DECISION SUPPORT SYSTEM FOR FAST ASSESSMENT OF INTERNAL EXPOSURE DUE TO INGESTION IN CASE OF A NUCLEAR ACCIDENT

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ABSTRACT

In this paper we describe interactive decision support system HARP for evaluation of human exposure due to severe nuclear disasters and for simulation of radionuclides propagation through the different compartments of the environment. Special focus is paid to modeling of migration of radionuclides into the agricultural products consumed by people and estimation of induced internal irradiation due to ingestion of contaminated foodstuffs.

INTRODUCTION

One of the most significant sources of anthropogenic radioactive pollution are severe disasters on nuclear power plants (NPPs). Even though these events are very rare, their impact on the environment is enormous and it takes a long time to radiation levels settle back to background values. In this paper we are concerned with consequence modeling in case of such an accident with focus on internal irradiation of people due to ingestion of contaminated foodstuffs. To achieve this goal, we have to: (i) simulate propagation of radionuclides into the agricultural products used for food production and (ii) estimate consequent internal irradiation due to consumption of foodstuffs produced from the contaminated plants and animals.

Presented decision support system (DSS) HARP (HAzardous Radioactivity Propagation) is a comprehensive set of user-friendly tools for detailed simulation of radionuclides propagation through the food chain. Propagation is simulated since their release up to migration to the human body through different pathways.

PROPAGATION OF RADIONUCLIDES THROUGH THE FOOD CHAIN

Severe accident on a nuclear facility can result into an aerial release of radionuclides into the environment when the radioactive material forms a plume advected over the terrain by the wind and dispersed by turbulence. Radionuclides travel through the environment along the same pathways as other materials. When radioactive materials deposit onto the ground or into the sea, they will be absorbed by crops, livestock and marine organisms and enter our food chain.

In case of a nuclear disaster, human body can be exposed to harmful effects of ionizing radiation by the means of external and internal irradiation. External pathways represent doses from the moving plume and from the deposited material. Internal pathways represent doses due to inhalation and ingestion. The ingestion is particularly significant from long-term perspective when the originally deposited material propagates through the food chain, i.e. when people consume contaminated foodstuffs.

DESCRIPTION OF THE DSS HARP

The system has been developed for more than 10 years. Since the first version, the system was vastly improved and nowadays it comprises a modern modeling and educational tool for emergency preparedness (Pecha et al., 2007). Fast simulation codes of the system are written in Fortran programming language and the graphical user interface (GUI) is in Python. This fact makes the system really platform-independent.

The core of the system represents an atmospheric dispersion model based on segmented Gaussian plume model (Hofman et al., 2008). The model evaluates basic radiological quantities on a polar grid up to $100km$ from the source. The model can simulate propagation of 132 different radionuclides in aerosol, elemental and organically bounded forms. In order to correctly treat the subsequent dynamic ingestion models, deposition and its time evolution is modeled also dynamically accounting for radioactive decay and environmental processes (migration and fixation).

Dynamic ingestion model simulates propagation of radionuclides through the food chain into livestock and human body. Transport of radioactivity into plants via root and foliar transport is assumed. Following consequent impacts on people are modeled: (i) doses due to ingestion of contaminated foodstaffs and (ii) doses due

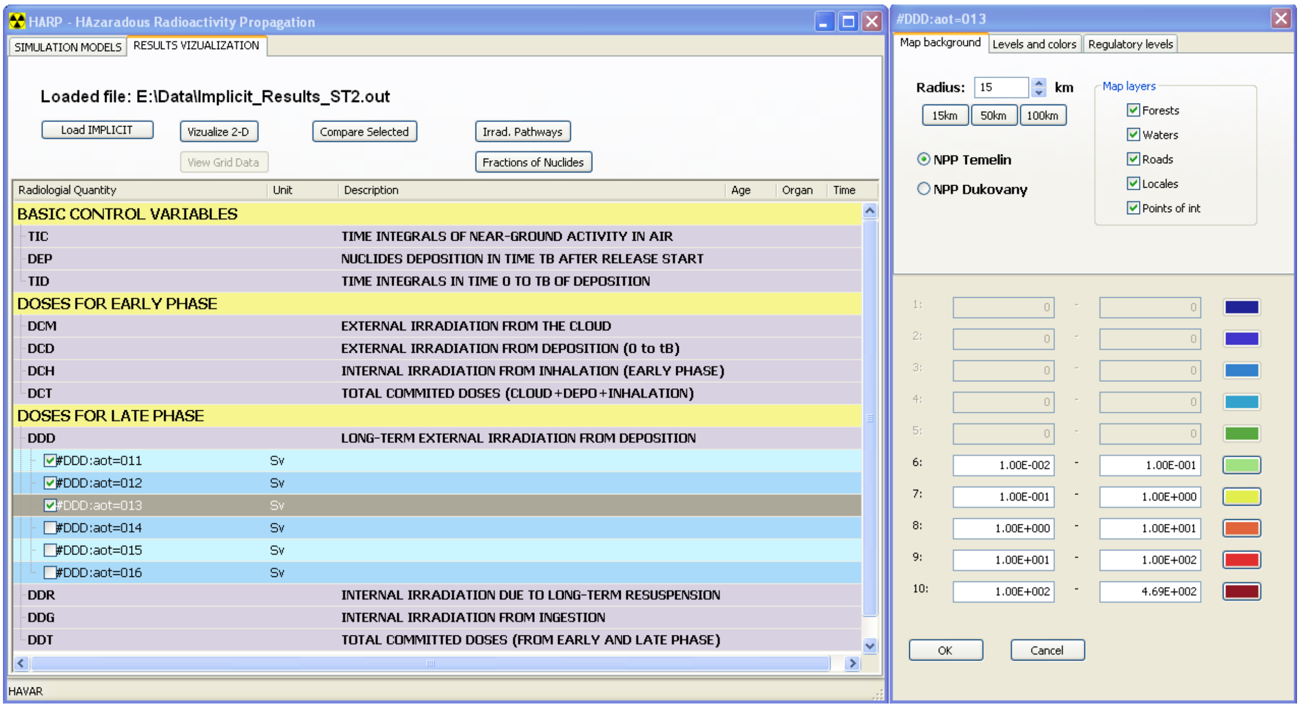

Figure 1: The main screen of the HARP visualization sub-system. Left: Tree structure representing list of all implicit outputs. More radiological quantities of interest can be calculated "on demand" using an interactive mode of the system. Right: Configuration panel for spatial visualization on a customizable map background with choice of map layers. Currently, the system is localized for sites of two Czech NPPs: Temelín and Dukovany.

to ingestion of animals fed by contaminated feedstuffs. In order to simulate radiation doses based on "average" behavior of consumers the concept of consumption baskets is used.

From the physical background of the problem is obvious that the setting of parametrized mathematical models used in the code is strongly dependent on many factor (Julian day of fallout, orography etc.). All the coefficients were updated to be in accordance with the Czech conditions. Special attention was given to the construction of gridded spatial environmental data necessary for the radioecological modeling: data on population density with according to different age categories, agricultural production, number of bred livestock, soil types etc.

All the components are easily accessible through the unified GUI which allows user to rapidly re-configure the models and simulate consequences with different setting. This approach helps to identify areas where the regulatory limits are exceeded. What is more, an effectiveness of some protective measures on population protection introduced in the ingestion pathway can be assessed in terms of averted doses.

Controls layout of the GUI for both models and the visualization sub-system can be summarized as follows:

1. SIMULATION PART:

   (a) Atmospheric Dispersion Model: Site-

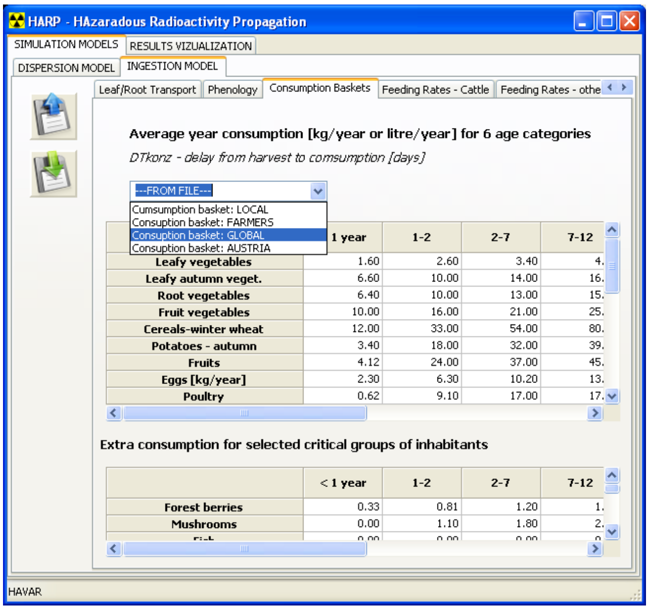

Figure 2: Overall view of the simulation part of the system. Tabs logically organizing GUI into the simulation and visualization parts are located at the top of the window. On the selected tab we see a panel for configuration of composition of consumption baskets for calculation of long-term internal irradiation due to ingestion. Besides the pre-configured baskets the user can define his/her own.

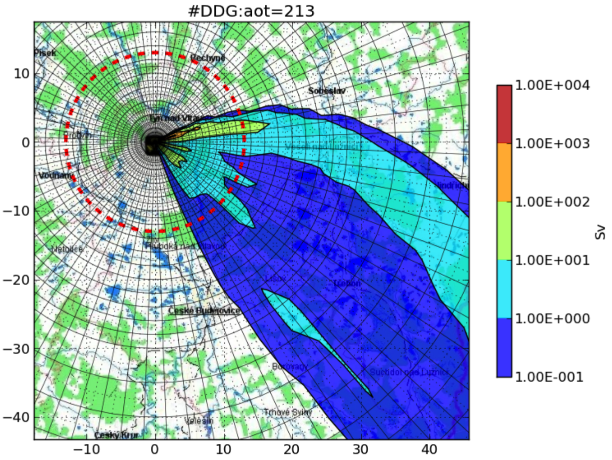

Figure 3: Spatial visualization of doses due to internal irradiation for adults 5 years after fallout. All the radiological quantities are evaluated on a polar network with 80×42 grid points up to 100km from the source.

specific parameters, plume depletion, influence of near-standing buildings, release segments and nuclide groups, meteorological conditions

(b) Dynamic Ingestion Model: Release-specific parameters, transport of radionuclides in soil, long-time deposition and resuspension, leaf and root transport, phenology, consumption baskets, feeding rates of cattle, feeding rates of other animals

2. VISUALIZATION PART: Spatial visualization on a customizable map background, directional analysis and pie charts of contributions to the overall committed dose from various irradiation pathways

In Figure 1, the main screen of the visualization part of the system is displayed. Configuration panel of the consumption baskets composition for calculation of long-term internal irradiation due to ingestion is in Figure 2.

ILLUSTRATIVE EXAMPLES

For demonstration purposes we simulate a massive release from NPP Temelín using Melk-ST2 scenario (our traditional configuration for testing of HARP). It was formulated within co-operation between the Czech Republic and Austria in the field of radiation-emergency preparedness (Prouza et al., 2004). This scenario simulates real dynamics for severe LOCA (Loss Of Coolant Accident) with partial fuel cladding rupture and fuel melting. The release is split up to 6 equivalent 1-hour segments with following radionuclides: Kr-88, Sr-90, Mo-99, Ru-103, Ru-106, Te-132, I-131, I-133, I-135, Cs-134, Cs-137 and Ba-140. Simulation was carried out using a retrospective meteorological forecast sequence from June 28, 2002 with release start at 00:00 UTM.

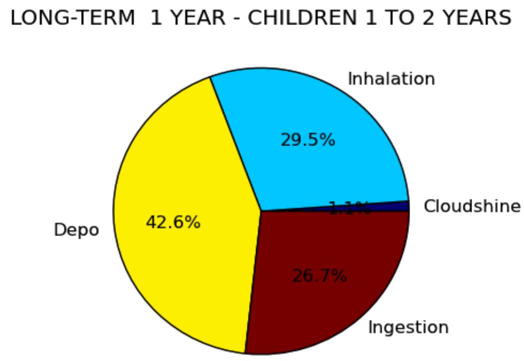

Figure 4: Total annual dose/committed dose for age category 1 to 2 years (in the year of fallout at coordinates [5,-5]km with respect to source). Total doses/committed doses from respective pathways: cloudshine 7.54E-03Sv, inhalation 1.99E-01Sv, deposition 2.87E-01Sv, ingestion 1.80E-01Sv.

Visualization of resulting spatial distribution of doses due to internal irradiation for adults 5 years after fallout is in Figure 3. The red dashed circle delimits the zone of emergency planning with radius 13km. Contributions of different pathways of irradiation to the overall dose are displayed in Figure 4 in form of a pie chart.

CONCLUSION

The intended poster will present decision support system HARP with focus on modeling of propagation of radionuclides in the food chain towards human body.

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