The European Journal of Mineral Processing and Environmental Protection
Vol.4, No.2, 1303-0868, 2004, pp. 144-151

ejmp&ep

Investigation of the potential of several plants for phytoremediation of nickel contaminated soils and for nickel phytoextraction

A. Cullaj[1], A. Hasko[2], I. McBow[3], F. Kongoli[3,*]

[1] *Department of Chemistry, University of Tirana, Tirana, Albania*
[2] *Department of Agronomy, Agricultural University of Tirana, Tirana, Albania*
[3] *FLOGEN Technologies Inc., 5757 Decelles Ave., Suite 511, Montreal, Quebec, H3V 1G5 Canada*

Received 15 May 2003; accepted 15 March 2004

ABSTRACT

Several industrial sites suffer from the contamination of soils from heavy metals, which are emitted among others by anthropogenic mining and metallurgical activities. Effective and economic physicochemical technologies for remediation of these sites remain complicated and costly. A new alternative remediation technique is the so-called phytoremediation. This is based on the ability of some plants to accumulate very high concentrations of metals from soils and thus providing the basis for a remediation of the contaminated sites. This technique as an emerging branch of natural biotechnology, has several advantages compared to the sophisticated physicochemical techniques of soil remediation. It is not only environmentally friendly but also its costs are quite low since it is solar driven. Furthermore plants can accumulate metals to such levels that the mineral recovery maybe feasible even in conventional Ni refinery or smelting operations.

In this work, the potential of many plants to accumulate nickel has been investigated in order to identify the species which offer the best phytoremedial potential for nickel contaminated soils in Albania. Field surveys have been made in five nickel-containing sites in order to identify the nickel tolerant species that have spontaneously grown in contaminated soils. Atomic Absorption Spectrometry measurements were carried out on 145 different plants collected. 16 of them were identified as having an hyper ability to accumulate nickel since they contained more than 10 000mg Ni per kg (DW). Seven taxa are of *Alyssum* genus and one of *Bornmuellera* genus of Cruciferae. The highest accumulation of nickel was present in aerial parts of *Alyssum murale* var. *chlorocarpum* Hausskn (25 500mg/kg or 2.5%) and *Alyssum markgrafii* O.E. Schulz (23 700mg/kg or 2.37%). The seeds germinated are more evidenced at *A.m.* var. *chlorocarpum*, about 63%. These plants are suggested as the most promising species to be used for phytoremediation purposes in nickel contaminated soils and phytoextraction of nickel.

Keywords: Contaminated soils; Phytoremediation; Phytoextraction; Nickel; *Alyssum*

1. INTRODUCTION

Some plants accumulate extremely high levels of certain metals. Those accumulating more than 1000 mg/kg of dry weight are usually called hyper-accumulators (Shaw, 1989; Baker, 1995; Salt *et al.*, 1995). These plants have been traditionally used as an indicator of mineral-rich sites in geological surveys as well as a bioindicator of contaminated soils during the monitoring of ecosystems. Recently they have attracted the attention of scientists due to their possible use in two new directions.

The first one is the so-called phytoremediation. This is the possibility to use these metal-tolerant hyper-accumulator plants to remove pollutants from environment or render them harmless (Chaney, 1983; Baker and Brooks, 1989). The attention has been focused on the possibility to use the accumulator plants to prevent pollution and at the same time remove hazardous pollutants from soils, waters and waste-waters by attempting to substitute harsh and very expensive conventional methods. Solar-driven photoremediation costs are normally quite low, sometimes only 10 percent of normal excavation, incineration and hazardous landfill costs. This is quite important if it is considered that the conventional cost for the remediation of 55,000 contaminated soils identified until 1993 in the European Union is evaluated to be 26,630 million ECU for a period of 15 years (European Environment Agency, 1995).

* Corresponding author. E-mail: fkongoli@flogen.com

The second direction is the so-called phytoextraction. It consists in using of hyper-accumulator plants for the extraction of valuable metals from those geological materials whose conventional mining cost is high and whose valuable metals concentrates are not so high to justify and make feasible the application of the current technologies. This is the case of most serpentine, lateritic serpentine, ultramafic and meteor-derived soils containing nickel. It has been claimed (Chaney, 1999) that nickel can be recovered by cultivating Alyssum, a hyper-accumulator plant, in nickel contaminated soils under sufficient conditions in order to permit Alyssum to accumulate nickel in above-ground tissues at concentration of at least 2.5% of air-dried tissue. In particular, plants from Brassicaceae family are known to be nickel and cobalt accumulators (Baker, 1995; Chaney, 1999).

Albania has a large surface covered by serpentine soils and has a high density of mines, especially for chromium, nickel and copper ores (Mining in Albania, 1992). Its nickel-iron reserves are evaluated about 220 million tons (containing 0.92-0.98% Ni , 0.063% Co and 42-45% Fe) and nickel-silicates reserves are about 102 million tons (containing 1.13% Ni and 0.043% Co) (Baldossore, 2002). Also during the period from 1986 to 1991 the production of nickel-iron ore was 5.4 million tons (The World Bank, 1992). As a result the contamination of soils with nickel in Albania is frequent due to emissions from various sources, mainly mining and metallurgical activities. It is also known that plants that accumulate metals are found in Albanian's rich serpentine outcrops (Hasko and Cullaj, 2000).

The aim of this paper is to present for the first time data of the wild plants species growing in nickel-containing serpentine soils in Albania, in order to identify the nickel-tolerant and hyper-accumulator species that could be used for phytoremediation and phytoextraction purposes. This work is part of a greater cooperative research project undertaken in several countries.

2. MATERIALS AND METHODS

Five principal serpentine sites of nickel-containing soils in Albania have been investigated:

Site 1: Bitincka (Korce), in South East, at an altitude of 700-1000m. It contains nickel-silicate and iron-nickel ores.

Site 2: Guri i Kuq (Pogradec), in South East, near Lake Ohri, at an altitude of 300-500 m. It contains serpentine with relatively high concentration of silicates of iron, nickel and cobalt.

Site 3: Perrenjas, in South East, where a mine of iron, nickel and cobalt is located (at an altitude of 300-400m).

Site 4: Pishkash (Librazhd), also in the South East, at an altitude of 400-500m, containing serpentine ore of iron, nickel and cobalt.

Site 5: Gjegjan (Puke), in North, at an altitude of 400-600m, containing silicate type ore with up to 2.6% of nickel.

Some plants were collected also in other sites.

Several field surveys were undertaken to collect and identify the serpentine flora with hyper-accumulator potentials. Several specimens from each plant species have been collected, botanically identified and a herbarium of plants has been prepared. (A detailed list of the collected plants at serpentine nickel-containing soils is given in Table I). A large wild-type collection of germplasm has been screened to identify the hyper-accumulating plants.

Seeds and/or propagules of the selected species have been collected in order to preserve and multiply the germplasm and to carry out studies under controlled conditions that allow a complete exploration of the potential of these species in hyper-accumulating nickel and possibly other valuable metals like cobalt and platinum group metals.

Chemical analyses of plants for nickel and cobalt content have been carried out by Flame Atomic Absorption Spectrometry using a Varian SpectrAA 10+ apparatus. Some soil samples from some sites have been also analyzed for nickel, cobalt, calcium and magnesium content. Digestion of dried plant samples was carried out by a wet mineralization procedure (with HNO_3+$HClO_4$) according to Haswell (1991). Digestion of soil samples was implemented by standard procedures using acid mixture of HCl+HNO_3+HF. All the reagents used are of Merck p.a. quality.

Table 1
List of plants collected at serpentine nickel-containing soils

Family	Species	Family	Species
Boraginaceae	Th. Medit. Anchusa variegata (2)		H. Eua. Centaurea uniflora Turra (2)
	H. Medit. Cynoglossum creticum (1)		H. Eua. Cichorium intybus (2,3,4)
	H. Eu. Echium vulgare (3,4)		G. Eua. Cirsium aevense (2,3)
	H. Medit. Echium italicum (1,2)		31.Medit. Cirsium italicum (1)

continued (Table 1)

Family	Species	Family	Species
	H. Eu. Myosotis arvensis (2)		Th. Adv. Conyza canadensis (2,4,5)
Buxaceae	Ch. Medit. Buxus sempervirens (3)		Th. Medit. Crepis neglecta (1,2)
Campanulaceae	H. Balk. Campanula hawkinsiana (4)		Th. Medit. Crepis setosa (4,5)
Caprifoliaceae	H. Medit. Sambucus ebulus (1,2)		Ch. Medit. Dittrichia graveolens (1,3)
Caryophylaceae	Th. Kozm. Cerastium glomeratum (1,2)		H. Medit. Dittrichia viscosa (2,4)
	Th. Medit. Herniaria hirsuta(1)		Th. Medit. Filago eriocephala(1)
	H. Medit. Lychnis viscaria (1)		Th. Eua. Filago vulgaris (2)
	H. Medit. Silene gallica (1)		H. Balk. Hieracium seriocophyllum (5)
	H. Medit. Silene italica (1)		H. Medit. Hypochoersis cretensis (2)
Chenopodiaceae	Th. Medit. Chenopodium botrys(5)		H. Medit. Inula ensifolia (1)
	H. Eu. Chenopodium multifidum(5).		H. Medit. Inula germanica (2,3)
Compositae	H. Medit. Achillea coarctata (1)		H. Eu. Inula crithmoides (4)
	H. Balk. Achillea grandiflora(1)		H. Medit. Leontodon taraxocoides(1)
	H. Eua. Achillea millefolium (5)		H. Medit. Picris hieracoides (2,4)
	H. Medit. Achillea nobilis (1)		H. Medit. Scolinus hispanicus (2,3,4)
	Th.Medit. Anthemis arvensis (1)		H. Eu. Senecio jacobea (3,4)
	Th. Medit. Anthemis cotula (2)		H. Eu. Scorzonera purpurea (4,5)
	H. Balk. Artemisia eriantha (2)		H. Eu. Tragopogon crucifolius (2)
	H. Eu. Aster sedifolius (5)		Th. Kozm. Xanthium spinosum (1,4)
	H. Eua. Carduus nutans (1,2)		Th. Kozm. Xanthium strumarium (2,3)
	H. Eu. Carduus acanthoides (3)		Th. Eu. Xeranthemum annum (2)
	H. Subm.Centaurea calcitrapa (1,2)		Th. Medit. Xeranthemum inapertum (1)
	Th. Kozm. Centaurea cyanus (2,3)	Convolvulaceae	H. Medit. Convolvulus althaeoides (1)
Cruciferae	H. Balk. Alyssum argenteum All. (4)		G. Kozm. Convolvulus arvensis (2,3,4)
	Ch. Balk. A.bertolonii sp.scutarinum(4,5)	Labiatae	H. Medit. Calamintha nepeta (1)
	H. Balk. Alyssum markgrafii (5)		H. Eua. Marrubium vulgare (1)
	Th. Kont. Alyssum murale(1,2,3,4)		H. Medit. Marrubium peregrinum (3)
	Th.Kont.A.m.var.subvirescens (1)		H. Medit. Mentha longifolia(2,4)
	Th.Kont. A.m. var. chalcidicum (1,2)		H. Balk. Mentha microphylla (5)
	Th.Kont.A.m.var.chlorocarpum (1,2,3,4)		H. Medit. Micromeria graeca (5)
	Ch.Balk.Bornmuellera baldaccii (4)		H. Medit. Salvia verbenaca (2,3)
	Th.Kozm. Capsella bursa pastoris (2,3,4)		Th. Medit.Salvia verticilliata (3,4)
	H. Balk. Erysimum graecum (1)		H Balk. Saturea montana (1,5)
	H. Medit. Erysimum repandum (1,3)		H. Medit.Scutellaria orientalis(5)
	H.Eu.Hesperis lacinata(5)		H. Medit. Stachys cretica (4)

continued (Table 1)

Family	Species	Family	Species
	H. Balk. Thlaspi ochroleucum(2)		H.Medit.Teucrium chamaedrys(5)
Dipsacaceae	H. Balk.Scabiosa silenifolia(5)		H. Medit. Teucrium polium (1,2)
Euphorbiaceae	H. Medit. Euphorbia myrsinites (1)		H. Eu. Thymus longicaulis (2,4)
	Th. Eua. Euphorbia helioscopia (2,3,4)		H.Medit.Thymus praecox (5)
Geraniaceae	H. Medit. Geranium purpureum (1)	Leguminosae	H. Medit. Dorycnium hirsutum (2,4)
	Th. Medit.Geranium rotundifolium(5)		H. Eua. Lotus corniculatus (2,3,4)
Graminaceae	Th. Medit. Aegilops geniculata (1)		Th. Medit Lotus ornithopodioides(1)
	Th. Medit. Aegilops uniaristata (1)		Th.Medit.Trifolium angustifolium (2,4)
	H. Eu. Agrostis canina (2)		Th.Eua. Trifolium arvense (1,2)
	Th. Medit. Aira capillaris (2)		Th.Eua.Trifolium campestre (2,3,4)
	Th. Medit. Alopecurusmyosuroides (2,3,4)		Th.Medit.Trifolium purpureum (3,4)
	Th. Balk.Briza humilis(5)		H.Eu. Ononis spinosa (1,4)
	Eua. Bromus erectus (3)		H.Medit.Vicia grandiflora (2,3,4)
	Th. Eu. Bromus racemosus(3,4)		Th.Eu.Vicia hirsuta (3,4)
	Th. Eua. Bromus squarrosus (1,2)		H.Eu.Vicia onobrychioides(2,3)
	Th. Eua. Bromus sterilis (2,3,4)		Th.Medit. Securigera securidaca(2)
	H. Eua. Dactylis glomerata (2,3,4)	Onagraceae	H. Eua.Epilobium dodanei (2)
	H. Balk. Koeleria eriostachya (1)	Papaveraceae	H.Medit. Fumaria capreolata (2)
	H. Medit.Holcus lanatus(5)	Plantaginaceae	H.Balk.Plantago holosteum (2)
	Th. Kozm. Poa annua (2,3,4)		H.Eu. Plantago lanceolata (2,3,4)
	H. Medit. Poa trivialis (2,3)		H. Eu. Plantago media (2,3,4)
	Th. Eu. Setaria viridis (2,4)	Polygonaceae	H.Kozm.Polygonum aviculare(1,2,3,4)
Hypericaceae	H. Eua. Hypericum humifusum(1,2)		H.Kozm.Rumex crispus (2,3,4)
	H. Eua. Hypericum perforatum (2,3,4)		
	H. Eu. Rumex obtusifolius(2,5)	Scrophulariaceae	H.Balk.Linaria peloponesiaca(2)
	H. Eua. Rumex sanguineus(1)		H.Medit.Linaria vulgaris(5)
Ranunculaceae	H. Eu. Anemone apenina (5)		Th. Eua .Parentucella viscosa(2)
	Th. Medit. Consolida orientalis(3)		H. Medit. Scrophularia canina (1)
	Th. Eu. Consolida regalis (2)		Th. Eua. Verbascum blattaria (1,2)
	Th. Medit. Delphinium peregrinum (1,2)		H. Eua. Verbascum thapsus (2,3,4)
	Th. Medit. Nigella arvensis (1)		Th. Eua. Veronica chamedrys (2,3,4)
	Th. Medit. Nigella damascena (1)	Verbenaceae	H. Kozm. Verbena officinalis (2,3,4)
Rosaceae	H. Eu. Alchemilla flabellata (5)	Violaceae	H. Medit. Viola alba (1)
	H. Eua. Potentilla rupestris (5)		Th. Kozm. Viola arvensis(2).

*The numbers in bracket refers to serpentine sites where the plants have been collected.
Serpentine sites are: 1. Bitincka (Korce), 2. Guri iKuq (Pogradec), 3. Prenjas ,4. Pishkash (Librazhd), 5.Gjegjan (Puke).

Instrumental parameters of measurements by AAS were optimized according the specialized literature. The precision of determinations resulted about 2-3% (as RSD). Recoveries of nickel additions using the method of standard additions were very good (from 95 to 104%).

3. RESULTS AND DISCUSSION

Field surveys and sampling at five metalliferous sites allowed the collection of 145 plant species that have been identified as belonging to 20 families. The most frequent occurred plant families are presented in Table 2.

Table 2
The frequently occurred plant families in five nickel-containing soil sites in Albania

No	Family	Number of species	%	Sites
1	Compositae	38	26.2	1 (14 sp); 2 (19 sp); 3 (9 sp); 4 (1 sp); 5 (6 sp)
2	Graminaceae	16	11.0	1 (4 sp); 2 (9 sp); 3 (7 sp); 4 (6 sp) ; 5 (2 sp)
3	Labiatae	15	10.3	1 (4 sp); 2 (4 sp); 3 (3 sp); 4 (4 sp); 5 (6 sp)
4	Cruciferae	13	9.0	1 (6 sp); 2 (5 sp); 3 (4 sp); 4 (6 sp); 5 (3 sp)
5	Scrophulariaceae	7	4.8	1 (2 sp); 2 (5 sp); 3 (2 sp); 4 (1 sp); 5 (1 sp)
6	Ranunculaceae	6	4.1	1 (3 sp); 2 (2 sp); 3 (1 sp); 4 (0 sp); 5 (1 sp)

The biggest numbers of species were found in Site 2 (Gur i Kuq) and in Site 1 (Bitincke) with respectively 60 and 47 species. Only 26 species are collected in site 5 (Gjegjan).

Table 3 presents 21 plants that resulted with the highest nickel concentration. It can be seen that the first 16 have the highest accumulation potential for nickel since they contain over 10 000mg/kg. It can also be noticed that the taxa most occurred is Alyssum: 11 Alyssum plants contain over 1% nickel and most of them are Alyssum murale and Alyssum Markgrafii. Five other Bornmuellera baldaccii (Deg.) Haywood plants also show a very good hyper-accumulation capacity for nickel with concentration from 1.16 to 1.92% Ni. However, a wide variation of metal accumulation is observed within the family and even within the various genera.

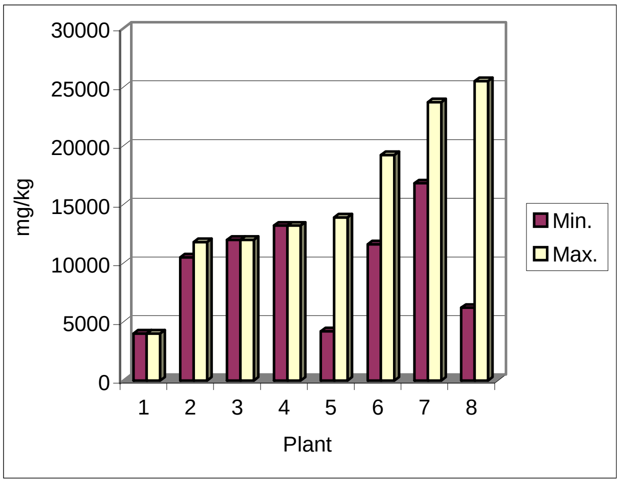
Table 3
Concentration of nickel (in mg/kg DW) in nickel-accumulating plants (aerial parts) growing in serpentine soils in Albania

No	Plant material	Sites	Ni mg/kg (DW)
1	Alyssum murale var. chlorocarpum Hausskn	Bitinckë (Korçë)	25500
2	Alyssum markgrafii O.E.Schulz	Gjegjan (Pukë)	23700
3	Bornmuellera baldacii (Deg.) Haywood	Gramsh	19200
4	Alyssum muralevar.chlorocarpum Hausskn	Bitinckë (Korçë)	18600
5	Bornmuellera baldacii(Deg.)Haywood	Pishkash (Librazhd)	16900
6	Alyssum markgrafii O.E.Schulz	Gjegjan (Pukë)	16800
7	Bornmuellera baldacii (Deg.)Haywood	Gramsh	16100
8	Alyssum murale var.chlorocarpum Hausskn	Bitinckë (Korçë)	15300
9	Bornmuellera baldacii (Deg.) Haywood	Gramsh	15200
10	Alyssum bertolonii subsp.scutarinum Desv.E.I.	Pishkash (Librazhd)	13900
11	Alyssum murale var.chalcidicum Janka	Gur i Kuq (Pogradec)	13200
12	Alysum murale var.subvirescens Formanek	Drenove (Korçe)	12000
13	Alyssum murale Walds et Kit	Rubik	11800
14	Bornmuellera baldaccii (Deg.) Haywood	Gramsh	11600
15	Alyssum murale var.chlorocarpum Haussk	Pishkash (Librazhd)	10900
16	Alyssum murale Walds et Kit	Gramsh	10500
17	Alyssum bertolonii subsp.scutarinum Desv.E.I.	Gjegjan (Pukë)	7600
18	Alyssum murale var.chlorocarpum Hausskn	Prenjas	6200
19	Alyssum bertolonii subsp.scutarinum Desv.E.I.	Krujë	5066
20	Alyssum bertolonii subsp.scutarinum Desv.E.I.	Korçë	4200
21	Alyssum argenteum All.	Shkodër	4000

From Table 3 it can be seen that there are eight taxa showing hyper-accumulation capacity for nickel; seven taxa are from Alyssum genus and one from Bornmuellera genus of Cruciferae. The highest level of nickel found in each taxa is shown in Figure 1.

Two species showing the highest accumulation of nickel resulted: Alyssum murale var. chlorocarpum Hausskn found in Site 1 (Bitincke) with 2.55% Ni and Alysum markgrafii O.E.Schulz found in site 5 (Gjegjan) with 2.37% Ni.

The lowest nickel content was found in two plants samples Thlaspi ochroleucum Boiss et Heldr (73.4 and 18.8mg/kg respectively). These species are mentioned in the literature as promising accumulators for zinc and cadmium.



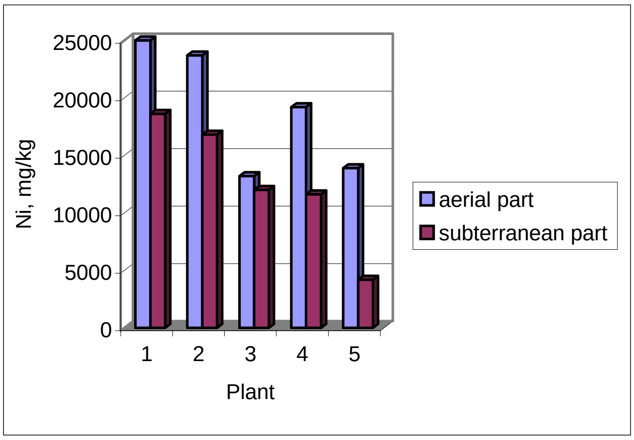
1 - Alyssum argenteum All (1 sample)
2 - Alyssum murale Walds et Kit (2 samples)
3 - Alyssum murale var. subvirescens Formanek (1 sample)
4 – Alyssum murale var. chalcidicum Janka (1 sample)
5 - Alyssum bertolonii subsp. scutarinum Desv. E. I. (4 samples)
6 - Bornmuellera baldacii (Deg.) Haywood (5 samples)
7 - Alyssum markgrafii O.E.Schulz (2 samples)
8 - Alyssum murale var. chlorocarpum Hausskn (5 samples)

Figure 1. Nickel levels in the accumulator plants in Albania

From eight samples of nickel hyper-accumulator plants seven are found in South-Eastern sites and only one (Alyssum Markgrafii, a serpentine endemic plant) is found in the North.
Cobalt content has also been determined in some samples of hyper-accumulator plants. The highest concentrations ranged from 8.9 to 15.8mg/kg and have been found in Alyssum murale var. chlorocarpum Hausskn.

The distribution of the accumulated nickel in various parts of the plants have been evaluated by analyzing aerial parts (leaf and stem) and subterranean (roots) of five species. The results, presented in Figure 2, show that in general most of nickel is accumulated by aerial parts of the plants. Proportion ranges from 3.31 in Alyssum bertolonii to 1.1 in Alyssum murale var. chalcidicum.

Biometric measurements of at least ten specimens for each plant of Alyssum genus have been carried out. The results are presented in the Table IV. The variability in the various organs is sufficient to allow the subdivision of Alyssum murale into three sub-specific categories (A.m. var. chlorocarpum, A.m. var. chalcidicum and A.m. var. subvirescens).



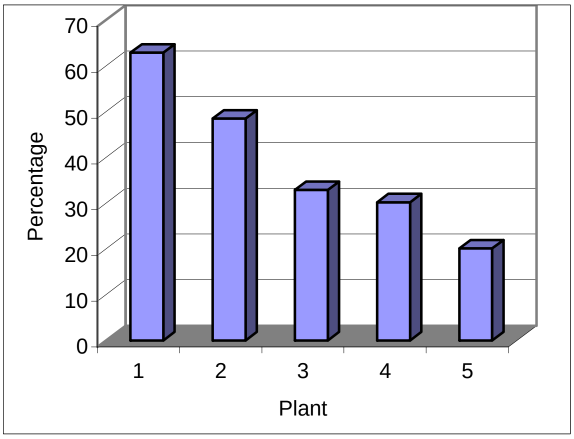
1 - Alyssum murale var. chloro.
2 - Alyssum markgrafii.
3 – Alyssum murale var. chalci
4 - Bormuellera baldacii
5 – Alyssum bertolonii

Figure 2. The accumulation of nickel in aerial part and subterranean part of plants

Table 4
The biometric measurements of various organs of Alyssum genus

Organs	*Alyssum murale*	*A. m. var. chloroccarpum*	*A. m. var. chalcidicum*	*A. m.var. subviescens*	*A.lyssum markrafii*	*A.bertolonii subsp scutarinum*
Silicula						
Length, mm	4.1	3.6	3.8	4.1	3.6	4.3
Width, mm	3.1	2.7	2.9	3.2	2.8	2.2
Stem						
Length, mm	1.6	1.1	0.8	1.4	1.1	1.1
Basal leaves						
Length, mm	25.2	23.9	21.6	24.1	27.7	19.8
Width, mm	4.8	3.8	3.9	4.2	6.9	6.2
Upper leaves						
Length, mm	19.1	20.3	16.1	16.4	17.5	16.7
Width, mm	3.6	4.1	3.4	2.8	7.5	2.2
Petals						
Length, mm	2.5	2.1	2.2	3.1	2.1	2.8
Sepals						
Length, mm	0.8	0.9	1.3	1.2	1.1	1.7
Seed						
Length, mm	2.9	2.1	2.3	2.8	2.9	1.1
Width, mm	1.8	1.5	1.6	1.8	1.9	0.8
Height, cm	48.7	51.5	53.2	45.3	51.7	31.7

The germinated power of seeds of five plants species have also been determined. The best result was obtained for seeds of Alyssum murale var. chlorocarpum Hausskn (almost 63%). The results are shown in Figure 3.



1-Alyssum murale var. chlorocarpum Hausskn
2-Alyssum murale var. chalcidicum Janka
3 – Alyssum murale Walds et Kit
4- Bornmuellera baldacii (Deg.) Haywood
5 – Alyssum bertolonii subsp. scutarinum Desv. E. I.

Figure 3. Percentage of seeds germinated for five species

The above-mentioned results are obtained for the wild species that grow spontaneously in nickel-containing soils. However, the cultivation of selected Alyssum genotypes in the conditioned soils can lead to adequate hyper-accumulation of metals in the plants in order to make feasible the recovery of the metals from these plants. It is suggested that with metal concentrations of as high as 2.5 to 5.0% in the above-the-ground tissues of plants, metal recovery becomes feasible. Some of the soil conditions that increase the accumulating ability for nickel and it phytoextraction might be a low pH of the soil (at a range of 4.5 to 6.2), low exchangeable calcium concentration and relatively high magnesium concentration and the addition of ammonium-containing fertilizer and chelating agents (Chaney *et al.*, 1999).

During this study the chemical analysis for Ni, Co, Ca and Mg of some soils from some of the sites has been carried out. They are presented in the Table 5. It can be seen that some of these soils have very favorable natural conditions for cultivation of nickel-accumulating plants. Much higher nickel accumulation is expected in selected species from this study by cultivating them in conditioned soils.

Table 5
Concentration of some metals in nickel-containing soils in % (w/w)

Sample	Nickel	Cobalt	Calcium	Magnesium
Gjegjan (Site 5)	0.13	0.027	0.397	2.45
Guri i Kuq (Site 2)	0.35	0.018	0.109	3.39
P1 (Site 4)	0.21	0.014	0.529	2.75
P2 (Site 4)	0.21	0.014	0.428	2.96
10 (Site1)	0.34	0.019	0.098	3.51
9 (Site 3)	0.14	0.030	0.535	2.65

4. CONCLUSIONS

Phytoremediation is a new promising biotechnological option for the remediation of the contaminated soils by heavy metals. This technique not only is low cost compared to traditional techniques but also can serve, when properly managed, to extract metals from the contaminated lands and/or from the low-content metal deposits (phytoextraction) and to possibly use than as one of the primary materials in the smelter feeds.

This work, as a part of a greater project in this field, investigated the potential of many plants to accumulate nickel in order to identify the species that offer the best potential for phytoremediation of nickel contaminated soils and for phytoextraction of nickel in Albania. It was found that

1) From 145 wild plant species collected in five serpentine nickel-containing soils in Albania, 16 hyperaccumulator plants are found, containing more than 10000mg/kg (DW) nickel.

2) From the seven taxa showing hyperaccumulator capacity, six taxa are from Alyssum genus and one is from Bornmellera genus of Cruciferae. Two species showing the highest content of nickel are Alyssum murale var. chlorocarpum Hausskn found in the South-East (Bitincke) with 2.55% Ni and Alysum markgrafii O.E.Schulz found in the Northern Albania (Gjegjan) with 2.37% Ni.

3) Cultivation of selected Alyssum genotypes in the nickel containing soils can lead to adequate hyper-accumulation of metal in the plants and this can be used for phytoremediation of the polluted soils and/or for extraction of valuable metals (phytoextraction).

REFERENCES

Baker, A.J.M. and Brooks, R.R., Terrestrial higher plants which hyperaccumulate metal elements - A review of their distribution, ecology and phytochemistry. Biorecovery, 1989, 1, 81-126.

Baker, A.J.M, Metal hyperaccumulation by plants: our present knowledge of the ecophysiological phenomenon. In: Will plants have a role in bioremediation? 14 th Annual Symp. Current Topics in Plant Biochemistry, Physiology and Molecular Biology. Columbia, MO, 1995, pp. 7-8.

Baldossore, G., Un sistema informativo territoriale per l'Albania ai fini dell gestione delle risorse naturale e dell'ambiente, Sviluppo Sostenibile per l'Albania, Seminario Internationale, Tirana, 2002, 141-142.

Chaney, R.L., Land treatment of hazardous wastes. ed. J.F. Parr, P.B. Marsh, and J.M. Kla., Noyes Data Corp., Park Ridge, NJ 1983, 50-76.

Chaney, R.L., Proc. extended abstracts from the 5th international conference on the biogeochemistry of trace elements. July 11-15, ed. W. Wentzel, Intern. Soc. Trace Element Research, Vienna, Austria, 1999, pp. 14-15.

European Environment Agency, Europe's Environment – The Dobris Assessment, Ed. by D. Stanners and Ph. Bourdeau, EEA, Copenhagen, 1995, pp.163.

Hasko, A. and Cullaj, A, Le Specie Iperaccumulatrici del nichel ad il loro Potenziale Utilizzo Durante la Fitodepurazione degli ambienti contaminati, Incontri Seminariali per la Valorizzazione della Biodiversita, 26-28 Ottobre, 2000, Tirana, pp. 32

Hasswell, S.S., Atomic Absorption Spectrometry, Theory, Design and Applications, Elsevier, Amsterdam 1991, 526 p.

Mining in Albania, Advertisement Supplement to Mining Journal. London, 1992, Vol. 318, No. 8172.

Salt, D.E., Blaylock, M., Kumar, N.P.B.A., Dushenkov, V., Ensley, B.D., Chet, I., Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. Biotechnology, 1995, 13, 468-474.

Shaw, A.J., Heavy metal tolerance in plants: Evolutionary aspects. New York, USA, CRC Press, 1989, 355 p.

The World Bank, Environmental review and environmental strategy studies. Albania, Final report for phase I, October 1992, 5-6.