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Demonstration of the Computer Code PC CREAM 08 Abilities to Evaluate Collective and Individual Dose Rates in Case of Accidental Release of Radioactive Isotopes in the Atmosphere

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Abstract. The presented work aims at demonstration of the capabilities of the PC CREAM 08 code to perform evaluation of the individual and collective dose rates for the public in case of radioactive materials pollution in the atmosphere and water. The input data for calculation includes: amounts and isotope content of the released radioactive materials, the geographical data, including population and agricultural data for the investigated region and weather conditions. The output is the distribution of the radioactive materials in the investigated region in the ground, water and food, which allows calculation of the individual and collective doses for the population at various locations.

The presented work was done only for demonstrational purposes and does not show any particular simulated or real accident neither includes any real input data.

Keywords: radioecology, radioactive pollution, individual dose rate, collective dose rate, pccream code

1 Introduction

There are two type of radioactive sources in the nature: natural and artificial. Natural radioactive sources are responsible for the natural background radiation, and the artificial sources, which are products from the industry. Accidental conditions in the nuclear sites may cause release of large amounts of the produced artificial radiation materials in the environment, which is many times larger than the natural background. This imposes the need to perform evaluations of the influence in such conditions on the public in the surrounding area.

Main objective of the radioprotection is to study and develop practices for protection of the people and the environment from the hazardous effects of the ionizing radiation. One of the main methods to perform such estimations is the method of the mathematical modeling by means of simulations, using validated computer codes.

PC Cream 08 is one of the validated tools allowing evaluation of the individual and collective doses for the population in the investigated area. The input for the calculation is the population, agricultural and weather conditions data, together with the amount and isotope content of the polluted material. The evaluation process itself involves many processes related to the radionuclides transport in the atmosphere and water, deposition and suspension in the ground and circulation in the food chains. In addition, the code evaluates the contribution of each type of radiation to the full irradiation load of the human body from various sources. The assessments include short and long term periods.

PC CREAM code is developed by the Health Protection Agency (HPA) at UK and is internationally recognized as a trusted tool for performing of radiological assessments for collective and individual doses in case of accidental release of radioactive nuclides to the environment.

2 Models in PC CREAM

The PCCREAM code consists of two main modules. First one is a compound module consisting of several specially dedicated modules representing different physical phenomena related to the transport of the radioactive isotopes in the atmosphere, water, their deposition in and further resuspension in the ground. The second main module of the code is the ACCESSOR module. It uses the information from the specialized modules mentioned above together with the population, agricultural and geographical data to perform the evaluation of the absorbed doses by the population in the considered region.

The individual modules/models used for this particular calculation in the PCCREAM code are as follows [1,4]:

2.1 The PLUME model

PLUME is a stream Gauss model for atmospheric dispersion [2], which takes into account the meteorological data during the accidental release, the land profile and the physical properties of the released radioactive material.

The model calculates the concentration of the activity in the air, deposition rates and the external dose rates absorbed as a consequence of irradiation from the nuclides in the cloud (gamma cloud) at different distances from the release point down the wind from the deposition site.

2.2 The GRANIS model

Using the GRANIS model the external exposure due to the gamma irradiation from radionuclides deposited in the soil is calculated. [3]. GRANIS describes the transfer of radionuclides through the ground layers and takes into consideration the attenuation of the radiation in the soil material in the case when dose assessment at 1 m above the ground is needed. The doses are calculated based on the preliminary amounts of deposited radionuclides given by the user. GRANIS is the only model in PC-CREAM which performs evaluation of the dose rates for the separate organs and the effective doses.

2.3 The FARMLAND model

FARMLAND [3] itself is a set of models used to predict the transfer of radionuclides in the food, grown in the soil after its pollution. The models consider the most widely used food for the human nutrition, like green vegetables, root vegetables, grain, cow milk and its derivatives, cow meat and liver, sheep meat and liver. The activities concentrations in each food type are calculated under a given by the user values depending on the amount of the deposited radionuclides.

2.4 The RESUS model

RESUS model could be used to perform evaluation of the concentration in the air, received as a consequence of resuspension of earlier deposited radionuclides. It uses a formula, derived by Garland [3], which is independent on the type of the considered radionuclides and takes into account only the difference in the lifetime of the given isotopes.

2.5 ASSESSOR module

The ASSESSOR module is used to perform the evaluation of the individual and collective doses for the preliminary defined models for dispersion and transport of the radioactive isotopes in the atmosphere, resuspension in previous depositions and the radiation exposure due to transport of the radioactive nuclides in the food chains, calculated according to the various models. The ASSESSOR module combines these data with the given model data for distribution of the agricultural production with respect to the release point to calculate the desired dose rates at the whole geographic area.

3 The Input Model for the Example Calculation

In order to present the PCCREM code simulation capabilities a simplified model for calculation was created on a hypothetical geographic map with radius of 100 km around the nuclear facility, containing single city with a farm producing food – cow milk, milk products, meat, liver, sheep meat, liver, green vegetables, root vegetables and grain in

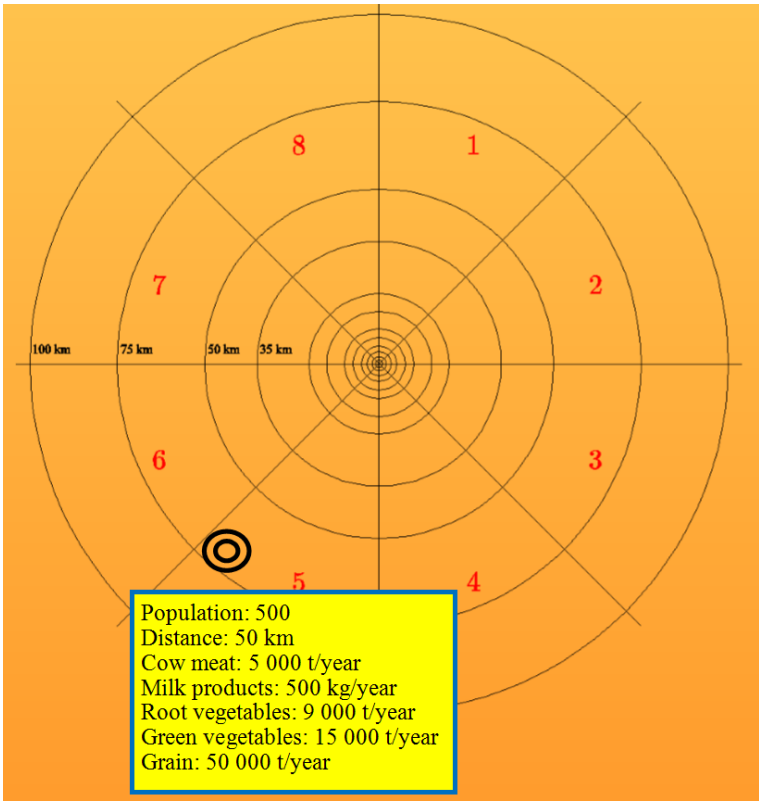

Figure 1. Sector distribution in the considered geographical model. The release of the radioactive material happens in the center of the plot. The position of the city is shown with double circle. The agricultural data are given in the inset.

Table 1. Pollution isotope content and its parameters

Radionuclides	Release amounts (Bq/y)	Speed of release (m/sec)	Washout coefficient (1/sec)
Ar-41	3.50E+09	0.00E+00	0.00E+00
C-14	1.00E+10	0.00E+00	0.00E+00
Co-60	1.00E+06	1.00E-03	1.00E-04
Cs-137	1.00E+05	1.00E-03	1.00E-04
Ba-137m (Cs-137)	Cs-137	1.00E-03	1.00E-04
H-3	1.00E+10	2.50E+00	0.00E+00
Pu-239	1.00E+04	1.00E-03	1.00E-04
U-235 (Pu-239)	Pu-239	1.00E-03	1.00E-04
Pu-240	1.00E+04	1.00E-03	1.00E-04
U-236 (Pu-240)	Pu-240	1.00E-03	1.00E-04
Sr-90	1.00E+06	1.00E-03	1.00E-04
Y-90 (Sr-90)	Sr-90	1.00E-03	1.00E-04
Xe-135	1.00E+08	0.00E+00	0.00E+00
Cs-135 (Xe-135)	Xe-135	1.00E-03	1.00E-04
Xe-138	1.00E+06	0.00E+00	0.00E+00
Cs-138 (Xe-138)	Xe-138	1.00E-03	1.00E-04

a predefined amount. The input data net is shown in Figure 1 with the module details.

The data for the isotope content of the release are chosen arbitrary among the typical isotopes typically found in the released nuclides in case of nuclear accident at a nuclear power plant in case of core failure and release of nuclear fuel and fission products in the environment. The input data with the relevant information are given in Table 1.

4 Results

The calculation is performed using the PCCREAM version 1.5 with database version 2.0. The selected results from the simulation are shown as pie charts in Figures 2, 3 and 4, where relevant description about the presented result in the figure is given. All charts are obtained directly from the code, which is an option for results presentation.

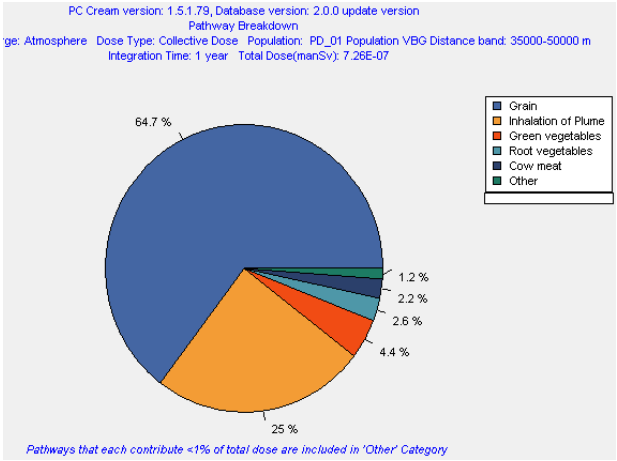

Figure 2. Integral collective dose for population after 1 year in the 35–50 km range.

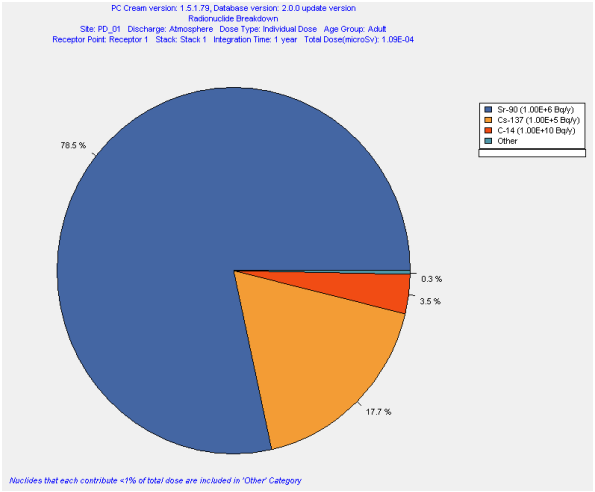

Figure 3. Individual dose for adult for 1 year, breakdown by radionuclides.

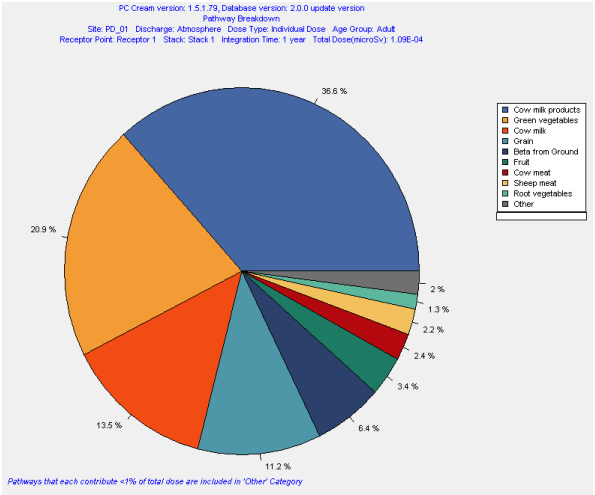

Figure 4. Individual dose for adult for 1 year, breakdown by the pathways.

5 Conclusions

The PCCREAM code is a powerful tool for environmental of the radiological individual and collective doses evaluation in wide time and distance ranges in case of accidental release of radioactive material. It allows detailed quantitative investigation of the spreading paths of the radioactive nuclides contributing to the overall absorbed dose by the population. Using this tool it is possible to develop measures and create emergency plans for various accidental scenarios, as well as to develop a safety analysis reports for the target nuclear installations.

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