Screening for accumulator plants in turquoise mine, Nyshabour (Iran)

Mahlagha Ghorbanli[1], Mozhgan Farzamisepehr[2]* and Nafiseh Sabohimogadam[3]

1.Department of Biology, Faculty of Science, Islamic Azad University, Gorgan Branch, Gorgan, Iran
2. Department of Biology , Faculty of Agriculture, Islamic Azad University, Saveh Branch, Saveh, Iran
3. Department of Biology, Faculty of Science, Payame Noor University of Tehran, Iran

Abstract

Heavy metal pollution is a worldwide problem. This study was conducted in a turquoise mine in Nyshabour (Iran) to find accumulator plant(s). Concentrations of metals were determined both in the soil and the plants growing in the mine. Concentrations of total K, Ca, Na, Mg, Mn, Zn, Fe and Cu in the mine area were higher than the control soil. The results showed that four dominant vegetations namely *Vincetoxicum scandens* Sommier et Levier., *Stachys lavandulifolia* Vahl., *Phlomis anisodonta* Boiss. and *Onosma bulbotrichum* Dc.prod accumulated heavy metals. Based on the results, it was concluded that *Stachys lavandulifolia* Vahl. is the best accumulator for Fe , but the best Cu accumulator is *Onosma bulbotrichum* Dc.prod.

Keywords: turquoise mine; metal accumulation; dominant plants; Fe; Cu

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Introduction

Nyshabour Turquoise Mine located at 53 km north western Nyshabour is a public mine. Its proved reserve is about 8671 tons with about 15 tons extraction every year (Wilkinson, 1987). Evidences show that turquoise mining in Nyshabour backs to hundreds of years ago but the mining activity with new equipments began in 1920 (Wilkinson, 1987).

The contamination of soil ecosystem with heavy metals (HM) is considered as a global environmental issue (Szyczewski et al., 2009). These HM have both natural sources like weathering/erosion of parent rocks and ores deposits and anthropogenic sources like mining, smelting, energy, electroplating, fuel production, power transmission, intensive agriculture, waste water irrigation, sludge dumping and dust (Chanpiwat et al., 2010; Wei and Yang, 2010). In the past century, anthropogenic activity especially mining and smelting have led to excessive concentration of major cations like sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn) and HM such as chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), zinc (Zn) and cadmium (Cd). Mining activities are producing waste tailings that pose serious environmental threats to aquatic and terrestrial ecosystems. In most mining activities, these waste tailings are left without proper management (Rodrigues et al., 2009; Rashed, 2010). Improper management results in oxidation of sulfide mineral, resulting in

*Corresponding author
E-mail address: farzamisepehr@iau-saveh.ac.ir
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metalliferous acidic mine drainage which in turn leads to leaching of concentrated metallic ions like Mn, Fe Cu, Pb and Zn (Vega et al., 2006). In soil ecosystems, the toxicity and mobility of these metals depend on various factors like total concentration of metals, specific chemical form and metal binding state and properties. These are also controlled by environmental factors like pH, electrical conductivity (EC) and soil organic matter (SOM) (Nyamangara, 1998). Heavy metals were considered as highly toxic environmental pollutants to ecosystems and human health (Megatelli et al., 2009, Muhammad et al., 2011). Different methods and techniques have been used to address HM contaminated soil and tailing deposits (Yanqun et al., 2005). However, phytoremediation with native plants is the best and most cost-effective technique for reclaiming HM contaminated lands (Desideri et al., 2010; Qi et al., 2011). Presently, more than 400 plant species have been identified as natural hyper accumulators of HM, useful for phytoremediation (Freeman et al., 2004). These include plants that can accumulate exceptionally high quantities of one or more kinds of HM (Wei et al., 2009). Like other developing countries, open dumping of mining waste and tailing deposits is a common practice in Iran. We need new and variable accumulator plants for phytoremediation in different climates, so new studies are still necessary to find new accumulator plants for using in different conditions. With this idea, the aim of the present study was to investigate accumulation capability of plants growing in the polluted sites of the Nyshabour Turquoise Mine, northeast of Iran.

Materials and Methods

Study area

Turquoise mine located in Nyshabour province, northeast of Iran (36̊, 32'-36̊, 37' N and 58˚, 24'- 58˚, 29' E) was studied as mine region with an area of 60 km^2 in this research. The oldest stones are belonging to Precambrian. In the andesitic regions of the mine, turquoise is scattered in perforation of volcanic rocks in hydrothermal phase and made one of the biggest turquoise mines of the world. The studied dried pond is about 6000 m^2 and has been out of use since April 2006. Recovering these highly polluted areas is necessary, because metals leaching can pollute both running and underground waters. Our observations showed that the vegetation was few and non-compact mainly located at the margins of the pool and rarely in the center.

Heavy metals determination

Soil samples were collected from the turquoise mine area, as polluted soil. Natural soil samples were collected at a distance of 5 km away from the mine site and designated as control. The samples were then tested to compare their heavy metals concentrations. At each plot, 10-15 samples of soil (depth 10-15 cm) were taken and sieved through a 1 cm sieve for heavy metal pollution analysis.

The plants were collected and their scientific names and characteristics were determined. To estimate the total metal content in the plants, root and shoot samples were harvested in spring (May 15th) and summer (August 15th) and then dried at 105 °C for 24h. Acid washing was performed for extraction and the extracts were reweighed in volumetric 100 ml Pyrex conical flasks. Metal determination was done according to the method described by Sawidis et al (1995). About 1 g of the plant matter was digested in 20 ml boiling concentrated nitric acid (65 %) which was especially purified for spectroscopy. The solution was boiled in a hot plate until light fumes were given off. Next, the samples were cooled down and the digests were filled up to 100 ml with de-ionized water and left overnight to allow the remaining soil particles to settle out of the suspension. Finally, 20 ml of each sample was used for heavy metal concentration measurements, using the flame atomic absorption method for K, Ca, Na, Mg, Mn, Zn, Fe, Cu (Analyst 800, Perkin - Elmer). The accumulator plants were identified and the concentrations of metals in the subjected plants were measured.

Statistical analysis

To detect a significant difference in the experimental groups and control ones, analysis of variance (ANOVA) followed by the least significant difference test (LCD) was performed (Chehregani et al., 2005). The data was represented as the means ± SE of 10-15 samples for experimental groups and 3 replications for control ones.

Results

This research studied the heavy metal concentration of flora in Nyshabour Turquoise Mine. Among the plants found in the turquoise mine (Table 1), 4 species -marked by bold type in the table- were dominant plants in studied area. The vital forms of all species in the studied area are shown in Fig. I. The evaluation of metals in the soil of the turquoise mine and the natural soil showed that contents of most heavy metals in the turquoise mine area were several times higher than natural soils (Table 2). Each data represented the means ± SE of 12 samples. The difference between turquoise mine area and natural soil was significant ($p<0.05$).

Moreover, determination of the heavy metals concentration in roots and shoots of the plants dominant in the mine area showed that some of them acted as accumulators (Table 3). Results showed that the amounts of zinc in some plants, including *Stachys lavandulifolia* Vahl., *Phlomis anisodonta* Boiss. and *Onosma bulbotrichum* Dc.prod were more than Zn content in the soil (Tables 2 and 3). The study also indicated that the best Cu accumulator plant was *Onosma bulbotrichum* Dc.prod (333.28 mg/kg) but other dominant species including *Stachys lavandulifolia* Vahl., *Phlomis anisodonta* Boiss. and *Vincetoxicum scandens* Sommier et Levier.

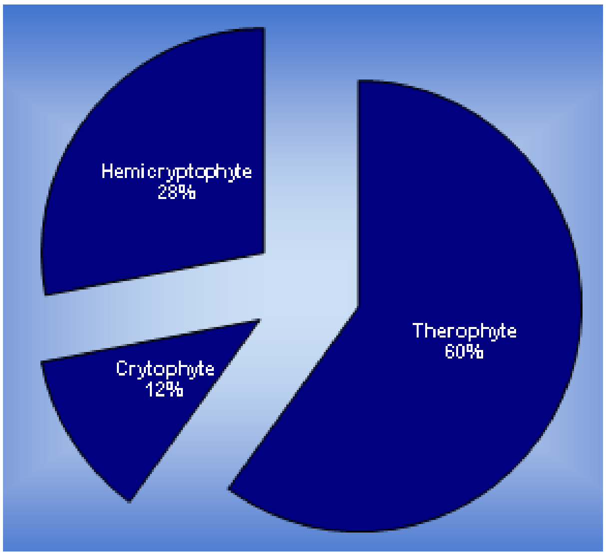

Fig. I. The vital form of flora in Nyshabour turquoise mine

Table 1
The flora of turquoise mine

Plant species	Family
Acantholimon erinaceum Lincz.	Plumbaginaceae
Aegopordon berardioides Boiss.	Compositae
Agrimonia eupatoril subsp. Eapatoria	Rosaceae
Allium baemanthoides Boiiss et Reut	Liliaceae
Allium stamineum Boiss.	Liliaceae
Anemone biflora Dc.	Ranunculaceae
Arnebia decumbens (uent.)	Boraginaceae
Arnebia hispidissima (lehm.) Dc.	Boraginaceae
Astragalus ispahanicus Boiss.	Fabaceae
Astragakus pseudo becki Sirj et Rech.f.	Fabaceae
Astragalus remotijugus Boiss.	Fabaceae
Astragalus semnanensis Bornm. Et Rech.f.	Fabaceae
Astrodaucus orientalis (L.) Drude.	Umbelliferaceae
Bunium persicum (Bioss) B. Fedtsch.	Umbelliferaceae
Bellevalia Dichroa Hausskn	Liliaceae
Cirsium arvense (L.)Scop.	Compositae
Drangos ferulaceae (L.) Lindl.	Compositae
Erodium ciconum (Jusl) L. Her ex Aiton.	Geraniaceae
Erodium graminum L.	Geraniaceae
Erodium pulverulentum (Cav.) willd	Geraniaceae
Ferula granumosa Boiss.	Umbelliferae
Gagea reticulata (poem)	Liliaceae
Geranium colinum steph.ex wiild.	Geraniaceae
Gypsophylla pilosa Hudson.	Caryophyllaceae
Lappula barbata (M.B)Gurke	Boraginaceae
Nepeta cataria L.	Labiateae
Nonnea caspica (willd) G.Don.	Boraginaceae
***Onosma bulbotrichum* Dc.prod**	Boraginaceae
Papaver arenarium M.B	Papaveraceae
Paracaryum rugulosum (D.C.) Boiss.	Boraginaceae
***Phlomis anisodonta* Boiss.**	Labiateae
Siebera nana (D.C.) Borum.	Compositae
***Stachys lavandulifolia* Vahl.**	Labiateae
Stellaria holostea L.	Caryophyllaceae
Tulipa cuspidate Stapf.	Liliaceae
Tulipa humilis Herb.	Liliaceae
Tulipa micheliana Hoo.	Liliaceae
Tulipa Schmidtii Fomin	Liliaceae
Verbascum macrocarpa	Liliaceae
***Vincetoxicum scandens* Sommier et Levier.**	Asclepiadaceae

also accumulated Cu considerably (Table 3). Analyzing the amount of Fe in the experimental plants showed that we can consider *Stachys lavandulifolia* Vahl. as the best Fe accumulator (2631.7 mg/kg) but the amount of Fe in other plants were also more than the Fe contents in the soli (Tables 2 and 3). The amounts of K, Ca and Na in the studied plants were lower than those of the natural soil. Finally, the contents of Mn and Mg were the same in the mine and natural soils.

Discussion

Heavy metals contamination of arable soil poses several problems, including phytotoxic effects of certain elements such as Cd, Pb, Zn and Cu, which are well known as micronutrients (Chehregani et al., 2005; Mengel and Kirkby, 2001; Susarla et al., 2002). Another and even a more serious problem of the polluted plant species is uptaking potentially noxious elements through food or forage and their transfer to the food chain and finally to humans (Nedelkoska and Doran, 2000). All heavy metals at high concentrations have strong toxic effects and are regarded as environmental pollutants (Chehregani et al. 2005, Nedelkoska and Doran, 2000).

The use of plants for environmental restoration is an emerging cost-effective green technology that is based on the use of metal-accumulating plants to remove toxic metals from the soil and water. In fact, phytoremediation has become a subject of intense public and scientific interest and a topic of many research studies (Salt et al., 1995; Raskin et al., 1997; Cunningham et al., 1995, Cunningham and Ow, 1996; Ike et al., 2007; Kumar- Maiti and Jaiswal, 2007). In this approach, plants capable of accumulating high levels of metals are grown in contaminated soils (Lasat, 2002). Interest in phytoextraction has significantly grown following the identification of metal accumulator plants. Accumulators are species capable of accumulating metals at levels 100-fold greater than those typically measured in shoots of common non-accumulator plants. Thus, an accumulator will concentrate more than 10 mg/kg Hg, 100 mg/kg Cd, 1000 mg/kg Co, Cr, Cu and Pb, 10000 mg/kg Zn, and Ni (Baker et al., 2000; Dahmani-Muller et al., 2000). Regarding different habitats, a wide variety of accumulating plants are needed for phytoremediation in different climatic conditions. Using the native plants is an interesting strategy to achieve this aim. According to the results of this study, *Stachys lavandulifolia* Vahl. and *Onosma bulbotrichum* Dc. prod. can be regarded as heavy metal accumulators while they differ regarding their accumulation ability. Both these plants are xerophyte species that grow in non-sufficient and

Table 2
Concentrations of some metals mg/Kg in turquoise mine of Nyshabor and natural soil (out of mine)

	K	Ca	Na	Mg	Mn	Zn	Fe	Cu
*Turquoise mine soil	90.0	67.8	36.0	85.0	173.0	29.60	187.0	16.5
[a]Natural soil	10.09	0.55	1.1	0.4	26.6	0.94	11.3	1.92

[a] The samples prepared out of the mine site
*Differences of metal concentration between mine and natural soil are significant at p≤ 0.05

Table 3
Concentrations of some metals (mg/Kg) in dominant plants at turquoise mine of Nyshabor

Species		K	Ca	Na	Mg	Mn	Zn	Fe	Cu
Vincetoxicum scandens Sommier et Levier.	shoot	1.2± 0.05	2.05± 0.04	0.05± 0.02	0.47± 0.06	166.4± 9.28	20.33± 1.41	597.26± 7.08	33.14± 2.74
	root	0.36± 0.04	1.69± 0.04	0.2± 0.03	0.36± 0.24	162.21± 6.11	26.72± 7.59	372.26± 6.02	30.23± 3.77
Stachys lavandulifolia Vahl.	shoot	0.36± 0.07	1.85± 0.14	0.13± 0.03	0.51± 0.22	77.34± 6.29	73.1± 4.52	19.2± 45.08	142.36± 3.12
	root	0.09± 0.01	1.93± 0.03	0.1± 0.02	0.35± 0.07	108.3± 3.33	77.16± 3.79	2631.7± 22.3*	61.86± 5.47
Phlomis anisodonta Boiss.	shoot	1.14± 0.54	1.24± 0.14	0.06± 0.02	0.27± 0.06	89.48± 3.66	51.00± 4.54	1961± 120.37	86.68± 2.58
	root	0.08± 0.01	3.56± 0.09	0.04± 0.01	0.35± 0.08	22.48± 2.14	32.00± 3.51	234.7± 12.20	32.19± 2.49
Onosma bulbotrichum Dc.prod	shoot	1.29± 0.64	4.72± 1.3	0.14± 0.03	0.54± 0.14	167.8± 5.41	147.9± 4.73	320± 26.85	269.7± 6.74
	root	0.19± 0.02	2.15± 0.3	0.08± 0.02	0.23± 0.04	58.9± 7.43	193.51± 4.93	21.95± 5.12	333.28± 6.42*

*Differences are significant at p≤0.05

poor soils. Based on the results, *Stachys lavandulifolia* Vahl. can be considered as an Fe accumulator. *Onosma bulbotrichum* Dc. prod on the other hand is the best Cu and Zn accumulator.

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