ASSESSMENT OF RADIATION DOSES DUE TO RELEASES TO THE BIOSPHERE FROM NUCLEAR WASTE REPOSITORIES

R. Korhonen and I. Savolainen
Nuclear Engineering Laboratory
Technical Research Centre of Finland
P.O.Box 169, Helsinki 18, Finland

INTRODUCTION

Estimation of radiation doses due to releases from nuclear waste repositories comprises phases covering first the near-field, i.e. the behaviour of radioactive waste products, canisters, buffer materials and rock and ground-water close to the repository, and second, radionuclide migration in the geosphere and, third, migration in the biosphere and accumulation of radiation doses. A full analysis chain is performed in Reference /1/, and in this paper some details of the last phase are discussed for the basic scenario of the Reference /1/. The biospheric model is described shortly and the calculational behaviour of two important radionuclides, Ra-226 and U-238 is shown. The total results for the basic spent fuel scenario are presented as an example of the type of information obtained from analyses.

The waste type analysed comprises the spent fuel of two BWR plant operations (1200 tU). The waste is emplaced in copper canisters and the repository is assumed to be located on the coast of the Baltic Sea at the depth of 500 m in hard crystalline bedrock /1/.

BIOSPHERIC MODEL

The release from the repository is assumed to flow via ground water to well, lake or coastal sea. The transfer of radionuclides in the biosphere is described employing a dynamic compartment model, and in each compartment the radioactive material is assumed to be distributed in two phases, solid phase or liquid phase, which is described with the distribution coefficient K_d. The transfer of radionuclides through the part of the biosphere where time-constants are short, as in plants and animals, is described with the employment of concentration factors. Radioactive decay and build-up of daughter-nuclides are taken into account in the model. The exposure pathways which are included in the model are radiation from ground or shoreline, swimming, boating, and ingestion of water, fish, milk, meat and grain. /2/ Figure 1 shows a typical compartment model employed in calculations for the local scale and Figure 2 for the regional (Baltic) and global scales.

The parameters which are needed to calculate the transfer of radionuclides in the biosphere can be divided into two groups. The first group includes parameters which are used to describe the compartments (masses and volumes) and connections between them (flows of water and solids from one compartment to another or outside of the compartment system). The second group of parameters are the nuclide- or element-dependent parameters, which cause that different radionuclides behave in a very different way in the biosphere. These parameters are half-life $T_{1/2}$ and distribution coefficient K_d.

RESULTS AND DISCUSSION

The radioactive half-lifes $T_{1/2}$ of the release nuclides considered vary between 10^3 - 10^{10} a, and the distribution coeffient K_d between 1 - $5 \cdot 10^6$ dm^3/kg. In the following, the behaviour of two in this respect very different radionuclides is studied. These nuclides, U-238 and Ra-226, belong according to calculations to the most important radionuclides in the discussed release scenario.

Table I shows the Ra-226 activity decaying in the local, regional and global scale compartments due to the Ra-226 activity release Q on the local scale. Table II presents the corresponding values for U-238 decay due to U-238 release. The greater K_d-value of the nuclide Ra-226 causes that a greater part of the Ra-226 activity than of the U-238 activity decays on the local scale. Also on the regional scale the accumulation of radionuclide Ra-226 to sediments is stronger in all compartments than the accumulation of U-238. In addition to the situation shown in Table I, the Ra-226 activity is, naturally, also formed by the decay of U-238, U-234 and Th-230 releases in the biosphere.

In Table III the main results of spent fuel dose calculations are shown. The estimated maximum dose rate for a critical person in the basic scenario is 0.02 mSv/a on the local scale and $3 \cdot 10^{-9}$ mSv/a on the global scale. The collective dose commitment in local scenario is $1 \cdot 10^3$ manSv and in global scenario $1 \cdot 10^5$ manSv. The accumulation rate of the collective dose on the global scale is, however, extremely small. The integrated collective dose over those 500 a when the dose rate is highest is $2 \cdot 10^{-2}$ manSv on the local scale and 1 manSv on the global scale. The most important pathways are drinking water from a local well and ingestion of fish. In the main case, where releases to the biosphere begin 10^6 years after disposal, the most important radionuclides belong to the decay chains 4N+2 (U-238 chain) and 4N+1 (Np-237 chain).

On the local scale the most important nuclides are Np-237 and Ra-226. In the case of Ra-226 the doses are in calculations mainly caused by the daughter-nuclide Pb-210. The sedimentation removes more Np-237 and Ra-226 activity from the lake compartment than the water flow from the lake. This is valid also in the case of the most important nuclides Th-229 and Ra-226 on the regional scale, because the K_d-values are relatively high. On the global scale the nuclide U-238 accumulates slowly in the Ocean (residence time 10^6 a). Because its half-life is very long, the sedimentation is also in this case a more important process in removing activity from the Ocean than the radioactive decay.

The accumulation of radioactive material in the sediments seems to be an important removal factor on the scales considered. Therefore it is essential to be able to model the transfer to sediments and the feedback from sediments correctly. The calculated behaviour of radionuclides can be compared with the behaviour of natural radionuclides. The ratios of the concentrations of daughter-nuclides to the concentration of U-238 mother-nuclide are in relatively good agreement in the calculated and measured situations /2/.

REFERENCES

/1/ KORHONEN, R., PELTONEN, E.K., SAVOLAINEN, I., HEINONEN, O.J., MUURINEN, A., VALKIAINEN, M., A comparative assessment of radiological impact due to nuclear waste disposal in hard crystalline bedrock. IAEA conference on radioactive waste management. Seattle, USA, May 16-20, 1983.

/2/ KORHONEN, R., SAVOLAINEN, I., Assessment of biospheric behaviour of releases from nuclear waste repositories. IAEA and CEC seminar on the environmental transfer to man of radionuclides released from nuclear installations, Brussels, Belgium, 17-21 Oct. 1983.

Table I Fractions of Ra-226 release Q decaying in the local, regional (Baltic) and global (Ocean) scale compartments ($T_{1/2}$ = 1600 a, $K_d = 3 \cdot 10^4$ dm^3/kg)

Scale	Lake/sea	Surface sediment 0-5 cm	Buried sediment 5-35 cm	Sediment sink	$\sum$
Local lake	$3.9 \cdot 10^{-5}$ Q	$5.0 \cdot 10^{-3}$ Q	$7.3 \cdot 10^{-2}$ Q	$7.2 \cdot 10^{-1}$ Q	$8.0 \cdot 10^{-1}$ Q
Baltic	$7.4 \cdot 10^{-4}$ Q	$4.6 \cdot 10^{-3}$ Q	$4.6 \cdot 10^{-2}$ Q	$6.8 \cdot 10^{-2}$ Q	$1.2 \cdot 10^{-1}$ Q
Ocean	$6.4 \cdot 10^{-2}$ Q	$5.8 \cdot 10^{-3}$ Q	$7.8 \cdot 10^{-3}$ Q	$7.6 \cdot 10^{-4}$ Q	$8.0 \cdot 10^{-2}$ Q
$\sum$	$6.5 \cdot 10^{-2}$ Q	$1.5 \cdot 10^{-2}$Q	$1.3 \cdot 10^{-1}$Q	$7.9 \cdot 10^{-1}$ Q	1.0 Q

Table II The fractions of a U-238 release Q decaying in various compartments ($T_{1/2} = 4{,}5 \cdot 10^9$ a, K_d = 500 dm^3/kg)

Scale	Lake/sea	Surface sediment 0-5 cm	Buried sediment 5-35 cm	Sediment sink	$\sum$
Local lake	$7.0 \cdot 10^{-11}$ Q	$2.0 \cdot 10^{-10}$ Q	$3.3 \cdot 10^{-9}$ Q	$8.9 \cdot 10^{-2}$ Q	$8.9 \cdot 10^{-2}$ Q
Baltic	$2.8 \cdot 10^{-9}$ Q	$3.6 \cdot 10^{-10}$ Q	$6.1 \cdot 10^{-9}$ Q	$2.5 \cdot 10^{-2}$ Q	$2.5 \cdot 10^{-2}$ Q
Ocean	$1.0 \cdot 10^{-4}$ Q	$2.0 \cdot 10^{-7}$ Q	$3.4 \cdot 10^{-6}$ Q	$8.8 \cdot 10^{-1}$ Q	$8.8 \cdot 10^{-1}$ Q
$\sum$	$1.0 \cdot 10^{-4}$ Q	$2.0 \cdot 10^{-7}$ Q	$3.4 \cdot 10^{-6}$ Q	1.0 Q	1.0 Q

Table III Calculated individual dose rates and collective doses due to releases from a spent fuel repository

Scale	Maximum individual dose rate (Sv/a) and the most important nuclides	Collective dose during the most exposed 500 a (manSv)	Collective dose 0-10^8 years (manSv)
Local	$2.0 \cdot 10^{-5}$ Np-237 , Ra-226	$1.8 \cdot 10^{-2}$ Np-237 , Ra-226	$1.2 \cdot 10^3$ Ra-226 , Np-237
Regional	$2.2 \cdot 10^{-12}$ Th-229 , Ra-226	$2.2 \cdot 10^{-2}$ Th-229 , Ra-226	$2.0 \cdot 10^3$ Ra-226 , U-238
Global	$2.6 \cdot 10^{-12}$ U-238 , Th-229	$1.3 \cdot 10^0$ U-238 , Th-229	$1.2 \cdot 10^5$ U-238

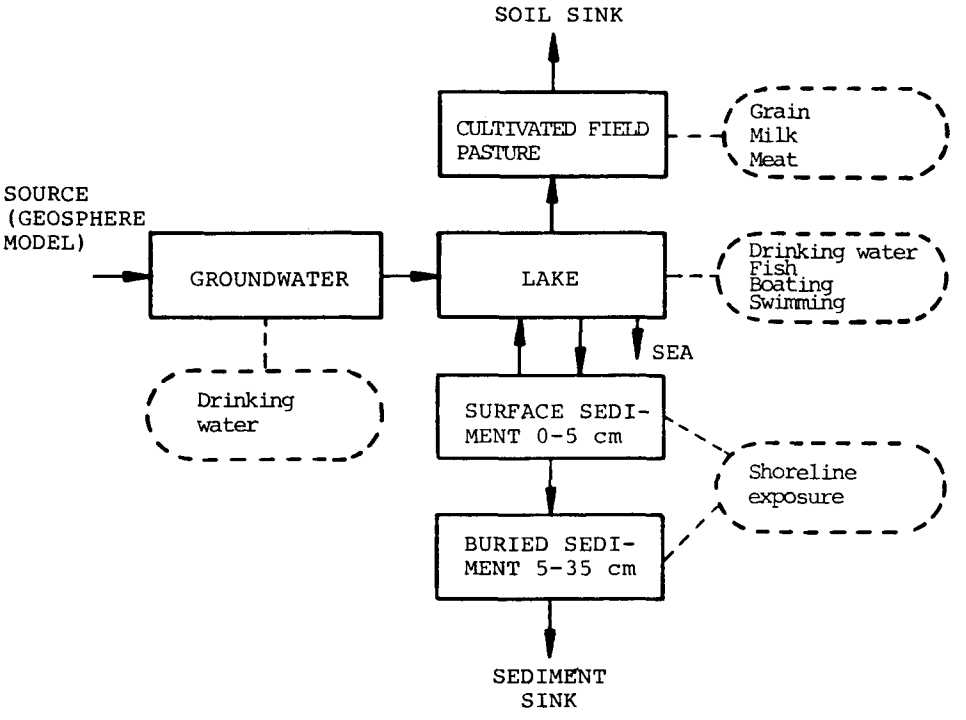

Fig. 1 Compartment model for local scale calculations.

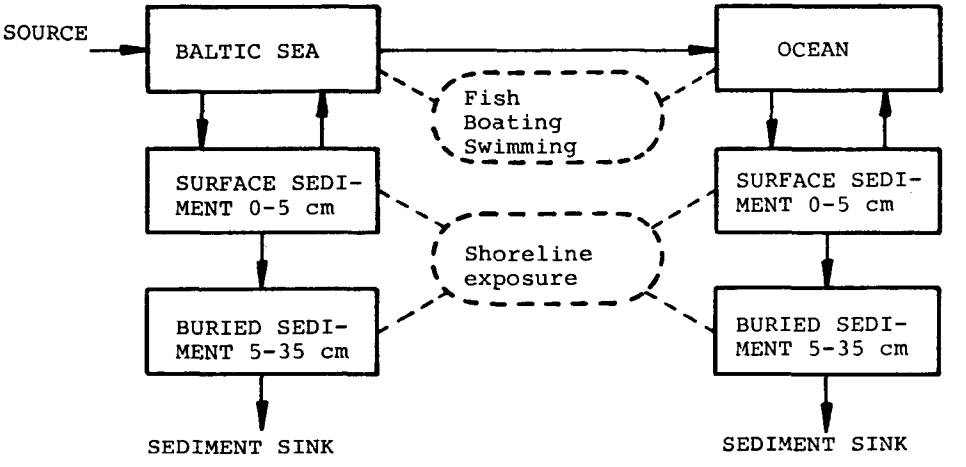

Fig. 2 Compartment model for regional and global scales.