Poplar and willow to manage trace element fluxes in productive systems

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Poplars and willows accumulate higher foliar concentrations of some trace elements than pasture. Combined with the high growth rates and ease of propagation, poplar and willow trace element accumulation can be exploited to improve the trace element nutrition of stock and reduce the negative effects of toxic trace elements in polluted soils.

Poplars and willows are ubiquitous in the many productive systems. Extensive plantings reduce erosion from hillsides and river banks, and provide supplementary stock fodder during times of drought. In addition to providing an emergency food source, poplars and willows as stock feed have proven health benefits including an improvement in fecundity. These benefits may be derived from high protein, tannin or trace element concentrations.

Feeding poplars and willows to stock may alleviate trace element deficiencies. Many pasturelands are deficient in cobalt, zinc and copper. Our experiments revealed that poplars and willows can have leaf cobalt and zinc concentrations that are six times higher than pasture growing in the same environment. However, poplars and willows may also introduce toxic trace elements into the animal's diet. In New Zealand, most pasturelands have elevated cadmium concentrations due to repeated applications of cadmium-rich superphosphate fertiliser. We found that the commonly-used New Zealand varieties of poplar, 'Kawa' (*Populus deltoides x P. yunnanensis*), and willow, 'Tangoio' (*Salix matsudana* x *S. alba*), accumulated cadmium at levels of up to 14 $\mu g\ g^{-1}$ in the dry leaves when grown in a soil containing just 0.6 $\mu g\ g^{-1}$ of this element. This concentration is above levels (1 –5 $\mu g\ g^{-1}$) shown to adversely affect livestock.

This century has seen an increase in phytoremediation using poplars and willows. Here, trees are planted on contaminated sites with the aim of reducing environmental risk. Commercial phytoremediation employs poplars and willows as biopumps to reduce contaminant mobility and enhance the *in situ* degradation of some organic contaminants. Due to their rapid establishment and high evapotranspiration, poplars and willows are effective in reducing the water flux through contaminated material. This results in less contaminant moving off-site, and creates an aerobic environment in the root-zone that favours the degradation of some pollutants.

Here we investigate poplar and willow phytoremediation of contaminated sites in New Zealand, which are associated with agricultural and silvicultural production. For example, an estimated 50,000 disused sheep dipping sites contain elevated levels of persistent pesticides such as dieldrin and sodium arsenate. Numerous sites associated with timber processing contain high levels of wood preservatives. Phytoremediation is well suited for the extensive, low-value contaminated land. Here we detail two phytoremediation case studies using both poplars and willows.

Many timber products contain pentachlorophenol (PCP), boron, or copper-chromium-arsenic (CCA) to protect the wood against decay. High concentrations of these preservatives occur in treatment and wood-waste disposal sites, and pose a risk to receiving waters through leaching. One such site is located at the base of the Coromandel peninsula, New Zealand. Sawdust and yard-scrapings dumped over 30 years from 1966 have produced a 3.6 ha pile with an average depth of 15 m. Geotechnical engineering ensures no surface or ground water enters the pile. A holding pond collects leachate that results from high rainfall events. Vegetation had failed to establish naturally. Consequently, evaporation from pile was negligible, indicated by the presence of saturated material at depths > 20 mm.

The annual rainfall of 1135 mm caused regular leaching into a local stream. Boron-rich leachate raised the stream concentration to >1.4 mg L^{-1}, the New Zealand Drinking Water Standard, especially in the summer months when stream flow was low. The site thus violated New Zealand's effects-based Resource Management Act, and the local authority demanded that the site be remediated.

In July 2000, HortResearch implemented a 1-ha trial using 10 poplar and willow clones and two species of *Eucalyptus.* Two *Populus deltoides* hybrid clones were best candidates for phytoremediation based on survival, biomass production and boron uptake. There was a large variation in tolerance of the trees to the wood-waste environment.

In July 2001, the remainder of the pile was planted at a density of 7000 trees ha^{-1}. Fertilisers were added periodically. A pump re-circulated leachate that occurred during the winter months and following high rainfall events. This leachate served as irrigation during the summer months. After three years of growth, the poplars had formed a closed-canopy over 50% of the pile. This figure increased to 80% the following year, with the tallest trees exceeding 8 m in height.

Before planting, the bare sawdust pile discharged boron-rich leachate during all months of the year. Following phytoremediation, the trees reduced the drainage to the three winter months. Summer is the greatest concern for waterways contamination because low stream flows result in less contaminant dilution. During winter, drainage may be released into a nearby stream at times of high flow when the risk of exceeding the New Zealand Drinking Water Standard is minimal.

Poplar leaves accumulated >1000 µg g^{-1} boron on a dry matter basis. Given the low concentrations of other contaminants, harvested poplar material could be applied to nearby horticultural land that is deficient in this boron. Periodic coppicing of the poplars could therefore remove boron from the site. Since the leaves contain most of the boron, coppicing should occur before abscission.

Our current research focuses on the effect of poplar roots on contaminant mobility. It is commonly assumed that plant transpiration and root-growth immobilise contaminants by reducing leaching, controlling erosion, creating an aerobic environment in the root-zone, and adding organic matter to the soil that binds metals. However, plant growth may also enhance contaminant mobility via plant uptake and by modifying the soil structure through the genesis of root-macropores, acting as preferential flow pathways. Preferential flow permits the rapid passage of contaminants through the vadose zone, creating a potential risk to receiving waters. There is a lacuna of knowledge on the plant-facilitated preferential leaching of trace elements, which are present in solution, or bound to mobile soil particles. Plant uptake of contaminants increases contaminant mobility if the shoots are consumed or otherwise redistributed via natural or anthropogenic means.