WISPAS
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PHYTOREMEDIATION OF HEAVY-METAL CONTAMINATED SOILS

Heavy-metal contamination of soils is a world-wide problem, and it is also common here in New Zealand, despite our 'clean green' image. Table 1 lists some forms of heavy-metal pollution in this country. Heavy metal pollution of the soil is cumulative - levels increase over time until the soil becomes unusable for production. Conventional treatments for these soils fall into three general categories: isolation, cleansing, and 'inerting'. Isolation may involve removal of the topsoil, covering with concrete or non-contaminated soil, or hydraulic isolation from surrounding areas. Cleansing involves the leaching of pollutants with acids. 'Inerting' is the addition of other chemicals to the soil which render the pollutants in a non-toxic form. Conventional procedures cost between US$ 100,000 to 1,000,000 per hectare. Furthermore these methods may leave the soil infertile, cause further pollution by leaching, or only be a temporary solution.

Rufus Chaney suggested, in 1983, that some heavy-metal contaminated soils may be cleaned by growing a crop of plants which accumulate the pollutants, then harvesting the plants and disposing of them in a 'safe area'. This process was termed *phytoremediation*, a summary of the operation is shown in Fig. 1. In 1993, McGrath and colleagues conducted the first experiments demonstrating that this process was feasible. Since these initial studies there has been a flood of publications on the subject and the appearance of an American company (*Phytotech*) specialising in heavy-metal phytoremediation. The cost these operations is estimated to be US$ 60,000 to 100,000 per hectare, around half the cost of the cheapest conventional operations. Unlike some conventional operations the solution is permanent, there is no pollution due to leaching, and the soil is left fertile.

Plants used for phytoremediation should be fast-growing, deep-rooted, easily propagated and accumulate the target metal. Poplars have three of the aforementioned properties making them good candidates for phytoremediation if they accumulate one or more of the heavy metals! An investigation is being carried out on the potential of the huge array of poplars developed by HortResearch for the phytoremediation of cadmium-contaminated soils such as most of New Zealand's pasture-lands.

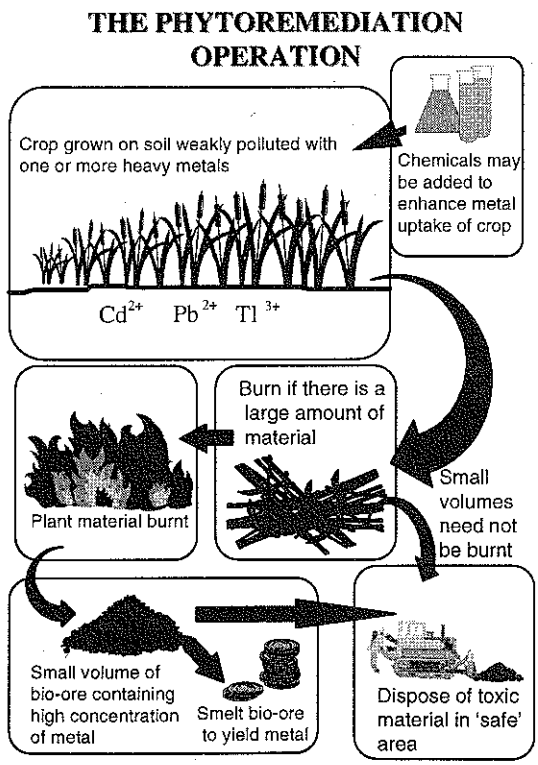

Figure 1: An overview of the phytoremediation operation.

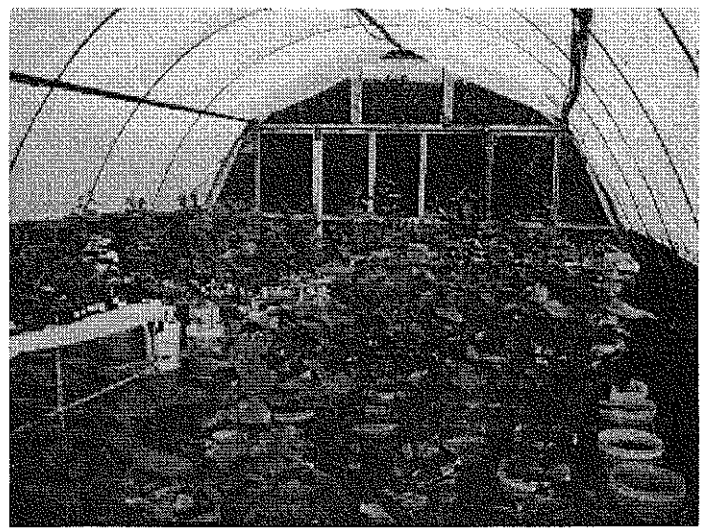

Figure 2: The poplars (1 month old here) used in the experiments.

Table 1. Forms of heavy-metal contamination in New Zealand.

Origin	Location	Metal(s)
Application of Cd-rich superphosphate fertilisers	Most pasturelands	Cd
Application of sewage sludge	Some-pasture lands and forestry areas	Ni, Cd, Zn, Pb
Copper based fungicides	Vineyards	Cu
Geothermal activity	Taupo volcanic zone	As, Hg
Base-metal mining	Tui mine, Te Aroha	Pb, As, Zn, Cd
Timber tannalising fluid	Small areas near timber-treatment plants	Cu, Cr, As

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The natural uptake of cadmium by poplars has been determined by growing them in soils with different cadmium loadings. In addition, the effects of adding chelating agents to the soil were investigated. Chelating agents are chemicals which bind strongly to metals rendering them soluble. It was hoped that metal uptake may be enhanced by the application of these chemicals. The chelating agents used were EDTA (ethylenediaminetetraacetic acid), DTPA (diethyltriaminepentaacetic acid) and NTA (nitrolotriacetic acid). Experiments were carried out in shade-houses at HortResearch, Palmerston North (Fig 2).

Fig. 3. shows the concentration of cadmium in above-ground portions of poplars grown in soil with different cadmium loadings. The results show that the cadmium concentration in the trees was higher than that in the soil. The highest bioaccumulation coefficient (metal in plant divided by metal in soil) occurs at low soil concentrations. Also shown in Fig 3. Is that the addition of EDTA to the soil causes a significant increase in plant cadmium uptake. NTA and DTPA induced similar responses to EDTA, but are omitted for clarity. EDTA degrades rapidly in the soil, so the addition of further pulses may further increase metal uptake. The addition of chelating agents did not kill the poplars, so the trees could still function and be used for subsequent harvests.

Results indicate that poplar has excellent potential for cadmium phytoremediation. If the plant-uptake in field conditions is similar to that has been achieved in these experiments then poplars could be used to decontaminated soils weakly contaminated with cadmium. Many years of fertilisation with superphosphate has increased levels of cadmium in New Zealand soils, in a few cases to levels above a self-imposed limit of 3 mg/kg. Soils with a cadmium loading above this limit cannot be used for production. An annual application of superphosphate fertiliser at a rate of 300 kg/ha adds about 10g Cd per hectare. With a single pulse of EDTA, poplars grown on a soil containing 4 mg/kg Cd (i.e. too high for agricultural pro ɔn) have a cadmium concentration in the dry above-ground bior .s o1 .g/kg. The biomass production of poplar under optimal conditions is 30 tonnes per hectare per annum. If we adopt a conservative approach and use a f'gure of 20 t/ha/yr, a single crop of poplars would remove 1.22kg of Cd/ha. This equates ' 122 years of fertiliser addition. A soil containing 4 mg/kg cadmium in the top 10cm of soil contains 4.8 kg of cadmium per hectare (ass..ming a bulk density of 1.2). A single crop of poplars treated with EDTA could reduce the soil cadmium-burden to 2.98 mg/kg, below the threshold of 3 mg/kg. Without the addition of EDTA, two croppings would be required.

Poplar phytoremediation would involve dense planting of poplar poles in the contaminated soil. Ground irrigation could be used to supply water, nutrients, and chelating agents to maximise growth and metal uptake. The above-ground biomass could be harvested in late-March, before leaf-fall. Since poplars coppice readily, no further planting would be required for subsequent crops. Over large areas the biomass could be used for fuel or paper production, offsetting the cost of the operation. Willows are already being grown for their biomass on contaminated soils that are unsuitable for agriculture in France.

Caution must be applied in extrapolating the results of these initial studies to field conditions. However, cadmium levels in poplars growing *in situ* on contaminated soils indicate that bioaccumulation factors under field conditions

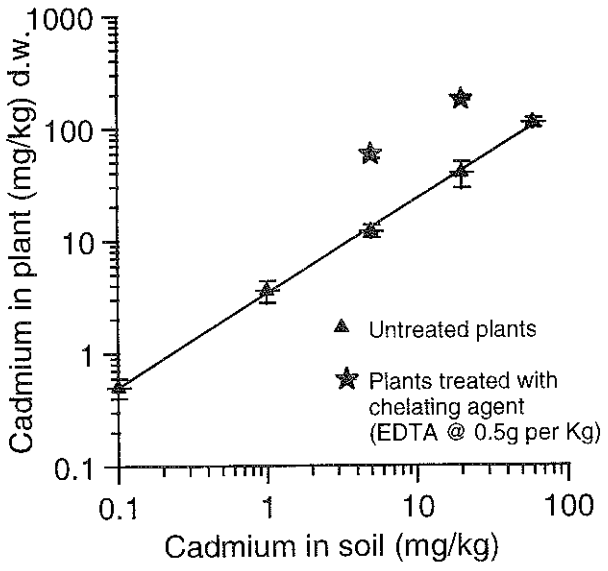

Figure 3: Cadmium in the dry above-ground matter of poplar, as a function of soil cadmium concentration

MICROMETEOROLOGY

This WISPAS **we honour as our *Professional* – the consultant meteorologist.**

"Maybe you should see a meteorologist about it."

PYSCHOLOGY

But psychology is a more tricky field, in which even outstanding authorities have been known to run in circles, describing things which everyone knows, in language which no one understands.

Raymond Bernard Cattell (1905-)
The Scientific Analysis of Personality (1965)
Harmondsworth (Pelican), p18

VACUUM

Entre le pénis et les mathématiques ... il n'existe rien. Rien! C'est le vide

Louis-Ferdinand Céline (1894-1961)
Voyage au bout de la Nuit
(Gallimard, Paris)

BIG WORDS – LITTLE WORDS

Long words name little things. All big things have little names, such as life and death, peace and war, or dawn, day, night, love, home.

Learn to use little words in a big way – It is hard to do. But they say what you mean. When you don't know what you mean, use big words. They often fool little people.

SSC Booknews
July 1981

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are the same, or better, than what has been obtained in this green-house study. Future work will involve small-scale field trialls and different regimes of chelating agent addition to maximise cadmium uptake. Poplars have the potential to provide a cheap method of cleaning up Cd-contaminated soils in New Zealand.

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