

### Background

At sites of large scale mining and processing of uranium ore, tailings and waste rock piles are today the most visible relics of the uranium extractive industry. These mining relics are constantly subjected to weathering and leaching processes causing the dissemination of radioactive and toxic elements and sometimes requiring remedial operations. The *in situ* remediation of waste rock piles usually includes their revegetation for minimizing the water infiltration and for increasing surface soil stability. Thanks to its biomass density and longevity, the perennial vegetation plays an important role in stabilisation of the water cycling. The buffer role of forest vegetation can reduce water export from watersheds as well as erosion and hydrological losses of chemicals including radionuclides from contaminated sites. If long term reduction of contaminant dispersion at revegetated uranium mining sites is to be fully appreciated, then the extent of radioactive contaminant availability to forest vegetation and ecosystem cycling as well as the possible economic valorisation of the woody products must be considered.

### Objectives

Our study focused on a Scots pine plantation established 35 years ago on a uranium waste rock pile (Wismuth GmbH) situated near Schlema (Germany). This investigation aimed at quantifying the mobility of uranium in the mining debris and its transport to the different tree compartments with emphasis on the processes involved. The influence of pine vegetation on uranium cycling dynamics was further assessed in terms of annual fluxes.



*During the period from 1946 to 1990, some 220,000 tonnes of uranium were produced in the mining district of Saxony and Thuringia (Germany). Wismut GmbH is in charge of the remediation program to safely isolate and control the enormous quantity of uranium production residue. Our study was conducted in cooperation with Wismut GmbH on dump H382 situated near Schlema in Saxony. The mining debris consisted of low grade ore dumped at that site from 1950 till 1958.*

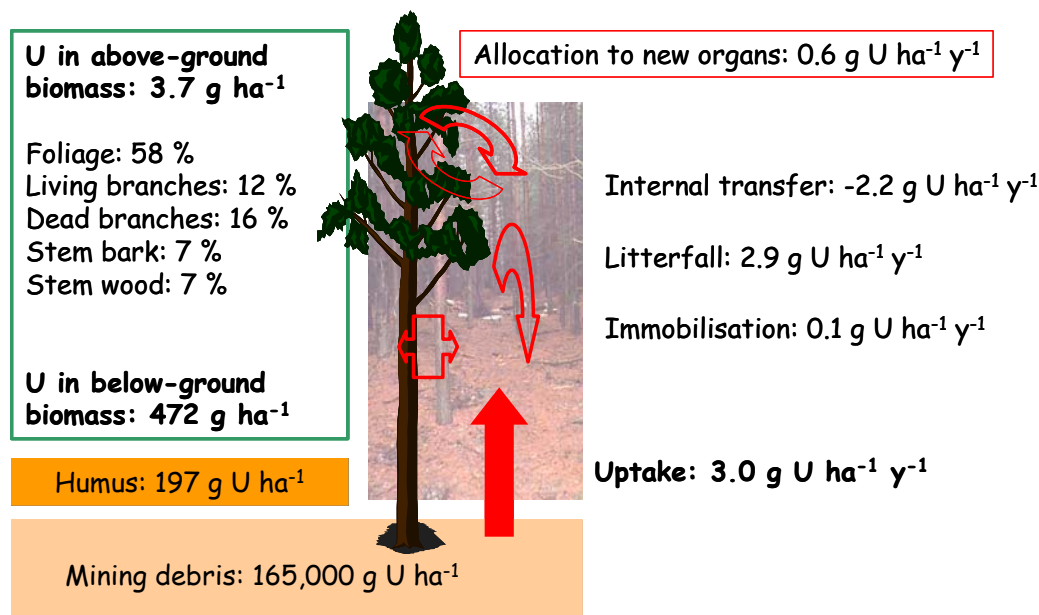
*Four average Scots pine were selected in a 35-year old plantation established on the plateau of the dump H382 and aliquots of the substrate were collected from three soil profiles. Samples of major tree compartments (stemwood, stembark, branches, twigs, needles, roots) were obtained from a destructive harvest of each tree. Soil and vegetation samples were transferred at SCK•CEN for determination of uranium levels by inductively coupled plasma mass spectrometer.*



## Principal results

### **Effect of vegetation development on uranium mobility in the mining debris**

With pine growth and biomass turnover, thick acid humus emerged at the surface of the substrate. Despite weathering of the alkaline mining debris, we did not observe a clear gradient with depth of the total uranium content ( $57\text{--}60\text{ mg dm}^{-3}$ ) which suggests a low vertical mobility of uranium in the profile. Increased uranium mobility mainly involved a translocation of uranium to metal-humus chelates in surface mineral layers (0-5 cm).



The quantitative description of the processes ruling the uranium distribution and annual recycling between soil and tree compartments showed that the amount of uranium taken up and translocated from roots to upper parts represents a minor fraction of the total pool in the mining debris. Due to a prevailing uranium accumulation within the foliage, a major part of the translocated uranium can be returned to the soil through litterfall.

### **Description of the uranium distribution in trees and processes involved**

Foliage was found to be the dominant uranium sink in standing tree (58 %) whereas uranium content in wood was lowest (7 %). The prevailing accumulation of uranium in the evaporative organs made it clear that most of the translocated uranium moved passively with the transpiration stream, almost certainly in a complexed form. The total uranium incorporated in the above-ground biomass amounted to about  $4\text{ g ha}^{-1}$  which is low compared to the average uranium content in the rooting zone (30 cm –  $165000\text{ g ha}^{-1}$ ). The stump and roots accumulated, however, 100 times more uranium than the upper part.

### **Quantification of the uranium cycling dynamics in terms of fluxes**

The net root uptake of uranium amounted to about  $3\text{ g ha}^{-1}\text{ y}^{-1}$ . The annual uptake exceeded by a factor 5 its allocation to new organs. That means that 80 % of the uranium transported from roots to upper portions of the tree was simply stored within older tissues, mostly senescing needles as corroborated by the high negative amount of the “internal transfer” flux for foliage. Litter fall returned to the soil  $2.9\text{ g uranium ha}^{-1}\text{ y}^{-1}$  whereas only  $0.07\text{ g uranium ha}^{-1}\text{ y}^{-1}$  i.e. ~2 % of the annual uptake was immobilized in perennial organs. By transferring to the soil 97 % of the uranium annual uptake, litter fall was shown to play a major role in tree detoxification.

### **Future developments**

The long term uranium distribution in a perennial vegetation cover will be compared with that of other radionuclides and trace elements before model development involving water and element cycling.

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### **Main reference**

Thiry, Y., P. Schmidt, M. Van Hees, J. Wannijn, P. Van Bree, G. Ruffykiri and H. Vandenhove. "Uranium distribution and cycling in Scots pine (*Pinus sylvestris* L.) growing on a revegetated uranium mining heap". Journal of Environmental Radioactivity (accepted for publication)