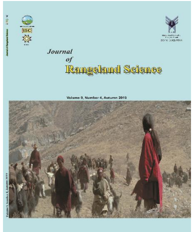
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Assessing Capability of *Artemisia aucheri* Boiss for Phytoremediation of Soils Contaminated with Heavy Metals

Mehdi Moameri[A*] and Farid Dadjoo[B]
[A] Assistant Professor, University of Mohaghegh Ardabili, Ardabil, Iran [*](Corresponding Author), E-Mail: moameri@uma.ac.ir
[B] MSc of Range Management, University of Mohaghegh Ardabili, Ardabil, Iran

Received on: 29/01/2019
Accepted on: 06/05/2019

Abstract. Phytoremediation is an efficient approach that uses plants to remediate the polluted environments. The aim of this research was to evaluate phytoremediation ability of *Artemisia aucheri* in the contaminated soil to Cadmium, Lead, Zinc and Nickel. A greenhouse experiment was performed to investigate the effect of Municipal Solid Waste Compost (MSWC) on phytoremediation efficiency of *A. aucheri* in 2017. For this, natural soil samples were taken from polluted soils of the rangelands around National Iranian Lead & Zinc Company-Zanjan, Iran. Then, MSWC with 0, 1, and 2 wt. was mixed with soil samples. Then, 4 kg pots were filled with this soil and seeds of *A. aucheri* were sown. After 6 months in the end of the experiment, plant samples were collected and shoot and root dry weights were measured and contents of Cd, Pb, Zn and Ni were estimated. To investigate the capability of *A. aucheri* to uptake and accumulate metals, the factors of Translocation Factor (TF) and Bio-Concentration Factor (BCF), and Remediation Factor (RF) were determined. The results indicated MSWC 2% uptake maximum Cd and Ni values in roots (80.80 and 10 $mgkg^{-1}$, respectively) and shoots (65.60 and 6.28 $mgkg^{-1}$, respectively) of the *A. aucheri*. Plants grown in pots treated with MSWC 2% had lower values of Pb in roots (3955 $mgkg^{-1}$) and shoots (24.40 $mgkg^{-1}$) as compared with control. Thus, it was concluded that *A. aucheri* can be an accumulator for Cd and Ni in the contaminated soils amended with MSWC. In contrast, usage of MSWC has been indicated to immobilize Pb and Zn in the soil. In general, *A. aucheri* can be used in raised phytoremediation Pb, Cd, Zn and Ni in the polluted soils. Evaluation of *A. aucheri* potential, however, needs future research of the impact of MSWC in the field conditions.

Key words: MSWC, Amendment, Remediation Factor, Accumulator

Introduction

Nowadays, there has been enhancing knowledge and concern about water, soil and air and ecosystem pollution all over the world. The primary source of heavy metal contamination has been resulted from human activities such as fuel production, mining and smelting, processing, combustion, pesticides and herbicides, chemical fertilizers, and increased urbanization (Mangkoedihardjo, 2008; Vatehova *et al*., 2012; Ebrahimi *et al*., 2014). These activities increase dramatic acceleration of heavy metal contamination in the soils. When the contents of heavy metals exceed the maximum allowable concentration in the soil, not only it can be harmful for human, but also it may have an adverse effect on soil ecosystems, animal health, biomass and crop yields, ecological health and finally human health (Basta and McGowen, 2004; Moameri and Abbasi Khalaki, 2017; Moameri *et al*., 2018).

Soil remediation methods including washing/flushing, excavation and fill, toxicity reduction, oxidation-reduction, ion exchange, incineration, reverse osmosis, immobilization, electro-kinetics, thermal desorption, solvent extraction, nitrification and encapsulation have been used to deal with soil pollutants (Mulligan *et al*., 2001; Moameri *et al*., 2015; Moameri and Abbasi Khalaki, 2017). However, such methods are expensive and often impracticable due to the large areas of heavy metals contaminated soils (Mangkoedihardjo, 2008; Tordoff *et al*., 2000). So, attention was given to green remediation and phytoremediation by which plant is applied to transform, detoxify and accumulate metals. The green remediation is cost effective, simple, efficient and environmental kindly (McCutcheon and Schnoor, 2003; Park *et al*., 2011). One of the options for lands impacted by heavy metals is *in situ* remediation, using amendments to reduce the bioavailability of heavy metals and to recovery polluted soils (Alvarenga *et al*., 2014; Park *et al*., 2011). Phytoremediation is a well and extremely admitted method for remedying the polluted soil (Song *et al*., 2019).

Application of amendments in polluted soils may be effective because they can change the behavior of heavy metals, their accessibility to plants, toxicity, immobilization/mobilization and leaching potential (Adriano *et al*., 2004). Amendments of organic and inorganic agents are used for immobilization of heavy metals in the contaminated soils with various benefits but organic agents could be better choice due to restoration of biological, chemical, physical properties and fertility condition of the soil (Park *et al.*, 2011). Different organic materials like municipal solid waste compost (MSWC), farmyard manure, (Sabir *et al*., 2015), composts, activated carbon, bio-solid and fertilizers are used for soil improvement and immobilization of heavy metals of polluted soils (Sabir *et al*., 2013; Alvarenga *et al*., 2014; Clemente *et al*., 2005). MSWC can increase plant growth and development because they serve as a slow discharge nutrients and also recover the nutrient condition and physical properties of the polluted soils (Wong, 2003).

The impact of organic agents on heavy metals bio-accessibility depends on the organic amendments microbial degradability, organic matter properties, salt amount and impacts on redox potential and soil pH as well as the soil components and heavy metals type (Walker *et al*., 2004). One of the most important organic amendments is municipal solid waste compost (MSWC). MSWC is abundant, inexpensive and accessible so that it can be used for phytoremediation in vast areas that are contaminated with heavy metals. Use of MSWC as soil amendment and/or fertilizers is developing significantly and might be occupied as a precious alternative to simply disposing of them (Lakhdar *et al*., 2016). In recent years, sewage sludge and MSW compost have received large attention because of their ready availability, low technology and low expense of the amendments (Lakhdar *et al*., 2011).

The plant selection is a very important process to consider in phytoremediation in the contaminated soils. The genus *Artemisia* is one of the largest and widely distributed genuses of the Asteraceae in Iran (Mahboubi and Farzin, 2009). *Artemisia aucheri* Boiss is named locally "Dermaneh" and is widely distributed in the mountains and semi-arid areas of Iran (Mozaffarian, 1996). The current research on *A. aucheri* for several reasons is as follows. The plant is a species of *Asteraceae* family that might be effective in removing heavy metals (due to large biomass and high adaptation ability in contaminated soils) as demonstrated by *A. scoparia* (Alirzayeva *et al*., 2006), *A. dubia* (Lei *et al*., 2011) and *A. aucheri* (Dalvand *et al*., 2014). In Iran, it is widely distributed and is able to grow under various climate and soil conditions (Mozaffarian, 1996). Industrial activities of Zanjan National Iranian Lead and Zinc Company have exposed the soil to heavy metals. As a result, it has caused the risks for rangeland ecosystems, animals and consequently people health. *A. aucheri* is one of the dominant plants distributed in this area and proper biomass for absorption heavy metals. Therefore, the aim of this research was to investigate *A. aucheri* Boiss for phytoremediation of soils polluted with heavy metals using field soil in the pot with amendment of MSWC added to the soil.

Materials and Methods

For the greenhouse cultivation, the soil was taken from the rangelands around Zanjan National Iranian Lead and Zinc Company area (36°36' and 36°38'N-48°37'33" and 48°38"E), an important industrial area of Zanjan, Iran. The altitude is 1700m above sea level. The climate of the region is semi-arid and cold (Sharifi *et al*., 2012). The average annual rainfall is 300 mm (Moameri *et al*., 2017).

Soil sampling was taken from soils contaminated in the rangelands around National Iranian Lead & Zinc Company - Zanjan, Iran in 2017. Soil required for greenhouse cultivation was derived from the root rhizosphere in which the chemistry and microbiology are influenced by plant growth, respiration, and nutrient exchange (0-30 cm, depth of roots activity) at 5 different points. It was a sandy loam soil. They were then air-dried and were sieved to 4 mm, and then, the chemical and physical properties and the concentration of Cd, Pb, Zn and Ni were measured (Table 1) using common methods (Du Laing *et al*., 2003; Khattak and Jabeen, 2012). These soil samples were applied as the substrate for *A. aucheri* cultivation in pots.

Pot preparation

Seeds of *A. aucheri* were collected from its habitats in Taleghan rangelands for cultivation in greenhouse. Seeds were kept for six months in storage. Some seeds characteristics such as seed purity (97%), seed germination (90%), and 1000 seed weight (0.37g) were measured. MSWC was taken from Karaj Municipality, Iran. Some of the MSWC characteristics are shown in Table 1. The MSWC was air-dried and were sieved through a 2mm mesh. Then, MSWC with 0, 1, and 2 wt.% (Sabir *et al*., 2015) was entirely mixed with soil. In the next step, 4 kg pots were filled with this soil. Twenty seeds of *A. aucheri* were sown in each pot with five replicates per treatment. Greenhouse temperatures (day/night) were 25 ± 4.5°C. The light for the plant growth was gained from the sun. The relative humidity of greenhouses was 60%.

Table 1. Some of physical and chemical properties of soil and MSWC

Property	Abbreviation	Unit	Soil	MSWC
Acidity	pH	-	7.6	6.9
Electrical conductivity	EC	(dS/m)	0.2	3.6
Nitrogen	N	%	0.07	1.4
Phosphorus	P	(mg/kg)	95	0.35
Potassium	K	(mg/kg)	200	0.63
Cation Exchange Capacity	CEC	($Cmol_c$/Kg)	19.5	25.8
CaCO equivalent	CCA	%	1.4	
Organic carbon	OC	%	0.58	16.77
Lead	Pb	(mg/kg)	6724	20.1
Cadmium	Cd	(mg/kg)	75	1.6
Zinc	Zn	(mg/kg)	1250	174
Nickle	Ni	(mg/kg)	103	45
Sand	Sand	%	68.8	
Loam	Loam	%	18.6	
Clay	Clay	%	12.6	

MSWC= Municipal Solid Waste Compost

Data collection

After 6 months of growth, plant samples were harvested and separated into shoots and roots, and washed with distilled water. Shoot and root dry weights were measured. Cd, Pb, Zn and Ni concentrations were measured according to standard methods (Du Laing *et al.*, 2003; Khattak and Jabeen, 2012). Then, the soil samples were gained from pots and dried in an oven for 48 h at 60°C (Moameri *et al.*, 2017; Moameri and Abbasi Khalaki, 2017). Some soil properties including EC, pH, CEC, organic matter, N%, available potassium and available phosphorus were measured by pursuing standard methods (Jafari Haghighi, 2003).

The total contents of Cd, Pb, Zn and Ni in soil samples were estimated after digesting soil with 4M HNO_3 acid (1:10 ratio) at 60°C water bath for 14 hours (Amacher and Selim, 1994). It was 75, 6724, 1250 and 103 $mgkg^{-1}$ Cd, Pb, Zn and Ni, respectively (Table 1).

In order to investigate the capability of *A. aucheri* to accumulate and uptake metals in their shoots and roots, factors translocation factor (TF) and bio-concentration factor (BCF), (Yoon *et al.*, 2006) and remediation factor (RF) (Sun *et al.*, 2011) were determined (Eq. 1-3).

1) $$TF = \frac{\text{Heavy metal concentrations in the shoot (mg/kg)}}{\text{Heavy metal concentrations in the root (mg/kg)}}$$

2) $$BCF_{shoot} = \frac{\text{Heavy metal concentrations in the shoot (mg/kg)}}{\text{Heavy metal concentrations in the soil (mg/kg)}}$$

3) $$BCF_{root} = \frac{\text{Heavy metal concentrations in the root (mg/kg}}{\text{Heavy metal concentrations in the soil (mg/kg)}}$$

4) $$RF = \frac{\text{Heavy metal concentrations in the shoot (mg/kg)} \times \text{shoot dry biomass (g)}}{\text{Heavy metal concentrations in the soil (mg/kg)} \times \text{weight of soil in the pot (kg)}}$$

Statistical analysis

Pot experiment was performed using a Completely Randomized Design (CRD) with five replications. The data analysis was done using one-way ANOVA and means were compared using the Tukey's test by SPSS version 22 (SPSS Inc., USA). All of the data were presented as mean ± Standard Error (SE).

Results and Discussion

Effect of MSWC on the plant dry weights and soil properties

MSWC treatments significantly ($p<0.01$) increased Shoot Dry Weight (SDW) and Root Dry Weight (RDW) of the plants as compared to those of the control (Table 2). SDW was maximum (11.82 g/pot) in pots amended with MSWC2% while it was minimum (4.94 g/pot) in the control pots. In addition, RDW was the maximum (7.12 g/pot) for pots treated with MSWC2% and also, it was the minimum for control plants. The plants treated with MSWC seemed to develop quickly during the early growth. In addition, results showed both SDW and RDW increased with enhancement percentage of municipal solid waste compost demonstrating that increasing the amount of MSWC improved the performance of the plants. So, it seems that MSWC have a favorable effect on growth factors of *A. aucheri.* Moameri and Abbasi Khalaki (2017) reported that MSWC due to nutrients such as nitrogen, potassium and phosphorus increased the growth and biomass of *Secale montanum*. In addition, Moslehi *et al*. (2014) who demonstrated growth features in the plants cultivated them in municipal solid waste.

Results showed that in pots amended with MSWC, soil pH and EC values increased as compared with control and their differences were significant ($p<0.01$) (Table 2). Application of MSWC enhanced soil pH with a significant increase in soil EC. High values of pH and EC in the MSWC may be due to the presence of high concentrations of soluble salt (Kasthuri *et al*., 2011). So, we should be more careful in choosing MSWC, and select MSWC higher quality and lower EC (Safari *et al*., 2014).

Nitrogen, phosphorus and potassium contents were significantly ($p<0.05$) enhanced by the addition of the MSWC treatments. Organic matter content was also increased by the treatments compared to those of the control. It seems that the reason is that MSWC application can improve soil quality refilling soil organic and supplying nutrients. Kasthuri *et al*. (2011) reported the characteristics of MSWC showing that a wide range of essential nutrients was found in the compost. They demonstrated that the growth and the yield of green gram and *Trigonella foenum-graecum* L. were enhanced by MSWC application up to 500 g. Lakhdar *et al*. (2016) and Logan *et al*. (1997) stated that Municipal Solid Waste (MSW) composts are possible to restore poor soil fertility because they contain great contents of organic matter that can improve the water-holding capacity, soil structure and nutrient accessibility. They stated that the usage of MSW compost in soil considerably increased NPK uptake, plant growth and wheat production. Pascual *et al*. (1999) indicated that 8-year amendment of an arid soil with the MSW compost at two various concentrations (6.5 and 26 t ha^{-1}) had a positive impact on the activity of enzymes involved in the N, P and C cycles as well as on biomass C. In addition, Medina *et al*. (2004) reported that MSW enhanced rhizosphere enzymatic activity related to nutrient uptake and plant growth. In general, it seems that application of MSWC improved soil biophysical and chemical characteristics, and as a result, it raised the plant biomass and growth (Moameri and Abbasi Khalaki, 2017).

Table 2. Effect of MSWC on root and shoot dry weights and soil properties

Treatments	SDW (g/pot)	RDW (g/pot)	pH	EC (ds/m)	N (%)	K (ppm)	P (ppm)	OM (%)	CEC (molc/kg)
Control	4.94±1.24[c]	2.14±0.35 c	7.57±0.0 c	0.75±0.10 c	0.07±0.0 c	204.0±8.0[c]	105.2±3.53 c	1.30±0.01 c	17.28±1.0 c
MSWC1%	7.38±0.62[b]	4.54±0.76 b	7.74±0.0 b	0.85±0.11 b	0.08±0.0 b	248.0±9.0[b]	116.4±3.54 b	1.90±0.0[b]	18.58±1.0 b
MSWC2%	11.8±1.11[a]	7.12±0.91 a	7.79±0.0 a	2.31±0.20 a	0.10±0.0 a	284.0±14.0 a	141.2±3.56 a	1.90±0.0[a]	19.26±1.2 a
MS values	60.83**	14.13**	0.67**	3.76**	0.001**	10666.6**	1694.9**	0.52**	5.08**

Different letters (a, b, c) within columns illustrate significant difference between treatments; * sig $p<0.05$. ** $p<0.01$.

SDW: Shoot dry weight; RDW: Root dry weight

Impact of MSWC on the content of Cd, Pb, Zn and Ni in the *A. aucheri* and soil

Concentrations of Cd, Pb, Zn and Ni in soil, roots and shoots of *A. aucheri* are presented in Table 3. Results showed the MSWC significantly increased Cd and Ni amounts in the *A. aucheri* roots and shoots compared to control. Organic amendments have been reported to show various effects on heavy metals extractability, which may depend on type of heavy metals, plant species and the nature of OM (Angelova *et al.,* 2010). Composts can enhance or decrease the availability of heavy metals in soils, depending on the level of pollutants, the soil and the compost (Alvarenga *et al*., 2009). Ghaly and Alkoaik (2011) reported that great MSW amounts increase the accessibility of metals and can supply micro-elements for the plants growth. Putwattana *et al.* (2010) revealed a considerable enhance in shoot Cd content and the total Cd uptake of plants when cow manure was used. Cao and Shiralipour (2003) stated that amendment with compost alone may initially enhance plant growth by improving the nutrient condition of the soil and by immobilization of heavy metals, but after degradation of the compost, the adsorbed metals might be released and become available again to plants and animals.

The results indicated that application of MSWC decreased Pb and Zn concentration in the *A. aucheri* roots and shoots. It seems that the MSWC led to the immobilization of Pb and Zn in the soil. Organic agents fixed heavy metals via absorption reactions which may be due to enhancement in surface charge and the presence of metal binding particles (Gondar and Bernal, 2009). Soil Pb is present in various appearance from easily leachable to recalcitrant ones because of interactions with different soil components and commonly its solubility is low (Bhattacharyya *et al*., 2008). The MSWC included a high amount of accessible phosphorous (Table 1), which could form highly insoluble pyromorphite with Pb (Lu *et al*., 2003). Thus, because of addition of MSWC, the availability of Pb and Zn to plant roots decreased with a raise in accessible P in soil (Bhattacharyya *et al*., 2008). Moreover, application of MSWC increased soil CEC and also diminished the absorption and accumulation of Cd and Ni in *A. aucheri* roots and shoots. Cations of heavy metals are often bonded to soil components because of soil CEC (Moameri *et al*., 2018). Thus, higher CEC of the soil leads to greater uptake and immobilization of the heavy metals (Gupta *et al*., 2013). The discharge of carbonates, salts and phosphates during the decomposition of OM may result in the formation of insoluble metal particles and restrict metal solubility. In addition, MSWC can also reduce heavy metal bioavailability depending on degree of humification in soil, soil pH and the types of metal and soil (Walker *et al*., 2003).

Table 3. Result of treatments effect on the content of heavy metals in plant and soil

Treatments	**Cd concentration** (mg/kg)			**Pb concentration** (mg/kg)		
	Soil	Root	Shoot	Soil	Root	Shoot
Control(0%)	31.00±1.24[a]	30.20±3.63[c]	22.10±1.67[b]	3955.00±60.93[b]	4103.15±104.58[a]	216.36±1.67[a]
MSWC1%	28.75±1.77[b]	72.60±2.28[b]	24.00±3.16[b]	3970.00±100.43[b]	3970.15±108.00[b]	82.40±2.19[b]
MSWC2%	27.40±2.37[b]	80.80±2.40[a]	65.60±2.96[a]	4103.15±62.01[a]	3955.00±112.00[c]	24.40±1.62[c]
MS values	16.53*	36.87**	2777.60**	33251.95*	47088.68**	48464.93**
Treatments	**Zn concentration** (mg/kg)			**Ni concentration** (mg/kg)		
	Soil	Root	Shoot	Soil	Root	Shoot
Control (0%)	826.90±30.99[a]	668.40±14.14[a]	468.00±2.28[a]	20.90±0.57[a]	4.30±0.43[b]	3.88±0.10[b]
MSWC1%	787.96±18.24[ab]	622.40±14.79[b]	459.20±25.40[b]	18.75±0.69[b]	8.20±2.06[a]	4.12±0.40[b]
MSWC2%	762.70±29.19[b]	460.00±10.52[c]	409.20±16.06[c]	17.70±0.55[c]	10.00±2.00[a]	6.28±0.17[a]
MS values	5230.25**	59933.60**	5029.06**	13.304**	42.45**	8.73**

Different letters (a, b, c) within columns illustrate significant difference between treatments; * sig $p<0.05$. ** $p<0.01$.

Effect of MSWC on indicators to assess the phytoremediation of *A. Aucheri*

Both TF and BCF can be used to evaluate a plant's capability for phytoremediation goal (Yoon *et al*., 2006). The effect of the MSWC application on criteria to determine the potential phytoremediation of heavy metals from the polluted soils to *A. Aucheri* is shown in Table 4. The highest values of TF_{Cd} and TF_{Pb} (0.91 and 2.24, respectively) were found in plants grown in MSWC2% treatment. The results indicated that TF_{Cd}>1 (TF_{Pb}=2.24); so, it shows that *A. Aucheri* has been classified as high- potential plants for Pb translocation from the roots to aerials organs. Thus, this plant can be effective in remediation of soil contaminated with cadmium by phytoextraction process. Plants representing TF and BCF amounts more than one are suitable for phytoextraction and they are hyperaccumulators (Yoon *et al*., 2006; Moameri *et al*., 2018). Putwattana *et al*. (2010) reported that *Ocimum basilicum* grown in Cd polluted soil and soil amendments with cow manure revealed a raise in TF amounts with the exposure time.

While by increasing the concentration of MSWC, TF_{Zn} was decreased. Moreover, effects of application MSWC on TF_{Ni} did not have a clear trend. In general, TF_{Cd}, TF_{Zn} and TF_{Ni} were less than one, which means the limited ability of Cd, Zn and Ni accumulation and translocation by the aboveground parts of *A. aucheri*. This indicates that the contents of Cd, Zn and Ni in soil were more than the aerial organs of *A. aucheri*. In addition, by enhancing the amounts of MSWC, BCF was increased for all metals. So, this plant based on TF (TF<1) and BCF_{shoot} (BCF_{shoot} <1) could play important roles in the elimination of metals through phytostablization process from polluted soils (Yoon *et al*., 2006; Ebrahimi *et al*., 2014; Moameri *et al*., 2017).

The RF is the ratio of heavy metals amount in plant organs to that in the soils demonstrating how efficacy metals are from the contaminated soils. Higher RF shows extraction efficiency of the heavy metals from the soil due to increased solublization of metals in the contaminated soil and vice versa (Sabir *et al*., 2015). The RF values for Cd, Zn and Ni with MSWC amendment were greater compared to the RF with control showing that these heavy metals were drawn out more effectively by the plants grown with MSWC (especially for the plants grown with MSWC2%).

Lower RF for Pb with MSWC indicated that this amendment was effective to stabilize Pb in soil compared to control. Sabir *et al*. (2015) reported the RF values with compost for Maize which was lower to corresponding RF amounts with farmyard manure displaying the stabilizing impact of compost on Ni, Cu, Zn and Mn in the soil.

Table 4. Effect of MSWC treatments on indicators to assess the ability phytoremediation of heavy metals

Treatments	Translocation factor (TF)				Shoot bioconcentration factor (BCF)			
	Cd	Pb	Zn	Ni	Cd	Pb	Zn	Ni
Control	0.32±0.03^{c}	0.82±0.01^{b}	0.89±0.03^{a}	0.91±0.07^{a}	2.82±0.23^{a}	0.03±0.00^{b}	0.58±0.26^{c}	0.21±0.02^{c}
MSWC1%	0.80±0.15^{b}	0.82±0.11^{b}	0.74±0.05^{b}	0.58±0.28^{b}	0.97±.02^{b}	0.01±0.00^{c}	0.75±0.03^{b}	0.47±0.17^{b}
MSWC2%	0.91±0.06^{a}	2.24±3.22^{a}	0.70±0.03^{b}	0.65±0.13^{b}	2.66±0.22^{a}	0.06±0.02^{a}	0.88±0.04^{a}	0.54±0.12^{a}
MS values	0.49**	4.17**	0.05**	0.14*	5.22**	0.003**	0.10**	0.15**

Treatments	Root bioconcentration factor (BCF)				Remediation factor (RF)			
	Cd	Pb	Zn	Ni	Cd	Pb	Zn	Ni
Control	0.89±0.04^{b}	0.02±0.0^{b}	0.52±0.18^{b}	0.19±0.00^{c}	0.88±0.16^{c}	0.07±0.01^{a}	0.70±0.06^{c}	0.23±0.02^{c}
MSWC1%	0.78±0.12^{b}	0.01±0.0^{b}	0.56±0.03^{b}	0.23±0.07^{b}	1.54±0.23^{b}	0.04±0.00^{b}	1.08±0.63^{b}	0.41±0.17^{b}
MSWC2%	2.41±0.29^{a}	0.05±0.0^{a}	0.61±0.02^{a}	0.34±0.17^{a}	7.07±0.64^{a}	0.02±0.00^{c}	1.59±0.44^{a}	1.05±0.32^{a}
MS values	4.17**	0.003*	0.01**	0.030**	2.13**	0.030*	3.12**	2.21**

Different letters (a, b, c) within columns illustrate significant difference between treatments; * sig $p<0.05$. ** $p<0.01$.

Conclusion

Results revealed that amending the soil with MSWC 2% led to a greater biomass accumulation of *A. aucheri* probably due to the high nutrient content present in this treatment and improving the soil physical, biological and fertility properties and enhancement of soil carbon potential. However, the quality of the MSWC is an important aspect to decrease environmental hazards. Application of MSWC 2% enhanced the Cd and Ni concentrations at the shoots and roots of *A. aucheri*. Cd and Ni absorption and accumulation were maximum (80.80 and 10.00 $mgkg^{-1}$, respectively) in roots of *A. aucheri* grown in MSWC 2%-treated pots. Thus, it is concluded that MSWC2% causes Cd and Ni in rhizosphere becoming more solvable and thus, their accumulation enhances on roots. So, it seems that this plant with MSWC treatment can be an accumulator for phytoremediation Cd and Ni in the contaminated soils. In contrast, usage of MSWC has been indicated to immobilize Pb and Zn in soil and reduced their content in the *A. aucheri* shoots and roots. So, phytostablization process might be used to remediate soil polluted with Pb and Zn. Evaluation of *A. aucheri* potential, however, needs further research of the impact of MSWC amendments in the field conditions. In general, *A. aucheri* can be used in raised phytoremediation Pb in the polluted soils by phytoextraction process and also, it can be effective in phytoremediation Cd, Zn and Ni by phytostabilization method.

References

Adriano, D., Wenzel, W., Vangronsveld, J. and Bolan, N., 2004. Role of assisted natural remediation in environmental cleanup. Geoderma, 122:121-142.

Alirzayeva, E.G., Shirvani, T.S., Alverdiyeva, S.M., Shukurov, E.S., Ozturk, L., Ali-Zade, V. M. and Cakmak, I., 2006. Heavy metal accumulation in Artemisia and foliaceous lichen species from the Azerbaijan flora. Forest snow and landscape research, 80: 339-348.

Alvarenga, P., DE Varennes, A. and Cunha-Queda, A., 2014. The effect of compost treatments and a plant cover with Agrostis tenuis on the immobilization/mobilization of trace elements in a mine-contaminated soil. International journal of phytoremediation, 16:138-154.

Alvarenga, P., Gonçalves, A.P., Fernandes, R.M., de Varennes, A., Vallini, G., Duarte, E., Cunha-Queda, A.C., 2009. Reclamation of a mine contaminated soil using biologically reactive organic matrices. Waste Management Research, 27(1):101-111.

Amacher, M. C. and Selim, H., 1994. Mathematical models to evaluate retention and transport of chromium (VI) in soil. Ecological modelling, 74:205-230.

Angelova, V., Ivanova, R., Pevicharova, G. and Ivanov, K., 2010. Effect of organic amendments on heavy metals uptake by potato plants. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 - 6 August 2010, Brisbane, Australia.

Basta, N. and Mcgowen, S., 2004. Evaluation of chemical immobilization treatments for reducing heavy metal transport in a smelter-contaminated soil. Environmental pollution, 127:73-82.

Bhattacharyya, P., Chakrabarti, K., Chakraborty, A., Tripathy, S. and Powell, M.A., 2008. Fractionation and bioavailability of Pb in municipal solid waste compost and Pb uptake by rice straw and grain under submerged condition in amended soil. Geosciences Journal, 12(1):41-45.

Cao, X.D., Ma, L.Q. and Shiralipour, A., 2003. Effects of compost and phosphate amendments on arsenic mobility in soils and arsenic uptake by the hyperaccumulator, Pteris vittata L. Environmental Pollution, 126: 157-167.

Clemente, R., Walker, D.J. and Bernal, M.P., 2005. Uptake of heavy metals and As by Brassica juncea grown in a contaminated soil in Aznalcóllar (Spain): the effect of soil amendments. Environmental pollution, 138: 46-58.

Dalvand, M., Hamidian, A.H., Chahooki, Z., Moteshare Zadeh, B., Mirjalili, S. and Esmaeil Zade, E., 2014. Comparing heavy metal accumulation abilities in Artemisia aucheri and Astragalus gummifer in Darreh Zereshk region, Taft. Desert, 19:137-140.

Du Laing, G., Tack, F.M.G. and Verloo, M.G., 2003. Performance of selected destruction methods for the determination of heavy metals in reed plants *Phragmites australis*. Journal of Analytica Chimica Acta, 49: 191-198.

Ebrahimi, M. and Madrid Díaz, F., 2014. Use of *Festuca ovina* L. in chelate assisted phytoextraction of copper contaminated soils. Journal of Rangeland Science, 4(3): 171-181.

Ebrahimi, M., Jafari, M., Savaghebi, Gh.R., Azarnivand, H., Tavili, A. and Madrid, F., 2014. Investigation of Heavy Metals Accumulation in Plants Growing in Contaminated Soils (Case Study: Qazvin Province, Iran). Journal of Rangeland Science, 4(2):91-100.

Ghaly, AE. and Alkoaik, FN., 2011. Effect of municipal solid waste compost on the growth and production of vegetable crops. American Journal of Agriculture Biological Science, 5(3):274-281.

Gondar, D. and Bernal, M. P. 2009. Copper binding by olive mill solid waste and its organic matter fractions. Geoderma, 149: 272-279.

Gupta, D. K., Corpas, F. J. and Palma, J.M. 2013. Heavy Metal Stress in Plants. Springer Heidelberg New York Dordrecht London, 245p.

Jafari Haghighi, M., 2003. soil analysis Methods: sampling and important physical and chemical analyses. Nedae Zoha Press. 240p.

Kasthuri, H., Shanthi, K., Sivakumar, S., Rajakumar, S., Son, H.K. and Song, Y.C., 2011. Influence of municipal solid waste compost (MSWC) on the growth and yield of green gram (*Vigna radiate* (l) Wilczek), fenugreek (*Trigonella foenum-graecum* l.) and on soil quality. Iranian Journal of Environmental Health Science Engineering, 8(3): 285-294.

Khattak, M. I. and Jabeen, R., 2012. Detection of heavy metals in leaves of *Melia azedarach* and *Eucalyptus Citriodora* as biomonitoring tools in the region of Quetta valley. Pakistan Journal of Botany, 44 (2): 675-681.

Lakhdar, A., Achiba, W., Montemurro, F., Jedidi, N. and Abdelly, C., 2016. Effect of Municipal Solid Waste Compost and Farmyard Manure Application on Heavy-Metal Uptake in Wheat. Communications in Soil Science and Plant Analysis, 40: 3524-3538.

Lakhdar, A., Scelza, R., Achiba, W., Scotti, R., Rao, M.A., Jedidi, N., Abdelly, C. and Gianfreda, L., 2011. Effect of Municipal Solid Waste Compost and Sewage Sludge on Enzymatic Activities and Wheat Yield in a Clayey-Loamy Soil. Soil Science, 176(1): 15-21.

Lei, W., Peishi, Q. and Ming, X., 2011 Phytoremediation prospects of heavy metals by indigenous plants growing in industrially polluted soils. Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM), 2011 International Conference on,. IEEE, 1628-1631.

Logan, T.J., Lindsay, B.J., Goins, L.E. and Rayan, J.A., 1997. Field assessment of sludge metal bioavailability to crops: Sludge rate response. Journal of Environmental Quality, 26:534-550.

Lu, Y., Gonga, Z., Zhanga, G. and Burghardt, W., 2003. Concentrations and chemical speciation of Cu, Zn, Pb and Cr of urban soils in Nanjing, China. Geoderma, 115: 101-111.

Mahboubi, M. and Farzin, N., 2009. Antimicrobial activity of Artemisia sieberi essential oil from central Iran. Iranian Journal of Microbiology, 1:43-48.

Mangkoedihardjo, S., 2008. Jatropha curcas L. for phytoremediation of lead and cadmium polluted soil. World Applied Sciences Journal, 4:519-522.

Mccutcheon, S. and Schnoor, J., 2003. Overview of phytotransformation and control of wastes. Phytoremediation: Transformation and control of contaminants, 358.

Medina, A., Vassilev, N., Alguacil, M.M., Roldan, A. and Azcon, R., 2004. Increased plant growth, nutrient uptake, and soil enzymatic activities in a decertified Mediterranean soil amended with treated residues and inoculated with native mycorrhizal fungi and a plant growth promoting yeast. Soil Science, 169:260-270.

Moameri, M. and Khalaki, M.A., 2017. Capability of Secale montanum trusted for phytoremediation of lead and cadmium in soils amended with nano-silica and municipal solid waste compost. Environmental Science and Pollution Research, 1-8.

Moameri, M., Jafari, M., Tabili, A., Motasharezadeh, B., Zare Chahouki, M. A. and Madrid Díaz, F., 2018. Investigating lead and zinc uptake and accumulation by Stipa hohenackeriana trin and rupr. in field and pot experiments. Bioscience Journal, 34(1): 138-150.

Moameri, M., Jafari, M., Tavili, A., Motasharezadeh, B. and Zare Chahouki, M., 2015. Assessing rangeland plants potential for phytoremediation of contaminated soil with Lead and Zinc Factory-Zanjan. Journal of Rangeland, 9:29-42.

Moameri, M., Jafari, M., Tavili, A., Motasharezadeh, B. and Zare Chahouki, M., 2017. Rangeland plants potential for phytoremediation of contaminated soils with lead, zinc, cadmium and nickel (case study: Rangelands around National Lead & Zinc Factory, Zanjan, Iran). Journal of Rangeland Science, 7: 160-171.

Moslehi, A., Fekri, M. and Fotovat, A., 2014. Effects of municipal solid waste compost and EDTA on the phytoremediation different levels of CD and Pb using helianthus. Journal of Soil Research, 28(2):421-431.

Mozaffarian, V., 1996. A dictionary of Iranian plant names: Latin, English, Persian, Farhang Mo'aser. 671p.

Mulligan, CN., Yong, RN. and Gibbs, BF., 2001. Remediation technologies for metal-contaminated soils and groundwater: an evaluation. Engineering Geology, 60(1):193-207.

Park, J. H., Lamb, D., Paneerselvam, P., Choppala, G., Bolan, N. and Chung, J.W., 2011. Role of organic amendments on enhanced bioremediation of heavy metal (loid) contaminated soils. Journal of hazardous materials, 185:549-574.

Pascual, J.A., Garcia, C. and Hernandez, T., 1999. Lasting microbiological and biochemical effects of the addition of municipal solid waste to an arid soil. Biological Fertilize Soils, 30:1-6.

Putwattana, N., Kruatrachue, M., Pokethitiyook, P. and Chaiyarat, R., 2010. Immobilization of cadmium in soil by cow manure and silicate fertilizer, and reduced accumulation of cadmium in sweet basil (*Ocimum basilicum*). Science Asia, 36(4):349-354.

Sabir, M., Ali, A., Zia-Ur-Rehman, M. and Hakeem, K.R., 2015. Contrasting effects of farmyard manure (FYM) and compost for remediation of metal contaminated soil. International journal of phytoremediation, 17:613-621.

Sabir, M., Hanafi, M.M., Aziz, T., Ahmad, H.R., Zia-Ur-Rehman, M., Saifullah, G.M. and Hakeem, K.R., 2013. Comparative effect of activated carbon, pressmud and poultry manure on immobilization and concentration of metals in maize (Zea mays) grown on contaminated soil. International Journal of Agricultur Biology, 15:559-564.

Safari, A. N., Bostani, A. and Omidi, H., 2014. Effect of amounts and times of replication of municipal solid waste compost on concentration of pb, ni and cd in soil and maize plant (*Zea mays* L.).

Sharifi, Z., Safari Sinegani, A.A. and Shariati, S., 2012. Potential of Indigenous Plant Species for the Phytoremediation of Arsenic Contaminated Land in Kurdistan (Iran). Soil and Sediment Contamination, 21:557-573

Song, B., Xu, P., Chen, M., Tang, W., Zeng, G., Gong, J., Zhang, P. and Ye, S., 2019. Using nanomaterials to facilitate the phytoremediation of contaminated soil. Critical Reviews in Environmental Science and Technology, 1-34.

Sun, Y., Zhou, Q., Xu, Y., Wang, L. and Liang, X., 2011. The role of EDTA on cadmium phytoextraction in a cadmium-hyperaccumulator Rorippa globosa. Journal of Environmental Chemistry and Ecotoxicology, 3:45-51.

Tordoff, G., Baker, A. and Willis, A., 2000. Current approaches to the revegetation and reclamation of metalliferous mine wastes. Chemosphere, 41, 219-228.

Vatehova, Z., Kollarova, K., Zelko, I., Richterova-Kucerova, D., Bujdos, M. and Liskovs, D., 2012. Interaction of silicon and cadmium in Brassica juncea and Brassica napus. Biologia, 67,: 498-504.

Walker, D.J., Clemente, R. & Bernal, M.P., 2004. Contrasting effects of manure and compost on soil pH, heavy metal availability and growth of Chenopodium album L. in a soil contaminated by pyritic mine waste. Chemosphere, 57:215-224.

Walker, DJ., Clemente, R., Roig, A. and Bernal, MP., 2003. The effects of soil amendments on heavy metal bioavailability in two contaminated Mediterranean soils. Environment Pollution, 122: 303-312.

Wong, MH., 2003. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soil. Chemosphere, 50: 775-780.

Yoon, J., Cao, X., Zhou, Q. and Ma, L.Q., 2006. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the total environment, 368:456-464.

ارزیابی توانایی گیاه‌پالایی *Artemisia aucheri* Boiss در خاک‌های آلوده به فلزات سنگین در محیط گلخانه

مهدی معمری[الف*]، فرید دادجو[ب]
[الف]استادیار دانشگاه محقق اردبیلی، *(نگارنده مسئول)، پست الکترونیکی: moameri@uma.ac.ir
[ب]کارشناس ارشد مرتعداری، دانشگاه محقق اردبیلی

تاریخ دریافت: ۱۳۹۷/۱۱/۰۹
تاریخ پذیرش: ۱۳۹۸/۰۲/۱۶

چکیده. گیاه‌پالایی روشی کارآمد است که از گیاهان برای پالایش محیط‌های آلوده استفاده می‌کند. هدف این تحقیق ارزیابی توانایی گیاه‌پالایی *Artemisia aucheri* در خاک آلوده به فلزات سنگین کادمیوم، سرب، روی و نیکل بود. برای ارزیابی تاثیر کمپوست زباله شهری بر توانایی گیاه‌پالایی *A. aucheri* آزمایش گلخانه‌ای در سال ۱۳۹۶ انجام شد. برای انجام این امر، نمونه‌برداری از خاک طبیعی، خاک‌های آلوده مراتع اطراف شرکت ملی سرب و روی زنجان، ایران انجام شد. سپس، کمپوست زباله شهری در سطوح صفر، یک و دو درصد وزنی به‌طور کامل با نمونه‌های خاک مخلوط شدند. سپس، گلدان‌های چهار کیلوگرمی با این خاک پر شدند و بذرهای *A. aucheri* در این گلدان‌ها کشت شدند. بعد از شش ماه در پایان آزمایش نمونه‌های گیاهی برداشت شدند و وزن خشک ریشه و اندام‌های هوایی و مقدار کادمیوم، سرب، روی و نیکل اندازه‌گیری شدند. برای بررسی توانایی *A. aucheri* در جذب و تجمع فلزات، فاکتور انتقال، فاکتور تجمع بیولوژیکی و فاکتور پالایش اندازه‌گیری شدند. نتایج نشان داد که تیمار کمپوست زباله شهری دو درصد، سبب جذب بیشترین مقدار کادمیوم و نیکل در ریشه (به‌ترتیب ۸۰/۸۰ و ۱۰ میلی‌گرم در کیلوگرم) و ساقه (به‌ترتیب ۶۵/۶۰ و ۶/۲۸ میلی‌گرم در کیلوگرم) گیاه *A. aucheri* شد. گیاهانی که در گلدان‌های تیمارشده با کمپوست زباله شهری دو درصد رشد کرده بودند، دارای حداقل مقدار سرب در ریشه‌ها (۳۹۵۵ میلی‌گرم در کیلوگرم) و ساقه‌ها (۲۴/۴۰ میلی‌گرم در کیلوگرم) نسبت به شاهد بودند. بنابراین نتیجه‌گیری شد که *A. aucheri* می‌تواند به‌عنوان انباشتگر کادمیوم و نیکل در خاک‌های آلوده که با کمپوست زباله شهری اصلاح شده‌اند، باشد. در مقابل، استفاده از کمپوست زباله شهری سبب عدم‌تحرک سرب و روی در خاک شد. به‌طورکلی *A. aucheri* می‌تواند در بهبود گیاه‌پالایی سرب، کادمیوم، روی و نیکل در خاک‌های آلوده مورد استفاده قرار گیرد. با این وجود، ارزیابی پتانسیل *A. aucheri* نیازمند تحقیقات بعدی تاثیر کمپوست زباله شهری در شرایط عرصه‌ای است.

کلمات کلیدی: کمپوست زباله شهری، مواد بهساز، فاکتور انتقال، انباشتگر