VEGETATIVE COVER FOR PHOSPHOGYPSUM DUMPS: A ROMANIAN FIELD STUDY

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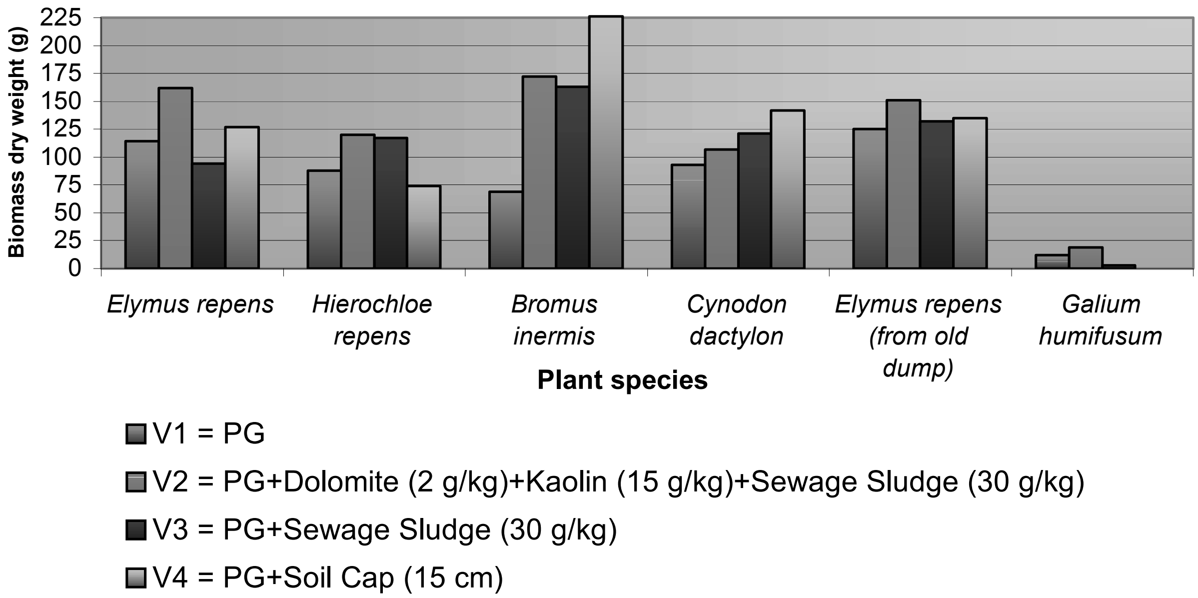
Abstract

Intensive mining and processing activities along the Romanian Black Sea Coast have resulted in the production of millions of tons of waste that has been disposed without any treatment in tailing dumps. At Navodari, 20 km north of Constanta harbor, over 3,000,000 m^3 of phosphogypsum, deposited in three stacks, represents a permanent threat to the surrounding environment and human population. High levels of toxic metals and radionuclides, along with elevated sulfate concentrations, are examples of problems associated with these stacks, according to a complex environmental characterization and risk assessment study. Consequently, vegetative cover might substantially reduce the risk of contaminant migration, under the coastal climate of high rainfall and strong winds. In this paper, a field research effort to cover phosphogypsum residue with suitable vegetation is presented. Several remediation schemes, based on greenhouse experiments have been successfully deployed in the field. These schemes used different combinations of soil amendments and plant species. Periodic investigations on plant growth and metal uptake, as well as enzymatic activities in the substrates were carried out. On the basis of this 18-month experiment, an efficient rehabilitation scheme is proposed.

Phosphogypsum (PG) is a calcium sulfate dihydrate ($CaSO_4.2H_2O$) byproduct of phosphoric acid production process from phosphate ore. PG is characterized by nutrient deficiencies and low pH values, which are the main concerns for successful establishment of vegetative covers (Patel et al., 1994). An environmental characterization study followed by a risk assessment identified specific problems associated with the Navodari PG disposal sites (Kontopoulos et al., 1998). These problems include: elevated concentration of sulphur (17.7 %) and radionuclides (Ra-226: 475 Bq/kg), high concentrations of metals in the soluble fraction of sequential extraction (in mg/kg: Fe-424, Al-64, Cu-26, Zn-8.7) and low neutral pH values (4-5.5). Due to the lack of vegetative cover and the fine composition of PG stacks, aerial transport of fine particles results in contamination of surrounding soils and crops, high risk of inhalation by residents, and solubilization of heavy metals and subsequent contamination of surface and ground waters. The application of vegetative cover to PG dumps has been considered as a viable remediation option. The goal of this cover is to reduce wind erosion and dust transport, isolate tailings, inhibit acid water generation and improve aesthetics.

Previous studies (Patel et al., 1994) on vegetative covers for PG stacks reported the need for amendment application in order to increase pH, improve tailing texture, and supplement nutrients. Greenhouse experiments conducted prior to field application (Komnitsas et al., 1999), evaluated 6 indigenous herbaceous species of plants and 4 combinations of growth substrate (V1-V4) as suitable for field application, illustrated in Fig.1. Small amounts of chemical fertilizers were added initially in order to supply N (NH_4NO_3 - 50 mg/kg), K (K_2SO_4 - 20 mg/kg) and Mg ($MgSO_4$ - 12 mg/kg). Plant growth was measured by dry weight production of aerial biomass after 1 year. Metal uptake in plants was determined biannually by wet digestion of aerial biomass and subsequent metal analyses. Enzymatic activities in substrates were analysed biannually based on: TTC reduction (for dehydrogenase), ammonium production following urea transformation (for urease) and phenol production from sodium phenilphosphate (for phosphatase). The capacity for plant growth on PG is illustrated for each plant species in figures 1 and 2, while changes in enzymatic activity are shown in Table 1.

Fig.1 Growth intensity of herbaceous plants on PG substrates (V1-V4) in the field application



All the herbaceous species, except *Galium humifusum*, had good growth in the field application, even when grown directly on PG (V1). The best growth was, as expected, in the variant with top soil, as well as in the one with dolomite + kaolin + sewage sludge. These treatments are, however, more expensive to apply on a large scale. The results are in agreement with the spectacular increase of all studied enzymatic activities. It is remarkable that after such a short period of growth, dehydrogenase activity exceeded soil values in the complex substrate (V2) with the best plant growth, although initial levels were much lower. This is an indication of the rich microbial population associated with the growth substrates, that stimulates plant growth and is stimulated, in return, by plants. It can be concluded that, once successfully established, the vegetative cover will develop by itself, without special care, and will stabilize the tailing piles.

Metal uptake analyses (not presented here) showed higher concentrations of metals (up to 7 fold more) in plants grown on PG substrates, than in the same plants grown on normal soil.

Table 1. Evolution of enzymatic activities in PG substrates

Exp. plot	Dehydrogenase activity (mg formazane/100 g dry sample/24 h@28^0C)				Urease activity (mg NH_4^+/100 g dry sample/24 h@28^0C)		Phosphatase activity (mg phenol/100 g dry sample/24 h@28^0C)	
	initially		after 12 months		initially	after 12 months	initially	after 12 months
	actual	potential	actual	potential				
V_1	3.85	5.76	15.74	28.61	0.23	3.70	7.35	35.63
V_2	5.42	17.20	24.00	82.56	0.45	5.97	11.58	55.37
V_3	7.39	19.56	29.71	76.89	0.43	7.88	12.34	50.49
V_4	12.61	27.78	25.61	38.80	43.33	58.40	59.35	62.56

Fig.2 Plant growth on Navodari PG substrates in the field application

Direct correlation was established between plant growth intensity, metal uptake and enzymatic activities in substrates. However, metal uptake levels after 1 year of growth were still below toxic limits for those species. This suggests a potential for additional uptake and long-term success of the cover. On the basis of this application, a practical scheme for vegetation covering of PG stack can be proposed.

References

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