Product review

Radioecological software package: an interactive computational system to simulate the behaviour of radionuclides in semi-natural environments

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Abstract

RSP (Radioecological Software Package) is an interactive support system that simulates the behaviour of radionuclides in semi-natural environments and the consequences on the population in terms of the external exposure. RSP consists of three modules: the first one, soil mobility, simulates the vertical transport of radionuclide in soil using the mathematical model RABES. The second module, soil-to-plant transfer, simulates the radionuclide soil-to-plant transfer process using the mean soil concentration in the root zone and values of soil-to-plant transfer factor reported in the literature. Soil properties, vegetation types and environmental conditions are taken into consideration in the simulation process. In the third module, dose assessment, the dose-rate factor in air at a height of 1 m above ground can be calculated for sources distributed in a slab of finite thickness and sources which are exponentially distributed with depth. The calculations are performed using DAGES Model, a Monte Carlo algorithm developed to simulate the photon transport for the soil/air configuration. A free copy of RSP can be downloaded from the web site: http://imasl-apat.unsl.edu.ar.

Keywords: Software; Modelling; Radioactivity; Radioecology; Simulation; Monte Carlo method

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1. Introduction

During the Chernobyl accident, large areas of semi-natural ecosystems were affected by radionuclide deposition. Later investigations have shown that the dose risk to man and the environmental radionuclide circulation persists in the long term. Predictive models are essential to take long-term decisions on the management of contaminated environments and to identify the main processes controlling the dynamics of radionuclides inside the ecosystems. The development of decision support software using these models is of importance for a more effective and friendly application of the models to real situations and for the subsequent analysis of the results.

With this purpose, different expert systems have been proposed dealing with forest ecosystems. For example FORIA system (Rafferty, 2001) provides a synthesis of published information concerning the application of radiological countermeasures in forest ecosystems and the secondary impacts derived from their application. ECORAD (Mamikhin, 1996) is a system designed to simulate the radionuclide dynamics in contaminated forest ecosystems. The RODOS system (Real-time On-line Decision Support system), Müller and Bleher (1997) was designed to evaluate the consequences and to suggest the most efficient countermeasures in case of a nuclear accident in Europe.

In the framework of a research collaboration programme between the National Environmental Protection Agency (ANPA, Roma) and the National University of San Luis (UNSL, Argentina), the Radioecological Software Package, RSP, has been developed, a friendly interactive software compatible with Windows 98 operating system or higher. RSP simulates the behaviour of radionuclides in semi-natural environments and the consequences on the population in terms of the external exposure. It consists of three modules. Module 1, soil mobility, simulates the vertical transport of radionuclide in soil. RABES I model (Toso and Velasco, 2001) has been used to determine the variation in time of the radionuclides in the vertical profile of soil and their mean concentration in each soil layer. The radionuclide soil pattern and its variation in time determined from Module 1 is used in the calculations carried out in the other modules of the system. Module 2, soil to plant transfer, has been designed to simulate the radionuclide soil-to-plant transfer process, using the soil concentration in the root zone and values of soil-to-plant transfer factor reported in the literature. In Module 3, dose assessment, the rate in air at a height of 1 m above ground can be calculated for sources distributed in a slab of finite thickness and sources which are exponentially distributed with depth. The calculations are performed using DAGES Monte Carlo algorithm (Rodrı́guez and Velasco, 1998). This code was developed to simulate the photon transport for the soil/air configuration.

An internal link with a graphic software (Origin 6.0, 1999) has been included to improve the graphic analysis of output results from the different modules of the system.

A free copy of the RSP software can be downloaded from the web site http://imasl-apat.unsl.edu.ar.
2. Software design and structure

Fig. 1 shows the architecture of RSP. The system is a friendly software compatible with Windows 98 Operating Systems. The main menu window of the system is shown in Fig. 2. Buttons to access each module are available in this menu.
To run each module, the system requires the parameter value and the initial condition of the simulation. Briefly, three windows make up the menu of each module:

1. a window for entering data and running the simulation,
2. a window for viewing the results as tables and/or graphics, and
3. a window for opening and deleting files.

Fig. 3a shows the Module 1 menu with the fields to complete in order to run the model:

Initial radionuclide soil deposition
Length of the simulation in years
Radionuclide decay constant
Initial deposition distribution
Expected equilibrium relaxation depth of the radionuclide soil distribution
Soil characteristics

From the output window of this module, Fig. 3b, the following variables can be obtained as a function of time from deposition, in table or graphic format,

radionuclide soil vertical profile
mean soil activity concentration in each soil layer
mean soil activity deposition in each soil layer
intercompartment transfer rate among soil layers
relaxation depth of the soil distribution

Module 2 computes the radionuclide concentration activity in plants using the soil concentration in the root zone (calculated in Module 1) and soil-to-plant transfer factor (TF) reported in the literature. Generic TF values obtained from Frissel et al. (2002) have been incorporated to simulate the radiocaesium transport from soil to plant. The procedure is mainly based on a reference TF value, which depends on soil properties (nutrient status, exchangeable K-content, pH and moisture content). At this stage, vegetation types must also be selected. Fig. 4 shows the input windows for Module 2. Running this module, the time trend of soil to plant transfer factor and the radionuclide concentration in plants can be obtained.

Fig. 5 shows the input window of Module 3. The input values to run this module are: the relaxation depth of the soil radionuclide distribution (in the case of exponential decrease profile), soil density, radionuclide energy, emission probability and radionuclide soil activity deposition.

For all modules, an internal link to Origin 6.0 (1999) software has been provided for a better quality in the graphic format of the output information.

Validation of RSP software has been performed using experimental data from Toso and Velasco (2001). Fig. 6 shows the relaxation length versus time for the experimental situation analysed. In this figure the curve corresponds to output of Module 1 of RSP for the initial configuration showed in the same figure.
Fig. 3. Module 1: a) Input and processing window, b) output window.
Fig. 4. Module 2: Input and processing window.

Fig. 5. Module 3: Input and processing window.
3. Conclusion

A system has been developed to simulate the behaviour of radionuclides in semi-natural ecosystems. The system utilizes three different models, each one as autonomous executable modules. It is possible to use any module separately.

The system runs under Windows Operating System, thus offering a user-friendly interactive regime. The user can establish conditions of deposition and choose the value of the most important environmental variables. Output results can be presented in graphical or table format.

References


