Plenary Presentation

In situ Remediation and Phytoextraction of Soil Ni.

Rufus L. Chaney1, Urszula Kukier2, Grzegorz Siebielec3, Yin-Ming Li3, Eric P. Brewer3, Carrie E. Green1, J. Scott Angle4, Richard J. Roseberg5, Alan J.M. Baker6 and Roger D. Reeves7. (1USDA-ARS, Beltsville, MD; 2Institute for Soil Science and Plant Cultivation, Pulawy, Poland; 3Viridian LLC; 4Univ. Maryland-College Park; 5Oregon State Univ.-Medford; 6Univ. Melbourne; 7Massey Univ., NZ)

Ni contaminated soils may be Ni phytotoxic depending on soil and plant properties. Little research on environmental Ni was specifically focused on persistent remediation of Ni phytotoxic soils. Successful revegetation at Sudbury provided an example of what could be achieved. But more knowledge was needed to determine the range of remediation technologies, which could achieve effective revegetation with a diverse ecosystem at low cost.

We undertook a soil Ni risk assessment and remediation research program to more fully understand Ni phytotoxic soils and developed methods for remediation. Key understandings of the risk assessment include 1) as Ni phytoavailability increases, sensitive plants suffer toxicity before animals which would consume the plants, or humans from either garden foods or soil and dust ingestion; 2) soil pH very strongly affects Ni phytoavailability, as do soil organic matter and hydrous Fe and Mn oxides; and 3) if Ni phytotoxicity was remediated, diverse ecosystems could thrive without removing the soil Ni.

In cooperation with Inco Ltd. and Viridian LLC, we undertook tests of soils variables, which affect Ni-phytotoxicity, plant species differences, and development of a complete phytoextraction technology for excessive soil Ni. Soils from Port Colborne, Ontario, were used in these tests, including the Quarry muck from a vegetable farm where Ni phytotoxicity occurred with many crop species, and a farmed Welland soil, which was very acidic. Interestingly, liming the Quarry muck induced Mn-deficiency and prevented remediation of Ni phytotoxicity until Mn fertilizer was applied. When Mn fertilizer and other fertilizers needed for a fertile calcareous soil were supplied, Ni-sensitive crops grew well on both soils. This observation was extended to 11 crop species, and to 10 organic and mineral soils with varied properties. At least for soils with as high as 6,000 mg Ni/kg, normal plant growth was observed when soils were made calcareous with dolomitic limestone and enough Mn was added to prevent deficiency. Field tests fully confirmed the success of this approach in Port Colborne. One basic finding from this work was the ability of soil Ni to fill phytosiderophores (secreted by grasses), which caused Ni-induced Fe chlorosis.

In separate work, we developed a complete Ni phytoextraction technology using the Ni hyperaccumulator, Alyssum murale. Over 200 ecotypes of several Ni hyperaccumulator species were collected in southern Europe; genetic differences in Ni hyperaccumulation, yield, and other phenotypic characters relevant to phytoextraction were observed. New cultivars were developed by normal plant breeding to combine favorable characters of Alyssum. All fertilizer and soil amendment needs for this new crop were characterized, as were herbicides, planting density, planting and harvest schedule, etc. Hardy A. murale, which attained up to 2.7% Ni in dry shoot biomass when grown on serpentine soils in Oregon, were common. Some were cold tolerant enough for Canada, and are perennial with annual harvest at early flowering. This species is very effective in obtaining soil phosphate compared to crop plants. And shoot Ni concentration increased with increasing soil pH even though soil solution Ni declined as pH increased. Last, the agronomic management needed for Ni phytoextraction at Port Colborne were addressed. Regional soils were contaminated only to the depth of tillage, were poorly drained, and seasonally very wet. Use of ridge-tilling so that more of the root system was aerobic, coupled with reasonable drainage, allowed effective growth of A. murale.

The last step in commercial phytoextraction/phytoremediation of Ni rich soils was recovery of Ni from plant ash. Ash (500 kg) from field grown Alyssum species was processed at Sudbury with ready Ni recovery. Plant ash is a simple matrix compared to common ore materials, offering inexpensive Ni smelting from phytoextraction biomass. Commercial phytoextraction from mineralized soils in Oregon has begun. The technology is necessarily limited to arable soils. Between phytoextraction and in situ inactivation of soil Ni, all Ni affected soils can be remediated at reasonable cost.
