The impact of harvest interval on short rotation coppiced willow plantations and phytoextraction of metals from biosolids.

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Domestic and industrial loading of metals/metalloids into the sewage stream can result in production of contaminated biosolids. Exceeding regulatory contamination limits can preclude these biosolids for reuse as a soil amendment in agriculture, forestry or land rehabilitation. Contaminants in these biosolids can however be reduced by phytoremediation or more specifically for metals by phytoextraction.

Salix species (Willows) have been shown to accumulate bio-available metals such as cadmium, zinc and nickel within their biomass when grown on metal-contaminated substrates such as biosolids. The amount of metals that can be removed in the harvestable biomass is the product of plant tissue metal concentration and the biomass produced. These factors are likewise determined by characteristics of the willow species/clone and the physico-chemical nature of the soil or biosolids. Previous trials (Laidlaw *et al*. 2008[1]) have shown that *Salix* growing in metal-rich biosolids produces leaves with higher concentrations of metal than stems. Further, annual harvesting of both leaves and stems together can increase metal removal up to 50% above a stem only harvest. For heavily contaminated soils and sludges reduction of contaminants to acceptable levels by phytoremediation can potentially take several decades. Increasing biomass production and/or metal uptake would increase the efficiency of this process by shortening the timeframe required. The present study aimed to assess the impact on phytoextraction efficiency of manipulating leaf and stem production through variations in harvest interval.

Small (n=16) high density (40K stems ha^{-1}) blocks of willows were planted in biosolids and harvested annually for two years. All blocks were irrigated with potable water by drip irrigation. In the third season the blocks were harvested at different intervals both within a growing season and between growing seasons. Blocks of willows were harvested 1) early summer, 2) late summer and 3) mid autumn. Group A blocks were harvested 3 times within the growing season, group B twice and group C once at the end of the growing season. Harvested biomass was divided into leaves and stems and weighed as dry matter. Sub-samples were analysed for metal content. A single harvest (22 t ha^{-1}) produced a greater biomass than the cumulative mass removed from two and three intra-seasonal harvests (12 and 8 t ha^{-1} respectively). In addition, multiple harvests did not increase the cumulative leaf harvest significantly and hence had little impact on overall contaminant metal removal from the biosolids.

Two models of a phytoextraction system incorporating a combined leaf and stem harvest in autumn were developed. Biomass production and metal concentration data from previous trials (Laidlaw *et al*. 2008) were incorporated into the models to compare the impact of 1-year and 2-year harvest rotations on cumulative metal extraction over a 7 year period. Models assumed biomass production was constant after year 3 and plant tissue metal concentration (uptake) was constant. One third of annual leaf production was removed at each harvest event with the remainder falling as litter. The models showed that annual harvests removed 13% more metal than a system based on biennial harvests. In addition a stem only harvest would remove 14%-24% less metal. The harvesting of leaf biomass contributes significantly to metal removal by a willow based phytoextraction system.

The results of this field trial and modelling indicate that early autumn harvests of stem and leaf produced the most efficient removal of contaminant metals from biosolids. This conclusion however needs to be validated with longer term data from field trials subject to 1 year rotations for a period greater than three years.

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[1] Laidlaw WS, Gregory D, Huynh TT, Godino M and Baker AJM (2008). "Phytoextraction of cadmium, zinc and nickel from contaminated biosolids by willows grown under field conditions." *23rd Session of the International Poplar Commission*, Beijing, P.R. China, October 2008.