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"Gheorghe Asachi" Technical University of Iasi, Romania

TRACE ELEMENTS EXTRACTION FROM METAL CONTAMINATED SOILS - IMPLICATION FOR RECLAMATION OF GOLD MINE AREAS

Ali Daryabeigi Zand[1*], Hasan Darabi[1], Lale Ghafouri[1*], Alireza Talari[2]

[1]*School of Environment, College of Engineering, University of Tehran, 23 Ghods St., 141556135 Tehran, Iran*
[2]*Muthe Gold Mine Corporation*

Abstract

Trace elements (TEs) in contaminated soils are considered as primary jeopardy issues in developing countries which can cause major concerns for this industry and also menace the surrounding ecosystems, human health and wildlife, so urgent reclamation methods are required. The present research aims to evaluate potential phytoremediation capability of selected plant species *Tamarix Spp.*, *Haloxylon Spp.* and *Malcolmia Africana* to grow in TE contaminated soils. Muteh Gold mine, a widespread mountainous area with mineralized soil and nine discovered ore deposits, two active gold mines and smelting sites, is located in the central part of Iran. In this research, three plant species are selected and cultivated in two main areas of the mine; Senjede mine and tailing dam. Then the plant tissues and rhizosphere soils are sampled and prepared for TEs analysis. The translocation factors (*TF*), bioconcentration factors (*BCF*) and biological accumulation coefficients (*BAC*) are determined in order to evaluate the phytoextraction potential of plants. Analysis of soils in different sites shows that Copper (Cu), Zinc (Zn), Lead (Pb) and Nickel (Ni) concentrations are up to 476, 88, 45 and 41 mg kg^{-1} for total metals. The highest concentration of Cu was found in *Tamarix Spp.* (141 mg kg^{-1}). According to the results of *TF*, *BCF* and *BAC*, we can conclude that *Tamarix Spp.* with *TF* of 3.27, 1.461 and 1.173 can be a temporary accumulator of Cu, Pb, and Zn, respectively. Generally, *Tamarix Spp.* and *Haloxylon Spp.* might be suitable candidate species for phytoremediation to clean-up soils from contaminations.

Key words: gold mine, phytomining, phytoremediation, phytotoxicity, trace elements

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1. Introduction

Metalliferous tailing dams host high concentrations of trace elements (TEs) such as copper (Cu), lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As). As one of the main supplies of TEs in the ecosystem, mine tailings are connected to significant environmental issues in numerous countries (Chen et al., 2015). The ecology of ecosystem, environmental quality, the human health and food security in areas neighboring the mining regions could be seriously threatened by metalliferous mine tailings and raised entrance of TEs into the environment (Deng et al., 2018).

The high concentration of metals could also devastate the soil fauna, disturb the normal plant growth, cause lack of essential nutrients, degrade the soil structure, increase the toxic level of several TEs, cause plant toxicity with stunted growth and poor crop yields. These mine tailings' pollution can be emitted by wind and water erosion. The polluted and destructed soils require reclamation and rehabilitation to prevent the entrance of toxic TEs into the food chain (Bech et al., 2012; Chen et al., 2016; Ma et al., 2016).

TE pollution is persistent, covert and irreversible, leaving technical challenges and attracting numerous physical and chemical approaches to remediate TEs contaminated soils (Burada et al.,

* Author to whom all correspondence should be addressed: e-mail: adzand@ut.ac.ir; l.ghafouri1989@ut.ac.ir; Phone: +989139131478; Fax: +983134404700

2017; Deng et al., 2018; Jordanoska et al., 2018; Li et al., 2014). Among them, chemical and physical reclamation methods has gained special attention. However, these methods have some limitations including being costly, requiring a lot of manpower, having irreparable impressions in soil structure, needing high amount of new soil to be covered and degradation of the soil native microflora.

Moreover, chemical methods can also cause secondary pollution issues. So, this research aims to develop efficient, environmentally friendly remediation solutions for the secondary pollution, and find cost-effective, landscape enhancing and long-lasting methods for decontamination of TE-polluted soils. Phytoremediation is a practical approach, which could be defined as the application of green plants to eliminate the toxic materials from the environment or to make these harmful materials innocuous, to control and stabilize the soil pollution (Ali et al., 2013; Barbes and Barbulescu, 2017; Bech et al., 2012; Bian et al., 2018; Cunningham and Berti, 1993; Yoon et al., 2006).

Two different functions of metal-tolerant plants against the high concentration of TEs are accumulation and exclusion (Ghaderian and Ravandi, 2012; Vaverkova et al., 2018). Based on this strategy, plant species dealing with metal contaminated soils could be categorized in three basic types (Ghosh and Singh, 2005; Mukhopadhyay and Maiti, 2010; Raskin et al., 1994): excluders, indicators, and accumulators. Excluders can be defined as plants with the ability to inhibit the entrance of metals to their aerial parts or retain the metal concentration of the soil within a stabilized range. Indicator species can concentrate the active metals in their aerial tissues, and generally express the amount of TEs in the soil. Accumulator species can accumulate the metals in their aerial parts, even far exceeding than the metal concentration in the soil.

The ideal plant species for remediating should ideally have the following characteristics (Ali et al., 2013): high growth rate, high accumulation of the target TEs, more above-ground biomass production, highly branched and widely distributed root system, translocation of the TEs from their roots to shoots, adaptation to prevailing environmental and climatic conditions, tolerance to the toxic effects of the TEs, easy cultivation and harvest, resistance to pathogens and pests, and repulsion to herbivores to prevent food chain contamination.

To the best of our knowledge, no prior attempts have been made to use three factors of translocation factor (*TF*), biological concentration factor (*BCF*) and biological accumulation coefficient (*BAC*) to determine the potential of the three selected plant species for being hyperaccumulator, accumulator or stabilizer in mineralized and metal contaminated soils. Therefore, the main goal of this research is to analyze the ability of *Tamarix Spp*., *Haloxylon Spp.*, and *Malcolmia Africana* to phytoremediate metal contaminated soils considering the distribution and extraction of metals between plant roots and shoots.

2. Material and methods

2.1. Site description

Muteh gold mining area is located 270 km southwest of Tehran, 60 km southwest of Delijan city and 45 km northwest of Meimeh city at the Muteh plain in the center of Iran at 51° 15′ to 59° 28′ E and 33˚ 22′ to 33˚ 49′ N at 1983 to 2498 m above sea level. The location of the study area is presented in Fig. 1 using Arc GIS ver. 10.3 software. The area has semi-arid climate with an annual rainfall of about 250 mm, mostly in winter and to some extent in the autumn and spring. The maximum and minimum temperatures in summer and winter in this area are about 27.7 °C and 0.1 °C, respectively. Currently, nine ore deposits have been discovered, two of which are under exploitation; Senjede and Chah Khatoon deposits. On average, over the past years, 150,000 tons of soil has been consumed annually. With a capacity of about 500 tons of ore per day and an extraction value of 2-4 grams per ton per day, a relatively large amount of tailings is produced, which includes almost all feeds of concentration factory, chemical materials and water. Produced wastes are damped at the tailing dams.

At present, the old tailing dam with a capacity of 1.7 million tons is filled and the current tailing dam with a capacity of 1.5 million tons is being filled. Ore concentration using flotation by cyanide solution (hydrometallurgical) methods, and smelting are carried out close to the mining sites, where dust and contaminated water cover the surrounding lands. In the present study, the collection of soil and plants is carried out from two different sites on the old tailing dam (site 1) and on the Senjede Mine which is currently inactive (site 2).

2.2. Plant species

The considered species in this research are *Tamarix* Spp., *Haloxylon* Spp. and *Malcolmia Africana* (Fig. 2), which are selected due to being native in Iran and also their natural ability to grow in arid sites with similar physico-chemical characteristics.

2.3. Soil sampling and preparation

Based on an ecological risk assessment of the study area, two polluted sites and a control site were chosen (Machado-Estrada et al., 2013). Prior to the beginning of the experiments, sampling of the soil was carried out on the tailings dam, Senjedeh mine (polluted soils) and the soil around the mine (control soil) from 0-20 cm depth as suggested by Perlatti et al. (2015) with three replications.

2.4. Plant cultivation

First of all, one-year-old branches of identified plants around the mine within the radius of one kilometer were taken in order to prepare seedlings of *Haloxylon Spp.* and *Tamarix Spp.*.

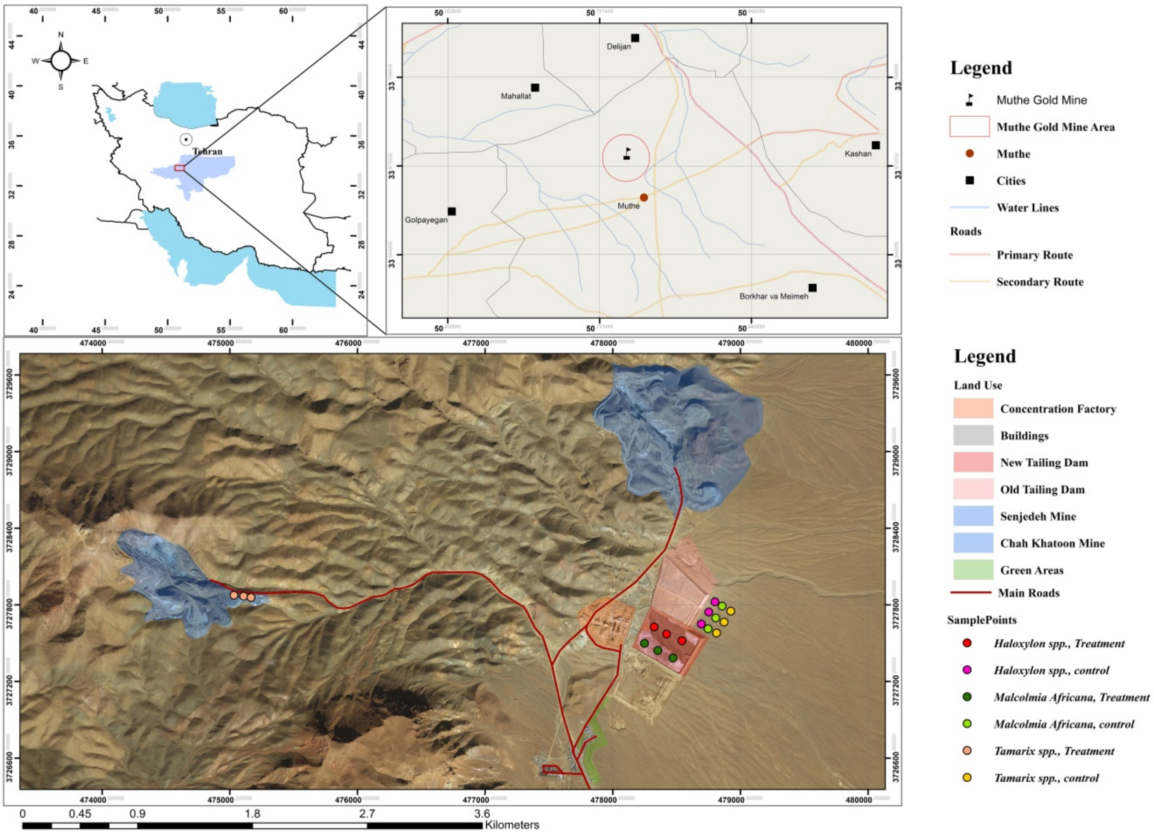

Fig. 1. Location of Muthe Mine Gold Area in Iran and the Sampling Points

(a) (b) (c)

Fig. 2. Plant species used in the research: (a) *Tamarix Spp.*, (b) *Haloxylon Spp.* and (c) *Malcolmia Africana*

The cuttings transferred to the greenhouse, without adding any nutrients as amendments. Five replicates of 1 kg pots were placed in the greenhouse. Then deionized water was added to keep the soil moisture up to 80% of the field capacity water content.

All the pots maintained during the 90 days of plant growth for *Haloxylon Spp.* and *Tamarix Spp.* (Andreazza et al., 2015). Followed by germination of the cuttings, the seedlings transferred to the Tailing dam and Senjede mine. *Malcolmia Africana* seeds were gathered from the areas around the mine within the radius of one kilometer and then cultivated in the sites in March 2016, due to the possibility of rapid germination and short growth period. Plants were irrigated once a week to maintain the required moisture content. After one year, sampling of the stems, roots, and rhizosphere soil at depth 0-20 cm was performed with three replications randomly for each plant in each region (Dimitrijević et al., 2016). At the same time, as the samples were taken from the other plants, the *Malcolmia Africana* samples were also cut.

2.5. Analysis of TEs in soil and plant tissues

The plant samples were collected in the polypropylene containers, then shoots and roots were divided mechanically. Plant samples were thoroughly washed with deionized water and running tap water for approximately 5 minutes to remove any soil particles attached to their surface and accumulated on aerial parts. Finally, the samples were oven dried at 70°C for 48 h (Lam et al., 2018).

The dried plant tissues (leaf, stem and roots) were weighed in order to measure the dry biomass, then milled into powder with a grinder, passed through a 2-mm sieve and stored in the polypropylene containers. Followed by weighing, 0.1g of plant samples were digested in Teflon bombs using the strong multi-acid method, HNO_3+ HF + $HClO_4$ (5:2:1, v/v). The total metal concentrations in digests were then determined by ICP-MS Agilent series 4500. All of the samples were dried in a hot box at 220°C for about 4 h. Analyses agreed with value of 5% (Pourret et al., 2016; Sun et al., 2016).

The soil samples were air-dried and sieved using a 2 mm plastic mesh sieve to homogenize the soil for ICP_OES analysis before wet digestion. About 20 to 25 g of soil samples were ground. Then the ground materials were digested (40% HF, 70% $HClO_4$, 65% HNO_3). All of the samples were dried in the hot box at 220°C for about 4 h, and extraction and digestion solutions from soil were measured via inductively coupled plasma-optical emission spectrometry (ICP-OES, Agilent Varian 735, Radial mood, nebulizer: V_Groove, USA) in three replicates (Bose and Bhattacharyya, 2008; Deng et al., 2004; Guo et al., 2014; Langella et al., 2014; Nirola et al., 2015; Novo et al., 2014).

2.6. Determination of plant metal uptake and accumulation

The tolerance and accumulating capability of the TEs in plants for extraction or stabilization purposes could be evaluated by translocation factor (*TF*), biological concentration factor (*BCF*) and biological accumulation coefficient (*BAC*) (Lorestani et al., 2011). *TF* shows the TEs' moving in plants tissues, which can be calculated using the following quotient (Das et al., 2014) (Eq. 1):

$$TF = \frac{C_{shoot}}{C_{root}} \tag{1}$$

where C_{shoot} is the metal concentration in shoot tissues and C_{root} is the metal concentration in root tissues. *TFs* <0.99 show that TEs are concentrated in roots, while *TFs* >0.99 indicate accumulation of TEs in the shoots (Deng et al., 2004; Olivares et al., 2013).

BCF can be computed by the following equation (Eq. 2):

$$BCF = \frac{C_{harvested\ tissue}}{C_{soil}} \tag{2}$$

where $C_{harvested\ tissue}$ indicates accumulation of TEs in harvested tissues and C_{soil} is the *TE* concentration in soil. *BCF* evaluates the capability of plants for phytoextraction purposes (Naser et al., 2018).

BAC is computed based on the concentration of *TE* in the shoots relative to the concentration of the same elements in soil (Malik et al., 2010) (Eq. 3):

$$BAC = \frac{C_{shoot}}{C_{soil}} \tag{3}$$

2.7. Statistical analyses

In all experiments three replicates were performed for each treatment, and *TF*, *BAC* and *BCF* were determined. The data was presented as means ± SD, and the statistical evaluations were carried out using the SPSS software package version 16.0 for windows.

3. Results and discussion

The weights of dry plants' biomass are illustrated in Tables 1 and 2. The highest dry biomasses of *Tamarix Spp*. shoots are observed in mine soil as 37.7, 14.0 and 25.9 g respectively, while in the control soil there were 8.1, 15.7 and 13.1 g. Also, dry biomasses of the roots in mine soils were 28.2, 8.1 and 18.15 g, while in control soils were 14.6, 13.5 and 11.5 g, respectively. The highest amount of dry biomasses of *Haloxylon Spp.* were emerged in tailing dam with three replicates as 14.0, 20.5 and 14.6 g for shoots and 8.6, 5.3 and 4.5 g for roots respectively, while the amount of dry biomasses of *Haloxylon Spp.* in control soil were 4.3, 2.8 and 2.4 g for shoots and 1.2, 0.7 and 0.8 g for roots respectively. The amount of dry biomasses of *Malcolmia Africana* in tailing dam was completely different. The highest dry biomasses of aerial tissues emerged in control soils as 24.4, 6.9 and 6.5 g, whereas in tailing soils were 2.5, 0.4 and 3.6 g, and the highest amount of roots observed in control soils as 0.6, 0.2 and 0.2 g while for tailing soils were 0.1, <0.1 and 0.1 g.

Table 1. Dry biomass of plant tissues in polluted soils(n=3)

Plants	***Plant tissues***	***Dry weight of plant tissues (g)***
Tamarix Spp.	shoot	25.9±11.9
	root	18.15±10.05
Haloxylon Spp.	shoot	16.366±3.592
	root	6.1±2.116
Malcolmia Africana	shoot	2.166±1.625
	root	0.096±0.005

Note: Values are mean ± Standard deviation of 3 replicates

Table 2. Dry biomass of plant tissues in control soils(n=3)

Plants	***Plant tissues***	***Dry weight of plant tissues (g)***
Tamarix Spp.	shoot	12.3±3.862
	root	13.2±1.571
Haloxylon Spp.	shoot	3.166±1.001
	root	0.9± 0.264
Malcolmia Africana	shoot	12.600±10.221
	root	0.333±0.230

Note: Values are mean ± Standard deviation of 3 replicates

The total concentrations of Cu, Pb, As, Zn and Ni in the soils of the three sampling sites (Senjedeh mine, the mine surrounding area, and the tailings dam area) prior the experiments are represented in the Fig. 3. Concentrations of Zn, Cu and Ni in the soil samples show relatively high levels. Total Cu concentrations in the soil samples collected from these sites were variable, ranging from 59 mg kg^{-1} around the mine to 476 mg kg^{-1} at Senjedh mine. It also can be seen in Fig. 3 that the amount of Zn at the area of the tailing dam is considerably high and variable, ranging from 7 mg kg^{-1} around the mine to 88 mg kg^{-1} at the tailing dam. All of the plants were able to grow in the contaminated soil of the mine and the tailing dam. The elemental analysis of dry aerial parts and roots of plants for Cu, Zn, Pb, Ni and As are shown in Fig. 4. Concentrations of Cu were variable, ranging widely from 9 to 141 mg kg^{-1}. The highest concentration of Cu was found in *Tamarix Spp.* aerial tissues (141 mg kg^{-1}), and the lowest was in aerial tissues of *Haloxylon Spp.* and *Malcolmia Africana* (9 mg kg^{-1}). The species which concentrate >1000 mg kg^{-1} of Cu, Zn, Ni and Pb can be known as hyperaccumulator species for mentioned elements (Baker and Brooks, 1989). *Tamarix Spp.* with 141 mg kg^{-1} in aerial parts and 43 in the roots can be a noticeable accumulator of this element. In the case of Zn in plants, the range was variable between 23.9 and 59.016 mg kg^{-1}. The highest Zn concentration was found in *Malcolmia Africana* roots. (59.016 mg kg^{-1}).

However, Pb, Ni and As were not considerable in plant tissues based on the Kabata-Pendias (2010). The concentration of Cu, Zn, Ni, Pb and As in the rhizosphere soil samples are shown in Fig. 5. Total rhizosphere soil concentrations for three plants were variable from 72 to 539 mg kg^{-1} for Cu, from 60 to 119 mg kg^{-1} for Zn, from 16 to 41 mg kg^{-1} for Ni, and from 10.4 to 18.9 mg kg^{-1} for As.

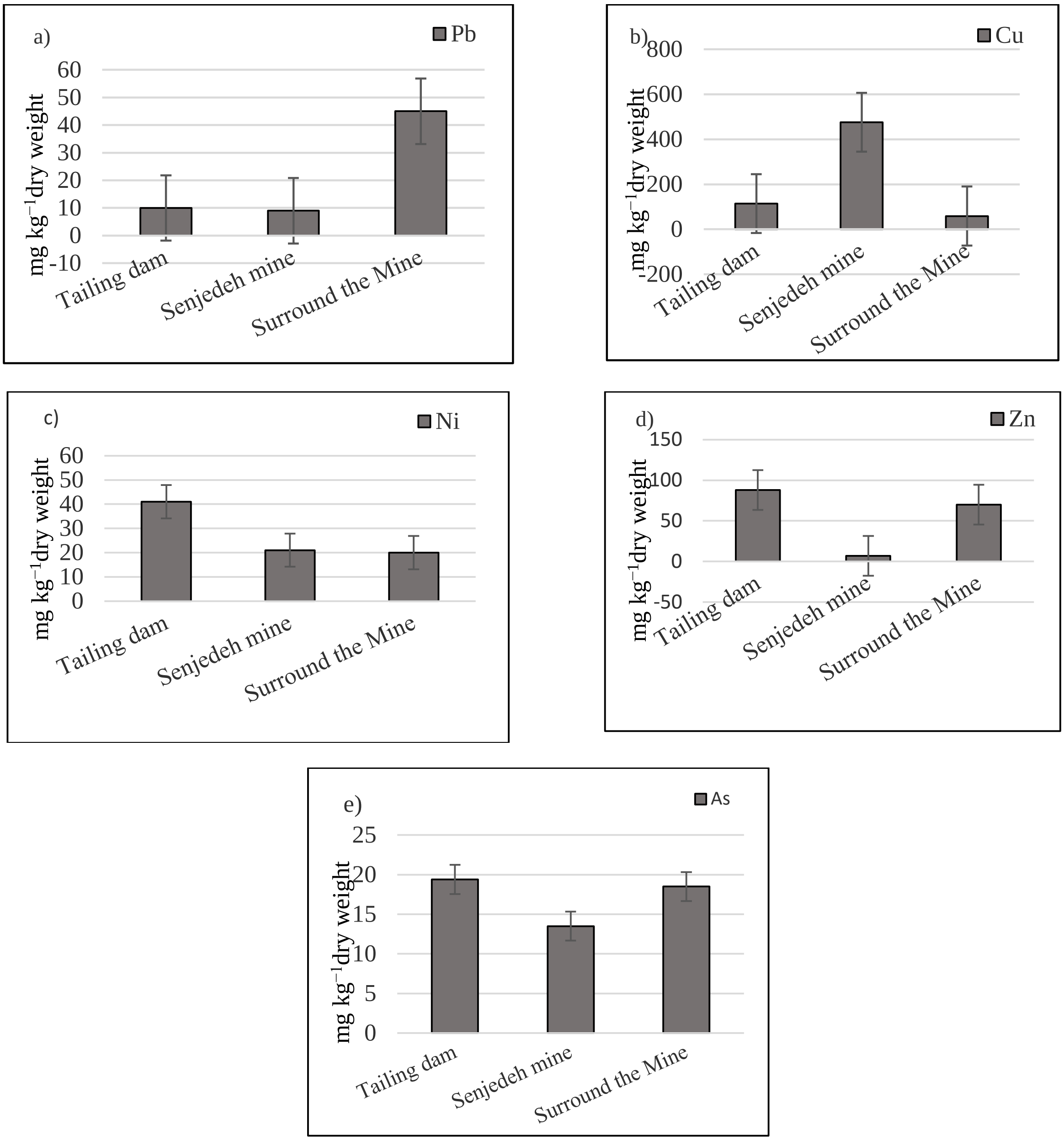

Fig. 3. Mean concentration of metals in soil samples before starting the experiments. n=3 (mg kg^{-1})

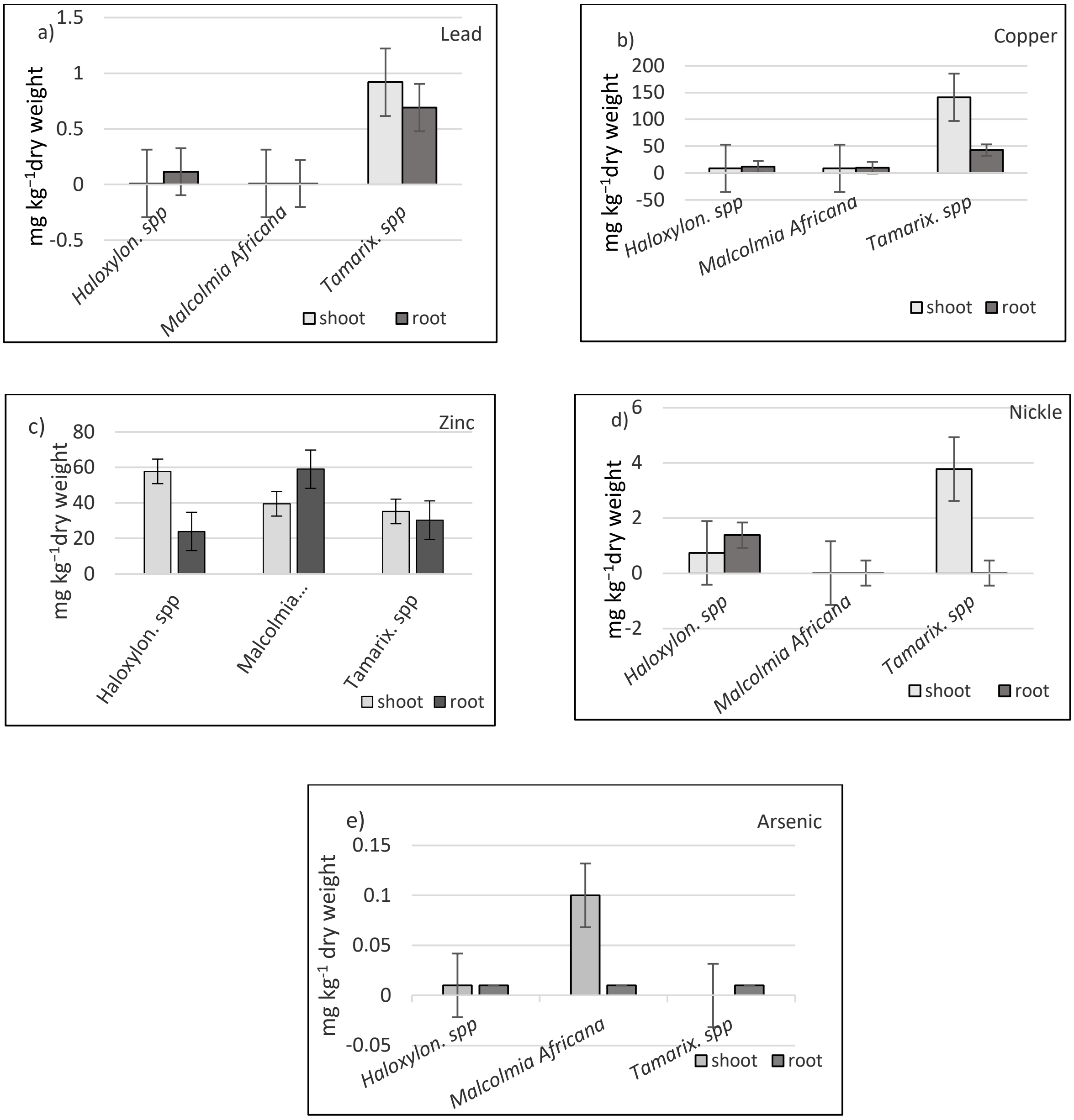

Fig. 4. The concentration of metals in plant tissues. n=3(mg kg^{-1})

The highest concentration of Cu and Zn were observed in *Tamarix Spp.* and *Haloxylon Spp.* rhizosphere soils by 539 and 119 mg kg^{-1} respectively, which were considerable compared to other elements such as Pb in all three experimented plants by 7, 7 and 6 mg kg^{-1} for *Haloxylon Spp. Malcolmia Africana* and *Tamarix Spp.* respectively. Also, the As concentrations were in a noticeable rang of 18.9, 18.4 and 10.4 for *Haloxylon Spp., Malcolmia Africana* and *Tamarix Spp.* respectively. TFs, BCFs and BACs are shown in Fig. 6. TF values for Cu, Zn and Pb are high in *Tamarix Spp.* Which represents its high capacity of translocating Cu, Zn and Pb by 3.27, 1.173 and 1.461 respectively. Although *Haloxylon Spp.* reached a relevant value of TF for Zn, Other plants did not show significant values in treatments**.** Desirable plant species to remediate TE-contaminated soils should have high metal uptake and accumulation capability, significant biomass establishment in contaminated soil, high growth rate, and extensive root system (Ghosh and Singh, 2005). There were some significant differences between the produced biomass of different treatments for *Tamarix Spp.* which was expected to grow less than the control treatment due to the high concentration of Cu in Senjedeh mine, but the results showed different manner of the plant.

The significant differences could be due to the fact that the elements of Cu, Zn and Ni are essential elements for plant nutrition, and this could be one of the reasons for its high growth rate in the Senjedeh mine. In addition, dispersed rainfall and the possibility of irrigation in different regions can be another effective factor in this category. Furthermore, *Tamarix Spp.* might have high tolerance to hard climate circumstance of the mine as a native plant. There was not any distinctive deifference between the dry biomasses of *Haloxylon Spp.* plants which cultivated in tailings and *Tamarix Spp.* grown in the mine soil.

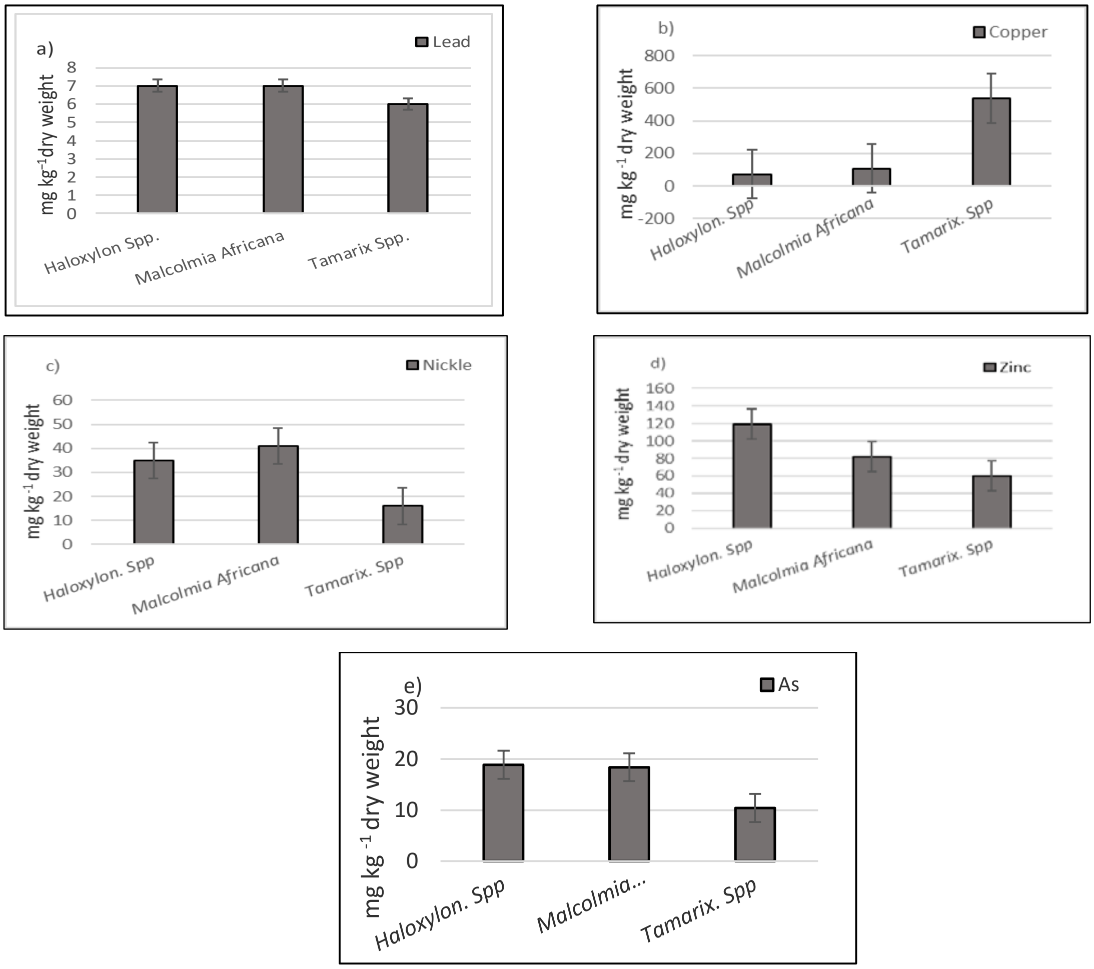

Fig. 5. The concentration of metals in rhizosphere soil samples. n=3 (mg kg^{-1})

Significantly and unexpectedly, the results of dry biomass of plants' shoots and roots of the tailing dam treatments and control soil showed similar results to *Tamarix Spp.* By comparing the amount of biomasses, it can be understood that the amount of biomass in tailing dam treatments was significantly higher than the control treatments.

In Cordero et al. (2013) research, the dry biomass of *Festuca Arundinacea* in treatments of gold ores without any amendment was only 28 % lower than the attained results of control soil, which is almost similar to our results. Based on Pérez-Esteban et al. (2013) hyperaccumulator plants are often sensitive to climate conditions and show low dry biomass, but in our research, although *Tamarix Spp.* and *Haloxylon Spp.* were not able to absorb high concentration of metals, survived in polluted soils without any significant symptoms and amendments. Substantial reduction of biomass produced in *Malcolmia Africana* can be one of the evidences of the high concentration of TEs limitations, which restricted normal development of plant growth in tailings (Tables 1, 2). The highest dry biomasses of aerial tissues also emerged in control soils as 24.4, 6.9 and 6.5 g, whereas in tailing soils were 2.5, 0.4 and 3.6 g and the highest amount of roots observed in control soils as 0.6, 0.2 and 0.2 g while for tailing soils were 0.1, <0.1 and 0.1 g., which means the high concentration of TEs might restrict the *Malcolmia Africana* growth.The difference between the dry biomasses of *Tamarix Spp.* and *Haloxylon Spp.* in polluted soils comapring to the *Malcolmia Africanas* plants was evident, which seems to show the ability of the two mentioned shrubs to be tolerant in areas with high concentration of TEs in comparison with *Malcolmia Africana*.

The normal growth of *Malcolmia Africana* cultivated in the tailing dam during the one-year study was affected by TE concentration. Different growth period of the plants might be another reason for the difference between the results of *Tamarix Spp., Haloxylon Spp.* and *Malcolmia Africana* in treatments. As Guo et al. (2014) also investigated the growth and biomass of *Oenothera glazioviana* and *E. Haichowensis* in Hoagland solutions with different Cu concentrations for 12 days, which resulted in no obvious effects on dry biomass of *O. glazioviana*. Cunningham and Berti (1993) described the definition of phytoremediation as the use of green plants to eliminate, contain, or render the environmental contaminants harmness. Almost low cost and maintenance requirements are some of the reasons for applying plants for remediation concerns.

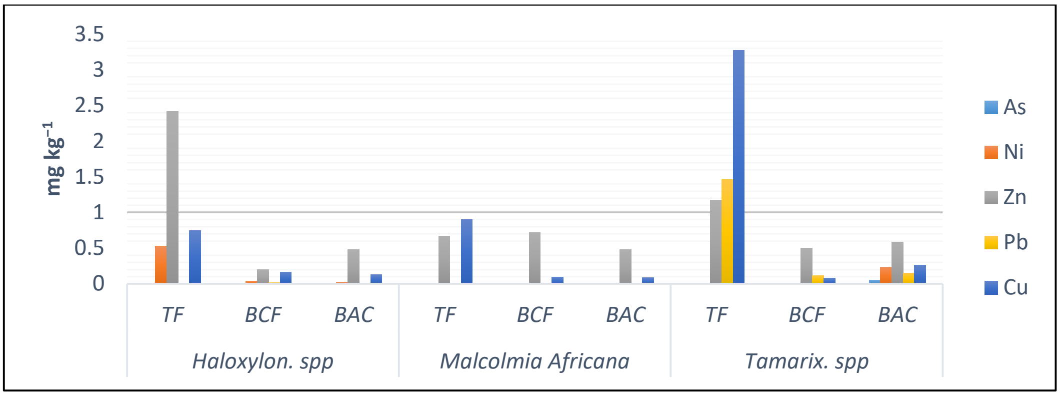

Fig. 6. Translocation factor (*TF*), Bioconcentration factor (*BCF*), and Biological accumulation coefficient (*BAC*) of elements

Since tailing soils are sources of water and air pollution by means of phytoextraction and phytostabilization techniques, the technology of phytoremediation has been used for stabilizing and removing the highly contaminated mine spoil and toxic elements from the tailings, respectively (Nouri et al., 2009).

One of the most important aims of the present research was to evaluate the capability of the species for phytoremediation goals. *TFs*, *BAC* and *BCFs* are usually used to assess a plant's ability in phytoremediation. By comparing the three mentioned factors, the capabilities of the plants in taking up TEs from soils and transferring them to the aerial parts can be compared. *TF*, *BCF* and *BAC* values higher than 1 can be used to assess the phytoextraction and phytostabilization potential of the plants (Concas et al., 2015; Lu et al., 2017; Malik et al., 2010; Nouri et al., 2011).

In this study, a total of 36 plant samples of 3 species were collected from 3 locations at the site. Concentrations of Cu, Zn, Pb, Ni and As in soils and plant biomass are provided in Figs. 3, 4 and 5. Based on the Kabata-Pendias (2010), ranges of maximum allowable concentrations for trace metals in agricultural soils for As, Cu, Ni, Pb and Zn are 15-20, 60-150, 20-60, 2-300 and 10-300 mg kg^{-1}, respectively. According to these ranges, Cu in Senjedeh mine is the only element which is upper than the allowable concentration of 476 mg kg^{-1}. Also As is almost high in tailing soils and Senjedeh mine, which seems to be toxic for the wildlife. According to Alloway et al. (1990), metal concentrations in plants have different variation based on plant species. In this study, none of the plant species accumulate metals higher than 1000 mg kg^{-1}, so based on Baker and Brooks (1989) none of the plants are hyperaccumulators. The maximum value of Cu was found in Senjedeh mine soils. In addition, *Tamarix Spp*. shoots and roots also contained significant amounts of Cu by 141 and 43 mg kg^{-1} respectively, which based on Kabata-Pendias (2010), the Cu concentrations in the roots and shoots of *Tamarix Spp.* were greater than the excessive or toxic level of Cu in plants tissues.

Also, the highest concentrations of Zn were observed in the *Malcolmia Africana* roots and *Haloxylon Spp*. shoots with 59.016 and 57.78 mg kg^{-1} respectively, and the lowest amount of Zn was represented in *Haloxylon Spp.* roots with 23.904 mg kg^{-1}, which according to Kabata-Pendias (2010) is the insufficient or normal level of this element. Almost all of the plants have the normal concentration of the other TEs. The results of the present study indicate that *Tamarix Spp*. can take up TEs including Cu and Zn from the contaminated soils and store them in their shoots, unlike a typical hyperaccumulator which is able to extract TEs from contaminated land at a higher rate and store them in body tissues (Sarma, 2011).

In a study by Cheraghi et al. (2011), 185 mg kg^{-1} and 150 mg kg^{-1} Cu was accumulated in *Chenopodium botrys* root and shoot, respectively. Furthermore, the capability of plants to endure and accumulate the TEs can be helpful for phytostabilization. Both factors, *TF* and *BCF* can be used for the assessment of a plant's potential for phytoremediation goals. We can compare the capability of different plants in translocation or taking up the TEs to aerial tissues by comparing *BCF*, *TF* and *BAC* (Yoon et al., 2006).

Fig. 6 represented the *TF*, *BCF* and *BAC* of TEs in the sampled plants grown in either the control soil, mine soil or the tailing dam. Results show that all the plants had *BAC*<1 for Cu, Pb, Zn, Ni and As. Eventually, none of them are suitable for phytoextraction of the TEs. Among studied plants *Tamarix Spp.* with *TFs*>1 for Cu and Zn elements, and *BCFs*<1, have the potential for phytostabilization of Cu and Zn. Also *Haloxylon Spp.* with a high *TF*>1 for Zn and *BCF*<1 shows its stabilization potential of this element. In Lu et al. (2017) report, *Tamarix Hispida* showed *BCF* and *TF*<1 for Ni and Cu and was able to be considered as the most adaptable plant for the phytostabilization in TE contaminated soils. According to the presented results in Fig. 6, *Tamarix Spp*. and *Haloxylon Spp*. would be recognized as qualified candidates for extracting Cu and Zn in contaminated soils. Reported by Cheraghi et al. (2011), because of high *BCF* and low *TF* for Mn, *C. bijarensis, C. juncea, V. speciosum, S. orientalis, S.*

barbata, and *C. botrys*; are recognized as the potential phytostabilization plants.

Moreover, the whole parts of the plants including their whole roots must be gathered from the polluted field in order to yield the TE phytoextraction. It can increase the extraction rate of TEs which is stored in the aerial tissues and root system of the plants. For the next phytoextraction operation, new plants must be replaced. This research indicates that *Tamarix Spp.* and *Haloxylon Spp.* were efficient in extracting the TEs from contaminated sites far less than hyperaccumulators, but high biomass of these plants can still accumulate a remarkable quantity of TEs such as Cu and Zn in their plant tissues. Also, we should emphasize that there might be some gaps between a fieldwork and pot experiments in greenhouse circumstance**.**

4. Conclusions

In this research, *Tamarix Spp.*, *Haloxylon Spp.* and *Malcolmia Africana* are cultivated in two main areas of Muthe gold mine in order to determine *TE* extraction capability of them. Regarding to this, three indicators of (*TF*), (*BCF*) and (*BAC*) are calculated. According to the results of these indicators, none of the collected herbaceous species were identified as superabsorbent, but the *Tamarix Spp.* had a *TF* of above 1 for the three elements of Cu, Pb and Zn (3.27, 1.461 and 1.173, respectively). It seems that, *Tamarix Spp.* as an indigenous species has the potential to extract the three mentioned elements.

The *Malcolmia Africana* did not show significant amounts in the study of all the indices. Also, *Haloxylon Spp.* shrub with a transfer factor of 2.417 for a Zn element seems to be able to transfer this element from roots to aerial parts. The potential of these plants as an absorbent of these elements requires more studies and experiments.

However, considering that all of the three species have the ability to grow in the polluted regions and adapt to the climatic conditions, they can be used as a buffer and a safe environment for wildlife to cover the area quickly, stabilize the soil and prevent the wind and water erosions to avoid the pollutants emission into the surrounding areas.

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