Geophysical Research Abstracts
Vol. 18, EGU2016-9794, 2016
EGU General Assembly 2016

Accumulation of germanium and rare earth elements in functional groups of selected energy crops cultivated on two different soils

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A field experiment was conducted to investigate the uptake of Ge and selected REEs in functional groups of selected crop species. Five species belonging to the functional group of grasses (Hordeum vulgare, Zea mays, Avena sativa, Panicum miliaceum and Phalaris arundinacea) and four species from the group of herbs (Lupinus albus, Lupinus angustifolius, Fagopyrum esculentum and Brassica napus) were cultivated in parallel on two soils with slightly alkaline (soil A: pH = 7.8) and slightly acidic (soil B: pH = 6.8) conditions. After harvest, concentrations of Ge, La, Nd, Gd, Er, P, Fe, Mn and Si in shoot tissues were determined with ICP-MS. Concentrations of Ge were significantly higher in grasses than in herbs. Conversely, concentrations of La and Nd were significantly higher in herbs, than in grasses. Highest concentrations were measured in Brassica napus (REEs) and Zea mays (Ge). Concentrations of Ge significantly correlated with that of Si in the shoots showing low concentrations in herbs and high concentrations in grasses, indicating a common mechanism during the uptake in grasses. Concentrations of REEs correlated significantly with that of Fe, indicating increasing concentrations of REEs with increasing concentrations of Fe. Cultivation of species on the slightly acidic soil significantly increased the uptake Ge in Lupinus albus and Phalaris arundinacea and the uptake of La and Nd in all species except of Phalaris arundinacea. This study demonstrated that commonly used field crops could be regarded as suitable candidates for a phytomining of Ge and REEs, since these species develop high yields of shoots, high concentrations of elements and are widely used in agricultural practice. Under soil conditions where bioavailability of Ge and REEs is expected to be low (soil A) accumulation can be estimated at 1.8 g/ha Ge in Z. mays and 3.7 g/ha REEs (1.5 g/ha La, 1.4 g/ha Nd, 0.6 g/ha Gd, 0.3 g/ha Er), respectively, in B. napus, assuming a constant high efficiency of phytoextraction in closed stands. Slight changes in soil properties like soil pH and fractions of REEs bound to organic matter significantly enhanced the uptake of Ge, La and Nd in plants. Thus, measures in soil management hold promise for enhanced phytoextraction of Ge and predominantly light REEs from soils, however, the impact of acidifying fertilizers and other soil amendments on the phytoextraction of Ge and REEs remain a field for further investigations.
These studies have been carried out in the framework of the PhytoGerm project financed by the Federal Ministry of Education and Research, Germany.