PHYTOREMEDIATION AND THE FATE OF HEAVY METALS IN DIGESTATED PULP

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Introduction

Phytoremediation is defined as the use of plants to contain, inactivate or remove pollutants from the environment. Phytoextraction aims to use pollutant-accumulating plants to effectively remove metals from the soil (Salt et al., 1998). In this process, plants concentrate part of the metals in harvestable parts, allowing effective removal of contaminants from the situ. Despite of the benefits, such as cost-effectiveness, carbon sequestration, soil quality improvement and biomass production, the practical implementation of this environmental friendly solution has been constrained by the long period necessary for remediate the area up to acceptable levels in comparison with conventional civil-engineering clean-up technologies (Thewys et al., 2010). Additionally, the resulting biomass, which often contains higher content of pollutants, can be considered as hazardous material. Hence, the use of biomass from phytoremediation sites for energy purposes, as a renewable energy source, could be alternative since management of pollutants is taken in consideration. Anaerobic digestion (AD), applied in this study, is a bio-chemical conversion process where biomass is converted by bacteria into methane in absence of oxygen, being the end products: biogas and digestate. Biogas can be used directly or upgraded to higher quality (by the removal of CO_2). It can be used for electricity, heating and as transport fuel (Mckendry, 2002). After fermentation, digestate can be transported back to field and be used as a substitute for mineral fertilizers. However, in case of biomass from heavy metal polluted sites, often such alternative is prohibitive due high metal content. During the AD process it is observed a reduction of the organic content, but not a reduction in metals. According to Kool et al. (2005), very small amount of metals can evaporate when bounded to other matter. As result, most of the metal removed remains. The concentration of metals in the digestate will consequently depend on the dry matter of feedstock, efficiency of AD and, ultimately, will determinate the possible use of the digestate. Therefore, additional experimentation and validations are required before the use of such kind of digestate for agriculture, industrial or any domestic use. In this context, the present study aims to present a reasonable alternative for the digestate based in the investigation of the trajectory of metal pollutant from remediated site.

Methods

The substrate used was the hybrid *Miscanthus x Giganteus*, planted at the city of Bytom, region of Silesia, Poland. The site is a polluted arable land with heavy metal concentrations (Cd, Pb and Zn) exceeding the permissible levels by 5 times (Table 1). The anaerobic digestion consisted of three repetitions of each treatment: miscanthus, silage (miscanthus) and control (inoculum from biogas plant), under thermophilic (55°C) and mesophilic conditions (35°C), totalizing 18 bioreactors. After fermentation, the residual digestate in each bioreactor was further processed by separation into a liquid fraction and a solid sludge fraction. Both were subsequently dried and mineralized using Microwave digestion system, Magnum 2 (Ertec). Their metal content was determinated by atomic spectroscopy ICP-MS Agilent 7900.

Results

Table 1. Heavy metal content before fermentation.

	Pb	Cd	Zn
Total soil content	621.087	23.473	2359.370
Bioavailable	LOQ	0.580	23.001
Miscanthus	59.53	1.62	166.18
Miscanthus (silage)	46.93	1.43	111.01

Values represent mean of three replicates samples in (mg/kg DM); LOQ - below limit of quantification.

It was observed very little mobility of the metals Pb, Cd and Zn from the biomass into the liquid. Once inside of plant cell, the excess of Zn, Cd and Pb can bind with N, S and O from enzymes and as well low molecular weight (LMW), such as LW acids. These Metal-LMW-ligand complexes can be transported into the vacuole, where they accumulate and react producing high molecular weight (HMW) – metal complexes. This process could be part of a detoxification strategy of plant (Clemens 2001; Cobbett and Goldsbrough 2002). Apparently this mechanism can explain the little dissolution of metals in the liquid phase even after long period of AD process (aprox. 30 days HRT). Consequently, the liquid phase of treatments did not present higher concentration of metals in comparison with the control.

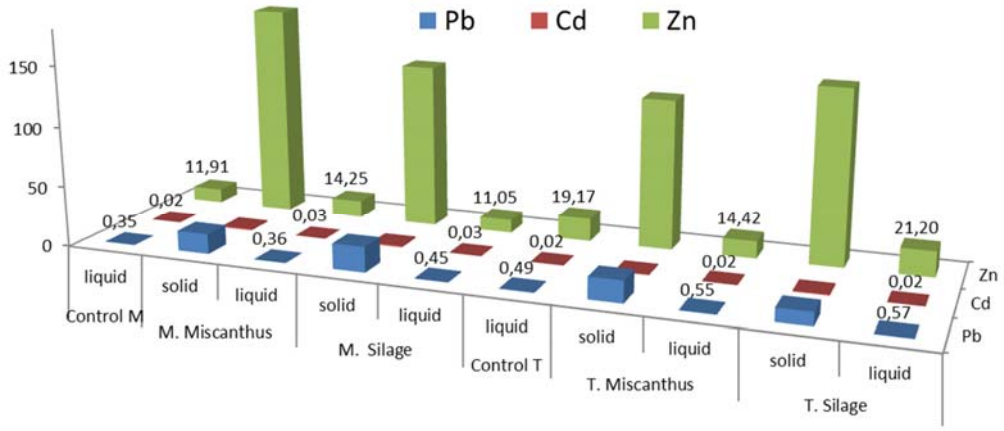

Figure 1. Content of heavy metals by fraction in comparison to control in (mg/kg DM)

Conclusion

The liquid fraction from digestate could be recycled back to biogas plant for feedstock dilution. The solid residue could be first dried using the heat from the CHP engine, and then could be thermally treated by pyrolysis or gasification with energy recovery and ashes containing heavy metals stored.

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