Chapter 16
Interactions of Fungi and Radionuclides in Soil

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16.1 Introduction

Following the development of nuclear weapons and the subsequent evolution of nuclear energy-generating industries, there has been considerable concern regarding the safe storage of radionuclide waste. Widescale release, in the aftermath of nuclear detonations or as the result of malfunction of atomic energy plants and reprocessing facilities, has also been a preoccupation. The International Commission on Radiological Protection recommendations on the ecological aspects of radionuclide release were discussed by Coughtree (1983), in which Heal and Horrill (1983) summarized element transfers within terrestrial ecosystems, highlighting the importance of organic soil horizons and their microbial communities as potential accumulators of both nutrient elements and radionuclides. This was a significant step forward from initial discussions of the impact of radionuclide fallout on ecosystems, where the involvement of fungi in regulating radionuclide movement was limited to one sentence in a paragraph describing radionuclide accumulation in organic horizons of forest soils, which may be related to fungal biomass (Osburn 1967). Now, in a more recent model of radiocesium migration in forest ecosystems, Avila and Moberg (1999) place fungal activity in the pivotal point of the diagonal of their interaction matrix, as one of the important biotic regulators of radionuclide movement in soils.

Concerns over global climate change and the limitations of conventional fuels is making the world consider alternative energy sources other than fossil fuels. One of these alternatives, nuclear energy, is already in use in many countries, although its expansion has been shadowed by the explosion of the reactor at Chernobyl, Ukraine in 1986. It is likely, however, that there will be future expansion of nuclear activity, which may lead to an increased possibility of local or widespread nuclear contamination of terrestrial systems. It is, therefore, essential that we have adequate knowledge of the behavior of radionuclides in a variety of environments and enough

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understanding of the biotic regulators of radionuclide movement to assist us in limiting potential damage and effecting remediation as efficiently as possible.

It is probable that future studies along those lines will point to fungi as an important component of environmental systems involving radionuclides. Indeed, Steinera et al. (2002) open their introduction by saying 'Fungi are one of the most important components of forest ecosystems, since they determine to a large extent the fate and transport processes of radionuclides (...)', and fungi have been suggested as being potentially important agents for bioremediation (Gray 1998; Skladany and Metting 1992). A brief review of the interactions between radionuclides and fungi (Zhdanova et al. (2005b) calls for greater understanding of the nature of these interactions, particularly from a molecular standpoint and from the point of view of using fungal and plant–fungal interactions in remediation of polluted systems.

16.2 Fungi as Regulators of Radionuclide Movement

16.2.1 Role of Saprotrophic Fungi

Saprotrophic fungi are involved in the decomposition of dead organic residues (plant and animal remains) in soil. In order to assimilate the end products of extracellular enzymatic activity, fungi present an enormous surface area of hyphae to their surrounding environment. As such, these organisms are well fitted to absorb other elements, including radionuclides, from the soil environment. Microbial immobilization of radionuclides was identified by Witkamp and Barzansky (1968), who showed that microbial communities on decomposing leaf litter and cellophane accumulated almost three times the amount of radiocesium immobilized by sterile equivalents. Witkamp (1968) measured radiocesium incorporation into the fungus Trichoderma viride from fresh or highly decomposed leaf litter and wood. He showed that the concentration factor in fungi decreased as the leaf litter source of cesium aged (2.36, 0.46, and 0.23 for litters of 4, 16, and 48 month-old leaf litter). The highest concentration factor (4.31) was found from freshly fallen wood. This pioneering work provided basic evidence to suggest that fungi could be significant ecosystem components in regulating movement of radionuclides in the environment.

Grassland soil saprotrophic fungi have been shown to have great potential for uptake and immobilization of radiocesium fallout (Olsen et al. 1990; Dighton et al. 1991). Assuming an average influx rate of 134 nmol Cs g⁻¹ dry weight of mycelium (determined from laboratory uptake studies) and an estimate of hyphal biomass of up to 6 g dry weight m⁻² of soil (determined by hyphal length measurements of field collected samples; Dighton and Terry 1996), Dighton et al. (1991) estimated that the fungal community of upland grass ecosystems in northern England would be able to take up between 350 and 804 nmol Cs m⁻¹ h⁻¹. These fungi might have accumulated a large percentage of the total Chernobyl fallout in the United Kingdom as the