THE USE OF ENERGY CROP SPECIES FOR PHYTOREMEDIATION OF HEAVY METAL CONTAMINATED SITES

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Introduction

Remediation of contaminated soils has become a long-term challenge as it addresses both scientific and technical aspects, as well as social issues (Pandey et al., 2016). Whereas heavy metals contaminated soils are unsuitable for food production, energy crops can allow the commercial exploitation of these soils by establishing biofuel feedstock production systems. In addition, the cultivation of plants offers opportunities for site remediation (Werle et al., 2016). A four-year field experiment has been carried out at heavy metal contaminated sites located in Poland (arable land) and in Germany (postindustrial site). The Polish test site is located in the Upper Silesia Industrial Region, in the proximity of a closed-down large lead/zinc/cadmium works contributing significantly to the pollution of local soils. The German site is a former sewage sludge dewatering plant, located in the north of the city of Leipzig. In 1990 the operation of the dewatering plant was abandoned and about 800,000 tons of sewage sludge remained in several basins. Experiment involves testing of 4 plant species: miscanthus (*Miscanthus* x *giganteus*), virginia mallow (*Sida hermaphrodita*), cordgrass (*Spartina pectinata*), and switchgrass (*Panicum virgatum*) to find the optimum one with respect to both energy crop yield and phytoremediation capacity. Differences between test sites as well as plant metal uptake after the first year of the experiments are presented.

Methods

Experimental plots were established in the Spring 2014, for each of the species 16m^2 plots with 49 plants were created. Before planting soil samples were taken to determine basic soil parameters, including total (*aqua regia*) and bioavailable (0.01 M $CaCl_2$ extraction) lead, cadmium and zinc concentration. After the growing season plant material was sampled during autumn (October) and winter (March) to determine differences in heavy metal uptake for tested species at both experimental sites. Plant samples were dried, homogenized, digested and analyzed among other for heavy metal content.

Results

Lead and cadmium contamination level in soil from Polish test site ranged from 357.6 to 646.3 and 13.42 to 26.41 mg kg^{-1} d.w. respectively, while for zinc the range was from 1273 to 2505 mg kg^{-1} d.w. Heavy metal concentration in soil exceed Polish limits for arable soil. The pH value was almost neutral, followed by moderate content of organic matter and low electric conductivity. The level of bioavailable forms of cadmium and zinc was high (about 5% and 2.5% respectively). In case of German site, lead and cadmium level in soil ranged from 462.5 to 696.8 and 25.29 to 39.34 mg kg^{-1} d.w. respectively. In case of zinc, the range was from 2864 to 4488 mg/kg. The pH value was neutral, followed by high (33 %) level of organic matter and electric conductivity. The bioavailability of metals in soil was very low, mainly due to high level of organic matter (Pb below detection limit, Cd 0.25 mg kg^{-1} d.w. and Zn 16 mg kg^{-1} d.w.).

Due to differences in metals bioavailability between the sites, caused mainly by level of organic matter in soil, varied plant metal uptake were observed (Table 1).

Table 1. Differences in heavy metal uptake by energy crop between experimental sites and sampling time

Plant species	Sampling time	Bytom			Leipzig		
		Pb	Cd	Zn	Pb	Cd	Zn
		(mg kg^{-1} d.w.)					
M. x *giganteus*	autumn	33.44±5.01	2.10±0.27	420±45	3.39±0.52	1.25±0.33	212±47
	winter	195.23±17.55	3.67±0.39	512±71	8.00±0.74	1.40±0.12	258±22
S. hermaphrodita	autumn	2.68±0.30	5.94±1.11	1577±159	3.79±0.49	1.58±0.33	116±9
	winter	bdl	10.38±1.95	1667±293	2.63±0.29	0.95±0.20	91±14
P. virgatum	autumn	109.53±3.83	2.18±0.60	480±40	lack of sample		
	winter	487.40±70.07	4.45±0.67	544±63			
S. pectinata	autumn	25.11±1.39	0.26±0.02	169±7	3.89±0.22	0.41±0.02	273±42
	winter	141.87±10.03	1.00±0.06	299±32	5.96±0.70	0.84±0.10	678±93

n=5, ±SE, bdl – below detection limit, lack of sample – not sufficient plant growth

Except lead uptake by *S. hermaphrodita* at Leipzig site, higher metal uptake was observed for plants species cultivated at Bytom test site. The highest lead concentration was observed for *P. virgatum,* while the highest cadmium and zinc concentration was found for *S. hermaphrodita* collected from Bytom site during winter sampling. Plant species grown at former sewage sludge deposit site were characterized by low metal concentration in the tissues. Heavy metal content in biomass collected during winter sampling was in most cases higher in comparison to autumn one.

Conclusion

Uptake of heavy metals by energy crop is determined by the metal bioavailability. Better remedial effect is reached during the winter sampling, which is moreover routine time for energy crop harvesting. The contaminated biomass might be the source of energy, but its processing should be carefully considered.

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