Studies on the Gamma Radiation Environment in Sweden with Special Reference to ^{137}Cs

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Abstract

Gamma radiation in the environment today mainly originates from naturally occurring radionuclides, but anthropogenic radionuclides, such as ^{137}Cs, contribute in some areas. In order to assess population exposure in case of fallout from nuclear weapons (NWF) or accidents, knowledge and monitoring of external gamma radiation and radionuclide concentrations in the environment is important. For this purpose 34 sampling sites were established in western Sweden and repeated soil sampling, field gamma spectrometry (*in situ* measurements), and dose rate measurements were performed. The variations in the activities between the different sampling occasions were found to be quite large. The naturally occurring radionuclides were the main source of outdoor dose rates. The uranium and thorium decay series contributed about equally to the total dose while the contribution from ^{40}K was somewhat higher. The dose rates were mainly correlated to the ground cover, with higher levels on asphalt and cobble stones than on grass.

The large scale deposition densities from NWF and the Chernobyl accident could be relatively well estimated by a model including the amount of precipitation and measured deposition at few reference sites. The deposition density from nuclear weapons tests in Sweden between 1962 and 1966 was found to be 1.42-2.70 kBq/m^2 and the deposition density from Chernobyl in western Sweden ranged between 0.82-2.61 kBq/m^2.

The vertical migration of ^{137}Cs was studied at the sampling sites in western Sweden and a solution to the convection–diffusion equation (CDE) was fitted to depth profiles. The vertical migration of ^{137}Cs was found to be very slow and diffusive transport was dominant at most locations. The apparent convection velocity and diffusion coefficient were found to be 0–0.35 cm/year and 0.06–2.63 cm^2/year, respectively. The average depth of the maximum activity was 5.4±2.2 cm. The fitted depth distributions for each location were used to correct *in situ* measurements and the results agreed relatively well with the ^{137}Cs inventories in soil samples.

A widespread deposition of radionuclides was caused by the Chernobyl accident and parts of Sweden were highly affected. Today, approximately 20 years since the latest deposition, ^{137}Cs can still be measured in the environment and contributes to additional doses to people. However, today people generally spend much time in their dwellings, and therefore, the radiation environment indoors is more important for the personal exposure. Dwelling and personal dose rate measurements in western Sweden (means: 0.099±0.035 µSv/h and 0.094±0.017 µSv/h, respectively) showed that concrete dwellings yield higher dose rates than those of wood. Measurements in a region with a high ^{137}Cs deposition (Hille in eastern Sweden) showed somewhat higher dose rates in wooden dwellings than in western Sweden (0.033 µSv/h and 0.025 µSv/h higher, respectively). The additional contribution from the Chernobyl ^{137}Cs fallout in Hille was estimated to be about 0.2 mSv/year.

Keywords: gamma radiation, caesium, ^{137}Cs, deposition, migration, precipitation, in situ, CDE, NWF, Chernobyl, soil sampling, field measurements, dose measurements, dose rate, TLD, natural radiation, Kriging

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