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Plant uptake and downward migration of ^{85}Sr and ^{137}Cs after their deposition on to flooded rice fields: lysimeter experiments with and without the addition of KCl and lime

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Abstract

In order to study the plant uptake and downward migration of radiostrontium and radiocesium deposited on to a flooded rice field, ^{85}Sr and ^{137}Cs were applied to the standing water over an acidic sandy soil in planted lysimeters. The plant uptake was quantified with the areal transfer factor (TF_a, m^2 kg^{-1}-dry plant). Following the spiking 14 days after transplanting, the TF_a values for the hulled seeds were 3.9×10^{-4} for ^{85}Sr and 1.4×10^{-4} for ^{137}Cs, whereas those for the straws were 1.3×10^{-2} and 3.2×10^{-4}, respectively. The ^{137}Cs TF_a from the spiking at the anthesis/milky-ripe stage was several times higher than that from the earlier spiking, whereas the difference was much less in the ^{85}Sr TF_a. Such an increase in the ^{137}Cs TF_a was attributed mainly to an enhanced plant-base uptake. The addition of KCl and lime after the spiking significantly reduced the TF_a values of both radionuclides. The reducing effect was greater for the later spiking. An appreciable fraction of the applied activity leached out of the lysimeter for ^{85}Sr, whereas a negligible fraction leached for ^{137}Cs. The leaching was remarkably increased by the KCl and lime addition for both. A conspicuous localization of ^{137}Cs with respect to the soil surface was observed. In a batch experiment, the ^{137}Cs concentration in the standing water decreased more rapidly than that of ^{85}Sr, both of which

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were fitted to the power functions of the elapsed time. To add KCl and lime slowed such decreases to lessen the distribution coefficients (K_d) of both ^{85}Sr and ^{137}Cs.

Keywords: ^{85}Sr; ^{137}Cs; Rice; Uptake; Migration; K_d; KCl; Lime

1. Introduction

Radionuclides released into the atmosphere from a nuclear installation can be deposited on to agricultural fields. If the radioactive release occurs during the rice-growing season, radionuclides are deposited not on to the soil but on to the standing water, because rice plants normally grow under flooded conditions. Another pathway for the radionuclide transport to arable land is the use of contaminated water. This pathway would be important particularly for rice, the culture of which requires a great deal of irrigation water.

Plant uptake of the activity deposited on to arable land is generally quantified with the mass-based transfer factor (TF_m) expressed as the ratio of the plant concentration (Bq kg^{-1}) to the soil concentration (Bq kg^{-1}). The TF_m is measured in the soil that is mixed well with the activity before planting so it cannot be applied to an acute deposition during plant growth. After such a deposition, most activity would stay near the soil surface until harvest and the plant uptake may greatly depend on the time of deposition. A solution to the problem is to use the areal transfer factor (TF_a, m^2 kg^{-1}), which is based on the unit-area deposition (Bq m^{-2}) at different growth stages. The term, areal transfer factor, is cited from Leung and Shang (2003).

The unit of TF_a is the same as that of the aggregated transfer coefficient, C_{ag} (IAEA, 1994; ICRU, 2001). However, the two parameters have different natures. The latter relates to natural and semi-natural ecosystems after the directly deposited activity on the plant has been removed or lost (IAEA, 1994). In contrast, the former deals with the ground deposition occurring together with the direct plant deposition mainly in arable land at the event of an accidental release. This means that the TF_a is one of the parameters applicable to predicting the radionuclide concentration in the plant that is growing while an accidental release occurs.

Many researchers (Myttenaere et al., 1969; Tsumura et al., 1984; Choi et al., 1991; Komamura and Tsumura, 1994; Mollah et al., 1998; Wang et al., 1998; Choi et al., 1999; Tsukada et al., 2002a) have reported the TF_m values of radiocesium and/or radiostrontium for rice. Almost nothing is reported about the TF_a values for rice except for the works of Choi et al. (1995); Choi et al. (2002a) and Leung and Shang (2003).

After the entry of radionuclides into rice fields, a fraction of the activity will migrate into the deep soil along with the percolating water. Radionuclides in the deep soil can ultimately arrive at remote areas by underground water movement. It is, therefore, also important to understand the downward migration of major