Managing the Environmental Effects of Swiss Banking

In most countries, environmental degradation results from wealth-generating activities. Agriculture is associated with persistent pesticide pollution, and the eutrophication of lakes. Mining generates metal-contaminated lands and manufacturing disperses contaminants into the atmosphere, waterways and soils. Switzerland has become rich by providing reliable and secure banks where investors can safely deposit their hoards. To avoid invasion and preserve their neutrality, the Swiss have maintained the second largest armed force *per capita* after the Israeli Defence Forces. The maintenance of the small-arms capability of this highly militarised nation requires an ample supply of readily available shooting ranges.

Each year, an estimated 400 tons of lead enter Swiss soils at some 2000 shooting ranges scattered throughout the country. Once in the soil, the bullets and bullet fragments oxidise through the weathering actions of air, water, organic acids and microbial activity. In addition to lead, shooting-range soils are burdened with antimony, nickel, copper, and other elements that are added to improve the ballistics of the ordinance.

We measured average trace element concentrations in thirty soils and plants from a disused shooting range in Lucerne. In the stop butt, we found average lead, antimony, copper and nickel concentrations of 10%, 0.5%, 0.4% and 0.09% respectively. This high metal burden may explain the failure of vegetation to establish (Figure 1), even though more than five years has elapsed since the last shot was fired. Lead, an element that is not usually considered mobile in the plant-soil system, is taken up by some plants on shooting ranges to concentrations of >0.1% on a dry matter basis. This creates an exposure pathway for this toxic element to enter the food chain. Worse, some 4 mg/kg of lead were found to be soluble in 0.1 M sodium nitrate, an extractant used in Switzerland to estimate the mobility of metals in soils. This indicates that in some places, lead from shooting ranges may raise the concentration in drinking water above the World Health Organisation's guideline of 0.01 mg/l.

Figure 1. Simone Bischofberger is investigating plant-soil interactions on a disused shooting range in the Canton of Lucerne, Switzerland. Here, the paucity of vegetation may be explained by average soil lead and antimony concentrations of 10% and 0.5% respectivly.

Metal contamination on shooting ranges is not limited to the stop-butts. Stray bullets and the redistribution of soil has elevated the average concentration of the whole four-hectare shooting range to >0.01% lead with hot spots of >1% lead. This amounts to a considerable area of contaminated land, given that shooting ranges account for 3.5 % of the total surface area of the Canton of Lucerne.

How can we manage the soil of disused shooting ranges? Conceivably, one could remove the stop-butts and reprocess the soil to recover the lead. However, it is impractical to remove of all the contaminated soil, or cap entire shooting ranges with non-contaminated material. Nor is there any technology that would permit the safe *in situ* decontamination of such sites. The only viable option is to use vegetation and soil conditioners to reduce the mobility of the contaminating trace elements, thereby reducing the exposure pathways to humans and ecosystems.

Since vegetation will eventually cover most disused shooting ranges, land managers could select plants that do not accumulate toxic metals in their aboveground portions and reduce the leaching of these metals into receiving waters. Intuitively, deep-rooted phreatophytic tree species may seem like a logical choice, since they would maximise evapotranspiration from the site, thus minimising drainage. However, roots of such deep-rooted trees may create preferential flow pathways that actually exacerbate contaminant leaching. We aim to improve the phyto-management of contaminated sites by elucidating the mechanisms of contaminant-root interactions.

Similar to other polluted sites, contaminants in shooting ranges occur heterogeneously. The interactions of roots with hotspots are of overriding importance on the contaminant fate. Root avoidance of hotspots will reduce contaminant mobility because of reduced plant-uptake. Conversely, when roots penetrate a hotspot, the plant may accumulate higher amounts of the contaminant and the contaminants may have a preferential flow conduit into receiving waters.

Until recently, a lacuna of non-destructive measurement technologies has hampered the visualisation of the growth and activity of living roots. The Paul Scherrer Institut (www.psi.ch), Villigen, Switzerland has developed a facility to visualise roots in soil using neutron radiography and tomography. Using this technique, we can investigate the response of roots to heterogeneously distributed contaminants in soil. Figure 2 shows the inhibition of root growth of a lupine in a zone of boron-spiked soil. Interestingly, lupine roots survive and grow in soil that is homogeneously spiked with boron. This may indicate the presence of a root-strategy.

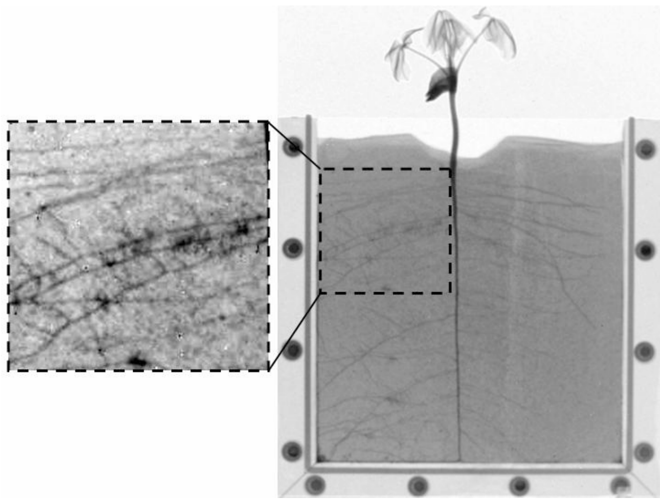

Figure 2. A neutron radiograph of a lupine growing in a 150 x 150 x 10 mm aluminium slab containing soil partitioned with 20 mg/kg added B in a 50 mm vertical strip on the right hand side of the image. The left hand 100 mm contained no added B.

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Neutron radiography can also reveal the water flux in the root zone. Figure 3 shows the water movement after we infiltrated 10 ml of water into the same plant as shown in Figure 2. Figure 3 shows not only the passage of the wet front, but also root-uptake and translocation to the shoots. Here, the downward movement of water was faster in the boron-spiked zone, where roots were scarce. We are developing experimental techniques and image processing tools to obtain quantitative data from such neutron radiographs.

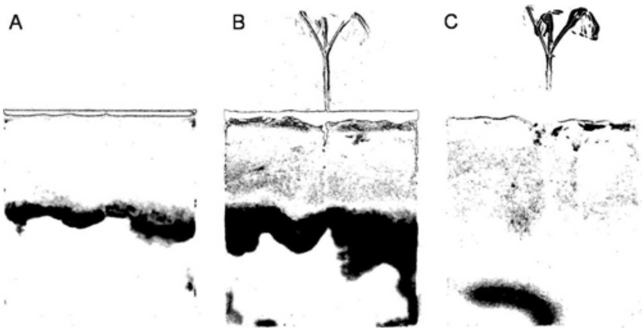

Figure 3. The change in water content of the plant shown in Figure 2 after the infiltration of 10 ml of water (A 1-2 min, B 2-5 min, C 28-40 min). The wet-front shows up as a dark band, while root water uptake is visible in B and C as a discontinuous grey area.

Using neutron radiography, we endeavour to elucidate contaminant root interactions on the single plant scale with the aim of producing more accurate whole system models of contaminant transport. However, to be useful in the real world, such models require validation at larger scales. We are investigating the role of roots in preferential flow using large lysimeters (Figure 4) covered with both shallow and deep-rooting vegetation. Following a rain event, we will intensively measure drainage from the lysimeters to investigate preferential flow and contaminant leaching.

Figure 4. Dr Stéphanie Roulier is unravelling the effect of root depth on preferential and contaminant transport using eight lysimeters (5 x 3.5 x 1 m) near the city of Lucerne.

Swiss banking is a boon for environmental science. It has resulted, indirectly, in a suite of metal-contaminated soils, a veritable living laboratory. Moreover, it has provided, though unfortunately not yet made available, the financial means that Switzerland needs to develop new environmental management technologies.

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Bottom Sealing to Reduce the Release Rate of CCA from Wood Posts

Copper, chromium arsenic (CCA) compounds are used extensively in the New Zealand timber preservation industry and all of the elements are potentially highly toxic to biota. In New Zealand vineyards, CCA treated timber posts are used at a density of around 600 posts per hectare. The release of CCA metal(loid)s can result in their accumulation in the soil, leaching into the groundwater and potentially taken up by the vines. Research has shown that components of CCA leach from the wood surface into the surrounding soil, thus elevating the concentrations of Cu, Cr and As in the vicinity of those structures (Robinson et al. 2006; Carey et al. 1996). Leaching of CCA preservatives from the treated posts involves a number of different processes, including initial loss of surface deposits and unfixed components, penetration of water into wood and hydrolysis or dissolution of the fixed components, and migration of preservatives to the surface of the wood.

During the timber treatment operation, the preservative penetrates into the timber through xylem vessels (Cooper and Churma 1990). Considering the leaching process, water containing CCA is more mobile along the longitudinal axis of the treated wood post followed by the movement along radial direction. Thus higher CCA concentrations have been measured underneath posts than to their side (Robinson et al. 2006). Therefore end-sealing might reduce the leaching of CCA from the timber posts via the end-grain.

In this experiment, three full round 11 cm diameter H4-treated pine wood posts were sealed with paint (Gripset Multi Purpose Bitumen Rubber) on the bottom to reduce the release rate of CCA. Three further unsealed posts were used as a control. The posts were submerged in a 50 L container of freshwater for eight months and water samples were collected at four week intervals to assess the CCA leaching losses from the posts.

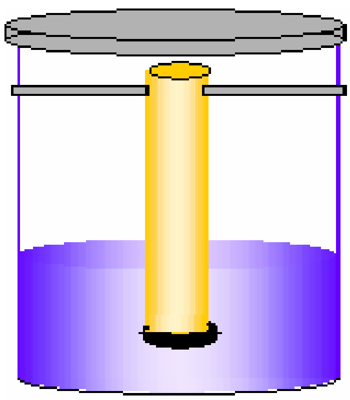

Figure 1. The experimental set-up of the CCA leaching study on H4-treated timber posts with sealing of the bottom.

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