LAND APPLICATION OF MUNICIPAL SLUDGE IN NEW HAMPSHIRE FORESTS: MINIMIZING THE RISKS TO GROUNDWATER QUALITY

Investigators: Dr. William B. Bowden and Dr. C. Tattersall Smith

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Problem and research objectives

The New England region is experiencing a rapid decline in the availability of landfill space to dispose of wastes generated by society. One solution is to reserve this limited space for highly toxic substances and to recycle appropriate wastes in beneficial ways. Municipal sludges constitute a significant volume of wastes that have in the past been landfilled, incinerated, or dumped in the ocean; practices that each have growing social and legal problems. As an alternative, some municipal sludges contain valuable nutrients and little or no toxic materials, and might be applied on nutrient-poor forest lands to improve soil conditions or to promote tree growth. However, to be a viable alternative, it is essential to establish that forest land application does not adversely affect ground and surface water quality, soil chemical characteristics, changes in plant species composition, or tree growth rates. In general, surface and groundwater contamination from land application of sludge can be minimized if sludge loading and mineralization rates do not exceed the capacity of the soil and vegetation to store various sludge constituents. Specifically, we hypothesize that if sludge applications are managed to minimize nitrate leaching, this will coincidentally minimize impacts due to phosphate, heavy metals, and toxic organic compounds, since nitrate is more mobile than most other sludge-derived constituents.

Principal Findings and Significance:

Soil solutions

Nitrate-N has been virtually undetectable in soil solutions from the untrenched (i.e. undisturbed, vegetated) areas of all treatment plots. In contrast, nitrate levels within the trenched (i.e. non-vegetated) areas began to increase dramatically in the fall of 1989, about 3-4 months after the sludge was applied. This result indicates that tree uptake can effectively block N mobility even at the 800 kg N/ha level. Once the tree barrier is removed (as in the trenched areas), ammonium from mineralization of the organic-N in the sludge is rapidly nitrified to mobile nitrate.

Our data indicate that cation exports from the trenched areas (dominated by Ca^{++} and Na^{+}) are largely balanced by NO_3^-, Sulfate, followed by Cl^-, are the next most important anions in the trenched soil solution. In the untrenched soil solutions, where nitrate is rarely present, sulfate dominates the anions, followed by chloride. Phosphate was never above detection limits in any lysimeter or treatment. Total alkalinity was measured in samples after April 1989 but tends not to contribute much to the anion sum. It is generally less important than chloride on a total charge basis. Ammonium was less abundant than any of the base cations in soil solution.

There was a highly significant, positive relationship between nitrate leaching and cadmium and zinc leaching. In contrast, we found no significant relationship between nitrate leaching and copper or lead leaching. We can not detect either nickel or chromium in our leachates. At low nitrate leaching levels, leaching of all six measured metals was also low.

Vegetation

Sludge additions clearly increased the nitrogen content of the overstory beech trees. Qualitative measurements indicate that the herb biomass (which was small initially) have not changed.

Soils

Analysis of all three soil samples data sets is complete for total Kjeldahl nitrogen, total phosphorus, and DTPA extractable metals. Data reduction of these analyses is currently under way. Exchangeable cations will be analyzed on selected samples, this fall.

Nitrogen mineralization

Mineralization rates were highest in the surface sludge/organic horizon samples during the summer and fall following sludge application. Deeper mineral soils had small amounts of either mineralization or immobilization during the August/September sampling period. Ammonium production peaked in the surface horizons (0 cm) during the first sampling period (July) for all treatments except for the control, which peaked during the second sampling period (August/September). During the first incubation period, ammonium production increased in direct relation to the amount of sludge originally added; controls had the lowest rates and the 800 kg N/ha treatment had the highest. Nitrate production was negligible during the first sampling period and peaked during the second, again in the surface horizons, for all treatments. Nitrate production was greatest in the mid-level (400 kg N/ha) treatment rather than the high-level (800 kg N/ha) treatment, suggesting the possibility that there was some inhibition of nitrification at the high loading rates.

Our data suggest that, as long as the loading rates are below 800 kg TKN/ha (operationally 400 kg TKN/ha might be a better target rate) and tree uptake is adequate, sludge applications should not lead to unacceptably high levels of nitrate leaching. Sludge additions stimulated nitrogen mineralization in surface soil horizons, for a short period of time. However, plant uptake was sufficient to minimize nitrification of this ammonium to nitrate, and so, prevented nitrate leaching. Furthermore, there appeared to be little or no mobility of other nutrients. Phosphate was virtually immobile. Base cation mobility was acceptably low, excepting calcium, which was added in enormous quantities in the sludge. Of the six heavy metals measured, only cadmium and zinc increased with nitrate leaching. Both metals remained below the current ambient water quality standards, even at high nitrate leaching levels.