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Full Length Article

Investigation of Lacan soil contamination with heavy metals and their accumulation in the regional plants

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ABSTRACT
Soil contamination around mines and related industries, is a global problem that has received much attention over the past three decades. During manufacturing process of Lacan`s lead and zinc factory in Mrkazi province, the release of large amount of various pollutants into the environment contaminate water and soil resources and also the air of that area. The objective of this study was to investigate the vegetation and soil contamination with heavy metal elements by measuring the levels of lead, zinc and cadmium in soil and vegetation of the area. In this study, samples from three species including Astragalus parrowianus, Gunjelia tournefori and Hurdeum bulbosum with the soil around their roots were collected in two contaminated and control areas and their cadmium; lead and zinc contents were identified and measured. Lead and zinc were measured after the digestion of the samples by Atomic Absorption Spectrophotometer and Cadmium analysis was performed using an ICP device. Statistical analysis of data was carried out using a variety of methods including multi-factor analysis of variance and independent t-test. The results showed that the levels of lead, zinc and cadmium in the soil surrounding industrial-mining unitsare734mg/kg, 7499mg/kg, 18.85mg/kg respectively and in the control area they are 77.8mg/kg, 273.6mg/kg , 2.5mg/kg and in the plants of the area surrounding the unit they are 251.8mg/kg, 1153.4mg/kg, 3.16mg/kg respectively and in the control area they are 44.85mg/kg, 48.4mg/kg,0.12mg/kg, respectively that indicate the great difference between the two areas. The mean of lead content in the surrounding plants of the factory also indicates that the accumulation of heavy metals in the roots of Gunjelia tourneforti and Hurdeum bulbosum was much more than above-ground organs but in the Astragalus parrowianus species no significant difference was observed between the amount of the accumulation in roots and above-ground organs.
Keywords: heavy metals, phytoremediation, zinc, lead, cadmium, the lead and zinc processing factory of Lacan

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INTRODUCTION

In the past decades the entry of human-originated contaminants such as heavy metals into the ecosystem has greatly increased and is considered as a serious threat to the life of earth`s ecosystem.

The existence of heavy metals in water, air and soil and the consequent contamination causes major environmental risks to human health and environment. Due to their accumulation characteristics and their durability and high resistance, the risks caused by them particularly for human and the living are intensified. Mining and processing of minerals as raw materials for many industries is considered as one of the major economic activities. This industry due to producing various contaminants, especially hazardous wastes that contain pollutants particularly heavy metals is considered as a contaminating and destructive industry [23]. To investigate the environmental problems caused by this industry scientists conducted numerous studies that some of them evaluated the effects of pollutants caused by mining and related industries by investigating the affected area`s vegetation [28], which shows the impact of these industries on the environment around them. Lead and zinc processing factory of Lacan is among these industries which is active in the field of producing lead and zinc concentrates. Considering the likeliness of contamination of the environment including pastures for livestock grazing, agricultural lands and residential places with heavy metals, carrying out some research in this field is essential. Throughout the study, variables such as the level of heavy metals in soil and vegetation will be estimated. The aim of this study was to measure the level of pollutants in the environment by investigation of soil and vegetation of the area. Due to the accumulation of toxic substances such as heavy metals (the accumulation process) as biological reagents, plant species are considered to be helpful bio indicators for investigation of existence and distribution of heavy metals around mines.

MATERIALS AND METHODS

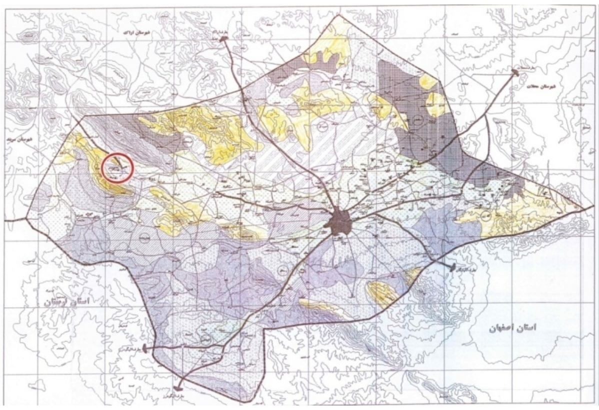
Introducing the factory and the study area

The main process of the Lead and zinc processing factory of Lacan is crushing the ore and the concentration of those elements using water cycle and flotation method. During this process industrial wastes are produced and without refining operations are directed to the tailings dam site. The tailings dam where wastes are stored is an open area of 10 to 15 hectares surrounded by an embankment so it is distinguishable from the surrounding areas. Solid was test have been accumulating over 40-50 years and have formed a solid mass. After entering this part as time passes, waste water dries and loses sits moisture and suspended particles containing metals and other compounds precipitate. When the tailings dam`s surface dries, blowing of the wind dispread these particles over the surrounding environment including pastures, agricultural lands and residential areas.

This factory is located 75 kilometers far from the southeast of Arak, 50 kilometers far from the southeast of Shazand and 45 far from the northeast of Khomein in rural areas of Lacan, the latitude and longitude are 52 41 33 and 48 43 49 and the height above the sea level is 2190 [12].

The climate of this area is semi-arid and the winter rainfall mostly includes snow and for spring it is rain. Vegetation is normal such as grass and dense thorny bushes like astragals.

Dry farming is used for grains. In farms which use irrigated farming different types of grains and sugar beets in addition to wheat are planted. In recent years drilling wells in different depths in order to access groundwater in a modern or traditional style has become widespread. The expansion of the wells has expanded the irrigated farming areas .There is no river in this area. Villagers provide the needed workers for the mine and the factory.



Picture (1) the map of Khomein and the location of lead and zinc processing factory

Sampling of the area`s vegetation

Plant samples were collected considering the growing season of plants in the region in the spring of 2012.Vegetation and soil sampling was performed based on the zoning map (prepared by Q homiand Hajatiin 2009), in two areas; an area without contamination (control area) and the contaminated area (at a radius of 200meters from the center of the tailings dam). The sampling was performed for 3 plant species including Gunjelia tourneforti, Hurdeum bulbosum and Astragalus parrowianus with three replications, for each species the plant samples were completely (aboveground and underground organs) picked and transported to the laboratory in paper bags and dried in 80 degrees to be tested. The reason for choosing Astragalus Parrowianus and Gunjelia Tourneforti was that prevalence in the surrounding and the control areas as the prevalent species and Hurdeum Bulbosum was chosen because of the aforementioned reasons in addition to the fact that some plants in their family were farmed as crops in the surrounding farms.

Sampling of the areas soil

Soil samples were collected from the plants in the sampling site and also soil samples were collected from the ground`s surface to a depth of 25cm, then they were mixed and transferred to the laboratory in plastic bags to be tested [9].

In vitro studies of plant and soil samples

Digestion and analysis of soil and plant samples

Samples were sieved using a 2mm sieve to measure the heavy metals in the soil, then about 2 g of the sieved soil was grinded into less than 80 microns in a porcelain mortar. Plant samples after being transferred to the laboratory first were washed by tap water then they were washed three times using distilled water. After that they were placed in paper bags and were dried inside an oven with 890° C for 24 hours. Then samples were ground using an electric grinder. The Digesdahl method was used for producing extracts from soil and plant samples. In this method, 5 g of the sample was weighed then using a funnel the weighed sample was inserted into the machine`s balloon and 4cc of normal sulfuric acid was poured on it, then the machine was turned on and when the temperature reached 430 degrees, the balloon was put inside it and after 10 minutes, 15 cc of hydrogen peroxide was added to the balloon to make the sample colorless, then after the balloon was cooled they made it reach up to 100 cc using demonized water and after passing from a filter paper it was poured into a Falcon tube. Atomic absorption spectrophotometer (modelGBC-AWANTA) was used to determine the concentration of zinc and lead in soil and plant samples and the amount of cadmium was determined by using a Varian model of ICD.

RESULTS

Data Analysis:

In order to analyze the data the statistical software SPSS (version 17) was used and the graphs were dawn using Excel 2010. Test method for determination of heavy metals in plants was Multivariate analysis of variance (completely randomized) and for soil analysis an independent t-test was used **[6].**

Standard values for heavy metals in soil and mushroom (EPA and WHO):

Table (1) the standard values of heavy metals in soil and mushroom (mg/ kg)

		arsenic	cadmium	copper	lead	zinc
Mushrooms(food)	WHO	0.5	0.5	40	2	60
soil	EPA	60	5	200	500	600

WHO: World Health Organization

EPA: Environmental Protection Agency America

Assessment of heavy metals in the soil surrounding factory (contaminated) and control area:

Table (2) the values of heavy metals in soil and contaminated areas

Values of heavy metals		mg/kg
Lead	contaminated area	820.3
	Control area	77.7
Zinc	contaminated area	7499
	Control area	274
Cadmium	contaminated area	18.8
	Control area	1.9

Lead:

Using a t- test data was analyzed and the research hypotheses stating the lack of equality in the mean of heavy metals in two regions were confirmed and the results and analysis of each tested metal is determined as follows:

The mean of lead in the soil of the area adjacent to the factory was 734mg/kg and it was higher than standard level, also the mean for lead in the soil of the control area was 77.7mg/kg which showed a difference of less than 10 times.

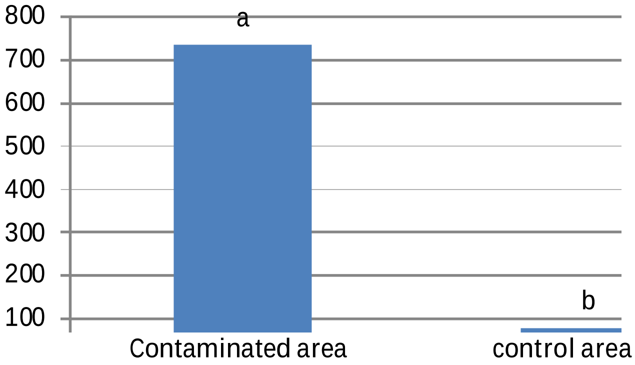


Figure (1) the mean value of lead in the soil of control and contaminated areas (mg/kg)

Zinc:

The mean for zinc in the contaminated area was 7499 that was higher than standard level and it was 274 in the control area. The comparison shows difference of more than 27 times.

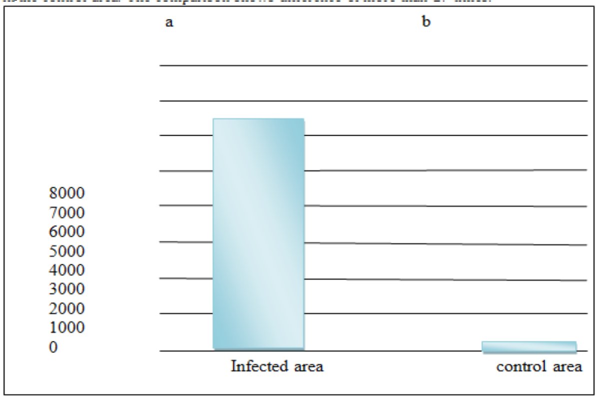


Figure (2) the mean for zinc in contaminated and control area (mg/kg)

Cadmium:

The lack of equality for the mean of the cadmium in two areas was confirmed according to the statistical analysis of the assumption. The mean for cadmium was .818 in the contaminated area and for the control area it was 1.9 mg. comparing the means shows a difference more than 9 times and also it indicates the contamination of soil adjacent to the factory.

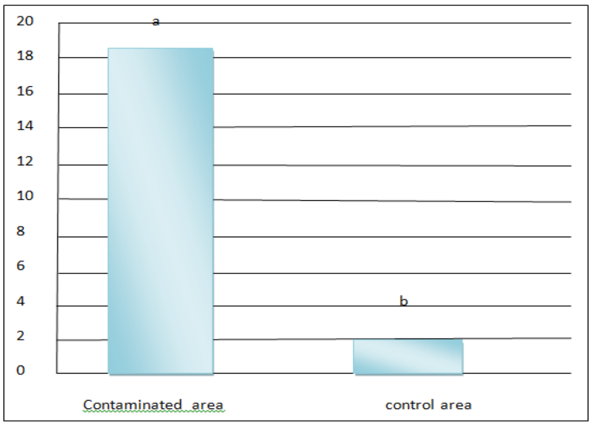


Figure (3) the mean for cadmium in the soil of contaminated and control areas (mg/kg)

Investigation of heavy metal elements in plants surrounding the factory area and the control area:

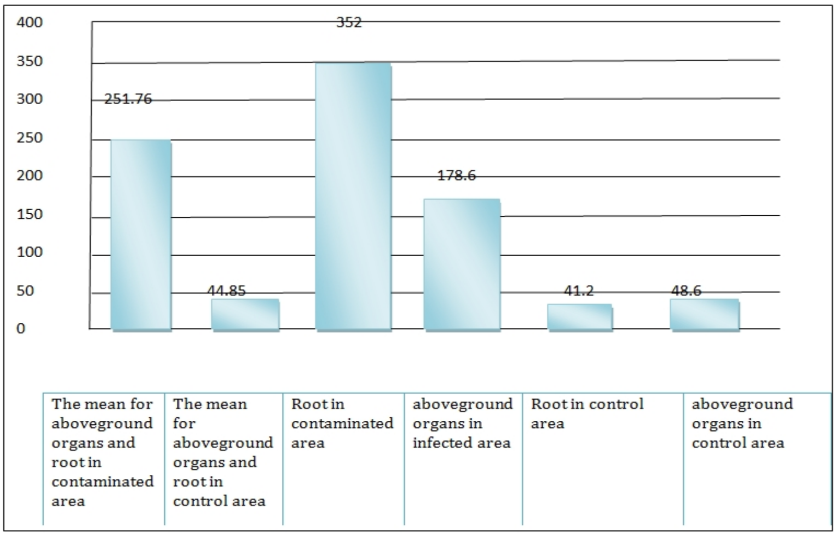
To investigate the hypothesis, analysis of variance of the data normality assumption was done using Kolmogorov-Smirnov test and Lon test was performed for the equality of variance [6].which indicates the potential for analysis of variance in the statistical analysis.

Lead:

Table (3) the effect of elements on the rate of lead uptake in plants

Elements	p-value	F	Partial Eta Squared	Sig.
Type of area	0.05<	F(1,24)=48.3	0.668	Significant effect
Type of plant species	>0.05	F(2,24)=0.767	-------	Without significant effect
Type of plant organs(root & aboveground organs	**0.05<**	**F(1,24)=6.8**	**0.22**	Significant effect
Interaction between type of area & type of species	>0.05	F(2,24)=0.35	-------	Without significant effect
Interaction between type of area & type of plant organs	>0.05	F(1,24)=8.1	-------	Without significant effect
Interaction between type of area, species, and organs	>0.05	F(2,24)=2.1	-------	Without significant effect

1: Statistical analysis showed that the effect of the area type (the area surrounding the factory and the control area) has been significant for the level of lead in the plant. The mean lead level in the plants surrounding the factory was 251.76 mg/kg and it was 44.85mg/kg for the plants of the control area that showed a difference more than 5 times.



3: The effect of the plant type on the lead absorption has been significant and the comparison of the means showed that the level of lead in the roots of all the tested species has been more than its level in the aboveground organs and this difference is higher in Gunjelia tourneforti than in other species. The mean of lead in the aboveground organs of Gunjelia tourneforti in the area adjacent to the factory is 140mg/kg and in the roots is 485 mg/kg which showed a difference more than 3 times. The mean of lead in the roots of the Hurdeum bulbosum species was 314mg/kg and in the aboveground organs was 150mg/kg showing a difference more than 2 times. The lead means in the roots of Hurdeum bulbosum was 257mg/kg and in the aboveground organs it was 250mg/kg indicating the least difference between the roots and the stem in the tested plants.

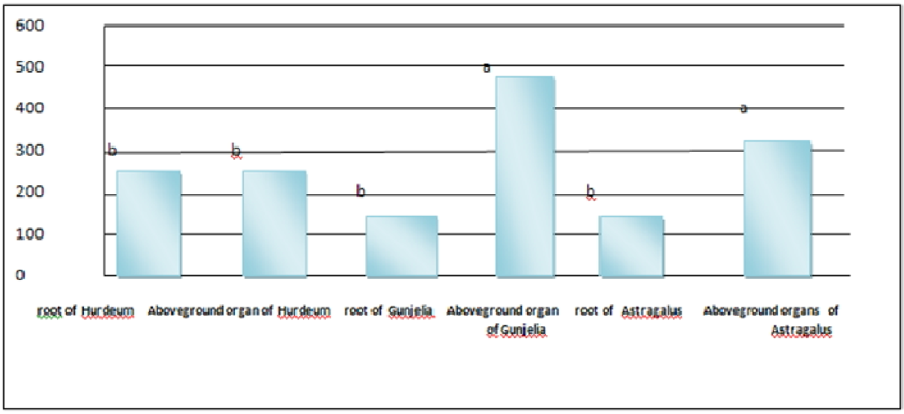


Figure (5) the level value of Pb in plant organs of the surrounding area of the factory (mg/kg)

The analysis showed that the interactive factors of the area type, plant type and the type of organ have not been significant in absorbing lead.

Zinc:

Table (3) the effect of elements on lead intake in plants

element	P-value	F	Partial Eta Squared	Sig.
Type of area	< 0.05	F(1,24)=22.3	0.48	Significant effect
Type of plant	>0.05	-------	-------	Without Significant effect
Type of plant organs	< 0.05	F(1,24)=6.3	0.21	Significant effect
Interaction between type of area & species	>0.05	-------	-------	Without Significant effect
Interaction between type of area & plant organs	< 0.05	F(1,24)=6.3	0.20	Significant effect
Interaction between type of species & organs	< 0.05	F(1,24)=48	0.29	Significant effect
Interaction between type of area, species, & organs	< 0.05	F(2,24)=4.6	0.27	Significant effect

1: Statistical analysis showed that the effect of the region (the area surrounding the plant and the control region) has been significant for the amount of zinc in the plant. The mean for zinc in the plants surrounding the factory was 1153.4g/kg and it was 48.4g/kg for the control plants showing a difference higher than 23 times.

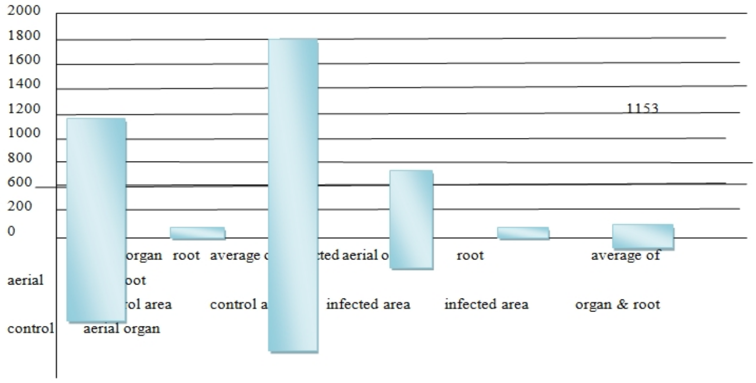


Figure (6) average value of zinc in aerial organs and roots

2: the confidence interval was 95% for the mean of zinc in the contaminated and control area (621.9, 1582.2) and in the different organs of the plant (-1072.8,-107.5)
3: The analytical results indicate that the effect of plants pieces on zinc uptake hasn`t been significant. But the mean analysis shows that Gunjelia tourneforti species contains higher levels of zinc in its organs.
4: the effect of the plant type on the amount of zinc uptake has been significant and the comparison of means shows that the level of zinc in the roots of Gunjelia tourneforti and Hurdeum bulbosum is higher than the aboveground organs and its level in Astragalus parrowianus in the aboveground organs has been more than its level in the roots in both areas. The mean of zinc in the aboveground organ of Gunjelia tourneforti in the area surrounding the factory was 213g/kg and it was 3137g/kg in the root showing a 14 times difference. The mean of zinc in the root of Hurdeum bulbosum was 1591g/kg and it was 404g/kg in the aboveground organ showing a difference of 3.9 times. The mean of zinc in the root of Astragalus parrowianus was 481mg/kg and it was 1094mg/kg in the aboveground organs showing that the aboveground organs are able to absorb zinc two times more than the root in the tested plants. In the control area the differences are less but the results are the same.

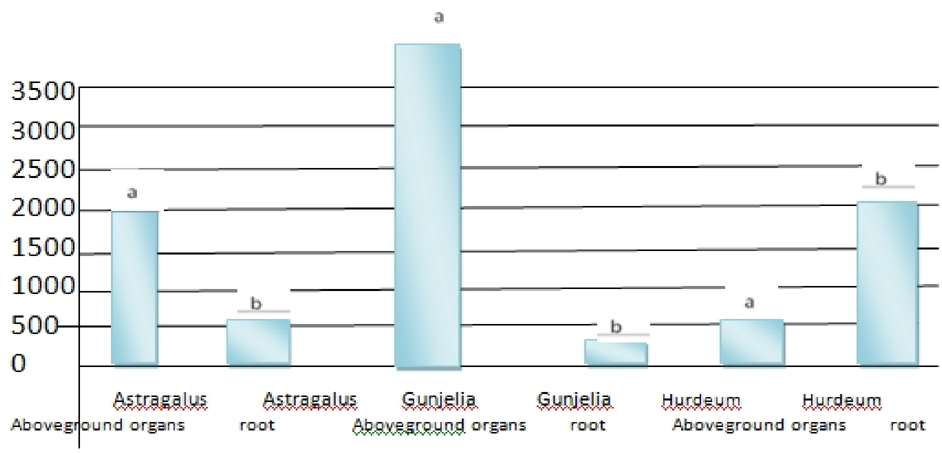


Figure (7) the mean of zinc in plant organs surrounding the factory (mg/kg)

5: the area type and the type of the plant`s species also organ type and 3 factors of area, type of species and type of the organ have interactive effects.
Cadmium:

element	P-value	F	Partial Eta Squared	Sig.
Type of area	< 0.05	F(1,24)=30.4	0.56	Significant effect
Type of plant	>0.05	-----------	- - - - - - - - - - - -	Without Significant effect
Type of plant organs	< 0.05	F(1,24)=10.7	0.3	Significant effect
Interaction between type of area & species	>0.05	- - - - - - - - - - - - -	- - - - - - - - - - - - -	Without Significant effect
Interaction between type of area & plant organs	< 0.05	F(1,24)=9.2	0.28	Significant effect
Interaction between type of species & organs	>0.05	F(2,24)=3.6	0.23	Significant effect
Interaction between type of area, species, & organs	>0.05	- - - - - - - - - - - -	- - - - - - - - - - - - -	Without Significant effect

Table (3) the effect of elements on cadmium uptake

1: the statistical analysis showed that the effect of the area type (the area surrounding the factory and control area) on cadmium level in plants has been significant. The mean level of zinc in the plants surrounding the factory was 16.3mg/kg and it was 12.0 in the plants of the control area which shows a difference of 25 times.

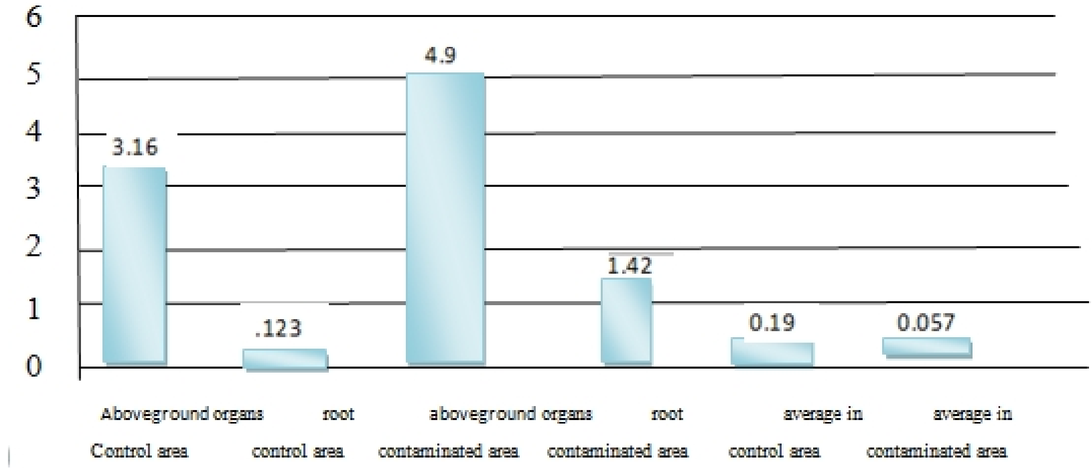


Figure (8) the mean level of cadmium in aboveground organs and root in the control and contaminated area (mg/kg)

2: The 95% confidence interval for the level of cadmium in the plants of the contaminated area and control area is (1.8, 4.1). Also the accumulation of this metal in the root with a 95% confidence interval (-2.9, -6.7) is more than the aboveground organs.

3: The effect of cadmium uptake on plant species is not significant. But investigation of the means revealed that Hurdeum bulbosum and Gunjelia tourneforti species contain more cadmium.

4: The effect of the plant type has been significant for cadmium uptake and comparison of the means showed that root generally has more capability for absorption than aboveground organs. The investigation showed that absorption in the root of Gunjelia tourneforti and Hurdeum bulbosum species is more than aboveground organs and in the Astragalus parrowianus species, its amount in the aboveground organ is a little more than root. The mean of cadmium in the aboveground organs of Gunjelia tourneforti in the area surrounding the factory is 0.3mg /kg and it is 6.8mg/kg in the root which shows a difference of 22 times. The mean of cadmium in the root of Hurdeum bulbosum is 5.7mg/kg and it is 1.5 in the aboveground organs which shows a difference more than 3.8. The mean of cadmium in the root of Astragalus parrowianus is 2.1mg/kg and it is 2.47 in its aboveground organs showing that the absorption of cadmium in the aboveground organs of tested Astragalus parrowianus is a little more than its root. The results, however, indicate that the uptake of cadmium in the organs of the area surrounding the factory is much greater than the control area. Although it showed that the highest uptake of cadmium in both tested areas has occurred in the root of Gunjelia tourneforti species.

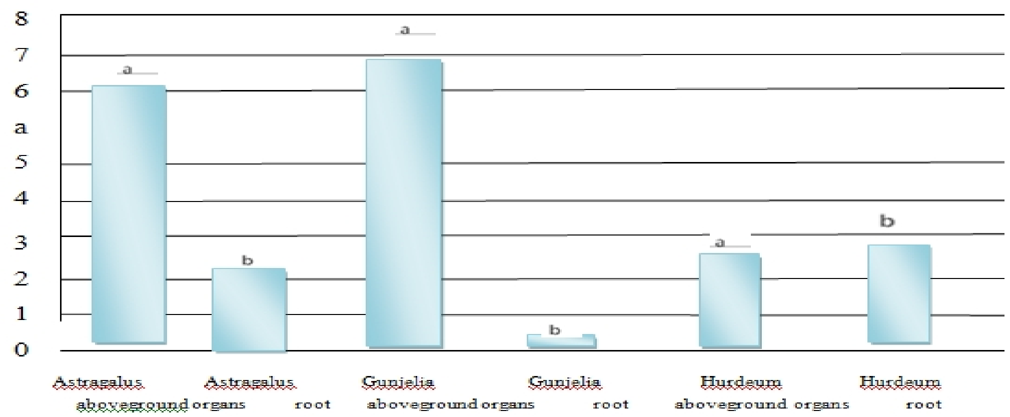


Figure (9) the level of cadmium in plant organs surrounding the factory (mg/kg)

5: the Type of area and type of the plant species and plant organ shave interactive effects. The type of the area and the type of the plant species and 3 factors of area type, species type and organ type lack the interactive effects.

DISCUSSION AND CONCLUSION

In generality can be concluded that the soiling the vicinity of the mine and lead-zinc processing factory of Lacan is contaminated with heavy metals more than the standard levels. These results are consistent with the research of Ghomi and Hajati [10] which was carried out investigating the soil and surface water samples by using geographic information system of this area. The results of the tests indicate that the plants surrounding the mining units contain much higher concentrations of heavy metals than the plants of the control area. These results are consistent with the research of Golchin and Shafiee [11] who studied the effect of the lead factory of zinc and lead of Zanjan on the contamination of the plants and crops and gardening products which revealed that the level of heavy metals of lead and cadmium in the crop plants of the area, particularly in the areas attached to the factory has been very high. Also, this study is consistent with the results of Del Rio and colleagues who studied more than 99 plant species in order to assess the increase of heavy metals from Aznalcollar mine in Spain; their research confirmed that many plant species including grass species contain high levels of heavy metal (lead, zinc, cadmium, copper).

(Del rio et al, 2002). It was also consistent with the results of Rodrigez, 2009 which showed that the level of heavy metals in agricultural and pasture and around the mine has been higher because of two major reasons including transmission of the contamination by the wind carrying the particles and the waste of the tailings dam. Separate Assessment of the plant samples indicates that the absorption of the heavy metal in the root is generally much higher than in the aboveground organs which are consistent with the research of Taji [3].

SUGGESTIONS

- Due to the heavy metal pollution of land surrounding the factory, avoid farming any plans or crops for human consumption.

-the tested plants had very high potential for absorption of heavy metals from soil, the reform, artificial and natural farming of them help to reduce soil contamination and prevent the entry of heavy metals in to the food chain and agricultural areas.

-we propose to plant Gunjelia tourneforti species in the pastures more than other species because it has the ability of accumulating the heavy metals and reducing this element in the soil and also according to the results, Gunjelia tourneforti stores the metal elements in its root more than other species and do not cause the entry of these elements into the food cycle by the livestock that feed from the aboveground organs of it.

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