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# Impact of sewage sludge and digestate soil amendment on the phytoaccumulation of potentially toxic elements in Alyssum murale, Fagopyrum esculentum, and Carthamus tinctorius

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Sewage sludge and digestates from anaerobic fermentation are increasingly considered soil amendments and organic fertilizers to close agricultural element cycles. Beside plant nutrients, organic materials may contain potentially toxic trace elements. Their application cause soil pollution and enhance plant–soil transfer of undesired elements. The processes involved could be potentially deployed for phytoextraction applications. In this study, *Alyssum murale*, *Fagopyrum esculentum*, *Lupinus albus* and *Carthamus tinctorius* were cultivated on heavy metal polluted soil from the post-mining area of Freiberg Germany, treated with 10% (dw basis) sewage sludge or 1% digestate. Effects of soil amendments on the accumulation of P, Fe, Mn, Zn, Cu, Cd, As, Pb in different plant species evaluated by comparing shoot element concentrations (ICP-MS) of treated plants with reference plants cultivated on the soil. Both sewage sludge and digestate had high concentrations of nutrients, especially of phosphorus (22 g/kg P) in sewage sludge and (9.6 g/kg P) in digestate) which were magnitude higher than in the soil (30 mg/kg P). Compared to soil, sewage sludge contained lower concentrations of Mn, Cu, As, higher concentrations (factor of two) Zn and similar concentrations of Cd, Pb, Ni. Compared to soil, the digestate was significantly enriched in Cu, Zn, Ni, Cd and depleted in As and Pb. Plants treated with digestate showed adverse effects on growth (*C. tinctorius*) and significantly reduced biomass. Plants treated with digestate were characterized by significantly higher concentrations of Mn, Fe, Zn, Cu (*Alyssum murale*) and higher concentrations of Mn, Fe (*F. esculentum*). In contrast, concentrations of Cd, Pb As remained unchanged. Due to detrimental effects on plant growth, the treatment of plants with digestate significantly reduced amount of elements accumulated, irrespective of plant species. In contrast, sewage sludge amended plants showed increased shoot yield (factor 2), and elevated concentrations of P, Mg and Zn.In addition sewage sludge significantly increased concentrations of Zn, Cu, Ni, Cd, Co in *A. murale* und *F. esculentum* (by a factor of 20) and to a less extend in *L. albus* and *C. tinctorius* (Factor 2). Considering the higher shoot yield of sewage sludge amended plants, the increased concentrations enhanced phytoaccumulation of Cu, Zn, Ni, Cd and Co, which decreased in the order *F. esculentum* > *C. tinctorius* > *A. murale* > *L. albus*. Specifically, the accumulation of Zn in *F. esculentum* increased from 394 µg to 6658 µg and from 111 µg to 590 µg in *C. tinctorius*. Similarly, the accumulation of Cd increased from 8 µg to 98 µg in *F. esculentum* and from 0.26 µg to 31 µg in *A. murale* when sewage sludge was added. The calculated mass balance of elements in pots and elements transferred into plant biomass revealed that plants

accumulated 1% of total P present in the pots. Concomitantly, a single plant of *F. esculentum* accumulated 16% and 5% of plant-available Zn and Cd by soil sequential extraction analysis. Our findings indicate that high biomass metal-accumulators like F. esculentum could be used for industrial pretreatment of sewage sludge while retaining their high fertilization value.