

STUDIES REGARDING THE ESTABLISHMENT OF PERENNIAL PLANT COMMUNITIES STIMULATED WITH BIOSOLIDS ON FLY ASH DUMPS

S. MASU*, V. RUS

National Research and Development Institute for Industrial Ecology, 2 Regina Maria Square, P. O. Box 254, 1600 Timisoara, Romania

E-mail: smarandamasu@yahoo.com

Abstract. This is a study regarding the storage of waste in a dump which seriously deteriorates the soil properties, both in the storage area and the surroundings. Application of fertilising materials (biosolids) on barren ground is often used for the introduction of organic matter and nutrients for plant growth on such soils. Two forage plant species were used: tall fescue (*Festuca arundinacea*) and sainfoin (*Onobrychis viciifolia*). *F. arundinacea* presented a higher degree of growth and density in comparison with *O. viciifolia*. The bioaccumulation degree of heavy metals (Fe, Cu, Cr, Ni, Zn and Pb) in the aerial tissue of plants was analysed. The addition of biosolids fertiliser caused a significant reduction of metal accumulation in tissues for both species. It may be concluded that the pollution caused by fly ash had a bad influence on the growth and development of *O. viciifolia* plants, even lethal. Plants of *O. viciifolia* gradually disappeared in the dry months of summer.

Keywords: fly ash, phytoremediation, biosolids, plants, heavy metals.

AIMS AND BACKGROUND

The present study aims to comparatively assess the way of adaptation of two plant species in a deposit of lignite fly ash. Study was conducted on experimental plots located on a closed fly ash deposit, fertilised with liquid biosolids and on a non-fertilised control land, located on the same site, in a period boosted by a climate regime and rainfall to ensure sufficient water supplies in that area. Efforts were made to obtain a vegetative layer that improves the landscape aspect and also uptakes, as much as possible, lower quantities of metals, in order to protect the wildlife and preserve the metals inside the fly ash deposit in the future.

The presence of pollutants in the environment may cause risk for human and animal health because pollutants accumulate eventually in various links of the food chain. The power plants based on the burning of fossil coal cause a continuous rise of material, forming large amounts of slag and fly ash, usually disposed in landfills near the power plant. The fly ash causes many deleterious effects on important areas of agricultural land and damage ecological systems. The restoration of destroyed

* For correspondence.

landscape is a big challenge. Often, on the area enclosed by the slag and fly ash deposits are plants that can survive under such conditions¹⁻³. The component materials consisting of fine particles that can be driven by air currents can easily be compacted at the impact with torrential rain, when the crusty formation tends to act as physical barriers for the exchange between ground and atmosphere, having little capacity for water retention due to porosity, lack of nitrogen and phosphorus nutrients⁴⁻⁶. These materials have enough carbon content to allow the formation of humus, but in the first phase of storage carbon is not accessible for the plants. To reduce the time needed for the formation of a natural layer of vegetation covering the land fly ash deposit, the land must be fertilised with accessible materials for plants^{1,2,5,6}. The fertilisation can be done with a fertiliser that is not accepted in other areas, such as fermented biosolids¹. The choice of plants for the vegetable layer is very important and must take into account the local conditions of climate and rainfall regime, geographical area, and plant characteristics¹.

EXPERIMENTAL

The experimental plots were fertilised with biosolids (municipal sludge) 25 t ha⁻¹ DM. The study was performed on an experimental block consisting of 12 experimental plots, 10 m² each. The experimental variants of the study were as follows: (1) fly ash-variant with no addition of organic fertiliser, as control; (2) fly ash-variant fertilised with organic fertiliser, biosolids. Two plant species were seeded: *Festuca arundinacea* and *Onobrychis viciifolia*; the sowing was done in September 2009.

The heavy metals were extracted from the soil samples by heating with aqua regia for 2 h, at reflux. After interrupting the heat, the system was left in stand-by for 16 h. Then the samples were diluted in a flask with deionised water exactly to 50 ml. Plant tissues were thoroughly washed with deionised water to remove any soil particles attached to plant surfaces. The tissues were dried (105°C) to a constant weight. Plant samples with precise weight are then brought to 550°C; to the residual materials 5 ml of concentrated hydrochloric acid were added, samples were maintained 30 min on a dry sand bath. After filtering those in a paper filter with small porosity, were taken to a calibrated flask with hydrochloric acid 1:1 solution. Plant and soil extracts analysis was done using a spectrophotometer, Varian Spectra AAS. Studies of quantitative ratios between plant species from the phytocenosis allow the completion of the ecological research on any bioce-nosis. Because the abundance is in direct relation with supremacy, a supremacy-abundance index was proposed by Braun-Blanquet³, taken into consideration the cover–abundance scale:

- (+) few individuals, a very small degree of covering <5%;
- (1) more individuals, but with small covering degree < 5%;

- (2) small abundance and limited covering degree 5–25%;
- (3) abundant individual, high degree of covering 25–50%;
- (4) abundant individual, good degree of covering 50–75%;
- (5) abundant individual and very good covering 75–100%.

RESULTS AND DISCUSSION

In Table 1 are presented the concentrations of heavy metals accumulated in the aerial tissue of the two species *Festuca arundinacea* and *Onobrychis viciifolia* which were sown in the experimental plots: Case (1): the amount of metals accumulated in plants grown on soils without fertiliser. *O. viciifolia* accumulates higher concentrations of metals than *F. arundinacea*, as follows: 17.1% Cr, 29.4–39.1% Ni, Cu, Zn and up to 61.2 % Fe; Case (2): the amount of metals accumulated in the plants grown on soils fertilised with biosolids. It is noted that the accumulation of Cu, Cr, Ni, Pb and Zn is similar for the two plant species, with the exception of Fe, which was accumulated 2 times more in *O. viciifolia* than in *F. arundinacea*.

Table 1. Metal concentrations accumulated in the aerial tissues of the two forage plant species *Festuca arundinacea* and *Onobrychis viciifolia*

No Experimental variants crt.	Plant species	Heavy metals mg/kg DM					
		Fe	Cu	Cr	Ni	Zn	Pb
1 control fly ash	<i>Festuca arundinacea</i>	1185.7	19.2	9.7	7.2	39.5	26.4
2 fly ash fertilised with biosolids	<i>Festuca arundinacea</i>	504.3	16.8	8.5	6.1	20.4	3.9
3 control fly ash	<i>Onobrychis viciifolia</i>	3066.0	28.3	11.7	10.2	64.9	11.8
4 fly ash fertilised with biosolids	<i>Onobrychis viciifolia</i>	1103.6	11.5	8.2	5.9	37.6	3.9

Case (1): the amount of metals accumulated in plants grown on soils without fertiliser. *O. viciifolia* accumulates higher concentrations of metals than *F. arundinacea*, as follows: 17.1% Cr, 29.4–39.1% Ni, Cu, Zn and up to 61.2% Fe.

Case (2): the amount of metals accumulated in the plants grown on soils fertilised with biosolids. It is noted that the accumulation of Cu, Cr, Ni, Pb and Zn is similar for the two plant species, with the exception of Fe, which was accumulated 2 times more in *O. viciifolia* than in *F. arundinacea*.

Comparing the quantities of metals accumulated from the same plant species harvested from the two types of control and experimental field fertilised with biosolids showed that the effect of accumulation reduction of metals Cu, Cr, Ni and Zn in tissues of aerial parts of *O. viciifolia*, after the addition of biosolids, was more intense than in *F. arundinacea*. *O. viciifolia* accumulated greater concentrations of Cu 59.3%, and Cr 29.9%, Ni 42.2 % than *F. arundinacea*. *O. viciifolia* had a smaller affinity for iron and lead than *F. arundinacea*; and the presence of biosolids

decreased the efficiency up to 20% regarding the accumulation of these metals. *F. arundinacea* tolerates better the environmental conditions of the ash deposit and took from the unfertilised soil lower quantities of metals than the leguminous species. The addition of biosolids fertiliser determined an important decrease of metal accumulation in tissues in both species. This revealed that organic matter played a more intense role for the plant, limiting the entry of metals in its aerial tissue and occurrence of heavy metals in environment. The analysis of the plant ecological abundance is presented in Table 2.

Table 2. Analysis of the ecological abundance for two plant species after Braun-Blanquet cover – abundance scale

Degree of soil covering	Control fly ash		Fly ash fertilised with biosolids	
	<i>Festuca arundinacea</i>	<i>Onobrychis viciifolia</i>	<i>Festuca arundinacea</i>	<i>Onobrychis viciifolia</i>
Very small (+)		x		
Small (1)	x			x
Limited (2)				
Increased (3)				
Good (4)			x	
Very good (5)				

In the case of the parcels fertilised with biosolids the degree of soil covering with plants ranged as follows: plants from *O. viciifolia* had a small degree (2) and those of *F. arundinacea* a good degree (4). It may be concluded that the pollution degree from ash had a bad influence on the growth and development of *O. viciifolia* plants, even lethal. *O. viciifolia* plants gradually disappeared in the dry months of summer. It must be underlined that *F. arundinacea* succeeded to adapt at high concentrations of Fe, Cr, Cu and Pb on the parcel fertilised with biosolids and for the hot conditions of summer. From the areas cultivated with these plants were harvested important biomass quantities. The quantities harvested from the control fly ash cultivated with *F. arundinacea* plants were of 311 kg/ha, and the quantities harvested from the fly ash fertilised with biosolids were of 2100 kg/ha.

CONCLUSIONS

The restoration of the damaged landscape of fly ash deposits, covering them with a vegetal layer was proposed. To provide the nutrients needed, the use of biosolids fertilisation was performed and then the fly ash cultivation with two forage species. *O. viciifolia* accumulated larger concentrations of metals from soils without fertiliser than *F. arundinacea*: Cr 17.1%, Ni, Cu, Zn 29.4–39.1%, and Fe more than 61.2%. The concentrations of Cr, Ni, Pb and Zn accumulated in the biosolids of the fertilised soils were similar for the two species of plants except iron which

was accumulated 2 times more in *O. viciifolia* species. The addition of biosolids fertiliser determined an important decrease of metal accumulation in the tissues of both species: organic matter reduced 2.5–5 times the entry of metals, such as Cu, Cr, Ni, in the aerial tissue of *O. viciifolia* compared to other species. The biosolids improved quantitatively and qualitatively the vegetation process and limited the occurrence of heavy metals in the environment. A vegetative layer that improves the landscape aspect was obtained, having also the capacity to uptake a lesser quantity of metals in order to protect wildlife and preserve the metals inside the fly ash deposit in the future.

REFERENCES

1. R. D. TRIPATHI, V. N. SINGH, U. N. RAI, A. KUMAR, M. B. ALI, B. KUMAR, M. YUNUS: Efficacy of Various Amendments for Amelioration of Fly Ash Toxicity: Growth Performance and Metal Composition of *Cassia siamea* L a m k. *Chemosphere*, **54**, 1581 (2004).
2. D. C. ADRIANO, A. L. PAGE, A. A. ELSEEWI, A. C. CHANG, I. STRAUGHAN: Utilization and Disposal of Fly Ash and Other Coal Residues in Terrestrial Ecosystems. A Review. *J Environ Qual*, **9**, 333 (1980).
3. D. A. WIKUM, G. F. SHANHOLTZER: Cover Application of the Braun-Blanket Scale for Vegetation Analysis in Land Development Studies. *Environ Manage*, **2**, 323 (1974).
4. N. DRAGOMIR, S. MASU, C. BOGATU, B. LIXANDRU, M. LAZAROVICI, C. CRISTEA: *In situ* Remediation of Soils Polluted with Heavy Metals. Using Supported Materials Part I. *J Environ Prot Ecol*, **10**, 45 (2009).
5. R. J. HAYNES: Reclamation and Revegetation of Fly Ash Disposal Site: Challenges and Research Needs. *J Environ Manage*, **90**, 43 (2008).
6. A. A. JUWARKAR, H. P. JAMHULKAR: Restoration of Fly Ash Dump through Biological Interventions. *Environ Monit Assess*, **139**, 355 (2008).

Received 24 February 2011

Revised 12 April 2011