Geophysical Research Abstracts, Vol. 7, 08101, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08101

Phytoremediation/stabilisation of dredged sediment derived soils with willow

F. M.G. Tack (1), P.Vervaeke (1,2), E. Meers (1), B. Vandecasteele (3)

(1) Laboratory of Analytical Chemistry and Applied Ecochemistry, Ghent University, Belgium

(2) Laboratory of Forestry, Ghent University, Belgium

(3) Institute for Forestry and Game Management, Geraardsbergen, Belgium

Introduction

Phytoremediation is the use of green plants to remediate soil and groundwater. For inorganic contaminants, it can be further categorized into phytostabilisation and phytoextraction. Interest in these approaches has particularly raised over the last ten years.

While fast growing willows and poplars are excellent producers of biomass, they have several other characteristics that make them promising for use in phytoremediation. Willows in particular are fast to propagate, achieve high annual biomass production and have a good tolerance against elevated metal levels. They can stabilise polluted substrates, recycle nutrients and accumulate pollutants in their tissues. The percolation of nutrients and metals through the soil profile can be significantly reduced on sites planted with willow stands as a result of their high evaporation, water use efficiency and interception [1].

Dredging of sediments is needed to maintain the depth of waterways. These sediments tend to accumulate contaminants. In Flanders, Belgium, only about 6-7% of the underwater soils is considered as non contaminated [2]. Nowadays, sediments dredged from inland waterways are mostly being land disposed in confined facilities. In the past, sediments have been disposed along the shores of the waterways without precautions for contaminants eventually present. As a result, many areas containing elevated metal contents because of historical sediment disposal have been identified along waterways in Flanders [3] [4] [5].

Because of the large areas and moderate pollution levels involved, the use of phytoremediation could constitute a valuable option to control and manage contamination in dredged sediment derived soils. These substrates are typically rich in nutrients and appear as a highly suitable substrate for willow growth [6]. Using a specially adapted approach called the SALIMAT-technique [6] willows can easily be introduced on the still wet, impassable substrate.

Different approaches for managing moderate levels of metal contamination in dredged sediment derived soils using willow trees have been evaluated in greenhouse and field trials on test sites. One approach is to use willow for stabilizing the substrate and controlling the contamination while leaving it in place. A different approach involves targeting towards the removal of metals from the substrate pursuing metal uptake in the above ground plant parts and removal of the produced biomass. This involves the use of high metal-accumulating species, whereas uptake may be further enhanced by the use of appropriate soil amendments such as metal complexing agents.

Fytostabilisation

To evaluate dredged sediment as a substrate for growing willows, a 20×150 m disposal depot (test site 1) was successfully planted with the SALIMAT technique, that involves the use of rolls of connected willow rods [6]. Rods of a *Salix fragilis* clone and a *Salix triandra* clone were equally mixed in each mat. This SALIMAT proved to be an economic and effective planting technique for large areas of wet substrate. A high-density fast growing stand characterised by shoot densities of up to 54 shoots/m^2developed rapidly. The average annual production amounted to 13.4 ton DM/ha. Results of foliar analyses indicated that both species were supplied with sufficient N, P, K and Ca to ensure optimal growth.

The mixture of the two clones did not result in a polyclonal stand as *Salix triandra* was suppressed by *Salix fragilis*. The development of a willow stand was unsuccessful on parts of the depot with a sand fraction higher than 60%. The combination of on land contaminated dredged sediment disposal and biomass production with willow cultures is a feasible land use option to integrate both land uses into the environment.

The produced willow biomass can be valorised in the production of renewable energy. Metal flows in an experimental small scale fixed bed downdraft gasification installation were assessed. Large amount of the metals, especially Cd and Zn, present in the wood are volatilized during gasification but can be recovered in various ash fractions. These must, because of their metal content, be recovered and stored with proper care. On-site gasification of harvested biomass proved promising to produce electricity and heat in short rotation forestry on disposed dredged sediments.

Phytoextraction potential

Due to the manner of substrate introduction in a dredged sediment disposal site, a texture gradient is usually imposed on the field. Remediation of the entire test site (test site 2) to below criteria for re-use as soil would take 83 years based on the extraction of the most limiting element (Zn). However, a period of 11 years would already suffice to reduce the heavy metal concentrations to below legal criteria in 42% of the total area of the field. Only Cd and Zn were removed in acceptable amounts. Based on observed biomass yield and uptake in harvestable plant parts, realistic annual removal rates from 25 cm of soil were estimated between 1.3 – 8 mg/kg Zn and 0.02 – 0.2 mg/kg for Cd. These modest annual removal rates imply that the technique is only applicable for (i) moderate exceedances over legal criteria, for (ii) sites which are not in need for other activities or for (iii) the reduction of the phytoavailable fraction from heavy metal enriched agricultural soils.

When considering the application of tree species for phytoextraction of heavy metals in a short rotation forestry (SRC) system, the fraction of heavy metals sequestered in the leaves is of particular importance. The fraction of heavy metals in leaves as percentage of aboveground plant parts was 49% for Cd, 34% for Cu, 49% for Pb and 62% for Zn. For optimal metal removal, the foliar material would need to be harvested as well. However, this implies rotation periods of one year and harvest during the active growing season before leaf fall. This may impair plant vigour, the ability to resprout from the cut stumps and may ultimately affect annual yield. The possible detrimental effects of one year rotations and harvest during active growth need to be assessed in future research.

Enhanced fytoextraction

Heavy metal extraction by willows may be enhanced by using soil amendments that enhance plant uptake. Previous research has focused predominantly on the application of EDTA for evaluation of enhanced phytoextraction potential on heavily polluted soils. Considering its high environmental persistence, the use of EDTA in this context is highly questionable. The combination of elevated persistence with its capacity to mobilise heavy metals increases the risks for leaching of mobilised heavy metals from the top soil layer after harvest. To assess the longevity of mobilisation effects of soil amendments, water extractable levels of heavy metals were evaluated in sediments treated with increasing levels of EDTA, citric acid and EDDS. Citric acid and EDDS were studied as more biodegradable alternatives for EDTA. While citric acid proved not capable of increasing soil solution metal concentrations in the calcareous dredged materials, growth of *Salix dasyclados*'Loden' on three different soils treated with 2.5 mmol/kg EDDS resulted in significant increases of Cu and Ni uptake in all soils in addition to Cd and Zn in one of the substrates. Still, obtained increases in metal uptake were too limited for the use of soil amendments to be feasible. As research in this area is still early, it remains worthwhile to continue exploring approaches to increase achievable removal rates.

References

[1] Schnoor J., Kicht L., McCutcheon S., Wolfe N., Carriera L., 1995. Phytoremediation: an emerging technology for contaminated soils. Environmental Science and Technology 29 , 318-323.

[2] De Cooman W., Vos G., D'Hondt P., Van Erdeghem M., Meers B., Van Wauwe P., Wuyts S., Peeters B. , 2004. Kwaliteit van oppervlaktewater. In: Van Steertegem M.(. (Ed.) , MIRA-T 2004. Milieumaatschappij en natuurrapport Vlaanderen: thema's. Vlaamse Milieumaatschappij, Aalst, België, pp. 303-314.

[3] Vandecasteele B., De Vos B., Tack F.M.G., 2002. Heavy metal contents in surface soils along the Upper Scheldt river (Belgium) affected by historical upland disposal of dredged materials. The Science of the Total Environment 290 , 1-14.

[4] Vandecasteele B., De Vos B., Tack F.M.G., 2003. Temporal-spatial trends in heavy metal contents in sediment-derived soils along the Sea Scheldt river (Belgium). Environmental Pollution 122 , 7-18.

[5] Vandecasteele B., Quataert P., De Vos B., Tack F.M.G., 2004. Assessment of the pollution status of alluvial plains: a case study for the dredged sediment-derived soils along the Leie river. Archives of Environmental Contamination and Toxicology 47 , 14-22.

[6] Vervaeke P., Luyssaert S., Mertens J., De Vos B., Speleers L., Lust N., 2001. Dredged sediment as a substrate for biomass production of willow trees established using the SALIMAT technique. Biomass and Bioenergy 21 , 81-90.