Canadian Network of Toxicology Centres

Metals In The Environment Research Network

SCIENCE BRIEF (June 2004)

METAL DYNAMICS WITHIN NORTHERN FOREST ECOSYSTEMS

ISSUE

Research on metals in terrestrial systems has generally focused on agricultural areas; there has been relatively little research done on metals within northern (or other) forest ecosystems. Little is known concerning cycling of metals by plants in forest ecosystems, or the contribution of groundwater to metals loadings to surface waters. Similarly, the relative uptake rates of different metals and their routes of uptake are virtually unknown. Thus, the relative risks of metals to these ecosystems are poorly defined. Previous to this research, there were no scientifically credible means to evaluate the risks posed by metals originating from industrial activities and deposited within northern forest ecosystems.

SIGNIFICANCE

This research has provided data and models that allow reasonable predictions of the movement of metals within northern forest soils, from the soil to forest plants and back to the soil. The models provide generic tools that can be adapted to specific situations to evaluate the effects of industrial metal emissions on northern forests. Research conducted at study sites downwind from two eastern Canadian metal smelters found that plant-associated transfer of metals to soil can be as important as current atmospheric inputs in maintaining elevated metals concentrations in surface soils. However, the metals in these forest systems (from both natural processes as well as the smelters) tend to occur in highly stable forms that likely have very low risk of causing

BACKGROUND

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The emission of metals to forest ecosystems, as a result of mining and smelting activities, occurs worldwide. In Canada, such metal deposition often is to northern forest ecosystems. A proportion of the deposited metals, together with metals from natural sources such as weathering of soil minerals, is taken up by the forest plants and cycles within the forest ecosystem. This study focused on four metals: copper, zinc, lead, and nickel. The dynamics of these metals were assessed for soil and ground water, with respect to uptake and cycling within four native plant species: red pine, black spruce,

white birch and white spruce. Three critical questions were addressed: (1) What is the distribution of metals among forest plants, and how does this relate to soil metal measurements? (2) What is the contribution of vegetation to soil metals? (3) Can single standards for metals be applied to similar soil types?

FINDINGS

This research, carried out through the Metals in the Environment Research Network (MITE–RN) program, answered the above three questions as follows. (1) Most of the plant-associated copper, lead and nickel was in the fine roots. Zinc was found primarily in foliage. Accumulation of metals differed significantly among plant vegetation compartments (foliage, fine roots, bark, trunk and branches). Free metal ion concentrations in soils were generally, but not always, better associated with accumulation of metals by plants than were total metal concentrations in soils. (2) Plant-associated transfer of metals to soils is of equal or greater importance than current atmospheric metal inputs in maintaining elevated metals concentrations in surface soils. (3) The nature of forest ecosystems has an equal if not greater impact on the biological availability of metals than the actual quantity of emissions, even within similar ecosystems (e.g., a single soil type). Thus, any soil quality criteria or guidelines for metals need to be specific to both soil type, and type of plant community.

CONTINUING RESEARCH

The above research has profound implications for risk assessments of metals in northern (and other) forest ecosystems. Additional research is needed to develop ecological endpoints that are based on forest function related to free metal concentrations in soil solutions. Such endpoints would form the basis for calculating critical additional (cumulative) loads of metals to forest ecosystems, taking into account existing metal loads in those systems. In other words, they would tell us what additional loadings of metals the forests could tolerate without damage.

ADDITIONAL INFORMATION

D. MacDonald, K. Taillon, D. Johnson, B. Hale and W. Hendershot. 2003. Modeling the effect of trace metal emissions on boreal forest soils. Human and Ecological Risk Assessment, volume 9, number 4, pages 723 to 747.

D. Johnson, D. MacDonald, W. Hendershot and B. Hale. 2003. Metals in northern forest ecosystems: role of vegetation in sequestration and cycling, and implications for ecological risk assessment. Human and Ecological Risk Assessment, volume 9, number 4, pages 749 to 766.

http://www.mite-rn.org/research/era/era.shtml

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