Article

Cadmium and lead absorption in soil and plants of *Cercis siliquastrum* and *Ailanthus altissima*

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Received 21 May 2019; Accepted 30 June 2019; Published 1 December 2019

Abstract
The plant growing on pollution area could represent a specific flora having potential hyperaccumulators, accumulators and excluder species. This study examines lead (Pb) and cadmium (Cd) contamination in two parks soils, leaves, and one-year branch trees in Alborz, Iran, and its potential phytoremediation. In this research, *Ailanthus altissima* and *Cercis siliquastrum* were selected among the species planted in the city of Karaj and investigated the absorption capacity of lead and cadmium by these species. 240 samples of leaf, branch, and soil prepared by Digest hal device for chemical analysis and extraction and the number of heavy metals in each sample was measured by ICP. The result indicated that the relationship between lead concentration in the soil and lead concentration in the stem of the Ailanthus (*Ailanthus altissima*) and the Judas tree (*Cercis siliquastrum*) in both regions was positive and significant.

Keywords phytoremediation; Ailanthus (*Ailanthus altissima*); Judas tree (*Cercis siliquastrum*); cadmium; lead; contamination.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Contamination of the environment by heavy metals has increased dramatically at the beginning of the 20th century, as a result of anthropogenic activities (Abdelhafez and Li, 2014; Lone et al., 2008; Prajapati and Meravi, 2014; Su et al., 2014). Several contamination sources contaminated large areas over the world, i.e., emissions from waste incinerators, car exhaust, residues from mining and military activities, smelting industry and the use of agricultural amendments (sludge or urban composts, pesticides, and mineral fertilizers (Abou-Shanab et al., 2011; Abdelhafez et al., 2012). Toxic heavy metal can pose a serious threat to human health, due to bioaccumulation in humans and it cannot be easily degraded, so the remediation of heavy metal contaminated soil is particularly important (Chishan et al., 2012). Several remediation technologies are available for treating heavy metals contaminated soils. To overcome this kind of environmental crisis, several researchers have reported various techniques for metal remediation in the environment (Xiong et al., 2012;

Kumar and Schröder, 2009). Among the methods, phytoremediation is desirable, environmental friendly cleanup, and economically effective technique that uses plant species to reduce contaminate aquatic or terrestrial sites contaminated by heavy metals (Abou-Shanab et al., 2011). Plants differed in their ability to accumulate heavy metals (Nouri et al., 2009; Kacalkova et al., 2015); for this concern, the selection of plant species for phytoremediation of heavy metals depends mainly on the ability of tolerant capacity and the biomass of the selected plant (Rezania et al., 2016; Wu et al., 2015). The high biomass of plant the high metal ions removed from the treated soil. Some plant species can accumulate high contents of heavy metals in their tissues; however, produce little biomass and are slow-growing plants, which makes it unfeasible to use these species in phytoremediation. The main purpose of this study is comparing the amount of cadmium and lead accumulated by leaves and one year branches of *Cercis siliquastrum* and *Ailanthus altissima* in order to determine the more suitable species for phytoremediation.

2 Study Area and Methodology

2.1 Study site

Alborz is one of the 31 provinces of Iran, centered in Karaj. Alborz Province was formed by the division of Tehran Province into two provinces, after the Parliamentary approval on June 23, 2010, and was introduced as the 31st province of Iran. In 2014 it was placed in Region 1. Situated northwest of Tehran, the Province of Alborz has 6 counties. Alborz Province is situated 35 km west of Tehran, at the foothills of the Alborz Mountains.

2.2 Data collection

In this study the two green-belt selected; Jahan (110753 m^2) and 22 Bahman (4422 m^2) selected for collecting the sample. Twenty trees (*Cercis siliquastrum* and *Ailanthus altissima*) were selected from each site and collected (soil, leaf and one year branch). Soils samples were collected at surface level (0–10 cm in depth). The aerial parts were sampled using a pair of stainless steel scissors. All samples were stored in polyethylene bags in the field and transferred to the laboratory within 4 h for preparation. After removal of visible pieces of plant residues, the soils were air-dried, crushed, sieved through a 2 mm screen. Samples (leaf & branch) were washed with tap water followed by de-ionized water to remove soil particles or dust adhering to the plant surface and dried with tissue paper. The collected samples were air-dried and sieved into coarse and fine fractions. Well-mixed samples of 2 gr each were taken in 250 mL glass beakers and digested with 8 ml of aqua regia on a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 mL of 2 % nitric acid, filtered and then diluted to 50 mL with distilled water (Khalid et al., 2012). Heavy metal concentrations of each fraction were analyzed by Atomic Absorption Spectrophotometer. Quality assurance was guaranteed through double determinations and use of blanks for correction of background and other sources of error. PH was measured potentiometrically in a 1: 2.5 soil–water suspension. EC was measured in the saturated soil-paste extract using the PL-700PCbench top conductivity. EC soil in zone 1 was 0.74 while pH was 8.1 also in zone 2 EC was 1.55 and pH was 8.23. Soil properties in Jahan Park and 22 Bahman Park were sandy clay loam and clay loam respectively.

2.3 Data analysis

All statistical analyses were performed using the statistical package SPSS 17.0. Correlation between Cd, Pb concentrations in the soils and in the plant was performed using the Pearson correlation procedure. The difference in Cd, Pb concentrations among plant and soil samples collected from different orchards was detected using one-way ANOVA, followed by multiple comparisons using the least significant difference. The level of significance was set at $p<0.05$ (two-tailed). Bio-Concentration Factor (BCF) of Heavy metals accumulation in agricultural soils is of increasing concern due to the food safety issues and potential health risks as well as its detrimental effects on soil ecosystems (McLaughlin and Singh, 1999). Bio-Concentration Factor (BCF) of Cd and Pb from soils to leaves and branches were calculated as follows:

BCF=Metal concentration in plants/ Metal concentration in soil

3 Results and Discussion

3.1 Heavy metal contents

Soil properties and heavy metal contents in soils and plants selected characteristics of the soil samples collected from this study are shown in Table 1. The levels of clay, high percentages of organic matter (N_2%) and the presence of carbonate (11–60%) seem to suggest important retention of heavy metals by these components in most of these soils. However, the high salinity in some fields (N4 dS/m) seems to facilitate the mobility of some heavy metals Cu, etc.

Table 1 Soil characteristics of two zones, Jahan Park and 22 Bahman Park.

Zone	Texture	Clay %	Silt %	Sand %	Salinity	Acidity	lime	Organic Matters	Organic Carbon %	Potassium ppm	Phosphor ppm	Total Nitrogen %
1	Clay Loam	46.87	33.53	19.60	0.43	7.36	45.83	0.50	0.71	260	5.4	0.21
2	Clay Loam	36.47	42.13	21.40	0.44	7.45	51	0.36	0.57	180	7.7	0.15

According to the results of soil analysis in zones 1 and 2, and at a depth of 0-20 cm from the soil surface, the mean concentration of lead and cadmium in the soil of the zone1, was about 12.24 and 50.40 mg/kg respectively, when using Ailanthus, and in the case of Judas tree, was 13.16 and 5.79 mg/kg respectively. The mean concentration of these metals in zone 2, was about 9.12 and 4.82 mg/kg when using Judas tree, and in the case of Ailanthus, was 9.46 and 4.32 mg/kg respectively. Table 2 shows the average concentration of metals in the soil.

Table 2 The concentration of metals in the soil exchangeable form (mg/kg) (n=20).

	Plant	Metal	Ave.	Max.	Min.	SD
Zone 1	*Cercis siliquastrum*	Lead	12.24	15.40	10.21	10.21
		Cadmium	5.40	6.41	4.33	4.33
	Ailanthus altissima	Lead	13.16	14.37	11.40	11.40
		Cadmium	5.79	7.10	3.90	3.90
Zone 2	*Cercis siliquastrum*	Lead	9.12	12.02	9	9
		Cadmium	4.82	6.12	3.25	3.25
	Ailanthus altissima	Lead	9.64	12.32	8.50	8.50
		Cadmium	4.32	5.51	3.42	3.42

According to the analysis, the concentrations of lead and cadmium in Jahan Park located in the 9th district and 22 Bahman Park located in the 5th district of Karaj city, the following tables are presented.

Table 3 Concentration of heavy metals in leaf and stem, zone 1 (mg/kg; n=20).

Plant	Metal	Ave.	Max.	Min.	SD
Cercis siliquastrum	Lead	2.4	2.9	1.10	0.41
	Cadmium	2.6	3.4	2.35	0.51
Ailanthus altissima	Lead	12	14.2	10.10	1.14
	Cadmium	11.38	12.3	8.90	1.27
Cercis siliquastrum	Lead	2.7	3.1	1.85	0.32
	Cadmium	2.5	3.7	2.05	0.64
Ailanthus altissima	Lead	13	16.1	10.80	1.17
	Cadmium	12	14.2	10.10	1.14

*significant at the level of 0.05.

As shown in Table 3, in zone 1, the mean concentration of cadmium in leaf and stem of Judas tree is 2.4 and 2.6, respectively, and the average concentration of lead in leaf and stem is 12 and 11.39, respectively. The maximum concentration of cadmium is related to the stem of the Judas tree and is 3.4 (mg/kg) and the minimum absorption is 1.10 (mg/kg) in the leaf of Judas tree. The maximum absorbed concentration of lead, 14.2 (mg/kg) is absorbed by the leaf of Judas tree and the minimum absorbed concentration of lead 8.9 (mg/kg) is in the stem. The results also showed that the mean concentration of cadmium adsorption by the stem of Ailanthus in the zone 1, is 2.5 (mg/kg), and in its leaf 2.7 (mg/kg), and in the case of lead in leaf and stem is 13 and 12 respectively. Also, the maximum absorbed concentration of lead, 16.1 (mg/kg) is absorbed by the leaf of Ailanthus, and the minimum concentration is 10.10 (mg/kg) absorbed by stem, and in the case of cadmium, the minimum concentration, 1.85, is in the leaf and the maximum, 3.7, is in the stem.

Table 4 Concentration of heavy metals in leaf and stem, zone 2 mg/kg (n=20).

Plant	Metal	Ave.	Max.	Min.	SD
Cercis siliquastrum	Lead	2.5	3.1	1	0.38
	Cadmium	2.8	3.7	2.23	0.20
Ailanthus altissima	Lead	12	14.9	11.05	1.00
	Cadmium	11	13.7	9.7	1.10
Cercis siliquastrum	Lead	2.3	2.59	1.43	0.29
	Cadmium	2.7	3.7	2.33	0.67
Ailanthus altissima	Lead	14	15.86	11	1.23
	Cadmium	11	14.54	9.79	1.18

* significant at the level of 0.05

The review of Table 4 shows that the mean concentration of cadmium by the stem of Judas tree is 2.8 (mg/kg) and by the leaf is 2.50 (mg/kg) and the mean absorbed concentration of lead for leaf and stem is 11 and 12, respectively. The maximum absorbed concentration of lead, 14.9 (mg/kg) by the leaf of Judas tree, and the minimum concentration is 9.7 (mg/kg) in stem, and in the case of cadmium, the maximum concentration, 3.7, is in the stem and the minimum, 1, is in the leaf.

Also, the maximum concentration of cadmium, 3.7 (mg/kg) is in the stem of Ailanthus, and minimum absorption of it, 1.43 (mg/kg) is in the plant leaf. The mean absorbed concentration of cadmium in leaf and stem is 2.3 and 2.7, respectively. The maximum concentration of lead is in the leaf, 14.9 (mg/kg) and the minimum of it, 9.79 is in the stem. The mean absorbed concentration of lead in the leaf and stem is 14 and 11 (mg/kg), respectively. Results of measurement of heavy metals, lead and cadmium in two species, Ailanthus and Judas tree in two zones of Karaj, performed that the maximum absorption of heavy metal is related to the leaf of Ailanthus, 14 (mg/kg). Also, the comparison of the mean absorption showed that the stem of both plant species had equal levels in the absorption of heavy metals ($p>0.05$).

According to the Tables 3 to 4, there is no significant difference in lead and cadmium adsorption, between leaf and stem of Ailanthus and Judas tree in zone 1 and 2. In fact, the comparison of the rate of adsorption of cadmium and lead in aerial parts of sampled plants (Ailanthus and Judas tree), showed that there is no significant difference ($p>0.05$) in these metals adsorption, between the leaf and the stem of Ailanthus of zone 1 in the compare of zone 2, and between the leaf and the stem of Judas tree of zone 1 in the compare of zone 2. The result of the investigation of the relationship between lead concentration in soil and this metal concentration in the stem of Ailanthus plant in both studied zones performed this correlation is significant at the 95% level, due to the $p>0.05$. The amount of correlation coefficient between lead in the soil and lead in the stem of Ailanthus in zone 1 is 0.451 and this correlation is positive and significant, due to the $p>0.05$. Also, the amount of correlation coefficient between lead in the soil and lead in the stem of Ailanthus in zone 2 is 0.432, that this correlation is positive and significant, due to the p-value. Therefore, you can say that by increasing lead concentration in the soil, the lead concentration in the plant stem is also increasing. So, the Ailanthus plant is an acceptable bioindicator for the lead metal . The result of the investigation of the relationship between lead concentration in soil and this metal concentration in the stem of Judas tree performed this correlation is significant at the 95% level, due to the $p>0.05$.

Table 5 Correlation matrix between lead concentrations in soil and stem samples zone 1 and 2.

		Pearson's correlation	Sig (p)
Zone 1	*Ailanthus altissima*	0.451*	0.043
	Cercis siliquastrum	0.345*	0.381*
Zone 2	*Ailanthus altissima*	0.432*	0.037
	Cercis siliquastrum	0.039	0.042

*Pearson's correlation significant at the level of 0.05.

The amount of correlation coefficient of lead in the leaf of a plant in zone 1 is 0.345 and this correlation is positive and significant, due to the p-value. The amount of correlation coefficient of lead in the stem of the Judas tree in zone 2 is 0.381, and this correlation is positive and significant, due to the p-value. The results show that by increasing lead concentration in the soil, the lead concentration in the plant stem is also increasing. So, the Judas tree is also an acceptable bioindicator for the lead metal. The result of the investigation of the relationship between lead concentration in soil and this metal concentration in the leaf of Ailanthus plant in both studied zones performed this correlation is significant at the 95% level, due to the $p>0.05$. The amount of correlation coefficient between lead in the soil and lead in the leaf of Ailanthus in zone1 is 0.362 and also, the amount of correlation coefficient in Judas tree is 0.315, and this correlation is positive and significant, due to the p-value. Also, the amount of correlation coefficient between lead in the soil and lead in Ailanthus plant in zone 2 is 0.352, and in Judas tree is 0.340, that this correlation is positive and significant, due to the p-value. Therefore, it can be stated that with increasing lead concentration in the soil, the concentration of the lead in the plant leaf, will increase.It is important to note that, the stored lead will return to nature in the fall season, due to the accumulation of lead in the leaf. Therefore, measures of authorities are required for gathering and eliminating these.

Table 6 Correlation matrix between lead concentrations in soil and leaves samples zone 1 and 2.

		Pearson's correlation	Sig (p)
Zone 1	*Ailanthus altissima*	0.362*	0.031
	Cercis siliquastrum	0.315*	0.042
Zone 2	*Ailanthus altissima*	0.352*	0.045
	Cercis siliquastrum	0.340*	0.033

*Pearson's correlation significant at the level of 0.05

The result of the investigation of the relationship between the concentration of cadmium in the soil and the concentration of cadmium in the stem of Ailanthus plant (both zones) performed that there is no correlation between cadmium in the soil and in the plant stem, due to the $p<0.05$. The result of the investigation of the relationship between the concentration of cadmium in the soil and the concentration of cadmium in the stem of Judas tree (both zones) performed that there is no correlation between cadmium in the soil and in the plant stem, due to the $p<0.05$.

Table 7 Correlation matrix between cadmium concentrations in soil and stem samples zone 1 and 2.

		Pearson's correlation	Sig (p)
Zone 1	*Ailanthus altissima*	0.350	0.61
	Cercis siliquastrum	0.320	0.51
Zone 2	*Ailanthus altissima*	0.470	0.530
	Cercis siliquastrum	0.41	0.64

*Pearson's correlation significant at the level of 0.05

The result of the investigation of the relationship between the concentration of cadmium in the soil and the concentration of cadmium in the leaf of Ailanthus plant and Judas tree (both zones) performed that there is no correlation between cadmium in the soil and in the plant's leaf, due to the $p<0.05$.

Table 8 Correlation matrix between cadmium concentrations in soil and levees samples zone 1 and 2.

		Pearson's correlation	Sig (p)
Zone 1	*Ailanthus altissima*	0.74	0.12
	Cercis siliquastrum	0.67	0.64
Zone 2	*Ailanthus altissima*	0.66	0.16
	Cercis siliquastrum	0.17	0.21

*Pearson's correlation significant at the level of 0.05

3.2 Bio-Concentration Factor (BCF)

In the study of heavy metals uptake by plants, the BCF index is of great importance. Therefore, this index was calculated in order to study and evaluate the ability of selected plants to clean up the environment from heavy metals. As outlined in Tables 4-11, the amount of bio-concentration factor of lead in studied plants, Ailanthus plant and Judas tree located in zone 1 and 2, is about 1, while the amount of this factor for cadmium in zones 1 and 2 is less than one. Therefore, the studied plants can be an appropriate bio indicator for the lead, but for cadmium, none of the plant tissues can be used as bio indicator. It should be noted that several factors, such as plant contact time, heavy metal concentration, age, plant biomass, also contribute to the absorption of metal by the plant.

Table 9 Bio concentration factor (BCF) zones 1 and 2 (n=20).

Metal	BCF	Zone 1		Zone 2	
		Judas tree	Ailanthus	Judas tree	Ailanthus
		SD± Ave	SD± Ave	SD± Ave	SD± Ave
Cadmium	Stem	0.48±0.21	0.47±0.17	0.5±0.44	0.63±0.38
	Leaf	0.44±0.25	0.44±0.38	0.58±0.29	0.53±0.32
Lead	1Stem	0.93±0.87	0.93±0.76	1.20±0.71	1.14±0.68
	Leaf	0.98±0.53	0.98±0.49	1.31±0.83	1.45±0. 95

The plants are divided into 4 groups based on the BCF index (Sangi et al., 2008):

None hyper-accumulator: BCF ≤ 0.01

Low hyper-accumulator: 0.01 < BCF < 0.1

Mid hyper-accumulator: 0.1 < BCF < 1

Super hyper-accumulator (Superabsorbent): 1 < BCF < 10

In previous studies, Lone et al. (2008) studied the absorption of lead and cadmium in several types of street broad-leaved species in China in natural conditions and introduced the index of metal accumulation in the foliage (MAI); they observed that *Catalpa speciosa* had the highest value of (MAI) among the other studied species. In addition, McCutcheon and Schnoor (2003) reported that the rate of lead absorption by *P. tremula* was more than *P. tremuloides*, by comparing the phytoremediation potential of the lead in two forested species of *Populus tremula* and *Populus tremuloides* in the Netherlands. The results obtained in this study were contrary to the results of Aftabtalab (2009), In his study, using a phytoremediation technique, researcher examined the ability of two species of the trees (*Platanus orientalis*) and (*Cupressus arizonica*) to absorb the two toxic elements of cadmium and lead through the leaf, and he performed that these two species are tolerant to high contaminant concentrations and the ability of leaves to absorb these pollutants, and these species have high capabilities. Stanislaw et al. (2013) studied the lead bioremediation ability of six species of trees and shrubs used in the green areas of the Netherlands, they reported the Lead absorption capacity of (*Robinia pseudo-acacia*) was about five times higher than other species studied. In another study, carried out by Khodakarami (2009), lead bioremediation ability by two species of *Quercus brantii* and *Pistacia atlantica*, was studied, the results showed in the case of accumulation of lead contaminant, these two forest species were placed in the category of superabsorbent plants, and It was determined that the *Pistacia atlantica* had the highest amount of leaf absorption, while the highest amount of root absorption was related to the *Quercus brantii*. Yanqun et al. (2007) in their study, reported that the *Salix cathayana* has known as a superabsorbent plant with a bio-accumulation factor higher than one.This research was conducted in natural conditions to investigate the ability of two species of Ailanthus (*Ailanthus altissima*) and Judas tree (*Cercis siliquastrum*), to absorb cadmium and Pb, finally, the results showed that there was no significant difference in the result of comparison of the adsorption of two cadmium and lead contaminants between two species in each region as well as between the regions. However, it should be noted that the ability of these two tree species to absorb heavy air elements such as cadmium and lead is different, and the potential for absorption of these two species is not the same (Baycu et al., 2006). There was also no significant difference between the two regions in terms of soil, so that there was no significant difference in the result of the comparison of the two elements separately in the soil of two regions, and it can be attributed to the fact that there is no significant transfer of pollutants from air into the soil in these areas. Fooder et al. (2003) investigated the interactions between Cd and Fe in the poplar species (Populus) and reported, with increasing cadmium leaf and stem absorption, the iron element transfer rate is significantly reduced, which leads to a significant reduction in photosynthesis and thus reduces the growth of the Poplar species.Finally, the results of this research that were conducted in completely normal conditions in two regions of Karaj, performed that the two studied species, Ailanthus (*Ailanthus altissima*) and Judas tree (*Cercis siliquastrum*), had no significant difference in the of absorption of heavy metals, cadmium, and lead, however, the absorbability of these two species in the fight against contaminating elements is different, and each one absorbs a certain amount of pollutants, which could have many reasons, but the main reason for this can be it, that the air pollution in the city of Karaj does not reach the threshold in the current situation. In this study, it was found that in these two regions only significant difference was observed between these two elements, cadmium and lead, somehow that comparison of cadmium and lead in each of the Ailanthus (*Ailanthus altissima*) and the Judas tree (*Cercis siliquastrum*) showed a significant difference, and the amount of lead absorbed by both species is greater than the amount of cadmium, may be due to the toxicity of the cadmium element and its harmfulness for plant life (Shahbazi et al., 2011).

4 Conclusion

The result indicated that the relationship between lead concentration in the soil and lead concentration in the stem of the Ailanthus (*Ailanthus altissima*) and the Judas tree (*Cercis siliquastrum*) in both regions was positive and significant. Therefore, it can be stated that with increasing metal concentration in the soil, the concentration of this element increases in the stem of these plants. So, the Ailanthus (*Ailanthus altissima*) and the Judas tree (*Cercis siliquastrum*) are considered as a proper bioindicator for the lead. Also, the results of this study showed that there is no significant difference between the two studied species of the Ailanthus (*Ailanthus altissima*) and the Judas tree (*Cercis siliquastrum*) in absorption of cadmium and lead in the present conditions of Karaj city, which can play an important role in taking appropriate decisions to prevent and control pollution in the city of Karaj.

Acknowledgment

The authors would like to express their appreciation to the Islamic Azad University and chemistry laboratory for their facilities and kind support.

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