CHAPTER 24

Use of Mathematical Models in Risk Assessment and Risk Management

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Introduction

Mathematical models of the transfer of radionuclides through the environment are used extensively in radiological protection. There are two main reasons for this. The first is that although it is relatively easy to detect radionuclides in environmental materials, it is impossible to take enough measurements to enable estimates to be made of the radiation doses to people from all the sources of current exposure. The second reason is that it is necessary for planning purposes to estimate doses to people in the future, both those from radionuclides that are already present in the environment and those from routine and accidental releases that may occur in the short or long term. It must also be remembered that it is not possible to actually measure the radiation dose to a person from the intake of radionuclides. The best that can be achieved is to measure intake, and even this is extremely difficult in the case of members of the public and involves a significant intrusion into people's lives. Thus, all doses from intakes are calculated, using mathematical models of radionuclide metabolism in the human body.

Initially, the models used in radiological protection were very simple and limited in scope. As knowledge of radionuclide transfer through the various parts of the environment increased, more complex and wide-ranging models were developed, and we have now reached the stage where, worldwide, many models are available for predicting radionuclide transfer through the atmosphere, the terrestrial environment, the marine environment, freshwater, and the geosphere (see, e.g., refs. 1–5). It is neither possible, nor necessary, in this chapter to describe all these models; attention here is limited to the types of models available for predicting radionuclide transfer through terrestrial food chains. The ways in which terrestrial food-chain models are used in assessing the risks associated with existing and planned nuclear installations are described, and examples of the results of such assessments are given. The use of assessment

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results in planning the management of risks is discussed and illustrated by case studies.

The final sections of the chapter deal with the use of models to estimate the radiological consequences of an accident soon after it has occurred and with quantification of the uncertainties in model predictions.

**Models Available for Predicting Radionuclide Transfer Through Terrestrial Food Chains**

The models available for predicting radionuclide transfer through terrestrial food chains can be divided into two categories: "equilibrium" models, which calculate the concentrations of radionuclides in foods under steady-state conditions, and "dynamic" models, which predict radionuclide concentrations in foods as a function of time after the initial input into the environment. Equilibrium models can be used in assessments of the radiological impact of continuous radionuclide releases but are of limited value in the context of accidental releases because in these cases no true equilibrium is reached. Dynamic models, on the other hand, can be applied to both continuous and discrete releases of radionuclides. Since the latter type of release is of most interest, the following discussion focuses on dynamic models.

Fig. 24.1. Basic structure of compartment models. \[
\frac{dN_A}{dt} = S - K_{AB}N_A + K_{BA}N_B - \lambda N_A
\]

S = input to compartment A, atoms per unit time; \(N_A\) = number of atoms in compartment A; \(N_B\) = number of atoms in compartment B; \(K_{AB}\), \(K_{BA}\) = transfer coefficients, per unit time; and \(\lambda\) = radioactive decay constant, per unit time.