

# Determination of Phytoextraction and Hyperaccumulating Capacity of Artemisa Dracunculus L and Erigeron Canadensis Plants of The Asteraceae Family.

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## Research Article

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# Abstract

One of its key aspects is the performance of plant extraction, the end-use of by-products and the recognition of its overall economic viability. Overall, phytoextraction seems to be a very promising technology for the removal of metallic pollutants from the environment and is being commercialized. In genetic engineering, support for the current plant phytoextraction list plays a major role. Because it makes it possible to insert which genes in genetically modified plants the plant to metabolize a specific pollutant. In the sequence to be used for phytoextraction. In Turkey, the steel industry and its subindustries operate intensively in Karabuk province. It is located in the western region of the Black Sea and grew rapidly. For this reason, plants that grow in areas and soil samples around their roots are with anthropogenic pollution were taken in connection with the steel industry and the building industry where the waste is discharged. For guidance, samples of plants and soils of the same species were collected from orchards where industrial pollution and agricultural activity have not occurred, in order to worth comparing them. Thus, the properties of the hyperaccumulator and accumulation were investigated. These are *Artemisa Dracunculul L (AD)* and *Erigeron Canadensis (EC)* in the Asteraceae family. As the BAF shoot values of the AD plant are Pb and Se > 1, this is an accumulator plant for Pb and Se. At the EC plant, this is an accumulator for Pb, as only Pb>1. Since Cr, Hg, Sn and Cl <1, these elements are presumed to be exclusionary. Also, the two plants can be classified as potentially Ni-hyperaccumulator plants because Ni is greater than 10 (Ni>10). BAF root of both plants has high phytostabilization capacity for Cd from Cd>1. The concentrations of Cd TF >1 in the leaf, stem and root indicate high phytoextraction efficiency and it can be said that it will exhibit high activity in soils contaminated by the Cd. In addition, due to the fact that the Cd concentrations of both plants are close to the hyperaccumulator plant BAF, studies can be carried out to evaluate them as Cd-hyperaccumulator plant in future studies.

# Introduction

Accumulation of heavy metals and metalloids can pollute soils such as emissions from rapidly expanding industrial zones, including metal mining and smelting (Chen et al. 2016), sewage sludge (Farahat and Linderholm 2015), electronic extraction and combustion of fossil fuels (Muradoğlu et al. 2015). Additionally, the use of phosphate fertilisers in agriculture (Hamzah et al., 2016; Rafique and Tariq, 2016). Animal manure, irrigation with wastewater. As well, water produced by the oil and gas industries originates from natural or man-made sources (Neff et al., 2011; Pichtel, 2016). Heavy metals are a group of hazardous inorganic chemicals that have not been completely identified. Lead (Pb), chrome (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni) are the most prevalent substances in polluted areas. (GWRTAC 1997). Soils are the major reservoirs of heavy metal accumulation released into the environment by the abovementioned anthropogenic activities and unlike organic pollutants which are oxidized to carbon by microbial activity, heavy metals cannot be decomposed by a biological or physical process, and they stay in the soil for a long time, creating a long-term threat to the environment (Suman et al., 2018). and their total concentration continues in soils long

after their introduction [D. C. Adriano 2003]. Once the heavy metals enter the soil, they are first adsorbed by the rapid responses (minutes, hours), followed by slow adsorption responses (days, years). As a result, they are converted to different chemical forms with variable bioavailability, mobility and toxicity [Shiowatana, J., 2001]. Direct ingestion or contact with contaminated heavy metals, which are transformed into soils in various forms, can enter the food chain by crops and they can accumulate in the human body by biomagnifying. Hence, they represent a significant threat to human health (Sarwar et al., 2010; Rehman et al., 2017). Moreover, the limited availability of land for agricultural production causes food insecurity and risks to ecosystems (McLaughlin, M. J, et al.,2000ab; J. Buekers., 2007). Therefore, remedial action is required to prevent heavy metals from entering terrestrial, atmospheric and aquatic environments and to reduce contaminated land (Gerhardt et al., 2017; Hasan et al., 2019). Various technologies exist to remediate metal-contaminated soils (Gupta et al., 2000). The simplest method is to excavate the upper layer of contaminated soil and bury it, or cover the contaminated area. However, there are disadvantages and risks involved. There is always potential for contaminant leakage during excavation, handling, transport and capping that could contaminate ground water. It is also very costly and time-consuming. Different techniques are available for the sanitation of soils contaminated by metals, such as chemical, physical and biological techniques. This is the use of hard chemicals for chemical washing in leaching of heavy metals using shelters in chemical methods (Sun, B., Zhao, F. J., Lombi, E., & McGrath, S. P. 2001). In physical-chemical approaches, high cost and inefficiency when pollutants are present in low concentrations degrade the soil ecosystem. And emerging secondary pollution (Ali et al., 2013; DalCorso et al., 2019). This is why researchers have studied plants that can decompose or degrade organic pollutants or eliminate and stabilize metallic pollutants. Following this, developed phytoremediation technology, a process that has been successfully tested in many parts of the world. Among these beneficial phytoremediation technologies, plants with potential such as phytoextraction (phytobioremediation), phytostabilisation and phytofiltration are commonly involved in restoring soils contaminated with heavy metals. Phytoextraction is the name given to the process by which plant roots extract metallic pollutants from the soil and carry them into the tissues of the topsoil. A plant used for phytoremediation needs to be tolerant to heavy metals, high biomass yield per hectare, rapid growth, high metal deposition capacity in leaf parts, and high bioaccumulation factor. (A. Scragg 2006; Jadia, CD, and Fulekar, MH.,2008). Continuous phytoextraction is based on the use of naturally occurring hyperaccumulating plants with exceptional metal accumulation capacity. To date, approximately 400 plant species from at least 45 plant families have reported overaccumulation of metals (Lasat, M. M., 1999; Ghosh, M., & Singh, S. P., 2005). The bioaccumulation of metals in plants is related to a wide range of factors Such as concentration and speciation of metals, soil and plant species properties, soil changes and physiological adaptations, plant stage and elemental properties (Remon et al., 2005; Nouri et al., 2009). Root rhizosphere of a plant for trace metal ions; This is a primary contact site which plays an important role in the accumulation of metals by filtration, adsorption and cation exchange, and by chemical changes of vegetal origin (Nouri et al., 2009; Nagajyoti et al., 2010). To determine the ecotoxicity of soil metals and Phyto-availability, plant communities should be examined to determine species diversity, toxic symptoms and metal concentrations in aboveground tissues (Remon. et al. 2005). In this study, plants adapted to the conditions of the region polluted by human activities were

found. And the Phyto-extraction&hyperaccumulator capacities of these plants were trying to be determined. The translocation factor (TF), bioaccumulation factor (BAF), and bioaccumulation factor (BAC) were calculated to evaluate phytoremediation and phytoextraction efficiency. They were assessed in addition to the booms and at the same time as the soil pollution loadings from which the samples were collected. These plants are *Artemisa Dracunculus* L. (D) and *Erigeron Canadensis* (EC) from the Asteraceae family.

## **Material And Method**

### **Study Area**

Karabük is a province in Turkey, where steel industries and their sub-industries are active. It is a province with 240 altitudes and mountain wooded areas located in the western Black Sea region that is growing rapidly. Plant and soil samples are from the (PS) location, which is considered to be anthropogenic pollution, which is the dump site where wastes from the iron and steel industry and construction industry are dumped (Figure 1). In comparison with these are samples (RS) taken from orchards, where there is no industrial pollution, urban particles and chemical fertilisation etc.

### **Plant & soil sampling.**

Samples of plants of the same species were obtained from 5 replicates in the area shown in Figure 1. By clearing, 2 cm of the soil surface where the plant samples were collected, the soil was collected 20 cm deep around the roots. In the comparison of soil and plant and soil samples using the same procedure, five replicates were also carried out in gardens that were not used in agricultural and non-polluting activities.

### **Preparing soil samples for analysis.**

10 soil samples with 5 replicates taken from 2 different species (AD and EC) around the roots of plants from their natural environment were taken to the laboratory. After a few days of air drying at room temperature, root or trash residues were cleaned. Soil samples from each plant type were blended with each other, then sieved with a 2mm sieve. After being stored in a 105°C oven for 48 hours until it reaches a steady weight, it was cooled in a desiccator. Subsequently, they were stored in sealed containers for testing.

## Analysis of heavy metal concentrations.

1 g of soil sample weighed from the dried soil samples. It was filtered via a 0.45 µm filter paper dissolved by aqua regia (3 ml of HNO<sub>3</sub> 9 ml of HCl acid). It was supplemented at 25 ml with distilled water and heavy metals in the soil were caught in the solution container. The soil solution obtained was read into the ICP-OES device. The content of heavy metals in the soil allowed total and available quantities of heavy metals to be determined.

## pH and EC analyses of soil.

To determine soil pH and electrical conductivity (EC), 20g of soil samples was weighed. The weighed soil samples were mixed with 50 ml of distilled water and allowed to settle. The pH and EC values of the precipitated soil samples were measured in the saturation extract with a 1:2.5 ratio, pH and EC meter with a glass electrode and a digital display.

**Table 1** Soil samples taken from plant root zones

	AD (PS)	EC (PS)	AD (RS)	EC (RS)
<b>pH</b>	6.80	7.07	7.92	7.21
<b>EC mikromhos/cm</b>	92.19	100.57	67.64	64.49
<b>Calc. %</b>	0.36	0.39	0.59	0.84
<b>OM %</b>	1.48	0.89	1.90	2.12
<b>Total N %</b>	0.10	0.03	0.06	0.06
<b>P ppm</b>	21.33	26.51	32.16	59.20
<b>K cmol/kg</b>	2.05	1.24	2.64	2.94
<b>Ca</b>	11.40	6.88	14.70	16.36
<b>Mg cmol/kg</b>	7.66	9.36	15.16	17.24
<b>Na cmol/kg</b>	2.56	2.29	3.68	1.01
<b>Total Ni</b>	2786	2291.25	255.21	210
<b>Total Cd</b>	335.83	323.07	23.21	22.55
<b>Total Pb</b>	1297.8	29.85	1157.25	30.3
<b>Total Cr</b>	3319	268.84	4209.92	245.96

## Preparation of plant samples for analysis

Samples of plants taken from 2 different plants brought to the laboratory were washed twice with distilled water. Then allow one day to dry at room temperature. Samples of air-dried, plants were divided in roots, stems and leaves. And samples of AD and EC plants taken as five replicates were mixed between their groups. It was dried in a compressed air oven at 80°C for 48 hours to obtain the dry weight of the samples. For the heavy metal contents of the dried samples, nitric acid-hydrogen peroxide (2:3) acid was added in 3 different steps. (1st step; at 145 °C for 5 minutes at 75% microwave power, 2nd step; at 180 °C with 90% microwave power. And 3rd stage (10 minutes at 40% microwave power at 100 °C) in a 40-bar pressure-resistant, microwave, damp combustion unit (speedwave MWS-2 products Berghof Instruments Harresstr.1. 72800 Enien Germany). (Merten 2005am) was then determined by reading in an ICP OES spectrophotometer (inductively coupled plasma spectrophotometer) (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA).

## Phytoremediation efficiency

The translocation factor (TF) and bioaccumulation factor (BAF) were calculated to evaluate the efficiency of phytoextraction of heavy metals. (Me et al., 2001; Yoon et al., 2006). TF is the ability of a plant to move metal from its roots to its shoots. But the bioaccumulation factor refers to the capacity of a plant to accumulate soil metals. An accumulator of plants with BAF shoot values >1 according to Baker in the classification of existing plants used as phytoremediation media. The plants for which the BAF shoot value was less than 1 were assumed to be excluded. Moreover, plants are classified as potential hyperaccumulators if the shoot values of BAF >10 (Ma et al., 2001).

### Translocation Factor (TF)

The translocation factor (TF), denoting translocation of metals from roots to shoots, was computed as the ratio of metal concentration in the shoots to those in the roots (Liu et al. 2014; Cui et al. 2007; Malik et al. 2010; Nouri et al. 2009), as follows:

$$TF = C_{\text{shoot}}/C_{\text{root}}$$

where  $C_{\text{shoot}}$  and  $C_{\text{root}}$  are metal concentrations in the shoot (mg/kg) and root of plant (mg/ kg), respectively (Rezvani and Zaefarian 2011).  $TF > 1$  signifies that the plant effectively translocate trace metals from the roots to the shoots (Baker and Brooks 1989).

### Bioaccumulation Factor (BAF)

The bioaccumulation factor (BAF) is determined for quantitative expression of metal accumulation in the plant shoots from the soil (Deram et al. 2006). It is determined as:

$$\text{BAF} = C_{\text{shoot}} / C_{\text{soil}}$$

where  $C_{\text{shoot}}$  and  $C_{\text{soil}}$  are metal concentrations in the plant shoot (mg/kg) and soil (mg/kg), respectively (Rezvani and Zaefarian 2011). Plants with different BAF values are categorized as excluder, accumulator and hyperaccumulator when BAF values are  $<1.0$ ,  $1.0-10.0$  and  $>10.0$ , respectively (Ma et al. 2001).

### **Bioaccumulation Coefficient (BAC)**

The bioaccumulation coefficient (BAC) is calculated as the ratio of metal concentration in the plant parts (roots, stems and leaves) to those in the external medium, such as soil, to qualify trace metal accumulation efficiency in plants (Zayed et al. 1998).

$$\text{BAC} = C_{\text{plant}} / C_{\text{soil}}$$

where  $C_{\text{plant}}$  and  $C_{\text{soil}}$  are trace metal concentrations in plant parts (mg/kg) and in soil (mg/kg), respectively. Four categories of trace metal accumulation are proposed: BAC value  $< 0.01$  categorizes a plant as non-accumulator,  $0.01-0.1$  as low accumulator,  $0.1-1.0$  as moderate accumulator, and  $1.0-10.0$  as high accumulator or hyperaccumulator (Sekabira et al. 2011).

### **Contamination factor (CF)**

Contamination factor (CF) is also called single pollution index (PI). Contamination factor is the quotient obtained by dividing the concentration of metals related to the target area by reference area. Their results are mostly associated with single pollution load, while their n-root was used for integrated pollution load index. The contamination factor can be calculated through the following formula as suggested by Harikumar et al. (2009)

$$\text{CF} = C_n / B_n$$

In above equation,  $C_n$  is the concentration of metals in the target area, and  $B_n$  is the metals concentration of the reference area (Plant soil concentration values were taken as  $C_n$  for total pollution. The limit values for heavy metals in soil in Turkey were selected as the reference zone for the CF) ( Table 3).

CF  $<1$  = Low CF (LP)

$1 \leq CF < 3$  = moderate CF (MP)

$3 \leq CF < 6$  = Considerate CF (CP)

$CF > 6$  very high CF (VHP)

(Inengite, A. K., Abasi, C. Y., & Walter, C. (2015).

### **Pollution load index**

Pollution load index (PLI) is simple statistical technique used to determine elemental contents in soil beyond the reference concentration and provide comprehensive information about the metals toxicity in respective samples (Tomlinson et al. 1980; Yang et al. 2011). Pollution load index can be determined through the following formula:

$$PLI = (CF_1 \times CF_2 \times CF_3 \dots \dots \dots CF_n)^{1/n}$$

where "PLI" represents the pollution load index, "CF" is the contamination factor, and "n" is the number of elements. The PLI ">1" indicates polluted, while "<1" indicates no pollution.

### **Enrichment Factor (EF)**

The enrichment factor (EF) is identified as an effective tool for evaluating the amount of pollutants in the environment (Franco-Uria et al., 2009). The EF for each component was calculated to assess anthropogenic effects on hazardous soil components using the following formula (Islam et al., 2014a).

$EF = (C_{HM} / C_{Fe}) / (C_{HMbackground} / C_{Febackground})$ . Where,  $(C_M / C_{Fe})$  sample.  $(C_M)$  The ratio of the concentration of hazardous elements in the soil sample.  $(C_{Fe})$  at the iron content, and the background  $(C_M / C_{Fe})$  is the same reference ratio. pre-industrial example In general, an EF value of about 1 suggests that a particular metal may be entirely from shell materials or from natural weathering processes. (Rashed, 2010).

Classification of enrichment factors (FE).

$EF < 2$  Low enrichment.

$2 \leq EF < 5$  Medium enrichment.

$5 \leq EF < 20$  Significant enrichment.

$20 \leq EF < 40$  Very high enrichment.

EF  $\geq$  40 Excessive enrichment.

If the calculated EF values are in the range of  $0.5 \leq EF \leq 1.5$ , it is stated that the metals in question are caused by natural corrosion processes. That is, the metals are of crustal (lithogenic) origin. If the EF value is greater than 1.5, the metals are not from crustal origin. Indicates that these trace elements come from point or non-point sources of pollution (anthropogenic). [Bergamaschi, L.2002].

**Table 2** Heavy metal concentrations of selected reference geological rocks (Turekian, K. K. and Wedepohl, K. H.,1961; Pehlivan, H.,2017).]

Element	Birim	Yerkabuđu	Şeyl	Kumtaşı	Kireçtaşı	Ultrabazikler	Bazalt	Derin Deniz Killeri
Fe	%	5	4.7	0.98	0.38	9.4	8.6	6.5
Zr	ppm	165	180	19	-	45	140	150
Cr	ppm	100	90	35	11	1600	170	90
Mn	ppm	950	850	50	1100	1620	1500	6700
Ni	ppm	75	70	2	20	2000	130	225
Cu	ppm	55	45	5	4	10	87	250
Zn	ppm	70	95	16	20	50	105	165
Cd	ppm	0.1	0.3	-	-	-	0.2	0.4
Pb	ppm	13	20	7	9	1	6	80
As	ppm	1.8	13	1	1	1	2	13
V	ppm	135	130	20	20	40	250	120
Sb	ppm	0.2	1.5	-	0.2	0.1	0.2	1

### Statistical Analysis.

Data were analyzed by ANOVA using SPSS software (version 22.0). Duncan's test was used to identify significant differences between the means ( $p < 0.05$ ).

## Discussion And Results

In order to prevent soil pollution, the limit values for soil pollutants allowed in Turkey and according to the WHO are given in Tables 3 and 4. Based on these values, the pollution factor and the pollution load index were computed, because the heavy metal levels in the soils in the area where the samples were taken exceeded the limit values.

**Table 3** Heavy metal limit values in the soil according to the soil pollution control regulation of the Ministry of Environment of the Republic of Turkey

Heavy Metals (Total)	6≤pH<7	pH≥7
	mg. kg <sup>-1</sup> dried soil into oven	mg. kg <sup>-1</sup> dried soil into oven
Lead	70	100
Cadmium	1	1,5
Chromium	60	100
Copper	50	100
Nickel	50	70
Zinc	150	200
Mercury	0,5	

**Table 4** WHO permissible limits for heavy metals in plant and soil. Source: WHO (1996)

Elements	*Target value of soil (mg/kg)	***Permissible value of plant (mg/kg)
<b>Cd</b>	0.8	0.02
<b>Zn</b>	50	0.60
<b>Cu</b>	36	10
<b>Cr</b>	100	1.30
<b>Pb</b>	85	2
<b>Ni</b>	35	10

According to this data, the pollution factor Cd is very high in the soil sample PS of AD plants. Moderately for Hg and Se. It was found to be significant for Cl. In order to understand the pollution dimension, the total pollution load index (PLI) > 1 in the PS content of the AD and EC plant samples was considered to be highly polluted soil. It was also identified as an excessive enrichment of Cd<sub>EF</sub> and Ni<sub>EF</sub> and anthropogenic pollution (Bergamaschi, L.,2002). Based on this data, the quantity of heavy metals extracted from the soil by AD and EC plants in the polluted area was calculated. According to the heavy metal concentrations in the leaves of the AD plant taken from the PS regions, at the concentrations in the leaves of the AD plant taken from the RS region; Cd 1269%, Cr 1400%, Hg 3150%, Pb 3959%, Ni 8600%, Sn 950%, Se 98233%, CL 2740%. In the plant of the EC, Cd 1270%, Cr 1200%, Hg 2400%, Pb 3348%, Ni 8100%, Sn 1000%, Se 102900%, CL 1963% accumulated more. If these increases are in the body part, for AD and EC, Cd 1274-1203%, Cr 957-1200%, Hg 2650-2400%, Pb 3925-3361%, Ni 8088-7250, % Sn 1500-1000%, Se 95900-66900% It was determined that was the ability to accumulate more heavy metals into aboveground components.

As a result of heavy metal analysis of soil and plant samples taken from both PS and RS fields, there were statistically significant differences in heavy metal accumulation between organs of both AD and EC plants. (P<0.05) (table 5). The translocation factor (LF) is an indicator of the accumulation of heavy metals in plants or the mobility of heavy metals in soil and quantify the differences in metal bioavailability in the plant as well. (Kalavrouziotis, IK 2012). According to the results of the analysis of

the samples taken, the accumulation of heavy metals was greatest in the aboveground parts and leaves of the plant samples collected from the polluted area. In individuals with AD-EC, from root to stem and leaf,  $TF_{Cd}$  (1.53<2.34-1.38<2.12),  $TF_{Cr}$  (5.29<6.42-4.92<6),  $TF_{Hg}$  (18.34<21.67-15<16.67),  $TF_{Pb}$  (1.84<2.48) 1.84<2.47),  $TF_{Ni}$  (35.01<53.86-30.95<47.47),  $TF_{Sn}$  (5.3<7-8<11),  $TF_{Se}$  (1.64<2.52-1.68<2.58). As a result of  $TF>1$  values -(Table 5). Hyperaccumulators are expected to effectively remove heavy metals from the soil, transport them to the shoot, and not store them in underground parts of plants. (Page, V. and Feller, U., 2015). They are also expected to tolerate elevated ingredients with no signs of toxicity (Wei, S., Anders, I., and Feller, U., 2014; Memon, A. R., and Schroder, P., 2009). Depending on the results of the analysis in the samples collected, the accumulation of heavy metals in plant samples from the polluted zone is highest in the aerial parts and leaves. The highest concentration of heavy metals is  $Pb>Cd>Ni>Se>Cr>Sn>Hg$  (Table 5). Heavy metals are transported from the roots to photosynthetic leaves through the current of transpiration in the xylem. (Page, V., Weisskopf, L., & Feller, U., 2006; Page, V., Blösch, R. M. & Feller, U., 2012). When released into the root xylem, free or chelated ions flow upwards into the xylem sap. Important for the concentration of heavy metals in the transpiration stream are the xylem charge in the roots, interactions with cell walls during transport of the acropetal, and selective removal of xylem saps. (Miyadate, H., 2011; Page, V., Blösch, R. M. and Feller, U., 2012). If no other redistribution occurs, heavy metals accumulate mainly in photosynthetically active leaves (perspiration).

**Table 5** Heavy metal concentrations in AD and EC plants (leaf-stem-root) and soils

plants	area	site	Cd	Cr	Hg	Pb	Ni	Sn	Se	Cl
AD	PS	Leaf	13.28a	0.90b	0.13b	32.47a	11.31a	0.21b	2.95a	28.40b
		Stem	8.66b	0.74b	0.11b	24.15b	7.37b	0.16b	1.92ab	2.73c
		Root	5.66c	0.14b	0.006c	13.10d	0.21d	0.03c	1.17b	13.18c
		Soil	2.93d	5.89a	2.31a	16.80c	1.04c	0.56a	2.96a	48.42a
	RS	Leaf	0.97a	0.06b	0.004c	0.80a	0.13b	0.02b	0.003b	1.00b
		Stem	0.63b	0.07b	0.004c	0.60b	0.09bc	0.01c	0.002b	6.93a
		Root	0.43c	0.16a	0.02b	0.30c	1.56a	0.03a	0.001b	0.43c
		Soil	0.08d	0.18a	0.05a	0.29c	0.03c	0.02b	0.07a	0.82b
EST	PS	Leaf	12.39a	0.78b	0.10b	27.93a	9.02a	0.22b	2.06ab	20.84b
		Stem	8.08b	0.64c	0.09b	20.77b	5.88b	0.16b	1.34b	2.76d
		Root	5.85c	0.13d	0.006b	11.32d	0.19d	0.02c	0.8b	9.55c
		Soil	3.05d	5.81a	2.53a	17.13c	1.16c	0.64a	4.34a	36.20a
	RS	Leaf	0.96a	0.06c	0.004c	0.81a	0.11b	0.02b	0.002b	1.01b
		Stem	0.62b	0.05c	0.003c	0.60b	0.08b	0.01b	0.002b	5.08a
		Root	0.39c	0.15b	0.02b	0.32c	1.28a	0.03a	0.001b	0.46d
		Soil	0.08d	0.17a	0.06a	0.29c	0.03b	0.02b	0.10a	0.62c

Numerous processes in soil can affect the solubility of heavy metals and therefore the availability of plants (Marschner, H., 1995). According to the concentrations of Cd, Ni, Cr, Hg, Pb, Sn, and Se in the plants collected from PS, it was observed that it was not stored in the root zone of the plant, but was efficiently taken from the soil and carried to the shoots. The result of analysis of plant samples taken from the zone

of heavy metal pollution (PS) and soil without heavy metal pollution (RS). However, following analysis of plant samples collected in the RS region, it was observed that they stored Ni, Cr and Sn in the root (Table 5). In some cases, plants store heavy metals such as Co, Cr and Fe in their roots and only a small portion reaches the shoot (Page, V., Weisskopf, L., and Feller, U., 2006; Page, V. and Feller, U. R. S. 2005). This retention is caused by insoluble (for example, root surface and root apoplasty) (Kosegarten, H. and Koyro, HW, 2001; Bravin, MN, 2008) or a compartment that prevents the release of xylems in cells (Yang, X., 2006; Richau),, KHA, 2009).

The BAF values were computed for phytoremediation efficiency as a result of them Cd (7.5-6.71), Cr (0.28-0.24), Hg (0.10-0.08), Pb (3.37-2.84), Ni (18.70-12.85), Sn (0.71-0.6), Se (2.04-0.78), Cl (0.92-0.65). According to these results, BAF<sub>shoot</sub> values of AD plants are accumulators for Pb and Se since Pb and Se > 1. In the EC plant it is an accumulator for Pb as only Pb>1. As Cr, Hg, Sn and Cl are less than 1, the two plants are assumed to be an exclusionary these elements. (Baker, 1981). In addition, since Ni is >10, both plants can be classified as potential Ni-hyperaccumulator plants. (Ma et al., 2001) (Table 6). Also, since BAF Cd-root>1, it has a high phytostabilization capability for Cd. Moreover, TF values of Cd concentration in leaf, stem and root show high phytoextractive efficiency, and it can be said that there will be significant activity in soils contaminated by Cd (Table 6). The translocation factor (TF) is an indicator of the accumulation of heavy metals in plants or the mobility of heavy metals in soil. It also quantifies differences in metal bio-availability for the plant (Kalavrouziotis 2012). Usually, higher metallic deposit in aboveground components with BAF. TF >1 has been shown to explain the high potential for metal extraction from contaminated sites (Wei and Chen 2006).

**Table 6** Phytoremediation efficiency charts

plants	parts	Cd	Cr	Hg	Pb	Ni	Sn	Se	Cl	
TF										
AD	TF <sub>leaf</sub>	2.34	6.42	21.67	2.48	53.86	7	2.52	2.15	
	TF <sub>stem</sub>	1.53	5.29	18.34	1.84	35.01	5.3	1.64	0.21	
	CF	101	0.13	5.12	1.24	0.4	0.05	1.8	3.7	
		VHP	LP	CP	MP	LP	NP	MP	CP	
	PLI	26.76								
	BAF	7.5	0.28	0.10	3.37	17.96	0.71	4.17	0.64	
	BAC	9.42HA	0.30MA	0.11MA	4.15HA	18.16hyp	13.4hyp	4.13HA	2.41HA	
EC	TF <sub>Leaf</sub>	2.12	6	16.67	2.47	47.47	11	2.58	2.18	
	TF <sub>Stem</sub>	1.38	4.92	15	1.84	30.95	8	1.68	0.29	
	Cf	97.98	0.12	5.45	1.10	0.33	0.05	1.76	2.77	
		VHP	NP	MP	VHP	NP	NP	MP	MP	
	PLI	19.05								
	BAF	6.71	0.24	0.08	2.84	12.85	0.6	0.78	0.65	
	BAC	8.69ha	0.27ma	0.08	3.50ha	13hyp	0.6	0.97	0.92	

The rate of phytoextraction was calculated using the following equation (Zhao et al. 2003). Metal contamination was assumed to occur only in the active root zone, in the top 20 cm of soil. It results in a total soil mass of 2600 t/ha (Supposing a soil mass density of 1,3 t m<sup>-3</sup>).

$$\text{of soil metal removed by one crop} = \frac{(\text{Plant metal concentration Biomass}) \times 100}{(\text{Soil metal concentration} \times \text{Soil mass in the rooting zone})}$$

Assuming both plants to produce 5 tonnes of biomass ha<sup>-1</sup> in a year, AD and EC plants are Cd (1.44-1.29%), Cr (0.05%), Hg (0.02 -0.01), Pb (0.65-0.55%), Ni (3.45 -2.47%), Sn (0.13-0.11%), Se (0.32-0.15%) Cl (0.12-0.13%) is capable of eliminating heavy metals from the soil. When biomass of the AD plant is harvested twice per year. Heavy metals Cd are expected to be disposed of from the soil in 35 years and Ni in 15 years.

Soil improvement by washing is regarded as a short-medium term technology. Field washing can take between one and three years. And removal-washing can take from six months to three years. The cleaning of the soil washing process within the site varies from approximately US\$24 to US\$64 per cubic metre of contaminated soil. Cleaning by removal can range from 70 to 187 USD/cubic metre. Therefore, when we try to clean up 260,000 t/ha of soil through in situ washing, and when 50 USD/tonne is calculated, the total cost is 13,000,000 USD. If the average cost of 150 USD/tonne is calculated for the washing carried out from its place, it creates an economical cost of 39,000,000 USD. The process takes approximately three years. due to the limitation of expensive and physical and chemical remediation methods such as degradation of the natural soil ecosystem, irreversible changes in soil properties, and creation of secondary pollution problems, Phytoremediation is becoming a better technology choice for remediation of heavy metal contaminated soil.

## Conclusion

As the BAF shoot values of the AD plant are Pb and Se > 1, this is an accumulator plant for Pb and Se. In the EC plant, it is an accumulator plant for Pb, since only Pb>1. Since Cr, Hg, Sn and Cl <1, those elements are considered exclusionary Furthermore, because, both plants can be classified as potential Ni-hyperaccumulator plants as Ni > 10. Also, both plants have a high phytostabilization capability for Cd from BAF Cd-root>1. The concentration of Cd TF >1 in the leaf stem and root part indicates a high phytoextraction efficiency. It can be said to be high efficacy in soils contaminated by the Cd. Due to the fact that both plants have BAF values close to the hyperaccumulator value, studies can be carried out to evaluate them as a Cd - hyperaccumulator plant in future studies.

According to our results, 21.94 g of Cd, and 18.68 g of Ni can be obtained from the soil from 1 ton of biomass in an area contaminated with Cd and Ni, and a mixture of gas or progress may be formed to generate thermal and electric energy by controlling the combustion and gasification of biomass, Or biomass combustion can produce in biominerals, especially after phytomisation of precious metals. High

concentrations of these metals in harvested biomass may also be 'diluted' to acceptable concentrations when blending with clean biomass in fertilizers and feed preparations.

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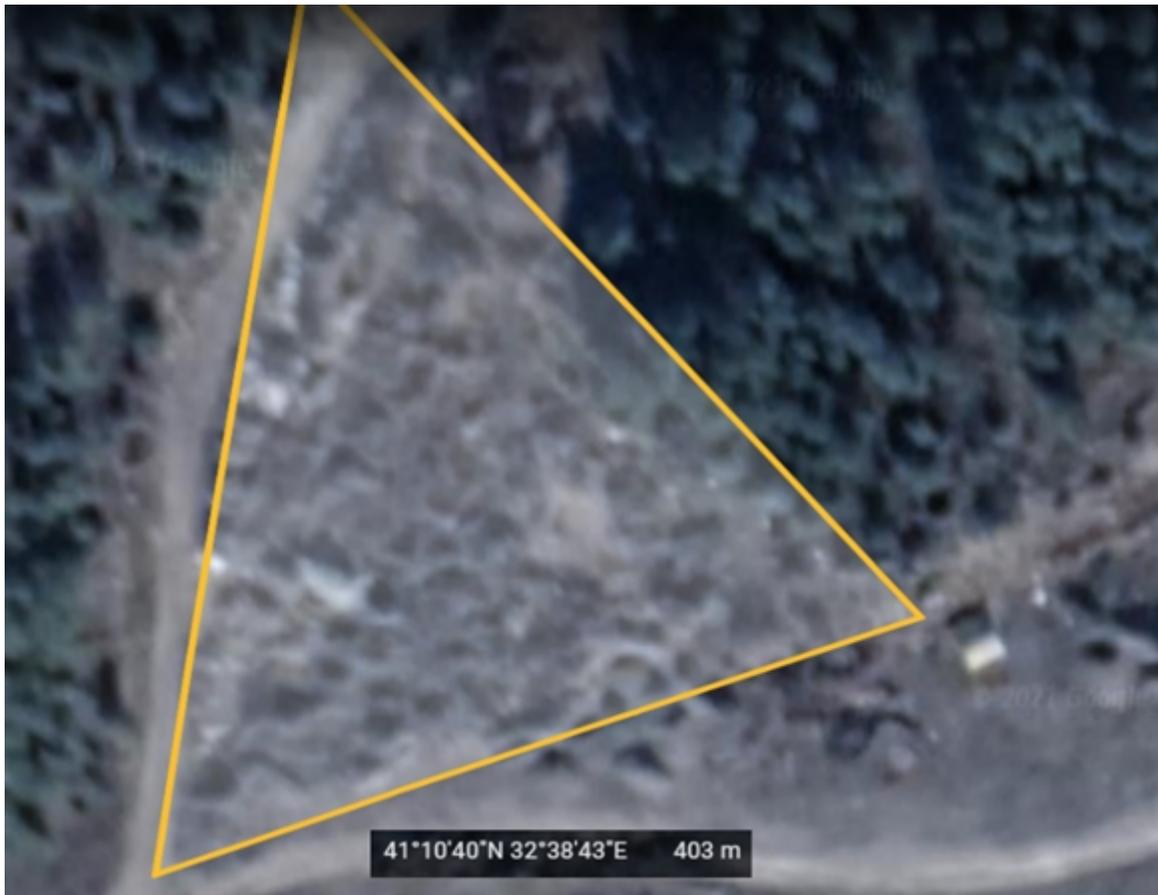
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## Declarations

Conflict of Interest: We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

## Figures



**Figure 1**

Polluted area (PS) from which plant and soil samples were collected.