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Identification of the Hyper Accumulator Plants in Copper and Iron Mine in Iran

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Abstract: The aim of present study was to identify accumulator plants that are effective for phytoremediation. We chose a mine of Iron and Copper named Hame Kasi that located western north of Hamedan city as a polluted area. In this region concentration of heavy metals is several times more than non-polluted area. Seventeen plant species and 6 soil samples were collected from this region for determination of heavy metals content. Atomic Absorption Spectrophotometer (AAS) was used for analysis of heavy metals in soil and plant samples, then tested plant species were grouped on the basis of their accumulation capability of heavy metals. The results of this research showed that there are some hyper accumulator plants in this area that can concentrate heavy metals in their different parts thus they can be used for remediation of polluted area.

Key words: Hyper accumulator plants, phytoremediation, heavy metal, pollution

INTRODUCTION

Heavy metal pollution causes potential ecological risk. Although many metals are essential, all metals are toxic at higher concentration, because they cause oxidative stress by formation of free radicals. Another reaszon why metals may be toxic is that they can replace essential metals in pigments or enzymes disrupting their function. Thus, metals render the land on suitable for plant growth and destroy the biodiversity (Ghosh and Singh, 2005). The clean-up of polluted soils is one of the most difficult tasks for environmental engineering. The main technique used is extraction with physico-chemical methods, which represent sophisticated techniques and which are accordingly expensive. They are suitable for relatively small soil volumes at sites where immediate action is required. To clean-up larger areas intended to be used for agricultural and gardening purposes, currently available methods are not satisfactory. Gentle methods are needed to clean-up soils which are moderately polluted and where soil fertility is seriously affected. Since most of the plant roots are located in the soil, it seems possible to decontaminate polluted soils by using metal accumulating plants, so called hyper accumulators. In contrast to other remediation methods, this method would not destroy the soil structure (Felix and Kasak, 2000). In fact these plants can be compared too solar driven pumps (Abdul *et al*., 2001). So, hyper accumulator plants can be used to uptake and/or mineralize toxic compounds. Plant ability to take up chemical elements from growth media is evaluated by a ratio of element concentration in plants to element concentration in soils and is called: BAC; Biological Absorption Coefficient (Kabata Pendias, 2000). This way of remediation is named phytoremediation. The base of phytoremediation, (phyto meaning plant and the Latin suffix remedium meaning to clean or restores) actually refers to soil cleaning of plant-based technologies that use either naturally occurring or genetically engineered plants for cleaning contaminated environments (Majeti *et al*., 2000). Another definition of phytoremediation, a promising method for cleaning of soil and water, is pollutant uptake or bounding by plants (Gabrriella and Attila, 2005). These metal hyper accumulator plant species can concentrate metal in their aerial parts, to levels far exceeding than soil (Ghosh and Singh, 2005). The aim of this research was to identify of hyper accumulator plants that were growing in the iron and copper main site as a polluted area.

MATERIALS AND METHODS

Plant preparation and analysis: Plant samples of different growing species were collected from surrounding area of Hame Kasi iron and copper mine (Hamedan, Iran). Plant samples were thoroughly washed with deionised water to remove any soil particles attached to the plant surfaces. The aboveground and underground tissue were then separated and oven dried (70°C) to constant weight. The dried tissue were weighed and ground into powder for metal concentration analysis. Metal analysis of the plant samples was carried out by acid digestion [Conc. HNO_3+$HClO_4$ (4:1, V/V)], then measured by using atomic absorption spectrophotometer (GBC Avanta, Australia) and compared with concentration in natural condition in plants.

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Soil preparation and analysis: Soils were sampled from the same sites and location points as the plants. The top 15 cm soil from between the plant roots was collected, air-dried for two weeks and then sieved through a 2 mm mesh. Samples were then analyzed for total metals (Cu, Zn, Fe and Mn) with 4 N + HNO_3, then measured by using atomic absorption spectrophotometer (GBC Avanta, Australia) (Wong and Brad Shaw, 2002). In this study BAC were calculated for heavy metal content (Fe, Mn, Zn and Cu) of each 17 plant species and shoots and roots of 4 plant species.

RESULTS AND DISCUSSION

Soils material analysis showed that concentration of subjected metals in the Main site were high than control (Table 1). As shown in Table 1 amount of Fe is 17 times, Mn is 12 times, Zn 12.5 times and Cu 11.2 times more than control soils.

Plant samples of different species were collected and amounts of some heavy metals were analyzed by using atomic absorption spectrophotometer. Results of analysis showed that concentration of some heavy metals are more than natural conditions (Table 2).

BAC, Biological Absorption Coefficient, analysis indicated that our subjected plants can be considered in four different groups (Table 3). The tested plant species were grouped by their capability of heavy metal uptake and sensitivity to high metal pollution:

- Species that had BAC between 1-10 known high accumulator plants.
- Species that had BAC between 0.1-1 known moderately accumulator plants.
- Species that had BAC between 0.1-0.01 known low accumulator plants.
- Species that had BAC <0.01 known non accumulator plants (Bini *et al*., 1995).

Identification of high accumulator, moderately accumulator, low accumulator and non accumulator plants were done with consideration of above mentioned criterions as following forms:

- Species of *Scariola orientalis*, *Cirsium comgestum*, *Chenopodium botrys*, *Cousina* sp. and *Verbascum speciosum* should be considered as high accumulator plants for Cu.
- Based on present results following plants should be considered as moderately accumulator plants: *Stipa barbata* for Fe, Mn, Zn and Cu, *Cousina* sp. and *Chenopodium botrys* for Fe, Mn and Zn, *Scariola orientalis* for Mn and Zn, *Acanthophyllum microcephalum* and *Chondrila juncea* for Mn and Cu, *Centaurea virgata* for Fe and Cu, *Cirsium comgestum* for Mn, *Astragalus verus*, *Ziziphora clinopodioides*, *Echinops ritrodes*, *Melica jacquem*, *Cousinia bijarensis* and *Heliochrysum armenium* for Cu, *Euphorbia macroclada* for Zn and *Verbascum speciosum* for Fe.
- Results indicate that following plants belonging to low accumulator plant group: *Cirsium congestum*, *Ziziphora clinopodioides*, *Echinops ritrode*, *Melica jacquem*, *Cousinia bijarensis* and *Heliochrysum armenium* for Fe, Mn and Zn, *Euphorbia macroclada for* Fe, Mn and Cu, *Cirsium lappaceum*

Table 1: Mean of metals concentration in polluted and control sites

Metal	Polluted soil (mg kg^{-1})	Control soil (mg kg^{-1})
Fe	33890.0	2078.0
Mn	385.3	32.8
Cu	119.0	10.7
Zn	1405.0	112.0

Each data represent means of 6 samples

Table 2: Concentration of metals in plant species

Plant name	Concentration of Fe (mg kg^{-1} DW)	Concentration of Mn (mg kg^{-1} DW)	Concentration of Zn (mg kg^{-1} DW)	Concentration of Cu (mg kg^{-1} DW)
Centaurea virgata	3470.0	33.0	56.0	21.0
Astragalus verus	2117.5	39.0	50.0	24.0
Chenopodium botrys	4145.0	175.0	276.0	56.0
Stipa barbata	5910.0	110.0	330.0	37.0
Ziziphora clinopodioides	1965.0	82.2	127.0	19.0
Cousinia bijareusis	907.5	6.0	45.0	25.0
Acanthophyllum microcephalum	520.0	174.0	90.0	17.0
Cirsium congestum	2900.0	164.0	70.0	57.0
Scariola orientalis	1317.5	76.0	113.0	87.0
Cousina sp.	6382.5	123.0	142.0	34.0
Chondrila juncea	240.0	54.0	110.0	17.5
Melica jacquem	1277.5	30.0	131.0	25.0
Echinops ritrodes	1455.0	23.4	126.0	14.0
Cirsium lappaceum	275.0	10.0	32.0	3.0
Heliochrysum armenium	892.5	6.0	120.0	16.0
Euphorbia macroclada	1445.0	3.0	111.0	13.0
Verbascum speciosum	15390.0	39.0	129.5	40.0
Amount in natural conditions	*	*	50.0	4.0

*: Data variable in different species

Table 3: BAC- s, Biological Absorption Coefficient, of plant samples in field study

Plant name	BAC for Fe	BAC for Mn	BAC for Zn	BAC for Cu
Centaurea virgata	0.1100	0.0660	0.0250	0.052
Astragalus verus	0.0670	0.0780	0.0220	0.600
Chenopodium botrys	0.1310	0.3530	0.1260	1.400
Stipa barbata	0.1800	0.2200	0.1500	0.920
Ziziphora clinopodioides	0.0620	0.0560	0.0580	0.470
Cousinia bijareusis	0.0288	0.0120	0.0200	0.698
Acanthophyllum microcephalum	0.0160	0.3510	0.0410	0.420
Cirsium congestum	0.0970	0.5000	0.0980	2.110
Scariola orientalis	0.0441	0.2300	0.1590	2.230
Cousina sp.	0.2100	0.3700	0.2000	1.260
Chondrila juncea	0.0076	0.1090	0.0500	0.430
Melica jacquem	0.0406	0.0606	0.0599	0.620
Echinops ritrodes	0.0462	0.0470	0.0570	0.350
Cirsium lappaceum	0.0087	0.0200	0.0140	0.070
Heliochrysum armenium	0.0283	0.0121	0.0540	0.400
Euphorbia macroclada	0.0292	0.0168	0.2460	0.068
Verbascum speciosum	0.4890	0.0780	0.0592	1.005

BAC = Ratio of element concentration in plant to element concentration in soil

for Mn, Zn and Cu *Astragalus verus* and *Acanthophyllum microcephalum* for Fe and Zn, *Verbascum speciosum* and *centaurea virgata* for Mn and Zn *Scariola orientalis* for Fe and *Chondrila juncea* for Zn.

- Species of *Cirsium lappaceum* and *Chondrila juncea* were known as non accumulator plants for Fe (Table 3).

The present field investigation shows that some plants can accumulated heavy metal from polluted areas and are found to absorb a wide range of soil metals (Fe, Mn, Cu and Zn) (Zayed *et al.*, 2002; Chehregami *et al.*, 2007). These species that do not appear to be affected by excessive metal contents may possesses metal resistance capabilities, or higher tolerance than more sensitive species, therefore, their utility for remediation is possible (Keller *et al.*, 2003). To this base and with considering of their high biomass, we suggest the plants of group 1 can be used effectively for phytoremediation processing. This is a novel report about their ability regarding Cu concentration. In fact this plants can be extract and concentrate Cu element from their environment thus they can use for cleaning Cu contaminated soil. The benefit of these technologies is the potential for low-cost remediation. This is accordance with finding of Kabata Pandias (2000) that stated Chenopodiaceous is one of the families that are good hyper accumulator of heavy metals and also Malayeri *et al.* (2005) showed that specie of *Scariola orientalis* is hyper accumulator plant for Zn, Cu and Pb, Cd, Ni and Fe metals.

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