pine was lower than the two other species.

The maximum extent of sequestration of manganese, both in soil and leaf was observed in elm.

With sequestration of cadmium, zinc, and lead, the extent of manganese sequestrated in the soil and leaf of pine was lower than that of two other species.

## Discussion

The aim of this study was to examine the extent of metals Cd, Zn, Pb and Mn in soil and leaves of planted around this factory in *Pinus eldarica, Ulmus umbraculifera* and *Quercus brantii* grown naturally there.

In the present study, the results of analysis of variance of the elements sequestrated in two depths of soil as well as sequestration in leaves indicated that there was a significant difference between the studied species. Comparison of means in each soil depth or leaf has been done among three species.

In environments contaminated with heavy metals, plant species can absorb part of these metals, thereby partially mitigating environmental contamination. The potential of accumulation of heavy metals in different plant species can be variable [21], which is most probably related to the physiological attributes of these species, such that some plant species, as superabsorbent plants can absorb much of heavy metals from the environment, without bearing any damage to themselves [22]. In contaminated environments, highly resistant tree species should be used, in order to be able to absorb parts of these contaminants by these trees and prevent diffusion of contaminants to the surrounding environments at least to some extent.

The results of this research indicated that the level of cadmium (0.553mgkg$^{-1}$) in the electro filter of factory is almost close to the level of cadmium sequestrated in the leaves and soil of the species. However, the level of lead (40.25mg kg$^{-1}$), zinc (3.92mgkg$^{-1}$) and manganese (3.74mgkg$^{-1}$) in the factory electro filter is far higher than the extent of sequestration of these three elements in the leaves and soil of the samples.

The results of sequestration of lead in the soil showed that across the three studied species, there is a special order, where with increased depth of soil, the extent of lead sequestration diminishes. Furthermore, sequestration of cadmium in oak and pine, sequestration of zinc in oak, sequestration of manganese in oak and elm diminishes with an elevation of soil depth. The extent of leakage of heavy metals to lower layers of soil depends on various factors, including accumulation and motility of metals, acidity, oxidation potential, soil material, concentration as well as type of competitive ion, organic compound content, cation exchange capacity, clay minerals, calcium carbonate, iron and manganese oxides, ionic power, soil material, special adsorption, size of soil particles, and properties of plant on absorption and desorption of metals [23].

The results of this research are in accordance with the researches of Samani Majd *et al.* [3], and Rotkittikhun *et al.* [24] Studies of Samani Majd *et al* [3] have shown that with absorption of heavy metals, clay colloids present in the soil surface prevent their leaching and transference to lower layers of soil. For this reason, the maximum level of heavy metal concentration can be observed in superficial horizons of soil.

In terms of comparison of sequestration of heavy metals in soil with leaves in the studied species, the results of the present study showed that the extent of sequestration of cadmium, lead, and manganese in soil across the three species was higher than the extent of sequestration of these metals in the leaves of the species. However, in contrast to these results, the extent of sequestration of lead was larger in the leaves of all of the three species than in soil.

The finding of this study elm showed the minimum extent of cadmium sequestration in soil and leaf. As with cadmium sequestration, the maximum extent of sequestration of zinc, both in the leaf and soil was observed in oak. On the other hand, the extent of zinc sequestrated in the soil and leaf of the pine was lower than that of other species. The results also indicated that as with sequestration of cadmium and zinc, the maximum lead sequestration, both in the leaf and soil was observed in oak. In addition, the extent of lead sequestrated in the soil and leaf of pine was lower than the two other species. In this study, it was found that oak is a species with a high sequestration potential, which is congruent with the results obtained by Dominguez *et al.* [25]. In their study, they found that the holm oak had a high tolerance against soil contamination with heavy metals, and its root enjoys a high potential for absorption of this metal. Furthermore, the results indicated that the maximum extent of sequestration of manganese, both in soil and leaf was observed in elm. In addition, as with sequestration of cadmium, zinc, and lead, the extent of manganese sequestrated in the soil and leaf of pine was lower than that of two other species. In their research, Shabanian and Cheraghi [26] compared the phytoremediation of Cd, Pb, Mn and Zn in two regions (control and contaminated) on tree species and found that in the contaminated region, the maximum extent of cadmium accumulation was observed in *Platycladus*, which is a needle-leaved species, which is incongruent with the results of this study. On the other hand, they concluded that in the contaminated region, the maximum extent of manganese accumulation was observed in *Ulmus*, which is in line with the results of this research.

Under conditions where air pollution has changed into one of the serious problems of most provinces of Iran and phenomena such as temperature inversion have complicated it, suitable plants are one of the most important solutions to tackle this problem. Accordingly, greater attention has been paid to plants as a remedy for air pollution in industrial regions; through the synthesis process and by absorbing carbon dioxide and converting it to oxygen, plants naturally absorb extra carbon of the air. Furthermore, the bad climatic conditions that are typical to industrial regions will be improved with elevation of the number of trees in those spaces, where the trees can act as natural air purifiers. The results of this study indicated that broadleaved species of oak and elm were far more successful than the needle-leaved species of pine in terms of sequestration of heavy metals [27]. These results are in accordance with the research conducted by Baycu *et al* [22]. They showed that broad leaved trees absorbed more heavy metals than needle leaved trees. It seems that, the old age of natural bases of oak is another reason of greater sequestration of heavy metals in the species in comparison with the two other species, which are man-made [28, 29].

From the results, it can be concluded that the contaminants of Ilam cement factory and especially heavy metals significantly influence the studied species. Overall, the results obtained from this research indicated that the greater extent of sequestration of metals is related to oak and elm which are species with a higher absorptive in comparison with absorbing contaminants of cement factory. Therefore, priority can be given to these species especially in the future plans for development of green spaces around this factory. Regarding to that the sequestration quantities of each heavy metal either in soil or in plant is much lower than the maximum standard concentrations for heavy metals (Zn, Cd and Pb) in agricultural soils and plants leaf, therefore it can be deduced that this factory has little dangers (threatening effects) on soil and trees planted around it. Thus, it is better to prioritize these two species in future plans for the development of green space. Evidently, the results obtained from such studies can be of great benefit in future plans of development of green space and selection of hyperaccumulator species in industrial environments especially cement factories.

The limitations of this research include lack of adequate budget and access to various parts of the cement factory. The suggestions are investigating the effects of pollutants on micro and macro organisms in soil, use of pollution reduction systems in accordance with international standards and development of green space around the factory.

## Conclusion

*Quercus brantii* and *Ulmus umbraculifera* have a greater potential in sequestration of heavy metals in comparison with *Pinus eldarica*. The contaminants of Ilam cement factory and especially heavy metals influence the studied species. The greater extent of sequestration of metals is related to oak and elm which are species with a higher absorptive in comparison with absorbing contaminants of the cement factory.

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