- ORAL PRESENTATIONS -

PREDETERMINATION OF AMENDMENTS FOR THE ENHANCED PHYTOREMEDIATION OF FLY ASH DUMPS

Smaranda Masu, Valeria Nicorescu

National R & D Institute for Industrial Ecology ECOIND, Branch of Timisoara, 300004 – Timişoara, 1 Piata Regina Maria, Romania
tel. 040256-220369, fax.040356-008220, smarandamasu@yahoo.com

Abstract. The phytostabilization of the slag and fly ash dumps was studied in an experimental block consisting of variants fertilized with different organic fertilizing agents, sewage sludge or biological sludge resulting from a slaughter house in the absence/presence of an organic stimulus. The organic stimulus was used during the sowing stage and subsequently through regular foliar applications on the grown crop. The organic stimulus Biocomplex 900 is based on a marine brown algae extract and comes from SC EKO GEA EAST SRL, Romania. The germination degree of *Lolium perenne* seeds was studied at the same time with the coverage degree of sown areas during different phenophases. The plant development and the amount of biomass harvested were monitored. The slaughter house sludge used ($0.5\ kg\cdot m^{-2}$) with the addition of Biocomplex 900 organic stimulus determined a rapid vegetation in the fertilized slag and fly ash variant along with green biomass harvests which was 2-3 times higher than in other experimental variants.

Keywords: slag and fly ash dumps, organic fertilizers, algae extract, *Lolium perenne*

Introduction

Plants that grow in poor soils often develop interdependence with bacterial soil communities which are influenced by soil type, plant species and the applied agricultural technology. Changes in soil chemistry due to treatment with fertilizing agents and/or amendment agents and changes in the plant's chemistry/biochemistry can alter the crops. But it is difficult to compare the results reported in the literature on this area and even more difficult to draw conclusions based on these results. It follows, however, that the soil type clearly influences the amount of plants tissue: the roots or the aerial parts [1-2].

Is reported in this research field the changes that may occur in the rhizosphere. It is known that the presence of toxic metals can have a long-term effect on ecosystems and a negative influence over phenomena associated with the soil's biology. Also it is known that the presence of metals in soil reduces in situ the microbial biomass, the activity of various enzymes and has a negative influence on the functionality of various ecosystem segments (the structure of the microbial community is changing). In time, it can be observed the tolerance phenomena in soil's bacteria [3-5]. The addition of organic fertilizer can increase the proliferation of microorganisms. The addition of organic fertilizers (conditioned sewage sludge, green compost waste, etc.) to a deposit of slag and fly ash, and sand waste bauxite caused a decrease in density of all old deposits. In the same time, the porosity and the water availability increased by the water retention capacity. The content of soluble carbon compounds has increased because of humic matter breaking phenomenon and also, the activity of some enzymes in the constitution of microbial consortium increased. The role of the organic matter is beneficial because it determines the change of soil's physical properties, in a positive way, as the soil aggregate stability and the microbial activity attached to it [5-6]. Brown algae extracts used as stimulating agents for the microbial activity have increased the speed of the organic compounds oxidation in the soil and the formation of bioavailability components from nutrients for microbial consortium and plants. Brown algae and their extracts are known for their contribution to the development of soil reactions involving components of fertilizers compunds found in the fertilizing agent and organic components of soil's matrix [5, 7 -8].

The aim of this paper is to study the influence of a bacterial inoculums based on brown seaweed and the process of grassing with the *Lolium perenne* species, heaps of slag and fly ash taking into consideration the following parameters: germination degree, coverage degree of the cultivated areas and the amount of biomass produced in a short time.

Experimental part

The study was conducted in fertilized variants with two types of sludge: sewage sludge and slaughter house sludge in quantities of 0.5-2.5kg·m^{-2} in the absence/presence of a development seaweed stimulus from SC EKO GEA EAST SRL for the bacterial needs in the transformation of unassimilated compounds into bioavailability compounds by plants. The experimental study was performed in four experimental blocks, in pots with a useful capacity of 5.5 kg/pot (the sown area was 0.075m^2/pot). Each experimental variant was made in three replicates.

The experimental variants are shown in Table 1.

Table 1

Experimental variants made for slag and fly ash culture

No	Experimental variants/Slag and fly ash treatment											
	Sewage sludge [kg·m^{-2}]						Slaughter house sludge [kg·m^{-2}]					
1	Block 1 without seaweed extract			Block 2 with seaweed extract			Block 3 without seaweed extract			Block 4 with seaweed extract		
*2	*vn1*	*vn2*	*vn3*	*vns1*	*vns2*	*vns3*	*va1*	*va2*	*va3*	*vas1*	*vas2*	*vas3*
3	0.5	1.0	2.5	0.5	1.0	2.5	0.5	1.0	2.5	0.5	1.0	2.5

*Line 2 description: *v*=experimental variant; *n*=sewage sludge; *s*=seaweed extract; *a*=slaughter house sludge;

Table 2 summarizes the physical-chemical characteristics of slag and fly ash dumps and the fertilizing agents used. The Biocomplex 900 brown seaweed extract was used in this study as bacterial inoculums. The product is not toxic to plants, animals, humans and is in the form of brown liquid with a fish smell. *Lolium perenne* species was used for vegetation (7 g/pot). During sowing with this plant, the soil was watered with a mixture of brown algae extract and water (ratio 1:50).

Periodically, crops were foliar watered with a watering mix based on seaweed extract.

The slag and fly ash used to supply vegetation pots was taken from areas where unburned coal/lignite residues are deposited (areas with a large amount of organic matter, 50.11 %).

Table 2

Nutrient content of slag and fly ash, and fertilizer agents

No.	Material	Physical-chemical characteristics				
		pH	Humidity [%]	Organic matter [%]	Total nitrogen content [%]	Total phosphorus content [mg/kg dry matter]
1	Slag and fly ash	6.3	50.57	50.11	0.0262	144
2	Sewage sludge	8.5	91.5	59.78	1.138	1107
3	Slaughter-house sludge	7.1	71.86	90.77	2.314	1126

The used slag and fly ash is an inert material which contains small amounts of nitrogen and phosphorus (see Table 1) and the carbon is present in un-bioavailability forms (pieces of 1-3 mm slag-dust are mixed with fly ash from burning lignite). The *Lolium perenne* crops are periodically checked out on: a. germination degree at three weeks after seeding; b. surface coverage after seven weeks; c. growth degree and on the amount of resulted green biomass at seven weeks after sowing.

Results and Discussion

Table 3 shows the germination, the cultivated area coverage and the amount of green biomass for the variant fertilized with sewage sludge in the absence/presence of seaweed extract.

Table 3

The germination, the cultivated area coverage and the amount of green biomass for slag and fly ash experimental variants fertilized with sewage sludge in the absence/presence of seaweed extract.

Parameters Date of sowing 01.06.2013.	Experimental variants/Slag and fly ash treatment					
	Sewage sludge without seaweed extract [kg·m^{-2}]			Sewage sludge with seaweed extract [kg·m^{-2}]		
Symbol	*vn1*	*vn2*	*vn3*	*vns1*	*vns2*	*vns3*
Germination [%]	30	40	50	15	60	70
Surface coverage after seven weeks [%]	Dry plants	90	80	60	90	90
Green biomass [g/pot]	Dry plants	8.6	13.1	3.4	10.5	8.14

The use of a small amount of sewage sludge, 0.5 kg·m^{-2}, resulted in the *Lolium perenne* seeds germination in an area with 30% total sowed material. The resulted plants suffered morpho-physiological changes (they become yellow and dry).

Subsequently, plants continue to dry gradually until the culture completely dies. An increase in the amount of fertilizer, sewage sludge added to the slag and fly ash quantity (1.0-2.5 kg·m^{-2}), determined a higher germination rate.

The seeds sprout gradually, reaching a germination degree of 40-50% in the third week from sowing.

The surface coverage, over a period of seven weeks after sowing was 80-90% for the *vn3* variant. Crops have a healthy appearance and a bright green color.

Thus, an increase in the amount of sewage sludge, of 2.5 times, produces a 1.5 times of biomass increase. The maximum amount of biomass produced per fertilized experimental variant was 2.5kg·m^{-2} and in the absence of the seaweed extract was 13.1g green biomass/pot. The seaweed organic stimulus added in the experimental variant fertilized with 0.5 kg·m^{-2} sewage sludge determined the formation of a vegetation layer during a period of seven weeks, with 60% coverage of sown area. Increasing the quantity of fertilizing agent with 1-2.5 kg·m^{-2} led to a boost of 90% to the covered area.

Crops have a healthy appearance and a bright green color. The amount of harvested biomass in the fertilized variant with 0.5 kg·m^{-2} sewage sludge and seaweed extract was 3.4 g green biomass/pot. Doubling the amount of the fertilizing agent to 1 kg·m^{-2} led to an increase, up to 3 times, of green biomass as opposed to the fertilized variant with sewage sludge of 0.5 kg·m^{-2}.

This amount is increased with 20%, relative to the amount obtained in a similar variant fertilized with 1 kg·m^{-2} of sewage sludge in the absence of a stimulus based on the brown seaweed extract. Increasing the amount of sewage sludge to 2.5 kg·m^{-2} didn't cause a similar increase of biomass harvested from this variant.

The amount of biomass was similar to that harvested from the variant fertilized with 1 kg·m^{-2} sewage sludge in the presence of a brown seaweed extract stimulus. The amount of green biomass resulted from the experimental variant treated with 2.5 kg·m^{-2} sewage sludge in the presence of a brown seaweed extract was lower than the amount of biomass harvested from the one fertilized with sewage sludge and in the absence of seaweed extract.

Table 4 shows the germination degree, the coverage in the cultivated area and the amount of biomass for crops fertilized with slaughter house sludge in the absence/presence of seaweed extract.

The addition of slaughter house sludge produces the germination of *Lolium perenne* with 5-20% in the first phase. The plants have a yellow color. The crop is presented as scattered cluster of plants.

Table 4

The germination, the coverage of the cultivated area and the amount of green biomass for slag and fly ash experimental variants fertilized with slaughter house sludge in the absence/presence of seaweed extract

Parameters Date of sowing 01.06.2013	Experimental variants/ Slag and fly ash treatment					
	Slaughter house sludge without seaweed extract [kg·m^{-2}]			Slaughter house sludge with seaweed extract [kg·m^{-2}]		
Symbol	*va1*	*va2*	*va3*	*vas1*	*vas2*	*vas3*
Germination [%]	10	30	5	80	40	10
Coverage after seven week [%]	60	50	60	90	70	35
Green biomass [g/pot]	3.5	3.85	6.9	14.8	4.35	1.6

The plant germination from the slaughter house sludge without seaweed extract fertilized variant (see Table 4) occurs also in the following weeks so that at the end of the observation period (seven weeks of growth) the occupied area is 50–60%. The area occupied by the perennial plant is about 20-30% lower than in similar cases of the experimental block's treated with sewage sludge. The amount of harvested plants is 3.5-3.85g green mass/pot when using a quantity of slaughter house sludge of 0.5-1kg·m^{-2}. The amount of biomass harvested from these options is 50% and 70% which is lower than in the variants treated with sewage sludge. The maximum amount of biomass resulted was 6.9 g green mass/pot while using 2.5 $kg \cdot m^{-2}$ of slaughter house sludge without seaweed extract. Adding the brown seaweed stimulus in a small amount (0.5 $kg \cdot m^{-2}$) of slaughter house sludge caused a very good and fast germination degree. Two weeks after seeding, 80% of the grains have emerged. The crop was healthy, green and formed dense clusters of plants. After seven weeks of growing, the plants have reached to cover 90% of sown area. The largest amount of harvested biomass was in the variants studied, being 10% higher than in the variant treated with 2.5 $kg \cdot m^{-2}$ sewage sludge, in the absence of an seaweed stimulus (the best option when treating ash with sewage sludge). The germination degree after two weeks was lower in two variants: the one treated with slaughter house sludge of 1$kg \cdot m^{-2}$ and respectively the one with 2.5 $kg \cdot m^{-2}$.

The germination degree was in the range of 10-40%, the minimum value corresponding exactly to the high fertility level of 2.5 $kg \cdot m^{-2}$. The increased of slaughter house sludge quantity reduced dramatically the coverage degree of the area sown with *Lolium perenne*. In the experimental variant fertilized with 1 $kg \cdot m^{-2}$ and treated with brown seaweed extract, the area coverage has reached 70% during seven weeks. The increased addition of slaughter house sludge to 2.5 $kg \cdot m^{-2}$ determined a 35% coverage of the cultivated area, after seven weeks (i.e. half of the coverage being resulted in the experimental variant treated with 1$kg \cdot m^{-2}$ slaughter house sludge and brown seaweed extract). The amount of green biomass obtained from the experimental variants of this device is reduced with the increase of fertilizing agent with the brown seaweed extract.

Conclusions

For the rapid grassing of inert slag and fly ash dumps it was necessary to ensure: 1.bioavailability optimum amount of nutrients for plant growth, which were provided by the use of organic fertilizer agents such as biological sludge; 2.stimulation of an adequate biogenesis in the rhizosphere to promote nutrients bioavailability, such as brown seaweed extract.

Best results and similar ones were obtained regarding the vegetation of slag and fly ash dumps either for variants fertilized with large amounts of sewage sludge without the addition of algae or either for variants fertilized with reduced amounts of sludge slaughter house with addition of extract.

To provide the necessary nutrients, it must be performed either by large quantities of sludge with minimum nutrients such as sewage sludge (2.5 $kg \cdot m^{-2}$) or reduced amounts of fertilization agents, i.e. 0.5 $kg \cdot m^{-2}$ slaughter house sludge but which contains an increased quantity of nutrients.

When large quantities of sewage sludge were used, it was not required to add a stimulating bacterial activity in the soil because the addition of fertilization agent ensures the biogenesis quality and quantity in the inert soil. Using a bacterial inoculums based on brown seaweed sludge didn't result in the creation of stimulating plant growth conditions and that is probably because sewage sludge associated with seaweed extract led to antagonistic effects that inhibit optimal development of *Lolium perenne* culture. When using small quantities of slaughter house sludge with a stimulating bacterial activity based on brown seaweed extract ensures the biogenesis quality and quantity introduced into inert soil and creates optimal conditions for plant development. Experimental variants fertilized with slaughter house and addition of bacterial inoculums ensures a synergistic formation of active biogenesis which allows bioavailability nutrient for plants and a culture of healthy plants with abundant *Lolium perenne* species.

References

1. BERG G., SMALLA K., FEMS Microbial. Ecology., **68,** 2009, p. 1.
2. KHAN M.S., ZAIDI A., WANI P.A., OVES M., Environ. Chem. Lett., **7,** 2009, p. 1.
3. DE ARAUJO A.S.F., DE MELO W.J., SING R.P., Rev. Environ. Sci. Biotechnol., **9,**. 2010, p. 41
4. PARK E. LABB D. PANEERSELVAN P., CHOPPALA C., BOLAN N., CHUNG J. W., J. Hazard. Mater, **185**, 2011, p. 549.
5. CRECCHIO C., CURCI M., PIZZIGALLO M.D.R., RICCIUTI P., RUGGIERO P., Soil Biol. Biochem., **36,** 2004, p. 1595.
6. LEE J.J., PARK R.D., KIM Y.W., SHIM J. H., CHAE D.H., RIM Y.S., SOHN B.K., KIM T.H., KIM K.Y, Bioresour. Technol., **93,** .2004, p. 21.
7. ZHONG ,W., GU T., WANG W., ZHANG B., LIN X., HUANG Q., SHEN W., Plant Soil, **326**, 2010, p. 511.
8. BALIK J., PAVLIKOVA D., VANEK V., KULHANEK M., KOTKOVA B., Plant Soil and Environ., **53,** 2007. p. 375.