ABSTRACT

The increasing need in the U.K. for disposal of sewage sludge on land is hampered by frequent contamination of sludge with potentially toxic heavy metals. This problem is most likely to cause adverse effects on human health when sludges are applied to agricultural soil. Forest soils may therefore provide an alternative safer system for sewage disposal, although the long-term nutrient cycling needs of forest crops must not be deleteriously affected. This thesis aimed to investigate the effects of application of heavy metal contaminated sewage sludge on long-term nutrient cycling in coniferous forest soil.

A field study was carried out at Ardross forest, northern Scotland where heavy metal contaminated sewage sludge had been applied to a peaty podzol at rates of 500 (low) and 1000 (high) kg N ha^{-1} before tree (Sitka spruce) planting. Nitrogen mineralisation rates determined by field incubation of sealed cores ranged from 3.7 to 4.5 and 7.3 to 9.4 kg N h^{-1} over the growing season (May to September, 1991) in soils amended with low and high rates of sludge respectively. For the control soil, to which no sludge had been added, mineralisation rates ranged from 2.4 to 2.9 kg N ha^{-1}. Mineralisation of residual sludge was estimated to be 0.56% and 1.14% in 1991, 8 years after sludge application at the low and high rates, respectively.

Soils brought back to the laboratory and repacked according to the field profile enabled microcosm studies to be carried out to further investigate possible changes caused to N-cycling processes in coniferous forest soil due to application of heavy metal contaminated sewage sludge, and to consider possible mechanisms of any such changes. In the microcosm study, the two rates of application of sewage sludge increased N mineralisation. A linear relationship was apparent between N mineralisation and the rate of sludge application. Increased N mineralisation was associated with an increase in active fungal mycelium, biomass N and soil animal population densities.

The availability of Cd, Cu, Mn, Pb and Zn was found to be related to the time of the year, with highest availability in Spring and Summer, and lowest availability in Winter. There was no evidence of any adverse effects in terms of heavy metals on the studied biological parameters and mineralisation rates in the field and microcosm studies. Total N, pH and moisture also increased due to sludge application.

The germination of spores of fungi isolated from the Ardross forest sites was used as a bioassay to identify the potential for heavy metals from sewage sludge to adversely affect the forest soil microbial community. However, heavy metal concentrations similar to those obtained through water extraction did not cause any toxic effects on the germination of *Penicillium notatum* and *Aspergillus flavus*. Only extracts sterilised by membrane filtration and autoclaving inhibited spore germination.

A laboratory perfusion study was carried out to assess whether heavy metals from sewage sludge may affect N mineralisation (ammonification and nitrification) in forest soil. Production of mineral N from perfusion columns ranged from rates equivalent to 0.15 to 0.21 kg N ha^{-1} d^{-1}. However, highest production of mineral N (NH_4-N and NO_3-N) was associated with perfusing solutions containing heavy metals (at concentrations realistic for sludge treated soils) rather than metal-free solutions. This may have been related to simple ion exchange rather than stimulation of N mineralisation by the heavy metals.

Overall, this thesis found sewage sludge to offer excellent long-term fertiliser value to forest soil with no discernible detrimental effects of entrained heavy metals. The thesis concludes by considering the limits currently set by the Forestry Commission for sludge disposal to forest soils and discusses them in relation to the findings of this combined field and laboratory study.