Experimental manipulation of urban soils: stability and mobility of heavy metals and arsenic in relation to soil carbon

Luke Beesley, Nicholas Dickinson

Faculty of Science, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK, l.beesley@2007.ljmu.ac.uk, n.m.dickinson@ljmu.ac.uk

Organic amendments can be used to improve the amount of carbon stored in degraded urban and brownfield soils that are currently well below saturation levels. However, organic matter also has a significant impact on the mobility and fate of residual pollutants in the soil (Clemente et al, 2008). Experimental manipulation of urban soils through application of composted greenwaste and biochar is described, in both field and laboratory experiments, in the context of residual metals and arsenic. A model of carbon storage in urban soils has been developed, based on detailed analysis of soil profiles, lysimetry, leachate analysis using rhizon samplers, Dissolved Organic Carbon (DOC) mobility and respirometry (using an open chamber respirometer). Soil profiles were excavated and rhizon porewater samplers were placed within the soil profile and amendments.

Significant differences in the solubility of individual dissolved elements within the porewater from the compost mulch layer were observed (Fig. 1). Mobility of Cu, Zn and Pb were correlated with DOC whilst As was not, indicating the possible rapid leaching of dissolved As through the soil profile. Large seasonal fluctuations in DOC concentrations in porewater from compost and control soils showed a large contributory effect of soil hydrology. Soil organic matter affects the dispersal of pollutants through its binding and buffering capacity and through decomposition. The decomposition of organic matter releases essential plant nutrients, whilst forming complexes (chelates) with heavy metals and binding organic pollutant residues, but the sorption and fixation capacity for heavy metals by humified organic matter in the long term is not well understood. Biochar, unlike compost, has a low soluble carbon content and may be able to effectively store carbon in soils without enhancing metal mobility. In this paper the results are interpreted in the context of (i) the realistic steady state or carrying capacity of C in urban and remediated brownfield soils. And (ii) whether there is a risk to groundwater quality from metals and As if organic materials are applied to contaminated soils.

References
Ecological and biological research on soil quality, ecological rehabilitation and sustainable management in North-East Romania

Geanina Bireescu, Lazar Bireescu

Biological Research Institute, Ecology and Biological Control Department, 700107 Iasi, Romania, bireescugeanina@yahoo.com, lazarbireescu@yahoo.com,

Soil quality evaluation is a tool to assess management-induced changes in the soil and to link existing resource concerns to environmentally sound land management practices. Ecological and biological research on soil quality was carried out in pasture ecosystems on Gleyc chernozem in humid areas of the forest steppe in Oroftiana and Liveni counties. From an ecological point of view, we analyzed a “constellation” of 20 main ecological factors and determinants, climatic and pedologic, through 8 quantitative classes of ecological size and 6 qualitative classes of ecological favorability. The main ecological determinants were by lack or excess: the low level of summer precipitations, the dry winds, the fine texture and the hard soil consistency in the summer season, the low aero-hydric regime of the soil, the soil treading, the excess of subsoil water. Using a matrix of ecological impacts (Leopold method, 1971 improved by Bireescu, 2007) we identified the main negative ecological effects which have induced the degradation of soil resources and structure of biocenosis. From a pedo-biological point of view we pointed out a moderate enzymatic activity (catalase, invertase, urease, total phosphatase and the Indicator of Enzymatic Activity Potential) because overgrazing and soil compaction affected soil enzymes. These ecological and biological studies pointed out the need of rehabilitation of these degraded lands through protective forest belts, drainage and rational grazing.

Table 1. The graphical matrix of ecological impact

<table>
<thead>
<tr>
<th>Ecological factors and determinants of negative impact</th>
<th>Low soil aeration</th>
<th>Soil treading</th>
<th>Decreased biological activity</th>
<th>Decreased trophic potential</th>
<th>Ruderalization and detrimental species</th>
<th>Soil compaction</th>
<th>Decreased ecosystem productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess of subsoil water</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>□</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Lack of drainage</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Hard summer soil consistency</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Low level of summer precipitations</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Fine soil texture</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Dry wind</td>
<td>□</td>
<td>□</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Overgrazing</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Legend: □ minor impact  ○ moderate impact  ● major impact

References

Groundwater radioactivity at the former uranium and radium mining region of Sabugal, Portugal, and environmental remediation

Fernando P. Carvalho, João M. Oliveira

Nuclear and Technological Institute, Department of Radiological Protection and Nuclear Safety, E.N. 10, 2686-953 Sacavém, Portugal, carvalho@itn.pt

In Sabugal county in the central region of Portugal, several radium and uranium mines were in operation during the first half of the 20th century. One mine, Bica Mine, the largest in this region was in operation until the late 80s. After the closure of mines there has been no environmental remediation works to cover the mining and milling waste heaps left on site. Recent concerns have been raised of potential radiological hazards by radioactivity measurements in underground waters of this region. Water samples collected at the former uranium mines, in irrigation wells nearby, and in drinking water supplies to villages in the region were analyzed for uranium series radionuclides by radiochemistry and alpha spectrometry. Water from the Bica Mine contained 4.4 Bq L$^{-1}$, 1.5 Bq L$^{-1}$, and 0.48 Bq L$^{-1}$ of dissolved $^{238}$U, $^{226}$Ra and $^{210}$Po, respectively, and these were the highest concentrations measured in waters from this region. Water samples from other mines were under 150 mBq L$^{-1}$ of $^{238}$U and $^{226}$Ra and even less for other radionuclides. Water from irrigation wells in the region generally displayed concentrations under 50 mBq L$^{-1}$ both for $^{238}$U and for $^{226}$Ra, although water from several wells in the surroundings of the Bica Mine displayed enhanced concentrations of dissolved uranium, reaching 820 mBq L$^{-1}$ of $^{238}$U, although not accompanied by high concentrations of other radionuclides, such as $^{226}$Ra, $^{210}$Po and $^{230}$Th. Enhanced uranium concentrations are likely due to migration of mine water from Bica Mine into the aquifer. Water from a local spring used to supply a village exceeded the recommended limit for alpha radioactivity in drinking water with 1.12 Bq L$^{-1}$. The overall assessment of radioactivity in water at this uranium mining region indicates that water resources were not significantly contaminated by the historic uranium mining activity. Nevertheless, mine water from Bica Mine require acid treatment to prevent dispersal of the acid and radionuclides into the aquifer and, thus, requires remediation. This is currently performed through active pumping of acid water from the underground mine for neutralization at the surface, a process that is costly in energy and chemicals. Other options, such as reduction of dissolved uranium $^{6+}$ to $^{4+}$ which may precipitate this radionuclide in the underground mine, could be implemented to prevent dissemination of radioactive water into the aquifer. Waste materials deposited on the surface at Bica Mine and at other mine sites contain high concentrations of radionuclides of the uranium family. Through erosion and leaching by rain water these waste piles may enhance natural radioactivity levels in the watershed of streams as observed elsewhere (Carvalho et al., 2007 a, b) and thus require adequate confinement. These aspects of legacy uranium mine sites and the need for environmental remediation are discussed.

References


Radionuclides in plants growing on sludge from uranium mine water treatment

Fernando P. Carvalho, João M. Oliveira, Margarida Malta

Nuclear and Technological Institute, Department of Radiological Protection and Nuclear Safety, E.N. 10, 2686-953 Sacavém, Portugal, carvalho@itn.pt

After closure, uranium mines may generate acidic and radioactive waters for many years. This acid drainage originates in the dissolution of sulphur from the rock but, in many cases, also from sulphuric acid used for the in situ extraction of low grade uranium ores. Neutralization of the acid with lime and co precipitation of radionuclides with barium sulphate in water treatment tanks, produces sludge (mud) that is disposed of in surface ponds. Most of radioactivity, especially uranium, originally in mine water is transferred to the sludge (Carvalho et al., 2006). Sludge remains in these ponds generally as a swamp where spontaneous vegetation develops. Accumulation of radionuclides by this vegetation was assessed to check the potential transfer of radioactivity into the terrestrial food chain.

Samples of vegetation growing in sludge ponds of the acid mine water treatment station of Urgeiriça uranium mine (North of Portugal) were collected in June 2007. Grass (Polygonum sp.), reeds (Phragmites sp.), and rush (Typha sp.) were washed with tap water and dried. Homogenates of samples were analyzed for the main radionuclides of the uranium family by radiochemistry and alpha spectrometry. Radionuclide concentrations in vegetation growing in the sludge ponds vary with the type of vegetation. Grass displayed the highest concentrations, attaining 62 Bq kg\(^{-1}\) (dry weight) for \(^{238}\text{U}\) and 25 Bq kg\(^{-1}\) (dry weight) for \(^{226}\text{Ra}\). Comparing these concentrations with pasture from the same region, grass from the sludge ponds contained 30 times more uranium than pasture, but about the same \(^{226}\text{Ra}\) concentration. Uranium concentrations in the sludge were about 180 times higher than in soils of the region. In spite of high concentrations in sludge, plants grown on the sludge did not accumulate radionuclides up to the same extent as soils, indicating that radionuclides probably were not fully available for bioaccumulation by plants. Nevertheless, vegetation growing on the sludge from uranium mine water treatment contained enhanced concentrations of uranium and uranium daughters. This vegetation may transfer radionuclides to grazing animals and is not suitable as livestock feed.

Table 1. Radionuclide concentrations in Bq kg\(^{-1}\) (dry weight) or Bq L\(^{-1}\) for water samples. Relative uncertainties are around 5% at 1 SD level.

<table>
<thead>
<tr>
<th>Sample</th>
<th>(^{238}\text{U})</th>
<th>(^{234}\text{U})</th>
<th>(^{230}\text{Th})</th>
<th>(^{226}\text{Ra})</th>
<th>(^{210}\text{Pb})</th>
<th>(^{210}\text{Po})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge</td>
<td>41600</td>
<td>40200</td>
<td>13400</td>
<td>1690</td>
<td>--</td>
<td>1180</td>
</tr>
<tr>
<td>Grass leaves</td>
<td>62</td>
<td>60</td>
<td>10</td>
<td>17</td>
<td>25.4</td>
<td>10.6</td>
</tr>
<tr>
<td>Reed leaves</td>
<td>2.8</td>
<td>2.6</td>
<td>2.3</td>
<td>58</td>
<td>16.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Rush leaves</td>
<td>7.6</td>
<td>7.8</td>
<td>1.6</td>
<td>3.6</td>
<td>10.2</td>
<td>4.5</td>
</tr>
<tr>
<td>Pasture</td>
<td>1.79</td>
<td>1.74</td>
<td>2.4</td>
<td>25.2</td>
<td>6.3</td>
<td>0.67</td>
</tr>
<tr>
<td>Soil from the region</td>
<td>230</td>
<td>235</td>
<td>300</td>
<td>615</td>
<td>290</td>
<td>290</td>
</tr>
</tbody>
</table>

References

Recovery of post-agricultural forest: Tree species determines soil properties and possibilities for ecosystem restoration

De Schrijver An¹, Baeten Lander¹, De Clerck Elke¹, Thomaes Arno², De Keersmaeker Luc², Staelens Jeroen¹, Wuys Karen¹, Hansen K.³, Vesterdahl L.³, Muys Bart⁴, De Neve Stefaan⁵ & Verheyen Kris¹

¹ Laboratory of Forestry, Ghent University, Geraardsbergsse Steenweg 267, B-9090 Gontrode (Melle) - Belgium, An.Deschrijver@Ugent.be, Lander.Baeten@Ugent.be, Elke.Declerck@Ugent.be, Jeroen.Staelens@Ugent.be, Karen.Wuys@Ugent.be, Kris.Verheyen@Ugent.be.
² Institute for Nature and Forest Research, Gaverstraat 4, B-9500 Geraardsbergen - Belgium, Arno.Thomaes@Inbo.be, Luc.Dekeersmaeker@Inbo.be.
³ Department of Forest Ecology, Danish Forest and Landscape Research Institute, Hørsholm Kongevej 11, DK-2970 Hørsholm, Denmark, kiha@Life.ku.dk, lv@Life.ku.dk.
⁴ Division Forest, Nature and Landscape, University of Leuven (K.U.Leuven), Celestijnenlaan 200E, B-3001 Leuven, Belgium, Bart.Muys@Biw.kuleuven.be
⁵ Department of Soil Management, Coupure Links 653, B-9000 Gent – Belgium, Stefaan.Deneve@Ugent.be

Reforestation of agricultural land in many European countries has progressed more slowly than anticipated. Many years’ fertilization has caused an accumulation of nutrients in the top soil layer. Phosphorus (P) has proven to be particularly persistent and elevated concentrations in soil and vegetation are found up to thousands of years after agricultural abandonment. This persistently elevated bioavailable P is a paradox for ecosystem recovery in post-agricultural forests: on one hand, higher P bioavailability stimulates stand productivity and tree growth but, on the other hand, it limits the development of typical forest plant communities (Baeten et al. in press) and associated organisms. Limitation of bioavailable P seems to be a necessity for the recovery of species-rich target communities and for the conservation of endangered species (Wassen et al. 2005).

Reforestation of agricultural land results in a decrease in soil pH with increasing forest age, but the extent and rate of soil acidification differs highly between tree species. Gymnosperm tree species are often contrasted to angiosperms because of their acidifying impact on soils. We will present data showing that rapid (within 2 decades) changes in soil properties can also occur beneath different broadleaved tree species. Ca concentrations in leaf litter seem to be the driving factor for differences between species: tree species with higher litter Ca concentrations such as *Populus* and *Fraxinus* support a significantly higher soil pH, base saturation degree and lower quantities of bioavailable aluminum compared to the Ca-poor *Fagus* and *Quercus* species. *Tilia* and *Prunus* trees are intermediate between these ‘soil preservers’ and ‘soil acidifiers’. Furthermore, tree species have a major influence on the short-term and long-term bioavailability of P. Below ‘soil acidifiers’ we found significantly higher bioavailable and slowly cycling P fractions compared to ‘soil preservers’ which mainly retained P in less soluble pools.

To date, there are no integrated studies on the long-term effect of different broadleaved tree species on soil properties in general and the bioavailability of P through soil acidification in particular. Most studies evaluating the bioavailability of P use extraction methods that only provide short-term dose-response insights into the readily available P pool for plants and soil microbes. However, for studying the role of P in recovering (semi) natural ecosystems, it is much more relevant to gain insight into time-scales extending a single growing season (Richter et al. 2006) and to include more slowly cycling P fractions. We discuss six common garden experiments in which broadleaved tree species have been planted on loamy agricultural soil for between 5 and 35 years. We argue that vegetation choice can be an important driver of regional biogeochemistry and biodiversity.

References
Biogeochemical aspects of rehabilitation of contaminated soil and sediment: an urban case study

Nicholas Dickinson, William Hartley

Faculty of Science, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK, n.m.dickinson@ljmu.ac.uk, w.hartley@ljmu.ac.uk

Brownfield land consisting of a closed old-style sanitary landfill, derelict former industrial land and an adjacent abandoned canal with 1.5m depth of contaminated sediment is being converted into an urban nature park. This paper describes the site investigation, risk assessment of the site and the practicalities associated with conversion of the site to manage risk, improve the nature conservation status and to demonstrate the use of sustainable soft end-use remediation techniques. No materials have been exported from the site, but recyclable wastes have been imported to stabilize pollutants and for habitat improvement. The challenge for the research component of the project was to understand the mobility and sustainable management of metals, arsenic and PAHs, both from disturbed canal sediment and from hotspots on land, in the context of human, groundwater and ecological receptors. Biogeochemical aspects of the rehabilitation are the focus of this paper.

Engineering work began in 2008, transferring sediment from the centre to the sides within the 15 m wide canal, leaving open water in approximately 50% of the width of the canal. The transferred sediment was retained using gabions and covered with a geotextile membrane and a variety of growth substrates that used recycled materials including green waste compost. Contamination hotspots aside from the canal were monitored whilst being amended with imported compost and other materials to create a diversity of habitats ranging from calcareous to acidic wildflower meadow communities. Complex mixtures of metals, arsenic (Table 1) and hydrocarbons (benzo [b] and [k] fluoranthenes, Benzo [a] pyrene and Dibenzo [a,h] anthracene) at highly elevated concentrations exist in the canal sediment. This residual contamination has little pollution linkage when permanently covered by non-flowing water largely due to the associated reduced, anoxic conditions that are maintained in the undisturbed sediment. When the sediment is disturbed or exposed, drying and oxidation brings about profound physical and chemical changes (Table 2). Associated changes in pH, Fe and S status rapidly cause some elements (including heavy metals) to become highly mobile.

Table 1. Total metal concentrations (mg kg\(^{-1}\); means \(\pm\) s.d.), pH and LOI of sediment [n = 166].

<table>
<thead>
<tr>
<th>As</th>
<th>Fe</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>397</td>
<td>46298</td>
<td>12</td>
<td>918</td>
<td>642</td>
<td>1370</td>
<td>2584</td>
</tr>
<tr>
<td>12</td>
<td>9333</td>
<td>6.6</td>
<td>177</td>
<td>135</td>
<td>425</td>
<td>1374</td>
</tr>
<tr>
<td>pH (wet sediment)</td>
<td>pH (dry sediment)</td>
<td>LOI (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td>5.7</td>
<td>26</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 2. Changing pH of canal sediment following exposure to the atmosphere for up to 41 days

<table>
<thead>
<tr>
<th>No. of days</th>
<th>0</th>
<th>4</th>
<th>6</th>
<th>16</th>
<th>20</th>
<th>24</th>
<th>36</th>
<th>41</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.85</td>
<td>4.57</td>
<td>4.03</td>
<td>4.67</td>
<td>4.28</td>
<td>3.96</td>
<td>4.42</td>
<td>3.67</td>
</tr>
</tbody>
</table>

Concerns in the hotspots aside from the canal related to five key contaminants present in surface soils at potentially significant concentrations: benzo(a)pyrene, bis(ethylhexyl)phthalate, hexachlorobutadiene, vinyl chloride and arsenic. However, the canal sediment presented a much more complex system within which to confidently manage contaminants in the medium- to long-term. Precautionary exposure scenarios have been modeled and are evaluated from a biogeochemistry perspective.

References

Arsenic stability at a grassland site overlying chemical waste

William Hartley, Nicholas Dickinson

Faculty of Science, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK, w.hartley@ljmu.ac.uk, n.m.dickinson@ljmu.ac.uk

A 6.6 ha grassland landscape, established on a former chemical waste site adjacent to a residential area, contains arsenic (As) in surface soil at concentrations 200 times higher than UK soil guideline values, following rehabilitation in the 1980s and to the restoration standards of that era (Hartley et al., 2009). The site is not recognized as statutory contaminated land, partly on the assumption that mobility of the metalloid presents a negligible threat to human health, groundwater and ecological receptors. Evidence based on several studies including data on the effect of organic (green waste compost) and inorganic (iron oxides, lime and phosphate) amendments on As fractionation, mobility, plant uptake and earthworm communities are evaluated in this paper.

Arsenic mobility was significant, largely related to dissolved organic carbon (Fig. 1) and phosphate; iron oxides immobilized As (Fig. 2). Plant uptake was low and there was no apparent impact on earthworms. The existing vegetation cover may minimize re-entrainment of dust-blown particulates that would otherwise present human health risk. Risks to other receptors are low, but results suggest avoiding disturbance and soil exposure, and compost and phosphate application that may mobilize As.

A realistic interpretation of the evidence is that surface soil at Merton Bank is contaminated with As, but currently appears to be relatively stable in terms of environmental mobility of this element. The metalloid generally is not mobile and strongly adsorbed in the soil. The reclamation carried out at Merton Bank in 1980 falls below acceptable modern standards, but appears to have remained relatively stable for the past 28 years. In common with many brownfield sites in this region and elsewhere in the UK, the approach to management is through Monitored Natural Attenuation (Environment Agency, 2004). Natural processes are unlikely to adequately resolve the pollution issues, but there is no evidence that suggests any exacerbation of risk. This site is not currently monitored in any form.

Surface soils will naturally accumulate organic matter from vegetation over time and potentially this could increase As mobility. Amending the site with recycled GWC or fertilizing with phosphate would not appear to be sensible options for sustainable site management. In terms of future management, clearly, iron oxides are worth considering as an amendment to reduce As mobility if remediation is required to prevent mobilization of the metalloid to the wider environment. To date, As mobility into deeper layers of the waste has not been investigated, which is a major shortcoming of the existing site characterization. More detailed studies of downward As migration, particulate re-entrainment and ecological monitoring at Merton Bank are required.

Reference

Figure 1. Relationship between concentrations of pore water As and water soluble organic carbon in untreated (o) and GWC (30% v/v) treated (A) Merton Bank soil.

Figure 2. Changes in labile As in Merton Bank soil as a function of amendments (1% w/w), assessed using the modified Dutch Leaching test (means ± s.d., n=3).
Carbon accumulation in young Scots pine (*Pinus sylvestris*) stands in reclaimed oil shale opencast mine

Helen Karu¹, Robert Szava-Kovats¹, Margus Pensä², Olevi Kull¹

¹ Institute of Ecology and Earth Sciences, University of Tartu, Lai 40, 51005 Tartu, Estonia, helen.karu@ut.ee, robert.szava-kovats@ut.ee
² NE Estonian Department, Institute of Ecology, University of Tallinn, Pargi 15, 41537 Jõhvi, Estonia, marpen@tlu.ee

An understanding of carbon dynamics in reclaimed mine spoils may enhance their potential future use to sequester carbon through better management. In Estonia, mining of oil shale in opencasts has degraded about 130 km² of land. *Pinus sylvestris* has been the main species planted on the levelled spoil, nowadays covering over 80% of the reclaimed area. The aim of this study was to estimate total carbon stock and its distribution along forest ecosystem partitions in three Scots pine stands growing in the Narva oil shale opencast, north-east Estonia. Sites were afforested with 2-year-old seedlings in 1990, 1983 and 1968. In 2004, a circular plot of 100 m² was established in each stand for the vegetation survey, soil profiles were sampled in 2005. Dry mass of different tree fractions was calculated using allometric equations derived from model tree data, understory biomass was measured in randomly placed sample quadrats.

Estimation of soil organic carbon (SOC) accumulation was made difficult by the presence of carbon-containing oil shale fragments in the soil; currently there is no definitive methodology to differentiate plant-derived recent carbon from fossil carbon. We determined the contribution of recent carbon to total SOC by combining measured radiocarbon activities of different soil horizons with a simple model of litter production and the record of atmospheric $^{14}$C. The share of recent carbon was 99–100% for the forest floor horizons and decreased with depth. SOC in the C-horizon originated mostly from oil shale, but contained also considerable amounts of recent carbon (16–39% of total organic carbon). This was presumed to be largely a legacy from pre-mining ecosystems.

Plantations of Scots pine showed remarkably good growth on calcareous and stony oil shale mining spoil, accumulating over 130 t C ha⁻¹ less than 40 years after establishment (Table 1). Most of the added carbon was allocated to tree biomass (76–87%), but the share of SOC was increasing with stand age. Recent carbon stock in topsoil (O and A-horizons) formed 5% of the ecosystem total in the youngest, 15% in the second and 24% in the oldest stand.

Table 1. Carbon stocks (t ha⁻¹) of Pinus sylvestris stands. The carbon content of all biomass fractions was considered to be 50%.

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Year of afforestation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1990</td>
</tr>
<tr>
<td>Stems</td>
<td>2.2</td>
</tr>
<tr>
<td>Needles</td>
<td>2.0</td>
</tr>
<tr>
<td>Living branches</td>
<td>1.7</td>
</tr>
<tr>
<td>Dead branches</td>
<td>0.04</td>
</tr>
<tr>
<td>Stumps and coarse roots</td>
<td>0.9</td>
</tr>
<tr>
<td>Shrub layer</td>
<td>0.5</td>
</tr>
<tr>
<td>Herb layer</td>
<td>0.1</td>
</tr>
<tr>
<td>Forest floor</td>
<td>0.1</td>
</tr>
<tr>
<td>A-horizon</td>
<td>0.2</td>
</tr>
<tr>
<td>Stand total</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Technological renovation influence on biogeochemical cycles in wetlands of North-East of Estonia

Veljo Kimmel¹, Marko Kaasik², Riinu Ots², Kaja Orupöld¹, Ülle Püttsepp¹, Tiitu Alliksaar³

¹ Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences
veljo.kimmel@emu.ee, kaja.orupold@emu.ee, ylle.pyttsepp@emu.ee

² Faculty of Science and Technology of Tartu University, marko.kaasik@ut.ee, vihmaauss@email.com

³ Institute of Geology of Tallinn University of Technology, tiitu.alliksaar@gi.ee

Power plants in North East of Estonia using oil shale as a fuel have had significant impact on ecosystem, both locally and in neighbouring countries. It has been reported that growth of trees has been accelerated due to excess nitrogen load, peat growth has stopped on about 100 quadrate kilometres due to excess alkaline deposition and fish biology has changed due to excess load of heavy metals and organic compounds. Recently many renovations have taken place in the power plants: 1) two boilers were renovated from pulverised bed (PB) combustion to fluidised bed (FB) combustion, 2) old boilers and lower stacks at Baltic Power Plant were decommissioned, 3) new electrostatic precipitators for removing particles from exhaust gases built. These renovations should have had an influence on the emissions and therefore on exposed ecosystems.

Studies carried out included: 1) modelling deposition with air distribution models SILAM and AEROPOL separately for gaseous compounds and different sizes of particles, 2) determination of current deposition loads with snow samples from an open area, 3) determination of longer period changes with samples of soils. Study period was 2008 and winter 2009. In samples main cations, anions and heavy metals were determined by ion chromatography and AAS. Determination of spherical fly ash particles by microscopy enable to separate particles from PB boilers from other boilers.

Results of modelling show that deposition of elements, compounds have changed significantly: 1) sulphur depositions should drop by factor of two, 2) fly ash emissions and also deposition should drop by factor of ten, 3) slight diminishing should occur also for nitrogen, 4) some compounds deposition like Cl and VOC should be increased. Samples of snow are in well agreement of modelling: 1) number of spherical particles in deposits have dropped 3-4 times, closer to stacks even a drop of ten times occur, 2) deposition of Ca dropped about 10 times showing diminishing fly ash particles, 3) similar patterns with fly ash was observable also for heavy metals., 4) deposition of Cl has increased slightly.

The study showed that renovation of power plants could soon result in a re-growth of peat on areas where earlier it has stopped due to too alkaline deposition.

References


Early growth, biomass production and root characteristics of silver birch, black alder and Scots pine on a reclaimed oil shale mining area

Tatjana Kuznetsova¹, Katrin Rosenvald², Krista Lõhmus², Ivika Ostonen², Aljona Lukjanova¹, Malle Mandre¹

¹ Estonian University of Life Sciences, Institute of Forestry and Rural Engineering, Department of Ecophysiology, Viljandi 18B, 11216 Tallinn, Estonia, tatjana.kuznetsova@emu.ee, aljona.lukjanova@emu.ee, malle.mandre@emu.ee
² University of Tartu, Institute of Geography, Vanemuise 46, 51014 Tartu, Estonia, katrin.rosenvald@ut.ee, krista.lohmus@ut.ee, ivika.ostonen@ut.ee

Young plantations of silver birch (Betula pendula), black alder (Alnus glutinosa) and Scots pine (Pinus sylvestris), the main deciduous species and coniferous used for mining area reclamation on oil shale mining spoil were investigated by analysing growth, biomass production and fine-root early adaptation strategies. One- and two-year-old plantations were used because the first years of stand development are most critical for tree survival in this stony alkaline (pH~8) wasteland with low nitrogen content. Survival of trees was measured, biomass allocation was assessed and the proportions of the root system in tree biomass (root ratio – RR) and of fine roots in the root system (FRR) were calculated. The short-root morphological characteristics: diameter (D), length, volume and mass of root tips as well as specific root length (SRL), specific root area (SRA) and root tissue density (RTD) were determined using WinRHIZO™ PRO 2003B (Regent Instruments Inc) in 15-20 samples per species; the number of tips in a sample was counted under microscope. SRL, SRA and RTD were determined for fine (D < 2mm) roots.

Survival of tree species after the first year ranged as follows: black alder ≥ Scots pine > silver birch; 93, 83 and 64%, respectively. Relative height increment of species was highest for Scots pine (0.63±0.01) in one-year-old stands, and for silver birch (0.43±0.01) in two-year-old stands. The largest aboveground biomass (B) occurred in black alder stand compared with other studied species in both growth seasons. Relative aboveground production (ΔB/B) was significantly higher for Scots pine in one-year-old stands, but in two-year-old stands this value didn’t differ between species. The higher fine root/leaf biomass ratio was proportional to the better survival of seedlings when comparing different tree species; black alder had the highest, and silver birch the smallest value. After the first growing season RR was similar in all species; the means ranged from 39% to 47% and FRR was for Scots pine twice as high than for black alder or silver birch, 77±6, 38±5, and 35±4%, respectively. After the second growing season RR was similar for deciduous species (51% – silver birch; 48% – black alder but significantly smaller for Scots pine (28%). FRR varied between 14 and 20%; impact of tree species was insignificant. The fine root SRA decreased and RTD increased with stand age for all studied tree species. Mean D of short roots decreased in order: D_pine > D_alder > D_birch. Comparing tree species, much higher short-root SRA and SRL values and lower RTD values were found for silver birch or Scots pine or black alder; SRL for silver birch, black alder and Scots pine after the first growing season was 365, 172, and 62, mg⁻¹, respectively. In deciduous trees mean SRL and SRA decreased with increasing stands age. The morphological adaptations of fine root system support the effective functioning of developing forest ecosystems on reclaimed oil shale mining area. The study showed that during first years after planting black alder was best adapted to harsh conditions of the mining substrate and hence it is the best choice for a reforestation of oil shale mining areas.
Greenhouse gas emission from UK upland is changed by water level restoration

Martin Lukac¹, Alexandru Milcu¹, Natasha McBean², Anna Bing³, James Stockdale³ and Sylvia Toet³

¹ NERC Centre for Population Biology, Imperial College London, SL5 7PY, m.lukac@imperial.ac.uk
² University of York,
³ University College London

Upland ecosystems in the UK are important stores of soil organic carbon, while their significance as sources or sinks of the greenhouse gases such as CO₂ and CH₄ is uncertain, particularly under changing climate and land management. We assessed the importance of a typical upland area for net exchange of greenhouse gases and measured the effects of moorland habitat restoration represented by drain blocking on greenhouse gas fluxes, vegetation structure and plant biodiversity. We have used the Ecotron, a controlled environment facility, to maintain mesocosms of two contrasting sizes at stable environmental conditions and at two water table levels. Intact mesocosms were extracted in March 2008, transported to the Ecotron where gas flux and soil water chemistry observations were carried out at monthly intervals until November 2008.

We successfully established the effect of the water table level on CO₂ (Fig. 1) and CH₄ fluxes, on soil surface heaving and light interception and reflectance. Bringing the water table level close to the surface has a significant positive effect on methane emission. Dark ecosystem respiration, on the other hand, is significantly diminished in high water table conditions. We also found that mesocosm size influences gas flux rates and does interact with water table effects, an effect that could be related to studied plant size and its sensitivity to the cutting of roots during mesocosm collection. In our case, observations from small (0.03m²) mesocosms did not appear to produce meaningful estimates of gas emission and the size of the mesocosms appeared to affect plant survival, especially that of heather. Large mesocosms (0.24m²), on the other hand, did show a greater degree of reliability and repeatability of results. For example, dark mesocosm respiration showed a lasting response to changed water table conditions in large mesocosms only. Net ecosystem exchange measured in light and gross photosynthesis were not significantly affected by the water table, but both fluxes, as well as ecosystem respiration, were significantly lower in small mesocosms.

Figure 1. Dark ecosystem respiration from small and large mesocosms (mg CO₂ h⁻¹ m⁻² ±st.dev.; note different scale).
Environmental impacts of hydrological restoration after peat extraction

Lars Lundin, Elve Lode, Monika Strömgren, Torbjörn Nilsson
Swedish University of Agricultural Sciences, Department of Soil and Environment, P.O. Box 7001, SE-750 07 Uppsala, Sweden, Lars.Lundin@mark.slu.se, Elve.Lode@mark.slu.se, Monika.Stromgren@mark.slu.se, Torbjorn.Nilsson@mark.slu.se

Restoration is highlighted in European land-use exploration. Peatlands used for peat harvesting is one such priority land use type. Considerable changes in site conditions have occurred during extraction of peat and new prerequisites exist as the very old peat bottom layers are exposed to land surface re-colonisation. Peatland restoration is therefore difficult. Management aims to focus initially on rewetting to restore hydrology and improve conditions for biogeochemistry and biodiversity.

In southwest Sweden, rewetting of two such areas started about ten years ago. Porla site inundation represents an ordinary nutrient poor site and Västkärr a richer site. Ecological characteristics of developed wetlands differ considerably and are reflected in remaining peat conditions, established hydrology and water chemistry, evidently being the driving force for established vegetation and limnic life, i.e. bottom fauna. Peat and mineral soil chemistry exert crucial influences on the developed biogeochemistry.

Before and after inundation, management investigations include soil sampling, monitoring of the site hydrology and water quality as well as effects of inundation on downstream watercourses, vegetation, limnic life and initial studies in gas exchange. Vegetation and surface soil conditions, partly with floating rafts, start to come into balance with new spontaneous Sphagnum colonisation. Water quality changed also with biological effects.

Changes in hydrochemistry after rewetting at the relatively nutrient poor Porla site were lowered pH, DOC, base cation content, sulphate and organic nitrogen. Sulphate decreased because a lack of oxidation of organic material in reduced bottom conditions initially released phosphorus. Organic nitrogen making up most of the total nitrogen decreased related to sedimentation. Nitrate first decreased because of less decomposition but increased due to nitrification of ammonia and organic nitrogen in free water, probably contributing to denitrification. At the richer West fen site, rewetting was associated with lowered pH, Ca, SO\textsubscript{4} and NO\textsubscript{3} content. DOC and phosphate increased the first years but later decreasing over time. Despite a lowered Ca content, pH increased probably dependent on the lack of sulphate production. This because turning to anaerobic conditions in the sediments and thereby releasing phosphate. After a few years P-release finished and PO\textsubscript{4} concentration dropped.

Peat site properties such as chemical conditions affect the greenhouse gas emissions and this was studied at the Porla site. The CO\textsubscript{2} emissions from the vegetation types varied, with the lowest emissions measured on the pristine mire and the drained bare peat. The CH\textsubscript{4}-fluxes showed a similar pattern as the CO\textsubscript{2} fluxes. The higher CO\textsubscript{2} emissions on tussocks on drained peat compared to the bare drained peat, can easily be explained by the respiration from living biomass. However, while the bare drained peat did not emit any CH\textsubscript{4}, the tussock on drained peat did. This suggests that the plants can (i) emit CH\textsubscript{4}, (ii) promote the transport of CH\textsubscript{4} from the soil to the atmosphere and/or (iii) promote the formation of CH\textsubscript{4} in the soil. Plant development partly reflect soil and hydrological conditions.
Use of ameliorants for preventing the contamination of soils with heavy metals

Saglara S. Mandzhieva1, Tatiana M. Minkina1, Olga G. Nazarenko2

1 Soil Science Department, Southern Federal University, 105, Bolshaya Sadovaya, Rostov-on-Don, 344006, Russia, minkina@bio.rsu.ru
2 Agro-Ecological Department, Don State Agrarian University, Rostov region, Persianovskiy, 346493, Russia

Introduction. A barrier function is an essential function of soil for protection of natural waters, air, and plants from pollutants. In this context the use of ameliorants could be developed for remediation of polluted soils with, based on mechanisms of strong metal fixation. The aim of this work was to study the influence of various methods of chemical remediation on heavy metal mobility in a Chernozem.

Materials and methods. The effect of different ameliorants on ordinary chernozem (Corg 2.55%; clay 58.0%; CaCO3 0.85%; pH 7.6) contaminated with heavy metals (HM) was studied in a long-term field experiment. Metals were added to the soil as acetates at the following rates (mg kg⁻¹): Pb 300 and Zn 96. These doses corresponded with usual level of obtained soil pollution by these metals in the Rostov Region. Chalk and glauconite were applied separately and together with manure after 2 months of artificial soil contamination. HM were extracted by 1 M NH₄Ac, pH 4.8; 1% EDTA in NH₄Ac, and 1M HCl. The sum of HM content in this parallel extracts characterize the weakly bound metal compounds (WB) (Minkina et al., 2008). The relative content of WB shows the metals mobility in soil. Metal contents in all solutions were analyzed by atomic absorption spectrophotometer.

Results and discussion. The application of ameliorants significantly decreased the mobility of metals (Table 1). Their effect depended on the ameliorant and was most significant at the simultaneous application of chalk and manure. This effect was presumably due to the strong binding of metals by carbonates through chemisorption and formation of low-soluble Zn and Pb compounds and to the additional fixation in the form of complexes at the addition of organic material (Minkina et al., 2007). Therefore, the share of weakly bound metal compounds in the contaminated soils decreased to the level typical for the clean soils or even below (in the case of zinc). The transformation of both metals, from less to more strongly bound compounds, was accelerated by ameliorants, but the rates of these processes for Zn were higher than for Pb.

Table 1. The total content and the ratio between the weakly (WB) and strongly (SB) bound Zn and Pb compounds during one year after the application of ameliorants

<table>
<thead>
<tr>
<th>Experimental treatments</th>
<th>Zn</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total content, mg/kg</td>
<td>WB, % of total content</td>
<td>Total content, mg/kg</td>
</tr>
<tr>
<td>Without metal addition</td>
<td>68</td>
<td>12</td>
</tr>
<tr>
<td>Metal (Me)</td>
<td>356</td>
<td>32</td>
</tr>
<tr>
<td>Me + glauconite</td>
<td>346</td>
<td>14</td>
</tr>
<tr>
<td>Me + manure</td>
<td>360</td>
<td>17</td>
</tr>
<tr>
<td>Me + glauconite + manure</td>
<td>363</td>
<td>15</td>
</tr>
<tr>
<td>Me + chalk, 2.5 kg/m²</td>
<td>350</td>
<td>13</td>
</tr>
<tr>
<td>Me + chalk, 5 kg/m²</td>
<td>347</td>
<td>16</td>
</tr>
<tr>
<td>Me + chalk, 2.5 kg/m² + manure</td>
<td>361</td>
<td>11</td>
</tr>
<tr>
<td>Me + chalk, 5 kg/m² + manure</td>
<td>359</td>
<td>11</td>
</tr>
</tbody>
</table>

Reference


Creating and restoring wetlands: Enhancing ecosystem services

William J. Mitsch
Wilma H. Schiermeier Olentangy River Wetland Research Park, The Ohio State University, 352 W. Dodridge Street, Columbus, Ohio 43202 USA, mitsch.1@osu.edu

Wetlands provide many ecosystem services such as cleaning water, mitigating floods and coastal damage, supporting biodiversity, and sequestering carbon. Yet we have lost wetlands throughout the world at an alarming rate in the 20th century. There are now significant opportunities to reverse that trend and create and restore wetlands, while conserving the wetlands that remain. Florida Everglades, coastal Louisiana (Costanza et al., 2006), the coastline of the Indian Ocean, and Mesopotamia in Iraq all are now involved in large-scale wetland restoration triggered by ecological or social disasters. At a very large scale, there has been discussion of restoring 20,000 km² of wetlands in the Mississippi-Ohio-Missouri River Basin in the USA to minimize the size of a 20,000 km² hypoxic zone in the Gulf of Mexico (Fig. 1; Mitsch et al., 2005a; Mitsch and Day, 2006). On a smaller scale, we are learning about the pace at which wetlands can be created and their ability to retain pollutants and sequester carbon with studies at the Olentangy River Wetland Research Park over the past 15 years (Mitsch et al. 2005b; Anderson and Mitsch, 2006; Fink and Mitsch, 2007). Self-design remains the guiding principle for these wetland creations and restorations.

References

Fig. 1. Mississippi-Ohio-Missouri River Basin in USA showing main source of nitrogen pollution and effect of that pollution in the Gulf of Mexico (Mitsch et al., 2005a)
Microbial biomass C dynamics and heavy metal mobility in long-term contaminated soils after amendment with chelates

Gabriela Mühlbachová
Crop Research Institute, Drnovska 507, 16106 Prague 6- Ruzyně, Czech Republic, e-mail: muhlbachova@vurv.cz

Heavy metal contamination is an environmental problem in industrial areas. The possibilities of removal of these elements are limited, therefore metal phytoextraction strategies by plants are popular. The mobility of lead in soils is limited due to its chemical characteristics, so methods supporting the metal uptake by plants are in development. One of the possibilities is soil amendment with chelates, which could increase metal availability for plants. On the other hand, addition of chelates can inhibit soil microbial characteristics (Ultra et al., 2005).

Soils from vicinity of a smelter of Pribram (about 60 km SW from Prague) for more than 200 years contaminated with lead, cadmium, arsenic and zinc were used for the experiment. Soil samples were sampled from the depth 0–20 cm. Arable and grassland soil of similar heavy metal concentrations were used for the experiment. Soils were after the removal of plant debris sieved at < 2 mm. The possibilities to increase heavy metal availability for phytoextraction were studied in the incubation experiment with addition of EDTA and EDDS into the contaminated soils. Contemporaneously, the microbial biomass C dynamics and respiratory activities were studied.

The microbial biomass C and metal dynamics after addition of chelates is shown in Fig. 1. Negative effects of the biodegradable chelate EDDS on the soil microbial biomass were observed during the first 10 days of the experiment, thereafter microbial biomass C contents increased. Higher metal availability was found only for Cu and Zn, which do not belong to the main contaminating elements in the area. The increase of mobile fractions of main contaminants Cd and Pb was not observed. The addition of EDTA inhibited significantly microbial biomass C. Respiratory activities in studied soils increased probably due to the process of destruction of soil microorganisms after EDTA addition and the release of C from microbial cells. Similarly, the increase of metabolic quotient (qCO₂) was observed after EDTA amendment. Mobile and organically bonded metal concentrations, particularly Pb, increased after EDTA addition.

The application of chelates, particularly EDTA, increased the heavy metal availability, however it is necessary expect lower microbial activities with all possible consequences.

Fig. 1. Dynamics of microbial biomass C and available metal fractions during the incubation experiment with addition of chelates.

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References
Biogeochemical consequences of grazing for weed control in a polluted and remediated area: risks of trace element ingestion by herbivores

José M. Murillo, María T. Domínguez, Paula Madejón, Teodoro Marañón

Institute for Natural Resources and Agrobiology, CSIC, PO BOX. 1052, 41080, Seville, Spain, murillo@irnase.csic.es, maidtn@irnase.csic.es, pmadejon@irnase.csic.es, teodoro@irnase.csic.es

Polluted areas require an active management in order to reduce the risk derived from pollution for human and ecosystem health. Afforestation stabilises the polluted soil, minimizing wind and water erosion, thus reducing the risk of migration of pollutants. In Mediterranean environments, weed competition can limit the survival and growth of afforested plants, since they compete for water and nutrients, and also constitute a favourable focus for wild fires. Herbage control by grazing is currently been considered in some restoration programs in Mediterranean areas. However, in afforested metal-polluted areas, the accumulation of metals in grasses may pose a risk to grazing livestock. We assessed the risk associated with managing pasture by grazing horses (non-edible livestock) in the Guadiamar Valley (SW Spain), where a large-scale restoration program was implemented after a major pollution incident. We analyzed the trace elements accumulation in grasses over different seasons, and assessed the potential ingestion of these elements by horses. Hair and faecal analyses of horses were also analyzed, as possible indicators of metal ingestion.

During the autumn, concentrations of trace elements in pasture were higher than in spring, due to a dilution effect of the greater biomass in the spring season. Only Cd (mean autumnal concentration ca. 0.5 mg kg\(^{-1}\)) and some values of Fe and Zn (less than 10% (Fe) and 2% (Zn) of the total samples analysed, derived from soil contamination of herbage) were comparatively high. The soil-plant transfer coefficients (TC) depended on the element and on the plant group, although, in general were low. The highest transference corresponded to some Cd and Zn in some Asteraceae species, such as *Senecio vulgaris* (TC from soils to leaves of 0.43 and 0.37, respectively). For other plant groups, such as Poaceae sp. and Fabaceae sp., the TC of these two elements was lower than 0.25. Estimated values of daily intake for horses were much lower than the poisoning ingestion values recorded in the bibliography (Table 1). In general, faeces analyses showed that essential element absorption is regulated by homeostatic mechanisms which control their accumulation, while non essential elements tend to be preferentially excreted from horses’ body. This pattern was also observed in faeces of other herbivores of the area, such as wild hares (*Lepus granatensis*). We conclude that grazing by horses could be considered in the management of the area, although 1) as caution, grazing should be avoided during periods with a low pasture biomass and 2) chronic exposure to metals should be assessed in the long-term.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Soil</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C</td>
<td></td>
<td></td>
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</table>

Table 1. Autumnal daily food intake of essentials (E) and non essential (NE) trace elements (Mean values ± SD) in the affected (n=90) and control (n=10) soils. Estimated food intake for horses in mg kg\(^{-1}\) body weight day\(^{-1}\) (data based on a daily food intake of 21 g of plant dry weight per kg of body weight). (* p < 0.05)
Our main aim was to evaluate the long-term recovery of a heavy-metal polluted forest ecosystem located close to a Cu-Ni smelter complex through the establishment of a functioning organic layer, and through revegetation using seedlings of native tree species and cuttings of native dwarf shrub species. We studied how the application of a mulch cover (mixture of household bio compost and wood chips) onto polluted forest soil affects 1) survival and growth of planted dwarf shrubs and tree seedlings, 2) spontaneous revegetation, 3) fate and mobility of soil Cu and Ni and 4) distribution of fine roots.

Native woody plants (Pinus sylvestris, Betula pubescens, Empetrum nigrum, Arctostaphylos uva-ursi) were planted on summer 1996 in mulch pockets on mulch-covered and uncovered plots. The mortality of the tree seedlings and dwarf shrub cuttings were recorded every spring and autumn during the ten year monitoring period (1996–2005). The spontaneously spread non-woody plant species were recorded in June 2002 and in August 2005. Soil samples for chemical analysis were taken in August 2005. Exchangeable Cu and Ni concentrations were determined by extraction with BaCl\(_2\) + EDTA followed by analysis by ICP-AES. Three seedlings or cuttings per plot were harvested after 10-years growth for biomass determination and element analysis. In addition, three volumetric soil core samples (core diameter 58 mm) for fine root biomass determination were taken in August 2005. Roots were washed out of the soil, and sorted under a microscope for living and dead, for tree species and understorey, and for root diameter (< 1 mm, 1–2 mm, >2 mm). Numbers of ectomycorrhizal root tips per root weight unit were counted under a microscope from 10% of the finest root (diameter < 1 mm) biomass of Scots pine.

Despite initial mortality, establishment was successful during the following ten years. Only 3.5% of Empetrum cuttings died on the mulch-covered plots, and 48% on the uncovered plots. Over half of the Arctostaphylos cuttings died in both treatments, but the survived plants have spread over a wide area. The mortality rate of Pinus was low, < 12% in both treatments. The mortality of Betula on the mulch-covered plots (48%) was higher than on the uncovered plots (17%). Natural recolonization of pioneer species (e.g. Epilobium angustifolium, Taraxacum sp. and grasses) and tree seedlings (Pinus sylvestris, Betula sp. and Salix sp.) was strongly enhanced on the mulched plots, whereas there was no natural vegetation on the untreated plots.

In the organic soil, exchangeable Cu and Ni tended to be lower in the mulch of pockets containing transplants than in those without. In the mineral soil, exchangeable Cu and Ni were relatively low and there was a considerable spatial variation between plots. The biomass of the living fine roots (mainly Scots pine) was significantly higher in the organic mulch layer spread on the experimental plots than in the polluted organic layer of the non-covered soil. Furthermore, the number of mycorrhizal root tips of Scots pine was much higher in the organic mulch than in the organic layer of the non-covered soil. The biomass of the living fine roots, as well as the number of mycorrhizal root tips, was also high in the uppermost part of the mineral soil (0–5 cm) on the mulch-covered plots.

We conclude that mulching of the metal-polluted site created a functioning organic layer by reducing exchangeable Cu and Ni and improving the water holding capacity, and subsequently increasing the amount of living fine roots and mycorrhizal root tips in the surface soil. Soil remediation was reflected as successful revegetation of the barren forest floor.
The effects of harvesting residues on natural regeneration, nutrient availability and uptake at a broadleaf restoration site in southern UK

Rona Pitman
Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH, UK, rona.pitman@forestry.gsi.gov.uk

Conservation and biodiversity have been of increasing importance in British forestry in the last 10 years, culminating in the commitment to reduce or remove conifer trees on sites known to have been previously native broadleaf forest (Thompson et al., 2003). The desired procedure is to change canopy dominants from conifer to broadleaf with ‘minimum intervention regeneration’. Conifer stands reaching maturity, or of low current economic value, such as Western Hemlock and Corsican pine have been targets for clear felling. In most cases forest practice has resulted in woody brash which has both chemical and physical effects on potential natural re-colonisation by trees, herbs and shrubs. The decay rate of Western hemlock (T. heterophylla) residue, previously determined from field situations, has been shown to be very slow. Investigations of residues from other species show that nutrient rich needles and twigs are the most important source for immediate forest regeneration but these researchers note that the quantitative role of developing ground flora as a sink for these nutrients remains unclear. A nursery study by Weatherall et al. (2006) with Sitka seedlings (P. stichensis) growing on decaying brash demonstrated uptake of nutrients within one year.

The objective of this study was to examine the effects of the manipulated brash on soil nutrients, particularly N, and their availability to support colonising ground flora and broadleaf tree seedlings. The physical and chemical effects of four treatments (light and heavy (x2) Brash, a coarse Mulch, and a Grass treatment) with a Bare control on the plants, soils and status of the residue have been compared over five years.

Initial site colonisation by Calluna and Carex sp after clearfell came from the seed bank and with Betula, (from mature trees) and Agrotis grass (experimentally seeded), the 4 dominants have spread across all treatments except Mulch. This has been a good plant suppressant, and remains 50% un-colonised. Birch growth is lowest in Grass and Mulch treatments and significantly greatest in the LtBrash treatment where it has locked up ~50 kgN.ha⁻¹ > the 5 years .Grasses and heathers competing for dominance in Grass and Bare plots, have taken up 10–15 kgN.ha⁻¹. The persistence of a dominantly heathland ground flora was unexpected and oak colonisation by acorn dispersal has been sporadic, despite good mast years. The release of N from different fractions of the residue has been followed by litterbag decay, and ground sampling of brash and mulch material. Separate decay constants (k) have been identified for the needle, small twig and branch fractions, each with a different lag time to initial N release. Biomass loss of brash branch material has been matched by similar increases in fragmentation. Within the mulch too there has been increasing proportion of ‘fines’, but also a total rise in biomass, which must result from fungal and bacterial in-growth during decomposition. C:N ratio of the mulch chip has declined, but N concentrations are still increasing, indicating continuing N lock-up. Soil solution DON measured in the underlying clay has remained at 15 kg Nha⁻¹ under Bare and Grassed treatments, but initial rise under Heavybrash and Mulch (to ~24 kgN ha⁻¹) has now significantly declined (~18kgN.ha⁻¹). With limited plant colonisation of the Mulch, which favours bracken, heather and conifer seedlings, this can only be attributable to fungal action. As DON is degraded preferentially by micro-organisms like pine and ericoid mycorrhizae, the success of heathers and conifers is to be expected - but the status of birch needs further investigation. Other broad leaf trees may be inhibited by the application of conifer brash yielding inaccessible forms of N through decay, and retention of conifer brash on restoration sites should be reconsidered, particularly as removal expense might now be offset by biomass income.

References
Recreating a functioning forest soil in reclaimed oil sands in northern Alberta, Canada

Sara Rowland¹, Cindy Prescott¹, Sue Grayston¹, Sylvie Quideau² and Gary Bradfield³

¹ Department of Forest Sciences, University of British Columbia, 3041-2424 Main Mall, Vancouver, B.C. V6T 1Z4, Canada
² Department of Renewable Resources, University of Alberta, 442 Earth Science Building, Edmonton, AB T6G 2H1, Canada
³ Department of Botany, University of British Columbia, 3529-6270 University Blvd, Vancouver, B.C. V6T 1Z4, Canada

During oil-sands mining all vegetation, soil, overburden and oil sand is removed, leaving pits several kilometres wide and up to 100 metres deep. These pits are reclaimed through a variety of treatments using sub-soil or a mixed peat-mineral soil cap. Using non-metric multidimensional scaling and cluster analysis of measurements of ecosystem function, reclamation treatments of several age classes were compared with a range of natural forest ecotypes to discover which treatments had created ecosystems similar to natural forest ecotypes and at what age this occurred. Ecosystem function was estimated from bio-available nutrients, plant community composition, litter decomposition rate and development of a surface organic layer.

On the reclamation treatments, availability of nitrate, calcium, magnesium and sulphur were generally higher than in the natural forest ecotypes, while ammonium, phosphorus, potassium and manganese were generally lower. Reclamation treatments tended to have more bare ground, grasses and forbs but less moss, lichen, shrubs, trees or woody debris than natural forests. Rates of litter decomposition were lower on all reclamation treatments. Development of an organic layer appeared to be facilitated by the presence of shrubs.

With repeated applications of fertilizers, measured variables for the peat-mineral amendments fell within the range of natural variability at about 20 years. An intermediate sub-soil layer reduced the need for fertilizer and conditions resembling natural forests were reached about 15 years after a single fertilizer application. Treatments over tailings sand receiving only one application of fertilizer appeared to be on a different trajectory to a novel ecosystem.
Restoring biogeochemical functions in highly degraded riparian wetlands: A comparison of degraded ecosystem responses

Curtis J. Richardson¹, Ariana Sutton-Grier¹, ², and Neal E. Flanagan¹

¹ Duke University Wetland Center, Nicholas School of the Environment, Levine Science, Durham, North Carolina, USA, curtr@duke.edu, nflanaga@duke.edu, sutton-griera@si.edu
² Smithsonian Environmental Research Center, Box 28, 647 Contees Wharf Rd., Edgewater, MD 2103,

The once tight connectivity of streams and wetlands has become separated in the highly developed landscape of today. For example, riparian wetlands in the North Carolina (NC) Piedmont are often highly impaired due to high N and P inputs, sediment load, coliform bacteria, and the lack of a connected functioning riparian floodplain ecosystem. At Duke University a stream and wetlands assessment park (SWAMP) was created to restore multiple sections of a highly incised Sandy Creek stream and riparian floodplain in a 484 ha watershed to improve water quality and reduce sediment load entering the Jordan Reservoir, increase habitat biodiversity and improve ecosystem functions within the wetland and stream complex. In Charlotte NC a highly degraded urban riparian wetland was fully restored by adding new topsoil and organic matter to enhance vegetation growth and biogeochemical processes like denitrification. Both restorations have created hydrologic functioning riparian and palustrine wetland areas along the restored streams, which now demonstrate varying degrees of denitrification potential (DEA) depending on soil organic matter content, nitrate concentrations and moisture (Table 1). Monitoring of storm events indicates (NO₃⁻· NO₂⁻)-N mass loads were reduced by 64% through the SWAMP project area, a trend which followed increased DEA. In the same storm event a 28% reduction in total phosphorus loads was measured. Importantly, the stream reductions in nutrients and coliform bacteria are minimal unless the adjacent wetlands are connected to water flow during storm events. A new innovative approach to wetland stream connectivity is presented. More information on site design can be found at www.env.duke.edu/wetland.

Table 1. A comparison of soil properties, DEA and microbial biomass at the Charlotte and the SWAMP restoration systems from samples collected from the top 15 cm of soil.

<table>
<thead>
<tr>
<th></th>
<th>Charlotte Wetland Restoration</th>
<th>Duke Forest SWAMP Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OM (%)</td>
<td>Moisture (%)</td>
</tr>
<tr>
<td>Mean (+/- 1 SD)</td>
<td>7.36* (2.59)</td>
<td>26.1* (16.5)</td>
</tr>
<tr>
<td></td>
<td>11.00* (1.83)</td>
<td>30.55* (7.68)</td>
</tr>
</tbody>
</table>

DEA = denitrification enzyme assay which is a measure of denitrification potential
* = significant difference in the parameter between the two systems (p< 0.01)

References
The role of afforestation in soil restoration: effects on soil nutrients in degraded volcanic soils in Iceland

Eva Ritter
Department of Civil Engineering, Aalborg University, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark, er@civil.aau.dk

Soil degradation and erosion is a severe problem in Iceland. A large part of this can be attributed to deforestation and the agrarian lifestyle of the first settlers; forest cover of 15–30% before this time (c.AD 874) was reduced to less than 1% of the land area within less than 200 years. With the loss of forests, soil erosion increased, causing the loss of soil organic carbon and thus valuable fertile land. This serious environmental problem continues still today. Afforestation has become an important tool in restoration and protection of Icelandic soils, but organized forestry did not start before 1899, and another 100 years passed before a Regional Afforestation Project Act was announced with the aim of increasing forest cover to 5% of the area below 400 m a.s.l. Afforestation in Iceland has to face many problems, such as the harsh climate, short vegetation periods, frost heaving in winter, damages by grazing sheep and horses, and the poor soils. Icelandic ecosystems are generally nitrogen (N) limited, and phosphorus (P) availability is poor owing to the high P fixation capacity of the volcanic soils. While fertilization can improve survival of seedlings, little is known about nutrients in maturing forests planted on the volcanic soils. The aim of this study was to investigate long-term development of soil nutrients in forest stands in Iceland (Ritter 2007; Ritter 2008).

Changes in soil nutrients were investigated in stands of native birch (*Betula pubescens* Enrh.) and introduced Siberian larch (*Larix sibirica* Ledeb.) of increasing age (14 to 100 years) and a treeless heathland in east Iceland. Soils were Andosols derived from basaltic material and rhyolitic volcanic ash. Total C, N and P in soil (0–10 and 10–20 cm depth) as well as base cations and Olsen-P were measured. Results revealed minor changes in the total content of C, N and P with stand age (Ritter 2007). The C content in 0–10 cm soil depth was significantly higher in forest stands older than 30 years than in heath land and the younger forests stands. Changes in the soil C pool were generally less than found in other Icelandic studies on land reclamation with grass. This was partly attributed to the fact that the present soils were already on a moderate C level prior to forest establishment compared to other Icelandic Andosols. Concentrations of N and total P in the mineral soil were not affected by stand age at all. Also soil K contents did not change with stand age, indicating a sufficient K supply (Ritter 2008). There was no significant effect of tree species. The cations Ca, Mg, and Na decreased with time after afforestation, which can possibly be related to the decreasing soil pH. The higher concentrations of Olsen-P and K in the upper soil layer as compared to 10–20 cm depth indicate a higher biotic control as opposed to the geochemical control of the other base cations. Olsen-P increased in the upper soil layer when forest soil developed under the growing forest stands (Ritter 2008). Hence, P supply may become less critical once the seedlings have survived the first years. This indicates that fertilization, which has been found necessary at or during the first years after planting, is not needed in older forest stands. Although changes are generally slow, the development of at least K and the macro nutrients investigated in this study must be considered positive for the growth conditions of the maturing trees. This is helpful to know for afforestation activities and the management of forests on the difficult soils in Iceland.

References
Microbially mediated nitrogen transformation processes in restored and channelized sections of a river corridor

Juna Shrestha¹, Emmanuel Frossard², Klement Tockner³, Jörg Luster¹

¹ Swiss Federal Institute for Forest, Snow, and Landscape Research, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland, juna.shrestha@wsl.ch, joerg.luster@wsl.ch
² Institute of Plant Sciences, Swiss Federal Institute of Technology, Eschikon 33, CH-8315 Lindau, Switzerland, emmanuel.frossard@ipw.agrl.ethz.ch
³ Leibnitz-Institute of Freshwater Ecology and Inland Fisheries, Mueggelseedamm 310, D-12587 Berlin, Germany, tockner@igb-berlin.de

Floodplains are highly appreciated for their ecological services, in particular biodiversity conservation, and flood protection. This has led to increased efforts to restore previously altered or destroyed floodplains. However, there is insufficient knowledge how the restoration affects other functional aspects of the river corridor, in particular to act as filter and buffer for potential water pollutants. The interdisciplinary project cluster RECORD was therefore initiated to increase mechanistic understanding of coupled hydrological and ecological processes in river corridors. A section of the river Thur corridor in Northeast of Switzerland is investigated, a large part of which has been re-naturalised by, e.g., removing embankments. In one of the sub-projects we study microbially-mediated nitrogen transformation processes in order to assess whether the restoration has led to an increase or decrease of the river corridor’s ability to act as sink for nitrogen.

The non-restored part of the river corridor is a rather homogenous managed pasture with mowing and grazing practice, while the restored section exhibits high spatial heterogeneity with distinct succession gradients of habitats from thinly-colonised gravel extending to mature forest with a dense reed zone and planted willows as intermediate habitats. In order to obtain an in-depth understanding of nitrogen cycling in the non-restored and restored section, the rates of the following processes are assessed in the various habitats: gross mineralisation, gross nitrification, immobilisation, potential denitrification, all measured in the laboratory, and in-situ soil N₂O efflux. Preliminary results indicate a generally increased microbial activity in the restored section, in particular in the two intermediate habitats (reed zone, planted willows) that are most strongly exposed to periodic flooding and, thus to continuous input of fresh sediments and organic matter (Table 1).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>soil respiration [mmol/m²/day]</th>
<th>N₂O efflux [µmol/m²/day]</th>
<th>CH₄ consumption [mmol/m²/day]</th>
</tr>
</thead>
<tbody>
<tr>
<td>pasture, non-restored section</td>
<td>225.7</td>
<td>17.0</td>
<td>-6.1</td>
</tr>
<tr>
<td>gravel, restored section</td>
<td>42.4</td>
<td>2.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>reed, restored section</td>
<td>323.9</td>
<td>38.0</td>
<td>-14.8</td>
</tr>
<tr>
<td>willow, restored section</td>
<td>318.4</td>
<td>15.0</td>
<td>-24.9</td>
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<tr>
<td>forest, restored section</td>
<td>192.0</td>
<td>10.9</td>
<td>-57.4</td>
</tr>
</tbody>
</table>
Soil carbon dynamics along a reconstructed Australian jarrah forest chronosequence following bauxite mining

Suman George, Robert Kelly, Paul Greenwood, Mark Tibbett
Centre for Land Rehabilitation, School of Earth and Environment, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia, sgeorge@cyllene.uwa.edu.au

Soil organic carbon (SOC) is the largest terrestrial pool of carbon on the planet and an increase in the size of this pool by just 5% has the potential to decrease the amount of atmospheric carbon by up to 16% (Baldock 2007). With many governments considering a carbon trading scheme, sequestration of carbon by soils may be economically beneficial and help offset the environmental impact of CO₂ emissions. Therefore, restoring native vegetation and ecosystem processes (such as nutrient cycling) within the soil to pre-mined levels is of high priority. SOC is one aspect of the soil that is affected by the mining and rehabilitation process. Soil organic matter is difficult to isolate and measure because of its complexity and heterogeneity. Many fractionation techniques have been devised to fractionate SOC into conceptual pools based on their turnover times within soil. The measurement of these pools of carbon can give an indication of the methods of stabilisation within an ecosystem.

Accumulation, distribution and soil organic carbon (SOC) quality in post-mined rehabilitation was studied at Boddington Bauxite Mine of Worsley Alumina Pty. Ltd. in southwestern Australia and benchmarked to adjacent unmined northern Jarrah forest soils. The soil profile was analysed to a depth of 20 cm for five restored forest age-classes ranging from 2 to 15 years. The quantity and quality of SOC in both bulk soils and particle-size based discrete carbon pools showed positive trends towards convergence with native forest levels. Parameters with a fast turnover such as litter layer and labile SOC pools were most successfully returned to pre-mining levels. The litter mass of sites rehabilitated for 15 years marginally exceeded the mass of unmined native forest which is attributed to a more productive plant community or decreased decomposer activity. SOC throughout the soil profile generally responded well to rehabilitation. The more labile (>200 µm) particulate organic carbon (POC) fraction was returned to comparable native forest levels (within significant levels; P≤0.05) at all depth intervals. Even though, the less labile POC fraction (200–53 µm) and humus (<53 µm) fractions showed some evidence of slowly returning towards native levels; however some significant differences were still evident. δ¹³C values of both POC fractions (> 200 µm and 200–53 µm) were consistently greater in rehabilitated sites compared the unmined control. This may be due to differences in floral species distributions; a view supported by the floristic analysis which shows species composition differences between rehabilitated and native forest. As opposed to these parameters, others have not yet returned to natural levels - a significant variance of potential concern was the C:N nutrient ratio for soil depths lower than 2 cm showed values progressively different from the native forest. This altered C:N ratio may be attributed to an increased dominance of N-fixing pioneers in the younger rehabilitated sites. This deviation of the C:N ratio from native forest may eventually be addressed by shifts in plant community with succession processes.

Reference
Lessons gained from French R&D programmes for pesticides dissipation by use of constructed wetlands

Julien Tournebize¹, Bernard Vincent¹, Cedric Chaumont¹, Christelle Gramaglia¹, Pascal Molle¹, Grill Jean-Joel¹, Nadia Carluer¹, Grison Denis², Agathe Euzen³

¹ Cemagref, (Antony, Lyon ou Montpellier) HQ: BP 44 Antony Cedex France, firstname.name@cemagref.fr
² Nancy II university, rue Godefroi de bouillon, 54000 NANCY FRANCE, GRISON@iutnb.uhp-nancy.fr
³ CNRS, UM=R PRODIG, 2 rue Valette 75005 PARIS. Agathe.Euzen@cnrs.fr

Pesticide pollution is a major treat of surface water quality in France. To comply with the European Water Framework Directive authorities have decided of a Phyto-Pharmaceutic Products (PPP’s) reduction plan, the major achievement of which being the50% reduction of intrants by year 2018. This plan only considers actions on farming practices and does not foresee any actions on transfers in catchments, even if these latest actions are expected to contribute to PPP’s reduction. Also, existing anti drift buffer strips have revealed inoperant vs PPP’s rural pollutions (and nitrates included) in two well identified situations which represents approximately 40% of the French total arable land: i) subsurface drained areas (the pollution by passes below the buffer) and ii) waterlogged area (pollution over passes when the water table is high). Considering that a significant part of the territory is not protected by the by default standard buffer techniques, and since constructed wetlands have shown efficiency in other countries but under different climatic and hydrologic conditions, the question of their adaptation to the French context raised recently.

Chance has been taken from two R&D research programmes¹ regarding constructed wetlands to improve the state of the art, to assess the performance from both scale pilots and on farm actual constructed wetlands and to find incentive economical, legal, social for further nationwide extension. The pilot requiring energy to recirculate the effluent, fully rustic processes have been installed, i.e. small constructed wetlands at the outfall of drained catchment. The catchments (approx 50 ha) were cultivated by farmers accordingly with as usual crops and practices, the size of the wetlands were minimised to facilitate acceptation, betting on a dynamic control of inflows to wetland as the research showed that the most of the pollution occurs during the very first peak events after PPP’s application. The wetlands were installed in parallel of the arterial main drain accordingly with two modalities, one forested and the second vegetated. Two contrasted regions have been chosen as well. In all cases climatic parameters water and PPP’s flows in and out have been measured and monitored.

Results of the programmes after one year of data are given here. Heavy PPP’s concentrations (up to 100 µg/l) have applied on the scale pilot with satisfactory reductions rates (between 50 and 80%) showing that on farm process is feasible if more rustic processes would show poor performance. The forested wetland has worked properly showing nil traces of PPP’s at the outfall back to the main drain. The vegetated wetlands had promised performance, but redesign has been operated to increase residence time and PPP’s dissipation. The result of this second campaign will be available for the congress. There is no aid and no by law obligation for such wetlands and heavy administrative engineering had to be applied to find incentives for farmers. Sociologic approaches and amenities assessments have revealed unsuspected relations of the farmers with the society and the environment, and vice versa. In the both cases the project have resulted of a co-construction where each actor had personal involvement. Even if Co-construction should be a driving line, solutions for appropriate incentives and land reallocation tools should be fought with politics and authorities in order to facilitate further realisations.

¹ ARTWET. EC life Project N° LIFE06 ENV/F/000133, acronym of ARTificial wetlands for PPP’s reduction, and TRUSTEA project, acronym of RUStic Treatment of Agricultural Water, a Cemagref funded project for involving Human and Social Sciences in engineering processes and risk management policies
Tree species affect soil metal redistribution: implications for phytoremediation

Lotte Van Nevel1, Jan Mertens2, Filip M.G. Tack3, Kris Verheyen1

1 Laboratory of Forestry, Department of Forest and Water Management, Ghent University, Melle, Belgium, Lotte.VanNevel@UGent.be
2 Faculty of biosciences and landscape architecture, University college Ghent, Ghent, Belgium
3 Laboratory for Analytical Chemistry and Applied Ecochemistry, Ghent University, Ghent, Belgium

Metal polluted soils pose serious risks for the ecosystem and public health, through leaching of metals to groundwater and dispersion in the food chain. Conventional soil sanitation techniques are technically and financially seldom feasible because of the spatial extent of metal pollution. Therefore, those degraded ecosystems are often afforested. Forests showed to play an important role in metal cycling and partitioning. But what are the limitations and possibilities for phytoremediation of metal polluted soils? This contribution will discuss the possibilities and limitations of phytoextraction, bioavailable contaminant stripping and phytostabilization, on the basis of in situ research. The phytoextraction technique showed great promise, but is in our opinion still limited to be applicable in the field. It was calculated that natural phytoextraction is limited due to the fact that, at present, no species is found that combines high metal uptake with high biomass. Moreover, there are practical implications as metal availability decreases upon successive croppings. For most trace elements, the technique of phytoextraction thus needs significant improvements to become practically feasible. A possible ameliorative variant of the phytoextraction technique is ‘bioavailable contaminant stripping’, which aims at the extraction of only the most labile, bioavailable metal pools. However, in order to apply this technique efficiently and safely, it is necessary to assess the kinetics of replenishment of the bioavailable metal pools in the long term. Nevertheless, even when the phytoextraction technique would be improved, applicability in the field might be restricted as metal uptake in aboveground biomass causes an important risk of contaminating the food chain or surrounding environments. Whenever phytoextraction is not applicable, phytostabilization might be a more promising technique, by aiming at reducing the metal mobility and thus the dispersion of the metals in the ecosystem. Trees seem well suited for phytostabilization purposes, due to their extensive root systems and high transpiration capacity. But on the other hand, tree growth might enhance metal leaching, because of soil acidification and production of dissolved organic matter. Hence, it is very important to select tree species for phytostabilization purposes that cause low soil acidification and do not translocate high amounts of metals to their leaves.

The tree species effects on metal redistribution in the ecosystem were investigated on 2 metal polluted sites, differing in soil characteristics as well as pollution source and forest age. On the one hand we investigated the redistribution of soil metals under 4 tree species on a dredged sediment disposal site with 33-year-old trees (poplar, oak, ash, maple). On the other hand we investigated the effects of 6 different tree species on Cd and Zn compartmentalization after 10 years of tree growth on agricultural, sandy soil near a former Zn-smelter (aspen, oak, silver birch, black locust, Scots pine, Douglas fir). The contrasting soil characteristics of the 2 investigated sites might give rise to other dynamics in metal fluxes. The dredged sediment site had a high pH (c. 7.7) and a high cation exchange capacity (CEC), while the sandy site had a low pH (c. 4.7) and a typical low CEC. Both studies revealed a clear redistribution of metals in the soil profile that was dependent on the tree species. These metal redistributions were more pronounced on the oldest site.

Poplar and aspen took up high amounts of Cd and Zn and this was associated with increased Cd and Zn concentrations in the upper soil layer. Silver birch took up Zn in its leaves, which was reflected in a slight accumulation of Zn in the top soil. The other tree species contained normal metal concentrations in their tissues and caused no metal accumulation in the top soil. Oak acidified the soil more than the other species and caused a decrease in the concentration of metals in the upper soil layer. Black locust had also been acidifying, although this was not represented in a decrease of metal concentrations in the top layer. Other soil parameters as organic matter (OM) and CEC might be the reason for that. Hence, poplar and aspen should be excluded in further afforestations and the acidifying species should be mixed with other species, in order to minimize the risk of metal dispersion in the ecosystem.
Hydrochemical and hydrobiological studies of lakes in the southern part of Arkhangelsk region of Russia

Taisia Ya Vorobjeva, Svetlana A. Zabelina, Sergey I. Klimov, Olga Yu Moreva, Natalia V. Shorina, Liudmila S. Shirokova
Institute of the Ecological Problems of the North, Arkhangelsk, RAS, vtais@yandex.ru

One of the major environmental problems is the preservation of high-quality fresh waters stored in large lakes of northern territories of Russia. However, small lakes, notable those located in the territory of National Parks, deserve a special attention because they may serve as a much faster indicator of global anthropogenically-induced processes occurring in the boreal environment. Small lakes investigated here have glacial origin, and they are represented by different types of reservoirs, characteristic for northwest of the European part of Russia, with distinct morphometric and hydrographic characteristics. Lakes of Rotkovetsky group have the surface area from 0.13 up to 2.1 km$^2$ and the maximal depths from 3.7 up to 16.0 m. According to their thermal stratification, they belong to epi- and metatermal types. Lakes of the southern part of Kenosersky national park have the area of 2.7 to 3.4 km$^2$ and the maximal depths of 6 up to 18 m are characterized by intra-reservoir hydrological exchange processes. In terms of thermal stratification, they belong to epi- and hypothermic types. In this work we present results of hydrologo-hydrochemical study conducted in July, 2007 on 3 lakes of Kenozersky National Park (Lekshmozero, Maselgsko, Vilno) located in the middle taiga zone southwest from Arkhangelsk, and 2 lakes situated in the Geobiopsheral station of Russian Academy of Science “Rotkovets” (Svjatoe, Beloe).

Our study revealed low mineralization of waters; specific conductivity is equal to 50, 100, 125, 55, 200 µS cm$^{-1}$ in lakes Maselgskoe, Lekshmozero, Svjatoe, Vilno, and Beloe, respectively. Due to lakes stratifications, intensive exchange processes between water and sediments occur under anaerobic conditions thus bringing about marked increase of concentration of the following components: Si: from 130µg l$^{-1}$ at the surface to 946 µg l$^{-1}$ at the bottom in the lake Maselgskoe; from 573 to 1232 µg l$^{-1}$ in the lake Lekshmozero; from 1056 to 2795 µg l$^{-1}$ in the lake Svjatoe; phosphates: from 2.7 up to 9.5 µg l$^{-1}$ in the lake Maselgskoe, from 4.5 up to 16 µg l$^{-1}$ in the lake Lekshmozero and from 7.7 to 16.7 µg l$^{-1}$ in the lake Svjatoe. Nitrates dominate the stock of dissolved mineral nitrogen in the lakes. Only in benthic anaerobic layer, the nitrate concentration increases up to 8 µg l$^{-1}$. Surface layer concentration of ammonium ranges from 15 to 42 µg l$^{-1}$ and from 26 to 54 µg l$^{-1}$ in lakes Lekshmozero and Maselgskoe, respectively. In the in deep anaerobic a layer, ammonia concentration increases up to 106 and 321 µg l$^{-1}$ in lakes Lekshmozero and Maselgskoe, respectively.

Potential negative tendencies of ecosystem development in lakes Maselgskoe and Lekshmozero are controlled by formation of oxygen deficiency in the bottom layers of deep-water stations during period of summer stagnation. The anoxic conditions are often formed in deep water layers of many productive small lakes of the region. The uptake of oxygen triggers the processes of anaerobic respiration which accumulates the reduced organic substances. The increase eol oxygen uptake on the oxidation of organic matter characterizes the intensity of mineralization processes both in water and bottom sediments. For example, in lake Maselgskoe, the aerobic mineralization of organic substances in the bottom horizon was maximal (0.07 mg C m$^{-3}$×day), while this parameter in the water column is only 0.01 mg C m$^{-3}$×day. Total mineralization of organic matter was evaluated to be 16.4 mg C m$^{-3}$×day, whereas the primary production was significantly higher and close to 260 mg C m$^{-3}$×day, that testifies the accumulation of organic substances in the lake Maselgskoe.

The concentration of dissolved organic carbon (DOC) in lakes of Kenozersky National Park revealed the maximal concentration which varied with the depth of the water column within the range of 14 to 21 mg l$^{-1}$. In shallow lake Vilno the DOC concentration was almost constant as a function of depth and equal to 9.0 - 9.1 mg l$^{-1}$, in accord with constant distribution of biomass with the depth. In the stratified lake Svjatoe, the DOC content varied from 5.8 to 16.6 mg l$^{-1}$ whereas in the lake Beloe, this parameter is equal to 16 mg l$^{-1}$. It is concluded that long-term monitoring complex monitoring is necessary, in order to establish regular time trends in the evolution of chemical composition, hydrological characteristics and production-mineralization processes and their link with climate change.
Effects of phosphatic amendment and acidic watering on the mobility and phytoavailability of Cd, Pb and Zn in highly contaminated kitchen garden soils

C. Waterlot¹, C. Pruvot¹, H. Ciesielski² and F. Douay¹

¹ ISA, Laboratoire Sols et Environnement, 48 boulevard Vauban, 59046 Lille cedex, France, c.waterlot@isa-lille.fr, c.pruvot@isa-lille.fr, f.douay@isa-lille.fr
² Laboratoire d’Analyses de Sols de l’INRA d’Arras, 62000 Arras, France, ciesielski@arras.inra.fr

For more than a century, the Metaleurop Nord lead smelter (closed in 2003) has contaminated the soils located in its neighbourhoods by its atmospheric emissions. Another smelter, located in the nearest town of the first one, have been in service since 1869 and produces zinc. The emissions generated by these two smelters have led to an important contamination of the surrounding soils. The main pollutants were Cd, Pb, Zn but also to a lesser degree Ag, As, Bi, Cu, Hg, In, Ni, Sb, Se, Sn, Tl. Compared with the regional agricultural values, Sterckeman et al. (2002) showed that the concentrations of metallic elements could be multiplied by a factor of 1 to 50. More recently Douay et al. (2008) showed a higher contamination level of urban soils than those of the agricultural ones in similar environmental context. This is the case for As, Bi, Hg, In, Ni, Sb, Sn but also Cd, Pb and Zn for which a transfer from the topsoil to the deeper layer was suspected. The authors explained that by the cultivation practices, the addition of ashes and various chemical products such as pesticides, herbicides. Moreover, previous works showed a transfer of Cd, Pb and Zn from the soil towards the roots and the foliar parts of different plants (grass, vegetables, trees) grown in this area (Bidar et al., 2007; Pruvot et al., 2006).

Based on these results, the objective of this study was to evaluate the effectiveness of phosphatic amendment on the mobility and phytoavailability of Cd, Pb and Zn in two contaminated kitchen garden soils located nearby these two smelters in comparison with an agricultural soil considered as a control. The chosen amendment was a mixture of hydroxyapatite and phosphate diammonium. In order to understand the behaviour of these pollutants in the selected soils, different extraction protocols were used. Firstly, mobility of the pollutants on the amended and non-amended soils was evaluated according to the Standards, Measurement and Testing programme and the selective extractions (CaCl₂, CH₃CO₂H and citric acid). Secondly, the step was supplemented by an evaluation of the impact of the amendment on the phytoavailability by using ryegrass (Lolium perenne L.). Two experiments were carried out. In the first one, soils and ryegrass were watered with distilled water (pH = 7). In the second one osmosed water (pH = 5.5) was used to evaluate the effects of the system acidified water – phosphatic amendment on the mobility and phytoavailability of Cd, Pb and Zn. After a two month incubation period, the selective extraction showed that the effectiveness of the studied amendment depended on the element, on the soil and on the pH of watering water. In a surprising way, the acid extractability of Pb in the soils watered with acid water is lower than those obtained with distilled water. Phosphatic amendment increased the biomass of ryegrass on the three soils on which distilled water was used. However, the biomass of ryegrass on two amended soils decreases with the acidity water. The results showed high concentrations of Zn in ryegrass grown on the amended soils. The increasing of the Cd phytoavailability in the second experiment was lower than in the first. For Pb, the results depend on the watering conditions and the physico-chemical parameters of the soils.

References


Nitrogen mineralization in rehabilitated quarries in Hong Kong

Hao Zhang and L. M. Chu

Department of Biology, The Chinese University of Hong Kong, Shatin, NT, Hong Kong, China,
zhanghao@cuhk.edu.hk, leemanchu@cuhk.edu.hk

Mineral N flux in soil was studied using an *in situ* soil incubation technique at different rehabilitated phases of three quarries in Hong Kong: Turret Hill (TH), Lam Tei (LT) and Shek O (SO). The three quarries were rehabilitated progressively and consequently had different phases in terms of restoration date. One phase (rehabilitated in 1994) was studied in TH; three phases (rehabilitated in 1998, 2001 and 2004) in LT; four phases (rehabilitated in 1998, 2001, 2004 and 2006) in SO. Results show that ammonification predominated over nitrification in TH and LT, while nitrification predominated in SO. Net NH$_4$ mineralization was significantly higher ($p<0.05$) in LT01 and LT04, and net NO$_X$ mineralization was highest ($p<0.05$) in SO98. Net N mineralization increased with increasing restoration age in SO, while these trends were not obvious in LT and TH. Leaching loss of N occurred in all phases, except LT04 and SO01 for NH$_4$. LT98 and SO98 had the highest leaching of N, while others had no significant difference ($p>0.05$). Plants took up more NO$_X$ than NH$_4$ in LT98, LT01, SO98, SO01 and SO06. Because of high leaching of N in summer, N uptake by vegetation only occurred in LT04 and SO04, while there were no significant differences among others ($p>0.05$). N flux fluctuated with the ecological development of vegetation and soil (Chu, 2003). Exotic species that are fast growing and tolerant to adverse conditions were mostly preferred in the revegetation of quarries in Hong Kong. With secondary succession that takes place after planting, N flux changed with site age and species planted. N deficiency is a potential problem in restored quarries as a consequence of high nitrification coupled with excessive leaching loss.

Table 1 N mineralization, leaching and uptake (µg g$^{-1}$ day$^{-1}$) in soils of different phases in three quarries.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Net N mineralization</th>
<th>Leaching of N</th>
<th>Uptake of N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH$_4$</td>
<td>NO$_X$</td>
<td>NH$_4$</td>
</tr>
<tr>
<td>TH94</td>
<td>0.149b</td>
<td>-0.076d</td>
<td>0.202b</td>
</tr>
<tr>
<td>LT98</td>
<td>-0.056cd</td>
<td>0.143cd</td>
<td>0.969a</td>
</tr>
<tr>
<td>LT01</td>
<td>0.680a</td>
<td>0.170c</td>
<td>0.200b</td>
</tr>
<tr>
<td>LT04</td>
<td>0.528a</td>
<td>0.122cd</td>
<td>-0.054cd</td>
</tr>
<tr>
<td>SO98</td>
<td>-0.192d</td>
<td>1.266a</td>
<td>0.063bc</td>
</tr>
<tr>
<td>SO01</td>
<td>-0.159d</td>
<td>0.464b</td>
<td>-0.152d</td>
</tr>
<tr>
<td>SO04</td>
<td>0.160b</td>
<td>0.205c</td>
<td>0.129bc</td>
</tr>
<tr>
<td>SO06</td>
<td>0.081bc</td>
<td>0.168c</td>
<td>0.084bc</td>
</tr>
</tbody>
</table>

Mean values followed by the same letter in a column are not significantly different at $p=0.05$ level by the Tukey's HSD test

Reference

Impact of hydrological process on ecosystem services in mitigation wetlands: Case studies in Ohio, USA

Li Zhang, Kay Stefanik, William J. Mitsch
Wilma H. Schiermeier Olentangy River Wetland Research Park, The Ohio State University, Columbus, Ohio 43202, USA

Mitigating the loss of a wetland requires an understanding wetland ecosystem services (e.g., water storage, water quality improvement, vegetation succession, aquifer maintenance, climate mitigation) is needed. This study provides case studies at the Olentangy River Wetland Research Park and others mitigation wetlands in Ohio, USA, demonstrating hydrological dynamics, water quality and vegetation succession after mitigation wetlands are created or restored. The mitigation wetlands at the Olentangy River Wetland Research Park receive 7 to 15 flood pulses each year, while other mitigation wetlands have less than 15 cm of standing water and are dominated by Eleocharis obtusa, Typha sp., Juncus sp., Leersia oryzoides. Eleocharis obtusa, and Cyperus strigosus. Net sediment deposits range from 127±17 g-dry wt m⁻² to 149±23 g-dry wt m⁻² for bottomland hardwood forested mitigation site. Mean retention rates for total nitrate-nitrite and total phosphorus (TP) were 60% and 80% respectively for riparian mitigation wetland. Pulsing events may accelerate biogeochemical processes from flooded sediment to surface soils. Restoration of seasonally flooded mitigation wetlands could stimulate potentially large nutrient releases, which would eventually lead to enhanced ecosystem services.