# Nickel hyper-accumulating species and their potential use for the phyto-remediation of polluted areas

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# Nickel hyper-accumulating species and their potential use for the phyto-remediation of polluted areas

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## Summary

The paper reports the results obtained in the identification of hyper-accumulating species in some zones of Albania. Six species, five belonging to *Alyssum* genus and *Bornmuellera* baldacii showed hyper-accumulating action better than high phyto-remediation. The species are of interest in particular for their potential use in the decontamination of mining zones.

**Key words**: hyper-accumulating species, decontamination, mining zones.

## 1. Introduction

Albania lies on a large area covered with serpentine soils, that occupy 30% of the total area.

These soils are rich in heavy metals. Regarding the chromium mineral deposits, Albania ranks first in the world, while it is third for the nickel deposits. The presence of mineral deposits and metallurgical industry have much affected on the pollution of the surrounding areas, compromising the health and life of people living in those areas.

The soil often are characterized by a relatively high concentration of Ni, Cr and Co as well as absence of nutritional elements like nitrogen, phosphorus and potassium (Holmgren *et al*., 1993). Some species, called "hyper-accumulating", have adapted themselves in these areas.

This study is aimed to identify, through the knowledge of serpentine flora, the tolerant species especially, those hyper-accumulating mainly in the mineral deposits containing nickel, and their use (phyto-remediation) in order to prevent the pollution of those areas. Phyto-remediation (Brown *et al*., 1994) is a new technique that is widely and recently used. It represents a new branch of biotechnology that is based on the use of plant species to prevent the pollution of soil, water and air from heavy metals. This method has a low economic cost, since it uses natural plants as raw material.

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## 2. Materials and methods

Over the last years the serpentine flora was studied mainly in the mineral zones containing Ni (Fig. 1).

Bitinckë (Korçë), a mine in the south-eastern of Albania, at 700-1000 m above sea level, with serpentine soils rich in Fe, Ni and Co.

Guri i Kuq (Pogradec), a mine in the north of Bitinckë at 300-500m, rich in deposits of Fe, Ni and Co.

Prenjas, a mine settled in the north of Pogradec, at 300-400m; rich in deposits of Fe, Ni and Co.

Pishkash (Librazhd), a mine settled in the northwest of Prenjas, rich in deposits of Fe, Ni and Co.

Gjegjan (Pukë), a mine placed in the north of Albania at 400-600m, rich in deposits of Ni up to 2.6%.

Numerous field surveys have been made to carry out this study with the purpose of collecting, working out, identifying and analyzing plant material (De Haro, 2000).

Ten samples, especially metal-tolerant plants, were taken for each species in order to create special herbaria of metallophytes (Baker, 1987).

The chemical analyses of plant samples related to nickel content were conducted by the method of "Atomic Absorption Spectrometry" with acetylene-air flames at the Department of Chemistry, University of Tirana.

## 3. Results and discussion

Throughout the study, 143 species were met (Tab. 1). The largest number of species was found in the mine zone of Guri i Kuq (Pogradec), (Fig. 2), while high percentage of species belonged to the representatives of *Compositae* family (Fig.3). Furthermore this flora was of Mediterranean type (Fig. 4).

The dominant biological element was the perennial Hemikriptofit (H.) (Fig. 5).

The chemical analyses of Ni content were conducted in 22 plant samples, 16 of which represented by *Alyssum genus*, while 6 represented by *Bornmuellera genus*.

The plant samples were first cleaned of the external substances, ground to powder and dried for 48 hours at 105C. Then, the samples were subject to disaggregation, mixing up with 0.5 g mix solution of $HNO_3$ and $HCLO_4$

(4:1 V/V). The analysis of Ni content was conducted in an atomic absorption spectrometry (Pye Unicam SP 9) by using the acetylene flame. If the plant sample contained on dry weight base more than 1000 µg/g Ni, hyper accumulating indicator was identified (Reeves *et al.*, 1996). The results of the analyses showed that 21 plant samples were hyper-accumulating (Tab. 2).

Some of these samples indicated high levels like: *Alyssum murale* var. *chlorocarpum* Hausskn (25,500 micrograms/g) and *Alyssum markgrafii* O.E.Shulz (23,700 micrograms/g).

In according to the species classification of hyper-accumulating indicators (Brooks, 1987), it results that above 72% of the analyzed plant samples belonged to the 1st category, which means that they contain more than 10,000 micrograms/g Ni.

Based on the results of the analyses, 6 were identified as hyper-accumulating metal-tolerant species, 5 of which belonging to *Alyssum* genus and 1 to *Bornmuellera* genus (Tab. 3). Furthermore, *Alyssum murale* Walds et Kit had the highest disseminating intensity in the mineral zones. The analyses also showed that the content of Ni changes in different plant organs (Tab. 4).

In order to identify the morphological diversity of the *Alyssum* spp. representatives, numerous biometric measurements were made in different plant organs; for each species up to 10 samples were measured biometrically (Tab. 5). The data are valuable for germplasm collection of these representatives to be used during phyto-remediation and for the sub-species categorization. *Alyssum markgrafii* O.E. Schulz and *Alyssum murale* var. chlorocarpum Hausskn, are the best indicators for germplasm.

The results also indicated that the distribution of nickel hyper-accumulating metal tolerant species is as follows: *Alyssum murale* Walds et Kit var., *chlorocarpum* and *chalcidicum*, *Alyssum bertolonii* subsp. *scutarinum* Desv.E.I. and *Bornmuellera baldacii* (Deg.) Haywood are found in the South mining zones, whereas *Alyssum markgrafii* O.E.Schulz is found in the North mining zones (Fig. 6).

The above data will absolutely be a potential source to implement phytoremediation of the areas polluted by heavy metals.

In the future, species like *Alyssum murale* var. *chlorocarpum* Hausskn and *Alyssum markgrafii* O.E. Schulz may be used during phyto-remediation in the most nickel-polluted zones, since the analyses indicate that these species contain a considerable amount of nickel and have excellent indicators for germplasm preservation.

## 4. Conclusions

The study of the serpentine flora in the nickel mining zones of Bitincka (Korçë), Guri i Kuq (Pogradec), Prenjas, Pishkash (Librazhd) and Gjegjan (Pukë), identified 143 Mediterranean species of a dominating perennial form "Hemicriptophyte" (H.). Meanwhile 6 Nickel hyper-accumulating metal-tolerant species were identified as well.

The results cast light on five nickel hyper-accumulating species of *Alyssum*: *Alyssum murale* var. *chlorocarpum* Hausskn (25,500 micrograms/g), *Alyssum markgrafii* O.E. Schulz (23,700 micrograms/g), *Alyssum bertolonii* subsp. *scutarinum* Desv. E.I. (13,900 micrograms/g), *Alyssum murale* var. *chalcidicum* Janka (13,200 micrograms/g) and *Alyssum murale* Walds et Kit (11,800 micrograms/g), whereas *Bornmuellera baldacii* (Deg.) Haywood (19,300 microgram/g) was identified in *Bornmuellera* genus. More than 72% of the analyzed plant samples belong to the first category of above 10,000 micrograms/g Ni.

The biometric measurements of different plant organs among the representatives of *Alyssum* genus highlighted the morphological diversity of these organs, which is important for these plants. Species like *Alyssum murale* var. *chlorocarpum* Hausskn and *Alyssum markgrafii* O.E.Schulz are optimum indicators for the nickel content and germplasm.

The best hyper-accumulating species identified during the study have great interest for the future, especially considering their potential use during phyto-remediation of the polluted mining zones.

## Acknowledgements

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Tab. 1. Floristic list

| No. | Species | Mining zones | | | | |
|---|---|---|---|---|---|---|
| | | Bitincka (Korça) | Guri i Kuq (Pogradec) | Prenjas | Pishkash (Librazhd) | Gjegjan (Puka) |
| 1 | Th. Medit. *Anchusa variegata* ( L.) Lam | | + | | | |
| 2 | H.Medit. *Cynoglossum creticum* Mill. | + | | | | |
| 3 | H. Eu. *Echium vulgare* L. | | | + | + | |
| 4 | H. Medit. *Echium italicum* L. | + | + | | | |
| 5 | H. Eu. *Myosotis arvensis* Hill. | | + | | | |
| 6 | Ch.Medit. *Buxus sempervirens* L. | | | + | | |
| 7 | H. Balk. *Campanula hawkinsiana* Hausskn. Et Heldr. | | | | | + |
| 8 | H. Medit. *Sambucus ebulus* L. | + | + | | | |
| 9 | Th. Cozm. *Cerastium glomeratum* Thuill. | + | + | | | |
| 10 | Th. Medit. *Herniaria hirsuta* L. | + | | | | |
| 11 | H. Medit. *Lychnis viscaria* L. | + | | | | |
| 12 | H. Medit. *Silene gallica* L. | + | | | | |
| 13 | H. Medit. *Silene italica* (L.) Pers. | + | | | | |
| 14 | Th.Medit.*Chenopodium* botrys L. | | | | | + |
| 15 | H.Eu.*Chenopodium multifidum* L. | | | | | + |
| 16 | H. Medit. *Achillea coarctata Poiret*. In Lam. | + | | | | |
| 17 | H. Balk. *Achillea grandiflora* Friv. | + | | | | |
| 18 | H.Eua.*Achillea millefolium* L. | | | | | + |
| 19 | H. Medit. *Achillea nobilis* L. | + | | | | |
| 20 | Th.Medit. *Anthemis arvensis* L. | + | | | | |
| 21 | Th. Medit. *Anthemis cotula* L. | | + | | | |
| 22 | H. Balk. *Artemisia eriantha* Ten. | | + | | | |
| 23 | H.Eu. *Aster sedifolius* L. | | | | | + |
| 24 | H. Eua. *Carduus nutans* L. | + | + | | | |
| 25 | H. Eu. *Carduus acanthoides* L. | | | + | | |
| 26 | H. Subm.*Centaurea calcitrapa* L. | + | + | | | |
| 27 | Th. Cozm. *Centaurea cyanus* L. | | + | + | | |
| 28 | *Centaurea uniflora* Turra | | + | | | |
| 29 | H. Eua. *Cichorium intybus* L. | | + | + | + | |
| 30 | G. Eua. *Cirsium aevense* (L.) Scop. | | + | + | | |
| 31 | 31.Medit. *Cirsium italicum* (Savi.) DC. | + | | | | |
| 32 | Th. Adv. *Conyza canadensis* (L.) Cronq. | | + | | + | + |
| 33 | Th. Medit. *Crepis neglecta* L. | + | + | | | |
| 34 | Th. Medit. *Crepis setosa* Hall. | | | | + | + |
| 35 | Ch. Medit. *Dittrichia graveolens* (L.)W. Gre uter | + | | + | | |
| 36 | H. Medit. *Dittrichia viscosa* (L.) W.Grauter. | | + | | + | |
| 37 | Th. Medit. *Filago eriocephala* Gusss. | + | | | | |
| 38 | Th. Eua. *Filago vulgaris* Lam. | | + | | | |
| 39 | H.Balk. *Hieracium seriocophyllum* Nejc et Zahn. | | | | | + |
| 40 | H. Medit. *Hypochoersis cretensis* (L.) Bory et Chamb. | | + | | | |
| 41 | H. Medit. *Inula ensifolia* L. | + | | | | |
| 42 | H. Medit. *Inula germanica* L. | | + | + | | |
| 43 | H. Eu. *Inula crithmoides* L. | | | | + | |
| 44 | H. Medit. *Leontodon taraxocoides* (Vill.) Merat. | + | | | | |
| 45 | H. Medit. *Picris hieracoides* L. | | + | | + | |
| 46 | H. Medit. *Scolinus hispanicus* L. | | + | + | + | |
| 47 | H. Eu. *Senecio jacobea* L. | | | + | + | |
| 48 | H. Eu. *Scorzonera purpurea* L. | | | | + | + |
| 49 | H. Eu. *Tragopogon crucifolius* L. | | + | | | |

%

| No. | Species | Mining zones | | | | |
|---|---|---|---|---|---|---|
| | | Bitincka (Korça) | Guri i Kuq (Pogradec) | Prenjas | Pishkash (Librazhd) | Gjegjan (Puka) |
| 50 | Th. Kozm. *Xanthium spinosum* L. | + | | | + | |
| 51 | Th. Kozm. *Xanthium strumarium* L. | | + | + | | |
| 52 | Th. Eu. *Xeranthemum annum* L. | | + | | | |
| 53 | Th. Medit. *Xeranthemum inapertum* (L.) Mill. | + | | | | |
| 54 | H. Medit. *Convolvulus althaeoides* L. | + | | | | |
| 55 | G. Kozm. *Convolvulus arvensis* L. | | + | + | + | |
| 56 | Ch.Balk. *Alyssum bertolonii* subsp.scutarinum Dsv. | | | | + | + |
| 57 | H.Balk. *Alyssum markgrafii* O. E. Shulz. | | | | | + |
| 58 | Th. Kont. *Alyssum murale* Walds et Kit. | + | + | + | + | |
| 59 | Th. Kont. *A.m. var. chalcidicum* Janka | + | + | | | |
| 60 | Th. Kont. *A. m. var. chlorocarpum* Haussku | + | + | + | + | |
| 61 | Ch.Balk. *Bornmuellera baldaccii* (Deg.)Heywood. | | | | + | |
| 62 | Th. Kozm. *Capsella bursa pastoris* (L.) Med. | | + | + | + | |
| 63 | H. Balk. *Erysimum graecum* Boiss et Heldr. | + | | | | |
| 64 | H. Medit. *Erysimum repandum* L. | + | | + | | |
| 65 | H.Eu.*Hesperis lacinata* All. | | | | | + |
| 66 | H. Balk. *Thlaspi ochroleucum* Boiss et Heldr. | | + | | | |
| 67 | H.Balk. *Scabiosa silenifolia* WaldsetKit. | | | | | + |
| 68 | H. Medit. *Euphorbia myrsinites* L. | + | | | | |
| 69 | Th. Eua. *Euphorbia helioscopia* L. | | + | + | + | |
| 70 | H.Medit. *Geranium purpureum* L. | + | | | | |
| 71 | Th.Medit.*Geranium rotundifolium* L. | | | | | + |
| 72 | Th. Medit. *Aegilops geniculat* Roth. | + | | | | |
| 73 | Th. Medit. *Aegilops uniaristata* Vis. | + | | | | |
| 74 | H. Eu. *Agrostis canina* L. | | + | | | |
| 75 | Th. Medit. *Aira capillaris* Hos. | | + | | | |
| 76 | Th. Medit. *Alopecurus myosuroides* Huds. | | + | + | + | |
| 77 | Th.Balk.*Briza humilis* Bieb. | | | | | + |
| 78 | Eua. *Bromus erectus* Huds. | | | + | | |
| 79 | Th. Eu. *Bromus racemosus* L. | | | + | + | |
| 80 | Th. Eua. *Bromus squarrosus* L. | + | + | | | |
| 81 | Th. Eua. *Bromus sterilis* L. | | + | + | + | |
| 82 | H. Eua. *Dactylis glomerata* L. | | + | + | + | |
| 83 | H. Balk. *Koeleria eriostachya* Panc. | + | | | | |
| 84 | H.Medit.*Holcus lanatus* L. | | | | | + |
| 85 | Th.Kozm. Poa annua L. | | + | + | + | |
| 86 | H. Medit. *Poa trivialis* L. | | + | + | | |
| 87 | Th. Eu. *Setaria viridis* L. | | + | | + | |
| 88 | H. Eua. *Hypericum humifusum* L. | + | + | | | |
| 89 | H. Eua. *Hypericum perforatum* L. | | + | + | + | |
| 90 | H. Medit. *Calamintha nepeta* (L.) Savi | + | | | | |
| 91 | H. Eua. *Marrubium vulgare* L. | + | | | | |
| 92 | H. Medit. *Marrubium peregrinum* L. | | | + | | |
| 93 | H. Medit. *Mentha longifolia* (L.) Hudson | | + | | + | |
| 94 | H. Balk. *Mentha microphylla* C. Koch. | | | | | + |
| 95 | H.Medit. *Micromeria graeca* (L.) Bentham et Roiche | | | | | + |
| 96 | H. Medit. *Salvia verbenaca* L. | | + | + | | |
| 97 | Th. Medit. *Salvia verticilliata* L. | | | + | + | |
| 98 | H Balk. *Saturea montana* L. | + | | | | + |
| 99 | H.Medit. *Scutellaria orientalis* L. | | | | | + |
| 100 | H. Medit. *Stachys cretica* L. | | | | + | |

%

| No. | Species | Mining zones | | | | |
|---|---|---|---|---|---|---|
| | | Bitincka (Korça) | Guri i Kuq (Pogradec) | Prenjas | Pishkash (Librazhd) | Gjegjan (Puka) |
| 101 | H.Medit.*Teucrium chamaedrys* L. | | | | | + |
| 102 | H. Medit. *Teucrium polium* L. | + | + | | | |
| 103 | H. Eu. *Thymus longicaulis* C. Presl. | | + | | + | |
| 104 | H.Medit.*Thymus praecox* Opiz. | | | | | + |
| 105 | H. Medit. *Dorycnium hirsutum* (L.) Ser.in DC. | | + | | + | |
| 106 | H. Eua. *Lotus corniculatus* L. | | + | + | + | |
| 107 | Th. Medit *Lotus ornithopodioides* L. | + | | | | |
| 108 | Th. Medit. *Trifolium angustifoilium* L. | | + | | + | |
| 109 | Th.Eua. *Trifolium arvense* L. | + | + | | | |
| 110 | Th.Eua.*Trifolium campestre* L. | | + | + | + | |
| 111 | Th.Medit.*Trifolium purpureum* Loisel. | | | + | + | |
| 112 | H.Eu. *Ononis spinosa* L. | + | | | + | |
| 113 | H.Medit.*Vicia grandiflora* Scop | | + | + | + | |
| 114 | Th.Eu.*Vicia hirsuta* (L.) S.F. Gray | | | + | + | |
| 115 | H.Eu.*Vicia onobrychioides* L. | | + | + | | |
| 116 | Th.Medit. *Securigera securidaca* (L.) Deg.et Dorfl. | | + | | | |
| 117 | H. Eua. *Epilobium dodanei* Will | | + | | | |
| 118 | H.Medit. *Fumaria capreolata* L. | | + | | | |
| 119 | H.Balk. *Plantago holosteum* Scop | | + | | | |
| 120 | H.Eu. *Plantago lanceolata* Scop. | | + | + | + | |
| 121 | H. Eu. *Plantago media* L. | | + | + | + | |
| 122 | H.Kozm. *Polygonum aviculare* L. | + | + | + | + | |
| 123 | H.Kozm. *Rumex crispus* L. | | + | + | + | |
| 124 | H. Eu. *Rumex obtusifolius* L. | | + | | | + |
| 125 | H. Eua. *Rumex sanguineus* L. | + | | | | |
| 126 | H.Eu. *Anemone apenina* L. | | | | | + |
| 127 | Th. Medit. *Consolida orientalis* (Gay.)Schrodinger. | | | + | | |
| 128 | Th. Eu. *Consolida regalis* S.F.Gray. | | + | | | |
| 129 | Th. Medit. *Delphinium peregrinum* L. | + | + | | | |
| 130 | Th. Medit. *Nigella arvensis* L. | + | | | | |
| 131 | Th. Medit. Nigella damascena L. | + | | | | |
| 132 | H.Eu. *Alchemilla flabellata* Buser. | | | | | + |
| 133 | H.Eua.*Potentilla rupestris* L. | | | | | + |
| 134 | H. Balk. *Linaria peloponesiaca* Boiss et Heldr. | | + | | | |
| 135 | H.Medit.*Linaria vulgaris* Mill. | | | | | + |
| 136 | Th. Eua .*Parentucella viscosa* (L.)Carmel. | | + | | | |
| 137 | H. Medit. *Scrophullaria canina* L. | + | | | | |
| 138 | Th. Eua. *Verbascum blattaria* L. | + | + | | | |
| 139 | H. Eua. *Verbascum thapsus* L. | | + | + | + | |
| 140 | Th. Eua. *Veronica chamedrys* L. | | + | + | + | |
| 141 | H. Kozm. *Verbena officinalis* L. | | + | + | + | |
| 142 | H. Medit. *Viola alba* Besser. | + | | | | |
| 143 | Th. Kozm. V*iola arvensis* Hurr. | | + | | | |

Abbreviations:

| **Plants** | **Floristic element** | **Mining zones** |
|---|---|---|
| Th. Annuals | Medit.-Mediterranean | I. Bitincka (Korça) |
| H. Perennials | Eu. – European | II. Guri i Kuq ( Pogradec) |
| G. Rhizome and bulbs | Eua.- Euro-Asian | III. Prenjas |
| Ch. Shrubs | Balk.- Balkan | IV. Pishkash (Librazhd) |
| | Cozm.- Cosmopolitan | V. Gjegjan (Puka) |
| | Adv.- Adventitious | |
| | Cont.-Continental | |

Tab. 2. Ni content in plant samples

| No | Plant samples | **Zone** | Content in µg/g |
|---|---|---|---|
| 1 | *Alyssum murale var. chlorocarpum Hausskn* | Bitinckë (Korça | 25,500 |
| 2 | *Alyssum markgrafii* O.E.Schulz | Gjegjan (Puka) | 23,700 |
| 3 | *Bornmuellera baldacii (Deg.) Haywood* | Gramshi | 19,300 |
| 4 | Alyssum muralevar.chlorocarpum Hausskn | Bitincka (Korça) | 18,600 |
| 5 | *Bornmuellera baldacii (Deg.) Haywood* | Librazhdi | 16,900 |
| 6 | *Alyssum markgrafii O.E.Schulz* | Gjegjan (Puka) | 16,800 |
| 7 | *Bornmuellera baldacii (Deg.) Haywood* | Gramshi | 16,100 |
| 8 | *Alyssum murale var.chlorocarpum Hausskn* | Bitincka (Korça) | 15,300 |
| 9 | *Bornmuellera baldacii (Deg.) Haywood* | Gramsh | 15,200 |
| 10 | *Alyssum bertolonii subsp.scutarinum Desv.E.I.* | Librazhd | 13,900 |
| 11 | *Alyssum murale* var.*chalcidicum Janka* | Gur i Kuq (Pogradec) | 13,200 |
| 12 | *Alysum murale* var.*chalcidicum Janka* | Gur i Kuq (Pogradec) | 12,000 |
| 13 | *Alyssum murale Walds et Kit* | Rubik | 11,800 |
| 14 | *Bornmuellera baldaccii (Deg.) Haywood* | Gramsh | 11,600 |
| 15 | *Alyssum murale* var.*chlorocarpum Haussk* | Librazhd | 10,900 |
| 16 | *Alyssum murale Walds et Kit* | Gramsh | 10,500 |
| 17 | *Alyssum bertolonii* subsp.*scutarinum Desv.E.I.* | Puka | 7,600 |
| 18 | *Alyssum murale* var.*chlorocarpum Hausskn* | Prenjas | 6,200 |
| 19 | *Alyssum bertolonii* subsp.*scutarinum Desv.E.I.* | Kruja | 5,066 |
| 20 | *Alyssum bertolonii* subsp.*scutarinum Desv.E.I.* | Korça | 4,200 |
| 21 | *Alyssum bertolonii* subsp.*scutarinum Desv.E.I.* | Shkodra | 4,000 |

Tab. 3. Distribution of Nickel hyper-accumulating species

| No | Species | Mineral zones | | | | |
|---|---|---|---|---|---|---|
| | | Bitincka (Korça) | Guri i Kuq (Pogradec) | Prenjas | Pishkash (Librazhd) | Gjegjan (Puka) |
| 1 | *Alyssum murale* Walds et Kit | + | + | + | + | |
| 2 | *Alyssum murale* var. *chlorocarpum* Hausskn | + | + | + | + | |
| 3 | *Alyssum murale* var. *chalcidicum* Janka | + | + | + | | |
| 4 | *Alyssum markgrafii* O.E.Sculz | | | | | + |
| 5 | *Alyssum bertolonii* subsp. *scutarinum* Desv.E.I. | | | | + | + |
| 6 | *Bornmuellera baldacii* (Deg.) Haywood | | | | + | |

Tab. 4. Content of Ni in different plant parts.

| No | Species | **Plant organ** | | **Content of Ni in μg/g dry weight** |
|---|---|---|---|---|
| 1 | *Alyssum murale* var. *chlorocarpum* Hausskn | leaves, stem | (upper part) | 25,500 |
| | | | | 18,600 |
| | | leaves, stem | (basal part) | |
| 2 | *Alyssum murale* var. *chalcidicum* Janka | leaves, stem | (upper part) | 13,200 |
| | | | | 12,000 |
| | | leaves, stem | (basal part) | |
| 3 | Alyssum markgrafii O.E.Schulz | leaves, stem | (upper part) | 23,700 |
| | | leaves, stem | (basal part) | 16,800 |
| 4 | *Bornmuellera baldacii* (Deg.) Haywood | leaves, stem | (upper part) | 19,200 |
| | | leaves, stem | (basal part) | 11,600 |
| 5 | *Alyssum bertolonii* subsp. *Scutarinum* (Desv.) E.I. | leaves, stem | (upper part) | 13,900 |
| | | leaves, stem | (basal part) | 4,200 |

Tab. 5. Summary of biometric data of different parts of *Alyssum* representatives

| No | Plant part | Species | | | | |
|---|---|---|---|---|---|---|
| | | Alyssum murale Walds et Kit | Alyssum murale var. chlorocarpu m Hausskn | Alyssum murale var. chalcidicum Janka | Alyssum markgrafii O.E.Schulz | Alyssum bertolonii subsp. scutarinum Desv.E.I. |
| I | Silikula | | | | | |
| | Length, mm | 4.1 | 3.6 | 3.8 | 3.6 | 4.3 |
| | Width mm | 3.1 | 2.7 | 2.9 | 2.8 | 2.2 |
| II | Style | | | | | |
| | Length mm | 1.6 | 1.1 | 0.8 | 1.1 | 1.1 |
| III | Basal leaves | | | | | |
| | Length mm | 25.2 | 23.9 | 21.6 | 27.7 | 19.8 |
| | Width mm | 4.8 | 3.8 | 3.9 | 6.9 | 6.2 |
| IV | Upper leaves | | | | | |
| | Length mm | 19.1 | 20.3 | 16.1 | 17.5 | 16.7 |
| | Width mm | 3.6 | 4.1 | 3.4 | 7.5 | 2.2 |
| V | Petals | | | | | |
| | Length mm | 2.5 | 2.1 | 2.2 | 2.1 | 2.8 |
| VI | Sub-petals | | | | | |
| | Length mm | 0.8 | 0.9 | 1.3 | 1.1 | 1.7 |
| VII | Seeds | | | | | |
| | Length mm | 2.9 | 2.1 | 2.3 | 2.9 | 1.1 |
| | Width mm | 1.8 | 1.5 | 1.6 | 1.9 | 0.8 |
| VIII | Height cm | 48.7 | 51.5 | 53.2 | 51.7 | 31.7 |

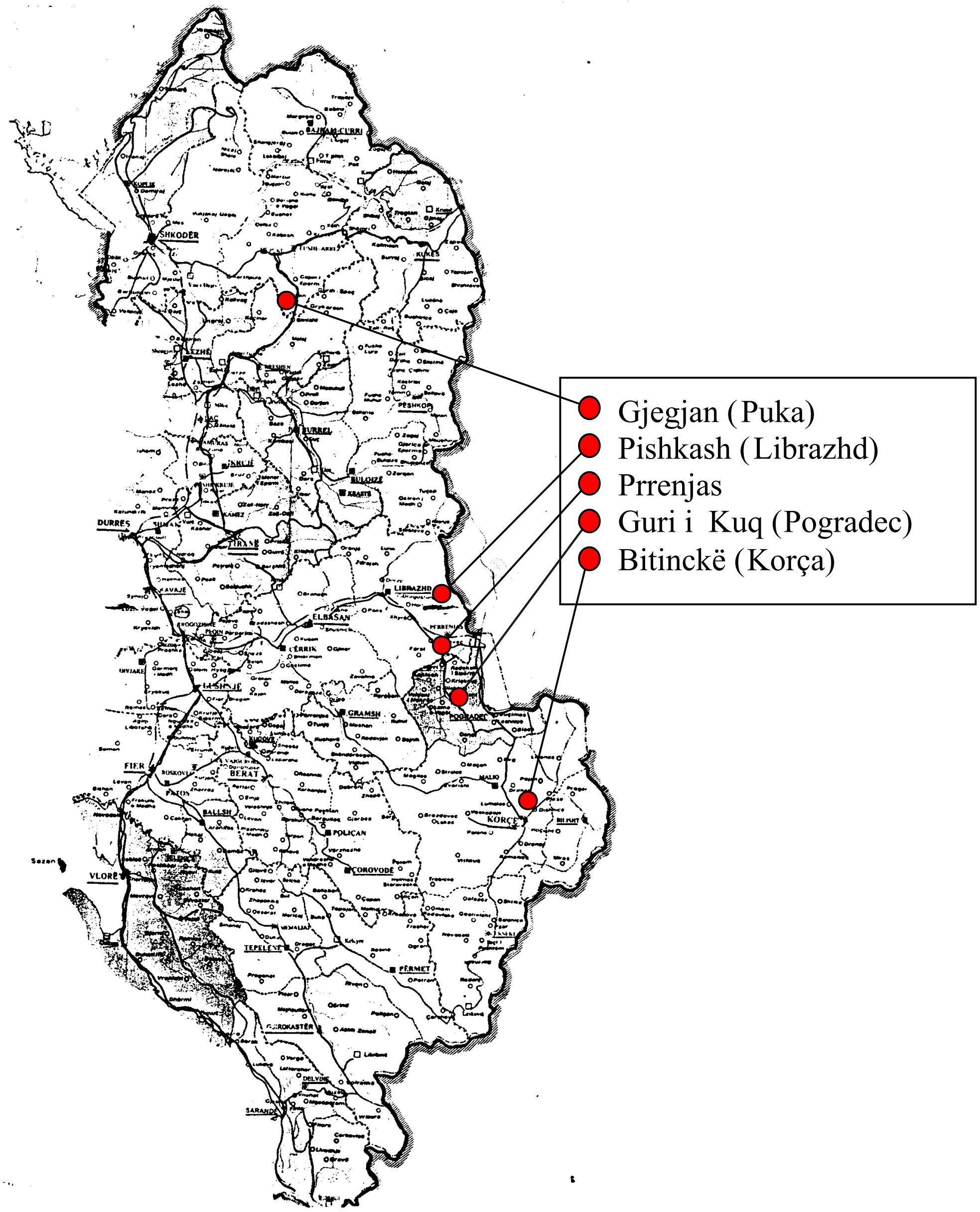


Fig. 1 Nickel mining zones studied in Albania

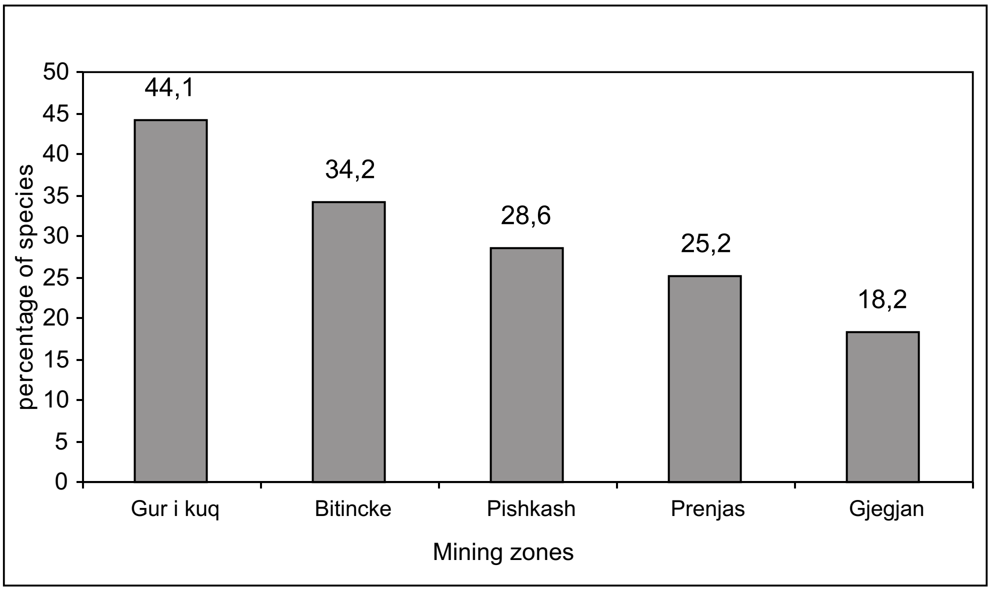


Fig. 2 Species found in the mining zones

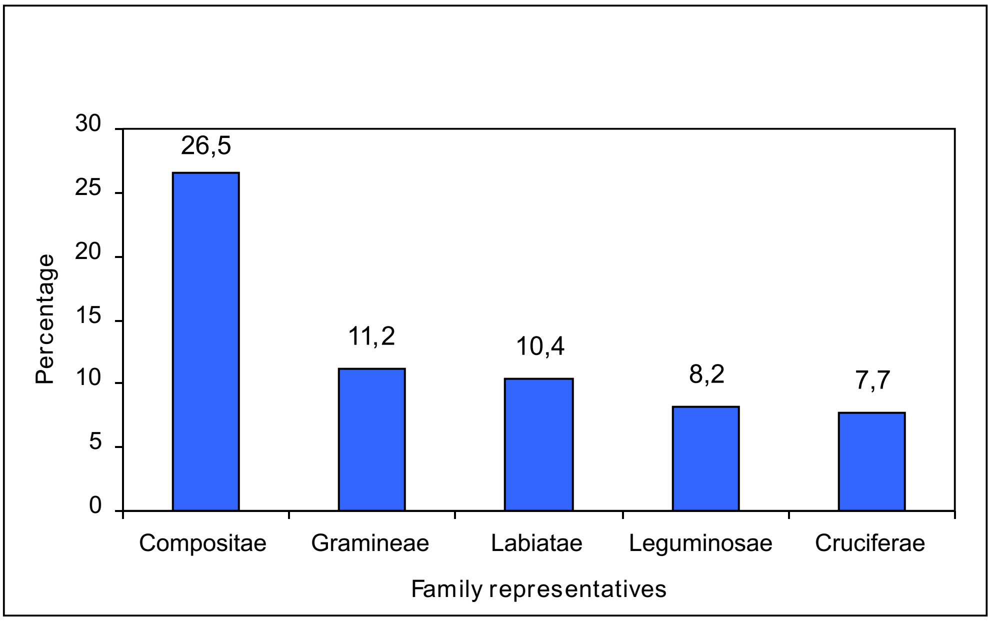


Fig. 3 Species distributed in families

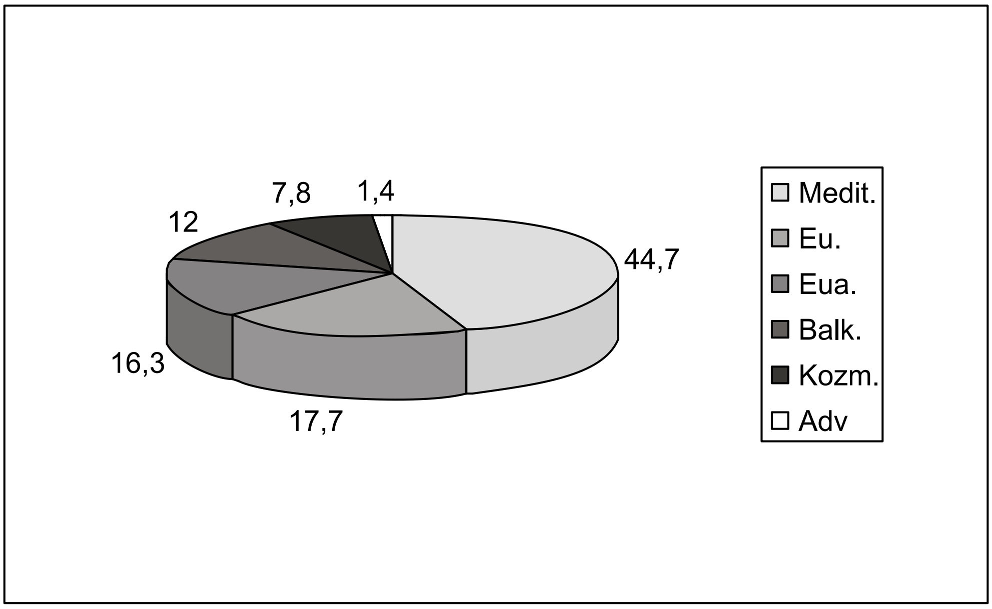


Fig. 4 Corological spectrum

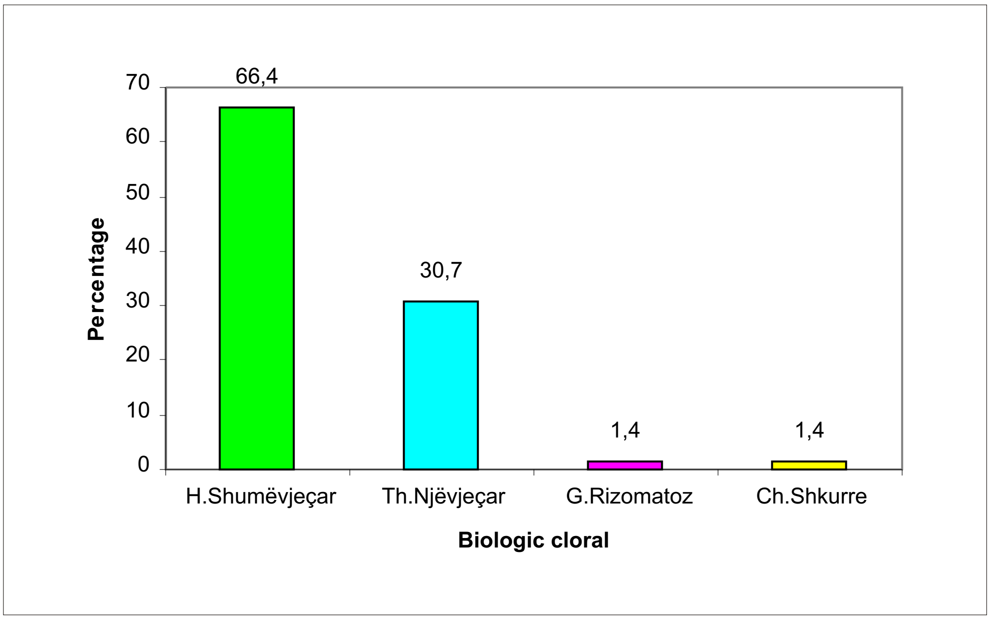


Fig. 5 Biological forms

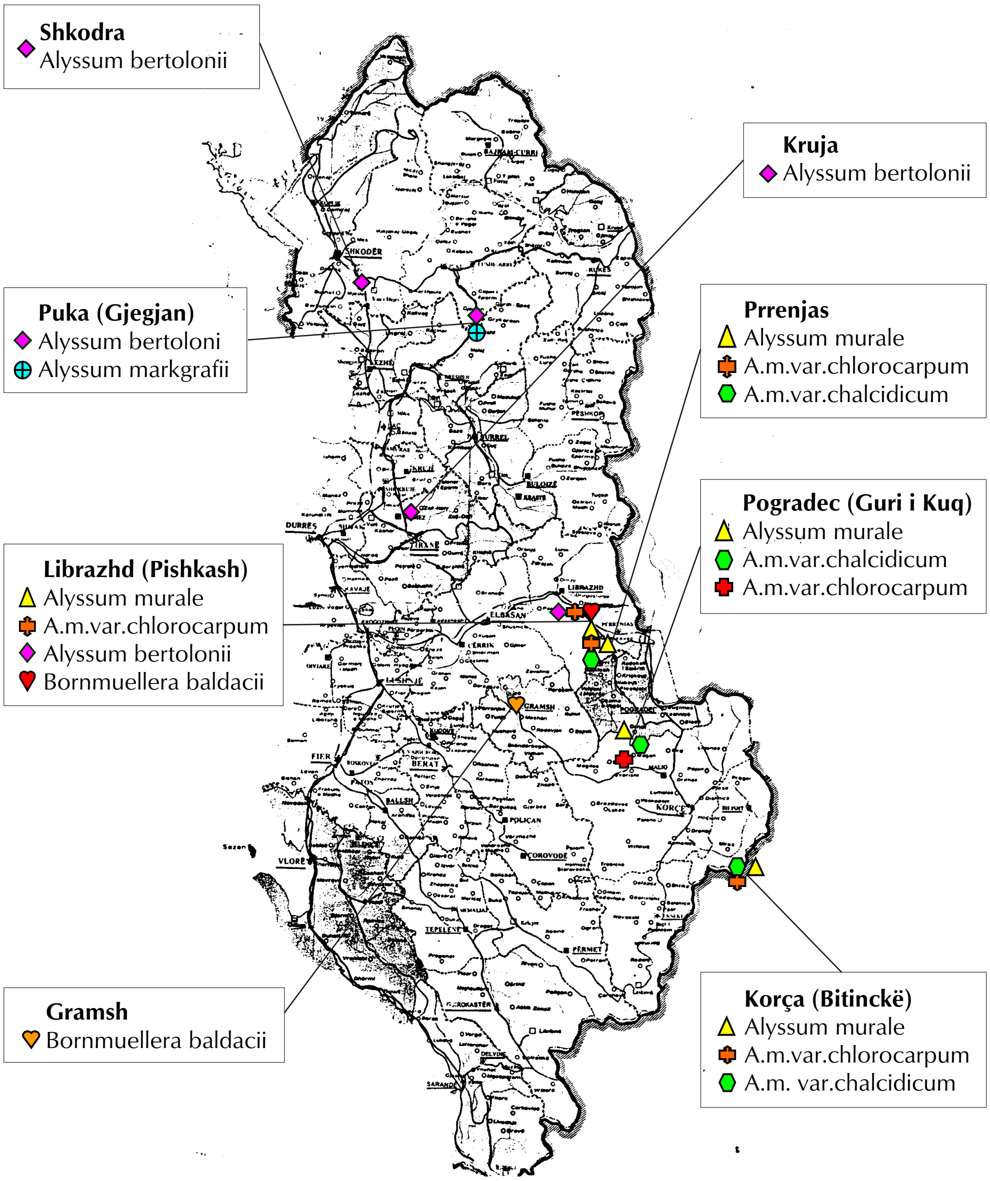


Fig. 6 Mapping of nickel hyper-accumulating species

# References

Baker, A.J.M. (1987). Metal tolerance. *New Phytol.*, 106 (Suppl.): 93-111.

Brooks, R.R. (1987). Serpentine and its vegetation . A multidisciplinary approach, *Ecology, Phyto-geography and Physiology Series*, vol. I re, Theodore R.Dudley, Ph.D. Portland Oregon, U.S.A.

Brown, S. et al., (1994). Phito-remedation Potential of Thlaspi caerulescens and Bladder Champion for Zn and Cd contaminated Soil. J. *Environ. Qual.*, 23: 1151-1157.

Haswell, S.S. (1991). Atomic Absorption Spectrometry, Theory Design and Applications, Elsevier, Amsterdam, Netherlands.

Holmgren, G.G.S. et al., (1993). Cadmium, Lead, Zinc and Nickel in Agricultural Soils of United States of America. J.*Environ. Qual.*, 22: 335-348.

Mining in Albania, (1992). *Advertisement Supplement to Mining Journal, London*, vol. 318, nr. 8172.

Reeves, R. et al., (1996). Nickel accumulating plants from the ancient serpentine soils of Cuba. *New Phytol.*, 133: 217-224.

Tutin, T.G. et al., (1964). Flora Europea, Vol.1, 2, 3, 4, 5.