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# Vegetation of the Ash Dump of the "Kosova A" Power Plant and the Slag Dump of the "Ferronikeli" Smelter in Kosovo

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**Abstract:** This study presents the results of a study on the flora and vegetation associated with the ash dumpof the "Kosova A" power plant and with a slag dump of a "Ferronikeli" smelter. With time, vegetation redeveloped on these dumps as a result of natural succession. In the ash dump of the "Kosova A" power plant, a total of 125 species were recorded (belonging to 29 families and 93 genera), whereas 72 species (belonging to 24 families and 58 genera) were recorded in the slag dump of the "Ferronikeli" smelter. Twenty-eight species were recorded in both locations. In the old parts of the ash dump of the "Kosova A" power plant, plants had established communities where three plant associations were recorded (*Echio-Melilotetum* Tx. 1942, *Bromo-Sambucetum ebuli* Br.-Bl. and *Sisymbrio-Diplotaxidietum tenuifolia*). The process of vegetation development at the ash disposal site indicates that natural colonisation had established the plant communities, which will provide protection against erosion and dust dispersion by wind.

**Keywords:** Ash dump, drenas, obiliq, slag dump, tolerant species

## INTRODUCTION

The Prishtina region, where the power plants "Kosova A and B" are located, is rich in natural resources, especially coal (lignite). The economy of this region has been based mainly on the exploitation of these natural resources and the region is known for the production of electricity, coal and mineral utilisation and smelters ("Ferronikeli" smelter). Because of industrial activity, the Prishtina region is considered to be the most polluted area in Kosovo, except for the Mitrovica region, which was the largest industrial area in former Yugoslavia. Kosovo is rich in lignite (containing approximately 13 billion tons), which is mainly used for power generation (85%) (Zeqiri, 1984). The lignite is burned in power plants, producing a total generator capacity of 1478 MW. As a result of the combustion of low-quality lignite, enormous quantities (about 1.6 million tons) of ash are released each year from ''Kosova A and B'' (Abdullahi, 2010) and then deposited on fertile cultivated land.

The wind easily spreads the ash especially from the surface of the dumps and from the open conveyor belt used to transport the ash from the power plant to the dumps. The wind lifts small ash particles and other dust into the air, worsening the quality of air already polluted by emissions of the power plant and dust dispersed by the smelting operations.

About 80% of ash particles are smaller than 10 μm and these small particles can spread quite far from ash dumps (KEK, 2006) to cause irritation and inflammation to the eyes, skin, throat and upper respiratory tract of humans. Around the "Kosova A and B" power plants, the incidence of respiratory (especially asthmatic), ocular and gastrointestinal disease is many times higher than in other regions. This high frequency of illness is also present in Prishtina because of its short distance from the power plants (ISHKEK, 2003). The ash particles may have additional negative consequences, including toxic, teratogenic and mutagenic effects (Borm, 1997; Smith *et al.*, 2006; Alija, 2001) and detrimental changes to physiological processes and plant populations (Pejcinovic *et al.*, 1988; Despotovic, 1989; Mustafa and Hoxha, 1998, 1983; Hajdari *et al.*, 2008).

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These environmental problems can be mitigated by revegetation of the ash dumps or use of the ash for a variety of purposes, such as the manufacture of cement, concrete, bricks and wood substitutes; for soil stabilisation, land reclamation and the construction of road bases and embankments; and as a soil amendment in agriculture (Asokan *et al*., 2005; Jala and Goyal, 2006). For the successful restoration and revegetation of a landfill, an investigation of plant adaptability and succession is needed in the area. The selection of appropriate plant species for reclamation using information generated from investigations of other landfills is a challenge because of the diversity of landfills.

The revegetation process is very slow because of chemical and physical soil factors that limit the establishment and growth of plant communities. Among the chemical limiting factors are an initially high soil pH, a low content of humus, high concentrations of soluble salts and phytotoxic levels of some elements (e.g., B) combined with deficiencies of others (e.g., N and P) (Carlson and Adriano, 1993; Adriano *et al*., 1978; Plank *et al*., 1975; Kukier *et al*., 1994; Sims *et al*., 1995; Wong *et al*., 1996). Physical limiting factors include natural compaction and cemented layers in the ash that restrict root growth (Haynes, 2009; Adriano *et al*., 1980; Haering and Daniels, 1991; Dosskey and Adriano, 1993; Carlson and Adriano, 1993; Pavlovic *et al*., 2004). Revegetation with tolerant plants is one of the cheaper alternatives for reclaiming abandoned landfills and the most eco-friendly. Revegetation stabilises the ash against wind and water erosion, reduces leaching by facilitating water loss as evapo-transpiration, provides shelter and habitat for wildlife and produces a more aesthetically pleasing landscape (Haynes, 2009; Morina, 2009). However, revegetation takes a long time; for example, it took 30 to 50 years for dry ash spoils in England to resemble a normal soil and to produce a birch and willow scrub woodland (Ader, 1985; Shaw, 1992).

The aims of this study were to characterise the naturally occurring flora on the ash dumps in Obiliq and on the slag dump of the "Ferronikeli" smelter in Drenas and to recommend tolerant species for the managed rehabilitation of these types of dumps.

## MATERIALS AND METHODS

**Study area:** The study was conducted from April 2008 to September 2010, in ash dump of the "Kosova A'' power plant (42º39′44″N, 21º05′57″E) (Fig. 1) located in Obiliq, approximately 5 km northwest of Prishtina and in waste dump of a "Ferronikeli" smelter in Drenas, (42º38′22″N, 20º54′49″E) (Fig. 2) located approximately 20 km west of Prishtina (Republic of Kosovo).

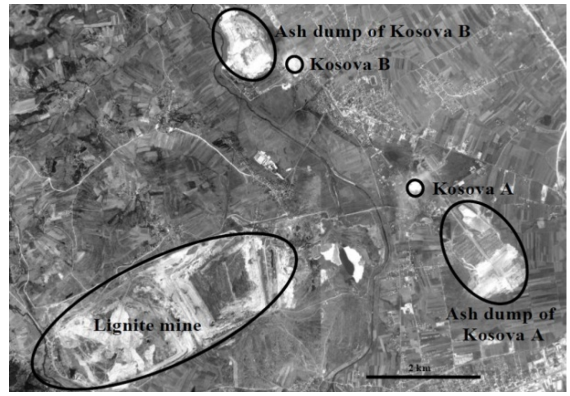


Fig. 1: Ash dumps of the "Kosova A and B" power plants

**Power plant ash dump:** Coal ash is produced mainly by the burning of coal. Each year, the "Kosova A and B" power plants burn approximately 7.5 million tons of lignite coal having a low caloric value (State of Environment in Kosovo 2008-2010). These plants have a total installed generator capacity of 1478 MW and they burn approximately 7.5 million tons of lignite coal per year, with a low caloric value (State of Environment in Kosovo 2008-2010), producing approximately 1.6 million tons of ash annually (Abdullahi, 2010). "Kosova B" alone discharges approximately 260 g/s of $SO_2$, 556 g/s of $NO_x$ and 376 g/s of dust (Varjoranta and Pietarila, 2005). *Just o*ne unit of "Kosova B" with a capacity of 200 MW emits approximately 25 tons of dust and ash/h, which is 74 times more than the maximum amount allowed by European standards (WHO, 2002). The ash dumps of "Kosova A and B" are located near the power plants, reach a height of 30-40 m and together cover about 160 ha of previously fertile cultivated land (Fig. 1). The surface of the ash dumps of "Kosova A and B", respectively, covers 110 ha with approximately 33 million tons of deposited ash and approximately 55 ha with about 17 million tons of deposited ash (INKOS, 2004). The ash has been deposited in the easiest and cheapest manner possible using dry methods and an open conveyor belt without concern for the environment. Usually, the ash is deposited on top of an earlier ash deposit as well as its established flora. This continuous layering of ash deposits reduces the vegetative surface, which covers 20-30% of the total area of the ash dumps and is an additional factor limiting plant growth.

The ash in which plants must grow contains various chemical constituents, such as humus 2.14-2.20%, potassium oxide ($K_2O$) >40% and phosphorus pentoxide ($P_2O_5$) 18.0-19.8% (INKOS, 2004). The chemical composition of ash produced by the

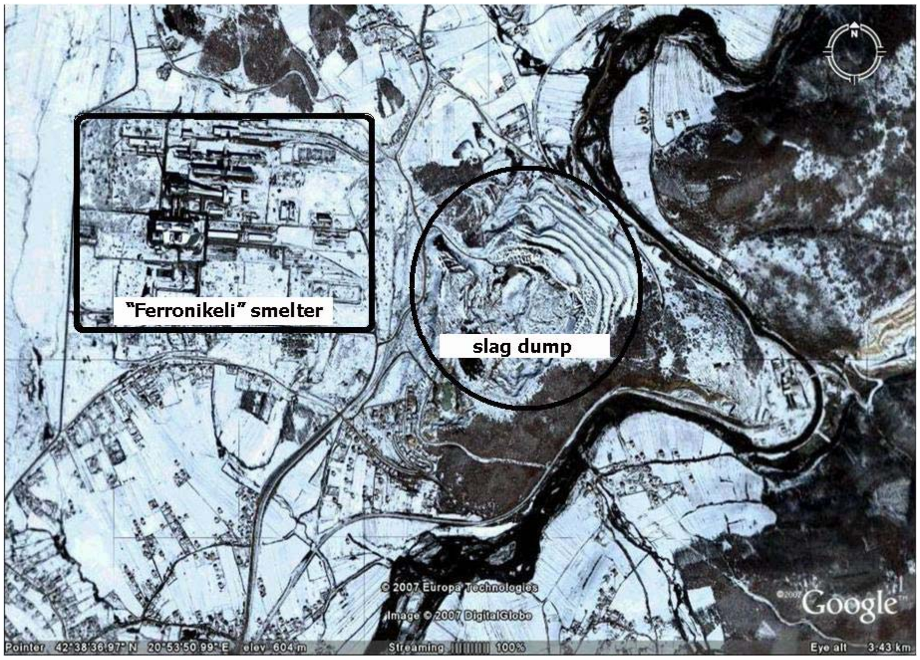


Fig. 2: Slag dump of the "Ferronikeli" smelter

Table 1: Chemical composition of sfly and bottom ash (KEK, 2006)

| | (%) | | | (mg/kg) | |
|---|---|---|---|---|---|
| Oxides | Fly ash | Bottom ash | Chemical elements | Fly ash | Bottom ash |
| $H_2O$ | 0.30 | 49.70 | As | 31.00 | 10.00 |
| $SiO_2$ | 36.00 | 51.00 | Ba | 610.00 | 420.00 |
| $Al_2O_3$ | 12.00 | 13.00 | Be | <2.50 | <2.60 |
| $Fe_2O_3$ | 7.60 | 6.40 | B | 580.00 | 230.00 |
| MgO | 3.50 | 2.20 | Cd | <0.50 | <0.51 |
| CaO | 27.00 | 8.00 | Co | 17.00 | 18.00 |
| $Na_2O$ | 1.00 | 0.74 | Cr | 160.00 | 180.00 |
| $K_2O$ | 0.97 | 15.00 | Cu | 47.00 | 43.00 |
| $TiO_2$ | 0.42 | 0.55 | Hg | 0.11 | <0.046 |
| $P_2O_5$ | 0.17 | 0.12 | Mo | 3.50 | 2.6.00 |
| $SO_3$ | 7.00 | - | Ni | 190.00 | 150.00 |
| $MnO_2$ | 0.24 | 0.21 | Pb | 18.00 | 16.00 |
| | | | Sb | 2.60 | <2.60 |
| | | | Sn | <2.50 | <2.60 |
| | | | V | 95.00 | 90.00 |
| | | | Zn | 68.00 | 84.00 |

combustion of lignite is given in Table 1. This ash shows an alkaline reaction (a pH of 7.9 to 8.6).

**Slag dump of the "Ferronikeli" smelter:** The slag produced by the "Ferronikeli" smelter is deposited in a nearby area of approximately 32 ha, where there is about 3 million tons of granulated slag. This granulated slag is a low-density material containing very light particles that are subject to being lifted into the air by a strong wind, thus worsening the quality of air already polluted by emissions of the smelter. The chemical composition of the slag is as follows: $SiO_2$ 59.6%, FeO 20.4%, CaO 3.5%, MgO 14.0%, $Cr_2O_3$ 1.5%, $Al_2O_3$ 2.2%, MnO 0.41% and elements such Ni, Co and Fe (Veliu, 2007).

The climate in the region is temperate and the most characteristic climatic features are a warm summer, a cold winter, maximum rainfall in winter and spring and considerable annual variation in the air temperature. The average annual temperature and precipitation is 12.6°C and 667 mm, respectively; however, both temperature and precipitation vary considerably during the year (Fig. 3). The average annual sunlight is 2,140

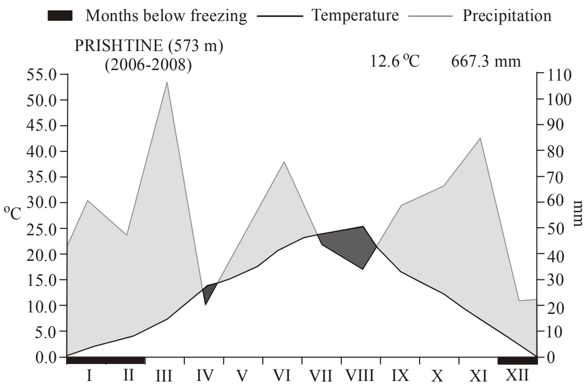


Fig. 3: Climate diagram for the Prishtina region

h. The wind predominantly blows from the north and northeast with an average velocity of 3 m/s (Kosovo Meteorological Institute).

**Floristic analyses:** The floristic inventory was carried out by periodic visits to the study area during two growing seasons (2007-2008). The study area for this floristic and phytosociological investigation was the entire surface of the "Kosova A" dump and the slag dump associated with the "Ferronikeli" smelter. Identification of plant species was made on fresh material and herbarium specimens collected in the field using identification keys provided by Demiri (1983), Pajazitaj (2004), Paparisto *et al.* (1988-2000) and Qosja (1966). Life form was determined according to Paparisto *et al*. (1988-2000) and Kojić (1982). Nomenclature follows (Tutin *et al*., 1964-1980); when taxa were absent from this reference, other sources were used and names eventually verified on the International Plant Names Index (www.ipni.org). The herbarium specimens are deposited at the Department of Biology, University of Prishtina.

The degree of similarity in the floristic composition between samples from the dump of the "Kosova A" power plant and those from the slag dump of the Ferronikeli smelter was calculated using Sorensen's Coefficient of Similarity (Kent and Coker, 1994).

**Phytosociological analyses:** Fifteen typical sectors of vegetation in the ash dump of "Kosova A" were studied using the relevés method to collect data on sector vegetation. In the selected relevés, phytosociological descriptions were compiled. Species abundance and dominance were evaluated using the scale of the Zurich-Montpellier school (Braun-Blanquet, 1964; Mueller-Dombois and Ellenberg, 1974).

The syntaxonomic nomenclature followed the respective references: Kojić (1982), Čanak (1978) and Horvat *et al*. (1974).

## RESULTS

**Structure of the flora on "Kosova A" ash dump:** A total of 125 plant species (Table 2) belonging to 93 genera and 29 families (Table 3) were recorded in "Kosova A**"** ash dump. Only one gymnosperm was recorded (*Juniperus oxycedrus*). Among the angiosperms, dicotyledons dominated, with the family *Asteraceae* most abundant (25.26%), followed by the *Fabaceae* (9.35%), *Brassicaceae* (7.22%), *Boraginaceae* (5.78%), *Lamiaceae* (4.20%) and less abundant families (Table 3). The monocotyledons were dominated by species of the family *Poaceae*, which represented 23.5% of the overall families. In old parts of the ash dump, the vegetation was quite well developed into established communities, whereas pioneer species dominated in new parts.

**Structure of the flora on "Ferronikeli" smelter slag dump:** In the slag dump of the "Ferronikeli" smelter, a total of 72 species (Table 2) belonging to 58 genera and 24 families were found (Table 3). Only one gymnosperm was recorded (Pinus sylvestris). Among the angiosperms, dicotyledons dominated, with the *Asteraceae* (12.5%) dominant, followed by the *Brassicaceae* (11.1%), *Fabaceae* (8.3%), *Rosaceae* (8.3%), *Salicaceae* (6.9%), *Lamiaceae* (5.6%) and less abundant families (Table 3). The monocotyledonous plants were dominated by species of the family Poaceae, which represented 11.1% of the overall families.

The *Asteraceae, Poaceae*, *Fabaceae* and *Brassicaceae* were the families represented by the most species in both ash and slag dumps (Table 3).

Only twenty-eight species were present in both sites. The Sorensen's Index indicates a 28.1% similarity between the flora of the ash dump of "Kosova A" and those of the slag dump near the "Ferronikeli" smelter. The two areas were quite different floristically because of different chemical compositions of the waste in the dumps.

Were found considerably plant species in the dump of the power plant (125 species) and the "Ferronikeli" smelter (72 species) compared to the ruderal flora of Kosovo, which total 258 species (Pajazitaj, 2000).

Following Raunkiær, the dominant life forms found in the ash dump of the "Kosova A" power plant included hemicryptophytes (54.0%), therophytes (32.3%), geophytes (6.5%), chamaephytes (4.0%) and phanerophyted (3.2%) (Fig. 4). A generally similar pattern occurred in the slag dump of the "Ferronikeli" smelter, where hemicryptophytes (54.9%) dominated, followed by therophytes (21.1%)

Table 2: List of all species encountered on ash and slag dumps

| Species | Ash dumps | Slag dump | Life form |
|---|---|---|---|
| **Spermatophyta** | | | |
| **Gymnospermae** | | | |
| ***Pynophita*** | | | |
| ***Cupressaceae*** | | | |
| *Juniperus oxycedrus* L. | + | - | Ph |
| ***Pinaceae*** | | | |
| *Pinus sylvestris* L. | - | + | Ph |
| ***Angiospermae*** | | | |
| ***Dicotiledones*** | | | |
| ***Asteraceae*** | | | |
| *Achillea millefolium* L. | + | + | H |
| *Anthemis altissima* L. | + | - | T |
| *Anthemis arvensis* L. | + | + | T |
| *Anthemis cota* L. Gay. | + | - | T |
| *Anthemis tinctoria* L. | + | - | Ch |
| *Artemisia absinthium* L. | + | - | Ch |
| *Carduus acanthoides* L. | + | - | H |
| *Carduus pycnocephalus* L. | + | - | H |
| *Centaurea solstitialis* L. | + | - | H |
| *Centaurea uniflora* Sibth. et Sm. | + | - | H |
| *Cichorium intybus* L. | + | + | H |
| *Cirsium arvense (*L). Scop | + | - | G |
| *Cirsium canum* (L.) All. | + | - | G |
| *Crepis paludosa* (L.) Moench | + | - | H |
| *Crepis vesicaria* Froel. | + | - | T |
| *Crepis pulchra* L. | + | - | T |
| *Crepis setosa* Hall. | + | - | T |
| *Hieracium pilosella* L. | - | + | H |
| *Hieracium* sp. | - | + | T |
| *Inula britannica* L. | + | - | H |
| *Inula helenium* L. | + | - | H |
| *Leontodon crispus* Vill. | - | + | H |
| *Matricaria inodora* L. | + | + | H |
| *Onopordum acanthium* L. | + | - | H |
| *Picris hieracioides* L. | + | - | H |
| *Ptilostemon afer* (Jacq) Greuter | + | - | H |
| *Scorzonera laciniata* L. | + | - | H |
| *Sonchu oleraceus* L. | + | - | T |
| *Sonchus arvensis* L. | + | - | H |
| *Stenactis annua* (L.) Nees. | + | - | H |
| *Tanacetum cinerariifolium* (Trevir.) Sch. Bip | + | - | Ch |
| *Taraxacum officinale* Web. | + | + | H |
| *Tragopogon dubius* Scop. | + | + | H |
| *Tragopogon pratensis* L. | + | - | H |
| ***Apiaceae*** | | | |
| *Anthriscus sylvestris* (L.) Hoffm. | + | - | T |
| *Bupleurum rotundifolium* L. | + | - | T |
| *Torilis arvensis* (Huds.)Link. | + | - | T |
| ***Brassicaceae*** | | | |
| *Alyssoides utriculata* (L.) Med. | + | - | Ch |
| *Alliaria officinalis* Andrz. (A. petiolata Bieb.). | - | + | H/T |
| *Barbarea vulgaris* R. Br. | - | + | H/T |
| *Capsella bursa pastoris* (L.) Medic. | + | - | H/T |
| *Calepina irregularis* (Asso) Thell. | + | - | T |
| *Camelina microcarpa* Andrz. | - | + | T |
| *Cardaria draba* (L.) Desv. | + | + | H |
| *Erysimum hieracifolium* L. | - | - | T |
| *Diplotaxis muralis* DC. | + | - | T |

Table 2: (Continue)

| Species | Ash dumps | Slag dump | Life form |
|---|---|---|---|
| *Diplotaxis tenuifolia* DC. | + | - | H |
| *Draba nemorosa* L. | + | - | CH |
| *Lepidium draba* L. | - | + | H |
| *Lepidium campestre* (L.) R. Br. | - | + | T |
| *Sinapis nigra* L. | + | - | T |
| *Sinapis arvensis* L. | - | + | T |
| *Sisymbrium altissimum* L. | - | + | T |
| *Sisymbrium loeselii* L. | + | - | H |
| ***Boraginaceae*** | | | |
| *Anchusa azurea* Mill. | + | - | H |
| *Anchusa officinalis* L. | + | - | H/T |
| *Echium vulgare* L. | + | + | H |
| *Echium italicum* L. | + | + | H |
| *Lappula echinata* Gilib. | + | - | T |
| *Myosotis arvensis* (L.) Hill. | - | + | Ch |
| *Myosotis* sp., | + | - | T |
| ***Convolvulaceae*** | | | |
| *Convolvulus arvensis* L. | + | - | G |
| ***Caprifoliaceae*** | | | |
| *Sambucus ebulus* L. | + | - | G |
| *Lonicera caprifolium* L. | - | + | Ph |
| ***Caryophillaceae*** | | | |
| *Dianthus* sp., | + | - | H |
| *Petrorhagia prolifera* (L.) P.W. Ball. et Heywood | + | - | T |
| *Silene vulgaris* Garcke | + | - | H |
| ***Chenopodiaceae*** | | | |
| *Chenopodium album* L. | - | + | Ch |
| ***Cistaceae*** | | | |
| *Fumana bonaparte* Marie et Petit. | - | + | Ch |
| *Helianthemum nummularium* (L.) Mill. | - | + | Ch |
| ***Dipsacaceae*** | | | |
| *Dipsacus sylvestris* Huds. | + | - | H |
| ***Euphorbiaceae*** | | | |
| *Euphorbia salicifolia* Host. | + | + | H |
| ***Fabaceae*** | | | |
| *Lathyrus aphaca* L. | + | - | T |
| *Lathyrus tuberosus* L. | + | - | H |
| *Lathyrus pratensis* L. | + | - | H |
| *Lotus corniculatus* L. | - | + | H |
| *Medicago sativa* L. | + | + | H |
| *Medicago lupulina* L. | + | + | H |
| *Melilotus officinalis* (L.) Pallas. | + | + | H |
| *Ononis spinosa* L. | + | - | Ch |
| *Trifolium repens* L. | + | - | H |
| *Trifolium pratense* L. | - | + | H |
| *Vicia lutea* L. | + | - | T |
| *Vicia hirsuta* (L.) S.F.Gray | + | - | T |
| *Vicia lathyroides* L. | + | - | T |
| *Vicia tetrasperma* (L.) Moech. | - | + | T |
| ***Gearaniaceae*** | | | |
| *Erodium cicutarium* (L.) L. Her. | + | - | T |
| *Geranium dissectum* Just. | + | - | T |
| ***Hypericaceae*** | | | |
| *Hypericum barbatum* Jacq. | - | + | H |
| *Hypericum perforatum* L. | + | - | H |
| ***Juglandaceae*** | | | |
| *Juglans regia* L. | + | - | Ph |
| ***Lamiaceae*** | | | |
| *Acinos arvensis* (Lam.) Dandy. | - | + | H |

Table 2: (Continue)

| Species | Ash dumps | Slag dump | Life form |
|---|---|---|---|
| *Ajuga chamaepitys* (L.) Schreb. | - | + | H |
| *Ajuga genevensis* L. | - | + | H |
| *Ballota nigra* L. | + | - | H |
| *Mentha aquatica* Huds. | + | - | H |
| *Salvia verticillata* L. | + | - | H |
| *Salvia sclarea* L. | + | - | H |
| *Stachys germanica* L. | + | - | H |
| *Thymus serpyllum* L. | - | + | Ch |
| ***Primulaceae*** | | | |
| *Anagallis caerulea* Schreb. | + | + | T |
| ***Plantaginaceae*** | | | |
| *Plantago media* L. | + | - | H |
| *Plantago lanceolata* L. | + | + | H |
| ***Papaveraceae*** | | | |
| *Papaver rhoeas* L. | + | + | T |
| ***Polygonaceae*** | | | |
| *Bilderdykia convolvulus* (L.) Dumort. | + | - | |
| *Polygonum aviculare* L. | + | - | T |
| *Rumex acetosella* L. | - | + | H |
| *Rumex crispus* L. | + | + | G |
| *Rumex patientia* L. | + | + | H |
| ***Rubiaceae*** | | | |
| *Galium aparine* L. | + | - | T |
| ***Rosaceae*** | | | |
| *Crataegus monogyna* Jacq. | - | + | Ph |
| *Fragari vesca* L. | - | + | H |
| *Pyrus communis* L. | - | + | Ph |
| *Potentilla inclinata* Vill. | - | + | H |
| *Potentilla reptans* L. | + | - | H |
| *Rosa arvensis* Huds. | - | + | Ph |
| *Rosa canina* L. | + | + | Ph |
| *Sanguisorba minor* Scop. | - | + | H |
| ***Ranunculaceae*** | | | |
| *Clematis vitalba* L. | + | - | Ph |
| *Delphinium regale* S.F. Gray | + | + | H |
| *Ranunculus millefoliatus* Vahl. | - | + | T |
| ***Scrophulariaceae*** | | | |
| *Digitalis lanata* Ehrh. | + | + | H |
| *Gratiola officinalis* L. | + | - | H |
| *Linaria peloponnesiaca* Boiss. et Heldr. | + | + | H |
| *Verbascum* sp., | - | + | H/T |
| *Veronica persica* Poir. | + | - | T |
| ***Salicaceae*** | | | |
| *Populus tremula* L. | - | + | Ph |
| *Salix* sp. | - | + | Ph |
| *Salix pentandra* L. | - | + | Ph |
| *Salix triandra* L. | - | + | Ph |
| *Salix purpurea* L. | + | - | Ph |
| ***Tamaricaceae*** | | | |
| *Tamarix parviflora* DC. | + | + | Ph |
| ***Urticaceae*** | | | |
| *Urtica dioica* L. | + | + | H |
| ***Violaceae*** | | | |
| *Viola arvensis* Murr. | - | + | T |
| ***Monocotiledones*** | | | |
| ***Juncaceae*** | | | |
| *Juncus effusus* L. | + | - | G |
| ***Liliaceae*** | | | |
| *Ornithogalum umbellatum* L. | + | - | G |

Table 2: (Continue)

| Species | Ash dumps | Slag dump | Life form |
|---|---|---|---|
| ***Orchydaceae*** | | | |
| *Orchis morio* L. | - | + | G |
| ***Poaceae*** | | | |
| *Agropyrum repens* (L.) Beauv. | + | - | H |
| *Arrhenatherum elati* (L.) Mert. et Koch. | + | - | H |
| *Alopecurus myosuroides* Huds. | + | - | T |
| *Agrostis* sp., | + | - | H |
| *Bromus mollis* L. | + | - | T |
| *Bromus sterilis* L. | + | + | T |
| *Bromus arvensis* L. | + | - | T |
| *Bromus racemosus* L. | + | - | T |
| *Bromus erectus* Huds. | + | - | H |
| *Bromus tectorum* L. | + | + | T |
| *Bromus madritensis* L. | + | - | T |
| *Dactylis glomerata* L. | + | + | H |
| *Festuca pseudovina* Hack. | + | - | H |
| *Festuca* sp., | + | - | H |
| *Hordeum bulbosum* L. | + | - | H |
| *Hordeum murinum* L. | + | - | T |
| *Haynaldia villosa* (schreb.) P.B | + | - | T |
| *Koeleria gracilis* Pers. | - | + | H |
| *Koeleria phleoides* (vill.) Peres. | + | - | H |
| *Lolium multiflorum* Lam. | + | - | H |
| *Lolium perenne* L. | + | - | H |
| *Phragmites communis* Trin. | + | - | H |
| *Poa* sp., | - | + | H |
| *Poa bulbosa* L. | - | + | H |
| *Poa pratensis* L. | + | + | H |
| *Poa trivialis* L. | + | - | H |
| *Sorghum halopense* (L.) Pers. | + | - | G/H |
| *Triticum villosum* M.B | - | + | H |
| *Vulpia myuros* (L.) Gmel. | + | - | T |
| *Vulpa ciliata* (Danth.) Link | + | - | T |

Life forms according Raunkiaer: Ch; Chamephytes: H; Hemicryptophytes: G; Geophytes: Ph; Phanerophytes: T; Threophytes

Table 3: Families and number of species founded on ash and slag dumps

| Nr. | Family | Number of identified species: Ash dumps | Slag dump |
|---|---|---|---|
| 1 | *Asteraceae* | 31 | 9 |
| 2 | *Poaceae* | 26 | 8 |
| 3 | *Fabaceae* | 11 | 6 |
| 4 | *Brassicaceae* | 10 | 8 |
| 5 | *Boraginaceae* | 6 | 3 |
| 6 | *Lamiaceae* | 5 | 4 |
| 7 | *Polygonaceae* | 4 | 3 |
| 8 | *Scrophulariaceae* | 4 | 3 |
| 9 | *Apiaceae* | 3 | 0 |
| 10 | *Caryophillaceae* | 3 | 0 |
| 11 | *Gearaniaceae* | 2 | 0 |
| 12 | *Plantaginaceae* | 2 | 1 |
| 13 | *Rosaceae* | 2 | 6 |
| 14 | *Ranunculaceae* | 2 | 3 |
| 15 | *Salicaceae* | 1 | 5 |
| | Other family with one specie/family | 13 | 13 |
| | Total family | 29 | 25 |

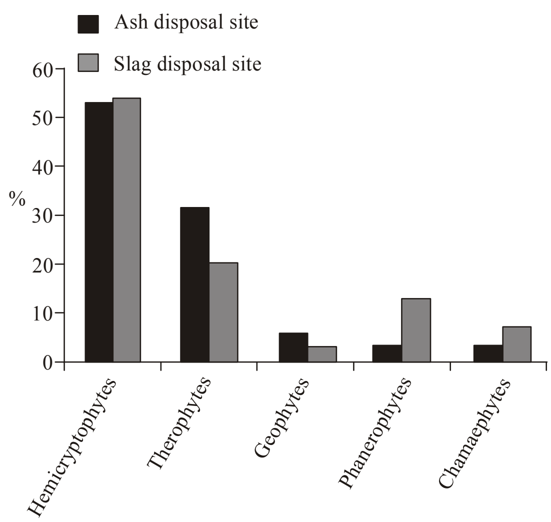


Fig. 4: Spectra of life forms compiled from species recorded on ash and slag dumps

phanerophytes (14.1%), chamaephytes (7.0%) and geophytes (2.8%) (Fig. 4).

The floristic investigation shows that 17 pioneer species were found in the ash dump of the "Kosova A" power plant: *Anthemis arvensis*, *Bromus arvensis*, *Cichorium intybus*, *Cirsium arvense*, *Cirsum canum*, *Convolvulus arvensi*, *Crepis setosa*, *Echium vulgare*, *Hordeum murinum*, *Lathyrus aphaca*, *Lathyrus tuberosus*, *Lolium perenne*, *Plantago lanceolata*, *Rumex acetosella*, *Sonchus arvensis* and *Sorghum halopense*. In contrast, the following 11 pioneer species occurred in the dump of the Ferronikeli smelter: *Ajuga chamaepitys, Anthemis arvensis*, *Delphinium regalr*, *Echium vulgare*, *Lonicera caprifolium*, *Matricaria indora*, *Medicago lupulina*, *Sanguisorba minor*, *Sinapis arvensis*, *Tragopogon dubius* and *Viola arvensis*.

In the ash disposal site of the "Nikola Tesla A" power plant, *Epilobium sp*., and *Cirsium sp*., (Pavlovic *et al*., 2004) *Tamarix gallica, Festuca rubra, Spiraea van-houttei, Lotus corniculatus* and *Medicago sativa* were recorded as pioneer species (Djurdjevic *et al*., 2006)

In the ash dump of the "Kosova A" power plant, 18 dominant species were recorded: *Alopecorus myosuroides*, *Bromus arvensis*, *Bromus sterilis*, *Carduus acanthoides*, *Cirsium arvense*, *Crepis setose*, *Diplotaxis tenuifolia*, *Echium vulgare*, *Galium aparine*, *Matricaria indora*, *Medicago sativa*, *Melilotus officinalis*, *Ononis spinosa*, *Papaver rhoeas*, *Plantago lanceolata*, *Rumex crispus*, *Sambucus ebulus*, *Sisymbrium loeselii*. Eight dominant plant species were recorded in the slag dump of the "Ferronikeli" smelter: *Bromus sterilis, Bromus tectorum*, *Chenopodium album*, *Dactylis glomerata*, *Helianthemum nummularium*, *Plantago lanceolata*, *Populus tremula*, *Salix purpure*, *Poa pratensis* and *Verbascum* sp.

**Plant associations in the "Kosova A" power plant:** During the approximately 50 years of ash disposal near the "Kosova A" power plant, species have created their own communities at the disposal site. Our investigations identified three plant associations at the ash disposal site: *Echio-melilotetum* Tx. 1942, *Bromo-Sambucetum ebuli* Br.-Bl. (1936) and *Sisymbrio-diplotaxidietum.*

The association *Echio-melilotetum* Tx. 1942 is recorded at six sites in the ash dump of the "Kosova A" power plant. This association occupies much of the surface of the older parts of the ash dump and the homogeneous vegetation of the association is dominated by the constant presence of *Melilotus officinalis* (Table 4). *Echium vulgare* and *Diplotaxis tenuifolia* are sub-dominant species. The association *Echio-meliloletum* Tx. 1942 is widely distributed as a ruderal association on the territory of the Balkan Peninsula (Hundozi, 1978; Horvat *et al.*, 1974). The association *Bromo-sambucetum ebuli* Br.-Bl. (1936) 1952 is dominated by *Sambucus ebulus*, whereas the sub-dominant species is *Bromus sterilis* (Table 4). This association was found in a ruderal association in Croatia (Hundozi, 1978).

The *Sisymbrio-diplotaxidietum tenuifolia* association is dominated by *Diplotaxis tenuifolia,* with *Sisymbrium loeselii* as the sub-dominant species (Table 4); this association was less developed than were the first two associations.

## DISCUSSION AND CONCLUSION

The results of this study suggest that the surface of ash and slag dumps is able to recover a diverse native flora. During field investigation, numerous plant species were found in both ash (125 plant species) and slag (72 plant species) dumps. The vegetational composition of the two sites was quite different (only 28 species were found in both sites) because of differences in the chemical composition of the waste dumps. The number of dominant species found in the ash dump of the "Kosova A" power plant was 18, whereas 8 species were detected in the slag dump of the "Ferronikeli" smelter. In addition, the plant species of the slag dump did not establish associations because the granulate structure and low density of the slag make it a poor substrate. Strong winds also remove the substrate because of its relatively light weight. Additional reasons for the absence of plant associations in the slag

Tables 4: Table of the recorded relevés

| Locality: | | Ash disposal site | | | | | | Ash disposal site | | | | | Ash disposal sited | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation: | | 577 | 578 | 574 | 571 | 576 | 573 | 577 | 578 | 574 | 571 | 576 | 577 | 578 | 574 | 571 |
| Exposition: | | | E | E | NE | SE | SE | E | E | W | SE | S | N | NE | E | W |
| Nr. of relieve: | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Plant specie | Life form | *Echio-melilotetum Tx. 1942* | | | | | | *Bromo-sambucetum ebuli Br.- Bl.* (1936) | | | | | *Sisymbrio-diplotaxidietum tenuifolia* | | | |
| *Melilotus officinalis* | T | 3.2 | 4.3 | 3.3 | 4.3 | 3.3 | 4.3 | . | . | . | . | . | . | . | . | . |
| *Echium vulgare* | T | 2.3 | +0.2 | +0.1 | +0.1 | . | +0.1 | . | . | . | . | . | . | . | . | . |
| *Ononis spinosa* | Ch | +0.2 | . | 2.4 | . | +0.1 | 2.3 | . | . | . | . | . | . | . | . | . |
| *Crepis setosa* | T | +0.1 | . | +0.1 | . | . | 1.2 | . | . | . | . | . | . | . | . | . |
| *Bromus sterilis* | T | 1.3 | 1.3 | . | . | 1.3 | . | . | . | . | . | . | . | . | . | . |
| *Festuca pseudovina* | H | 1.3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Diplotaxis tenuifolia* | H | +0.1 | . | . | 2.2 | 1.1 | +0.1 | . | . | . | . | . | . | . | . | . |
| *Cichorium intybus* | H | +0.1 | . | 1.1 | . | +0.1 | . | . | . | . | . | . | . | . | . | . |
| *Cirsum arvense* | G | +0.1 | . | . | . | 1.2 | 2.3 | . | . | . | . | . | . | . | . | . |
| *Salvia sclarea* | H | +0.1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Matricaria indora* | T | +.2 | . | 1.1 | 1.1 | . | . | . | . | . | . | . | . | . | . | . |
| *Gratiola officinalis* | H | 1.1 | . | +0.1 | . | 1.3 | +0.5 | . | . | . | . | . | . | . | . | . |
| *Alopecurus myosuroides* | T | 1.2 | . | . | 1.2 | . | . | . | . | . | . | . | . | . | . | . |
| *Lappula echinata* | T | +0.1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Bromus arvensis* | T | 1.1 | +0.2 | +0.2 | 2.3 | . | . | . | . | . | . | . | . | . | . | . |
| *Tragopogon dubius* | H | +0.1 | +0.1 | . | +0.1 | . | +0.1 | . | . | . | . | . | . | . | . | . |
| *Convolvulus arvensis* | G | +0.1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Vicia hirsuta* | T | . | 1.2 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Plantago media* | H | . | 1.2 | . | . | 1.3 | 1.2 | . | . | . | . | . | . | . | . | . |
| *Artemisia absinthium* | Ch | . | 1.3 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Picris hieracioides* | H | . | +0.2 | . | . | 1.1 | . | . | . | . | . | . | . | . | . | . |
| *Lolium perenne* | H | . | +0.1 | . | . | . | 2.2 | . | . | . | . | . | . | . | . | . |
| *Delphinium regale* | T | . | +0.1 | . | . | 2.3 | +0.1 | . | . | . | . | . | . | . | . | . |
| *Petrorhagia prolifera* | H | . | +0.1 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Centaurea solstitialis* | T | . | . | 1.3 | . | . | . | . | . | . | . | . | . | . | . | . |
| *Stenactis annua* | T | . | . | +0.1 | 2.4 | +0.1 | . | . | . | . | . | . | . | . | . | . |
| *Plantago lanceolata* | H | . | . | +0.1 | . | . | +0.1 | . | . | . | . | . | . | . | . | . |
| *Ballota nigra* | H | . | . | . | 1.2 | 1.2 | . | . | . | . | . | . | . | . | . | . |
| *Medicago sativa* | H | . | . | . | +0.2 | +0.2 | . | . | . | . | . | . | . | . | . | . |

Table. 4 : (Continue)

| Locality: | | Ash disposal site | | | | | | Ash disposal site | | | | | Ash disposal sited | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation: | | 577 | 578 | 574 | 571 | 576 | 573 | 577 | 578 | 574 | 571 | 576 | 577 | 578 | 574 | 571 |
| *Sambucus ebulus* | G | . | . | . | . | . | . | 5.4 | 5.5 | 5.4 | 4.4 | 4.3 | . | . | . | . |
| *Bromus sterilis* | T | . | . | . | . | . | . | 2.3 | . | 3.2 | 2.2 | 3.2 | . | . | . | . |
| *Galium aparine* | T | . | . | . | . | . | . | 2.3 | 1.3 | . | . | +0.1 | . | . | . | . |
| *Crepis pulchra* | T | . | . | . | . | . | . | +0.1 | . | . | +0.1 | 1.1 | . | . | . | . |
| *Crepis setosa* | T | . | . | . | . | . | . | +0.1 | . | . | +0.2 | . | . | . | . | . |
| *Torilis arvensis* | T | . | . | . | . | . | . | 1.2 | 2.3 | . | . | 2.1 | . | . | . | . |
| *Rumex crispus* | H | . | . | . | . | . | . | +0.1 | 1.2 | +0.1 | 1.3 | 1.2 | . | . | . | . |
| *Sonchus arvensis* | G | . | . | . | . | . | . | . | 1.1 | . | . | . | . | . | . | . |
| *Silene vulgaris* | H | . | . | . | . | . | . | . | +0.1 | . | +0.1 | +0.1 | . | . | . | . |
| *Poa pratensis* | H | . | . | . | . | . | . | . | . | 2.4 | . | +0.1 | . | . | . | . |
| *Convolvulus arvensis* | G | . | . | . | . | . | . | . | . | +0.1 | +0.1 | . | . | . | . | . |
| *Echium vulgare* | T | . | . | . | . | . | . | . | . | +0.1 | +0.2 | +0.1 | . | . | . | . |
| *Poa trivialis* | H | . | . | . | . | . | . | +0.1 | 2.1 | . | +0.1 | 1.1 | . | . | . | . |
| *Diplotaxis tenuifolia* | H | . | . | . | . | . | . | . | . | . | . | . | 3.4 | 3.1 | 2.3 | 3.3 |
| *Sisymbrium loeseli* | H | . | . | . | . | . | . | . | . | . | . | . | 1.3 | 1.2 | +0.3 | +0.2 |
| *Lolium perenne* | H | . | . | . | . | . | . | . | . | . | . | . | +0.1 | . | +0.1 | 2.3 |
| *Matricaria indora* | H | . | . | . | . | . | . | . | . | . | . | . | 1.3 | . | 1.3 | 1.3 |
| *Convolvulus arvensis* | G | . | . | . | . | . | . | . | . | . | . | . | +0.1 | . | . | . |
| *Medicago sativa* | H | . | . | . | . | . | . | . | . | . | . | . | +0.2 | 1.2 | 1.2 | +0.1 |
| *Carduus acanthoides* | H | . | . | . | . | . | . | . | . | . | . | . | +0.1 | +0.2 | . | . |
| *Cirsum arvense* | G | . | . | . | . | . | . | . | . | . | . | . | 1.1 | +0.2 | +0.1 | 1.3 |
| *Bromus mollis* | T | . | . | . | . | . | . | . | . | . | . | . | . | 1.3 | . | 1.2 |
| *Plantago lanceolata* | H | . | . | . | . | . | . | . | . | . | . | . | . | +0.3 | 1.3 | +0.1 |

dump are the very low capacity to hold water and the high toxicity of the slag. Plant associations were also absent in new parts of the power plant ash dump; however, three plant associations were identified in the older parts of the ash dump as a result of a long period of succession. Plant species and their communities undergo several stages of development. The first stage consists of the appearance of pioneer species, which can be annual and perennial weeds characterised by high ecological plasticity (usually found in the new parts of the ash dump). The pioneer vegetation modifies the soil substrate and creates preconditions for the development of the next types of vegetation in the succession series (Connell and Slatyer, 1977; Luken, 1990; Myster and Pickett, 1994). The establishment of plant communities after a relatively long life of the old part of dump indicates that the ecological niches became occupied and that the plant associations underwent syngenesis. The establishment of plant cover, especially in old parts of the dumps, results in successful control of erosion.

The long time required for the establishment of plant associations can be explained by the existence of a number of factors that are unfavourable for seed germination and plant development: a deficiency of nutrients, the presence of toxic compounds (such as heavy metals) and an inadequate hydrological regime, among other limiting factors (Pandey and Maiti, 2008;

Roy *et al*., 2002). These factors explain the complete absence of vegetation on fresh ash and slag dump. Conversely, the absence of trees in new parts of both the ash and slag dumps and the small number of trees found in old parts of both types of dump indicate that trees cannot become established at the initial stage of succession.

The coverage of ash and slag dumps with appropriate vegetation is essential to stabilise the surface against wind and water erosion and to provide an aesthetically pleasing landscape. The plant material used for revegetation should include species able to grow in substrates high in trace elements. The use of fast-growing trees for dump reclamation would result in mono-specific vegetation able to control erosion and dust, but this choice would be inappropriate because of the loss of biodiversity. The best way to attain successful reclamation and the preservation of biodiversity is to sow seeds from a mixture of native species that include pioneer and abundant species that have proven their tolerance to the site conditions. Thus, it is particularly important to achieve the same biodiversity that was present before degradation or those which characterise the surrounding of non-degraded areas (Palik *et al*., 2000). For that reason, the selection of appropriate plant material is of crucial significance for a successful reclamation that includes the recovery of biodiversity (Holl, 2002; Pensa *et al*., 2004). Another consideration when selecting plant material for reclamation is to avoid using alien species, which can become invasive and over-run surrounding areas through seed dispersal. Non-native species may quickly provide cover to stabilise soils, but these species require regular mowing and periodic fertilising to maintain plant vigour. These species may also become invasive, competing more effectively than do native plant species and they generally provide little food or cover for birds or other wildlife. In addition to species that colonise naturally, in continued reclamation, other plants, mostly tuftgrass and cereal species that occur naturally in the herbaceous plant communities in the same region, could be used.

The climate diagram (Fig. 3) shows the annual variation in temperature and precipitation at the study area indicates that the appropriate time to sow seed falls within months four and five this 2-month period is characterised by increasing temperature and a high water content of the soil because of rainfall in previous months. This period also corresponds with the beginning of the vegetative period in Kosovo.

For effective revegetation, the surface of the site should be covered with a cap of soil or organic amendments, which speeds up the reclamation process. Topsoil acts as a source of natural vegetation, so topsoil can function as a seed bank for achieving species diversity (Beauchamp *et al*., 1975; Howard and Samuel, 1979).

These initial studies on the succession of plant communities in waste disposal sites should continue to gain a better understanding of the potential ecological benefits that may accrue from the appropriate use of vegetation to reclaim waste landfills.

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