TRAINING SIMULATOR FOR ANALYSIS OF ENVIRONMENTAL CONSEQUENCES OF ACCIDENTAL RADIOACTIVITY RELEASES

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Introduction

The paper presents software system HARP designed for fast assessment of radiological consequences of accidental releases of radionuclides into the living environment. Transport of activity is studied from initial atmospheric propagation up to 100 kilometeres from the source of pollution. Corresponding model of atmospheric dispersion and advection based on segmented Gaussian plume approach is formulated which can approximately account for release dynamics and short term meteorological forecast. Implemented numerical difference scheme enables to approximate simulations of important parent-daughter pairs formation. Subsequent deposition processes of advected admixtures and food chain activity transport are modeled. The deterministic estimation based on radiation doses resulting from external irradiation and internal activity intake is applied. The product is presented here from viewpoint of its utilization such a training tool for decision support staff. User-friendly interface for input definitions of the task is offered both for atmospheric dispersion and ingestion parts. Countermeasure subsystem offers user-friendly tool for analysis of various interventions for steering of mitigations of accident consequences.

Chain of pollution transport models

The model chain includes **advection** and **dispersion** of pollutants during its propagation in atmosphere, their **deposition** on terrain and subsequent transport through various **food chains** causing inner radioactivity activity intake into human body.

Atmospheric dispersion and deposition Complicated scenario of release dynamics have to be synchronized with available meteorological forecasts so that drifting of radioactive plume over the terrain can be satisfactorily modeled. We have used experience from various modifications of Gaussian model of admixtures dispersion in atmosphere [3][2][6]. For our purposes an approach of segmented Gaussian plume scheme has been adopted. We are utilizing short-term meteorological forecast being generated at point of release by the Czech meteorological service. Hourly changes of wind speed and direction, Pasquill class of atmospheric stability and precipitation are forecasted for the next 48 hours. Using assumption of activity conservation, the release dynamic is segmented into equivalent number of hourly segments. Each such segment is modeled in its all subsequent hourly meteophases when stepwise segment movement is driven by meteorological forecast for the corresponding hours. Interactive input of atmospheric "hot data" is provided which enables easy evaluation of alternative runs.

Food chain transport Special dynamic ingestion model has been developed for quantification of risk from consumption of contaminated food for case of accidental fallout in arbitrary Julian day in a year which takes into account current vegetation state of growth due to vegetation periods.Customization details for the Czech Republic are mentioned in [1].

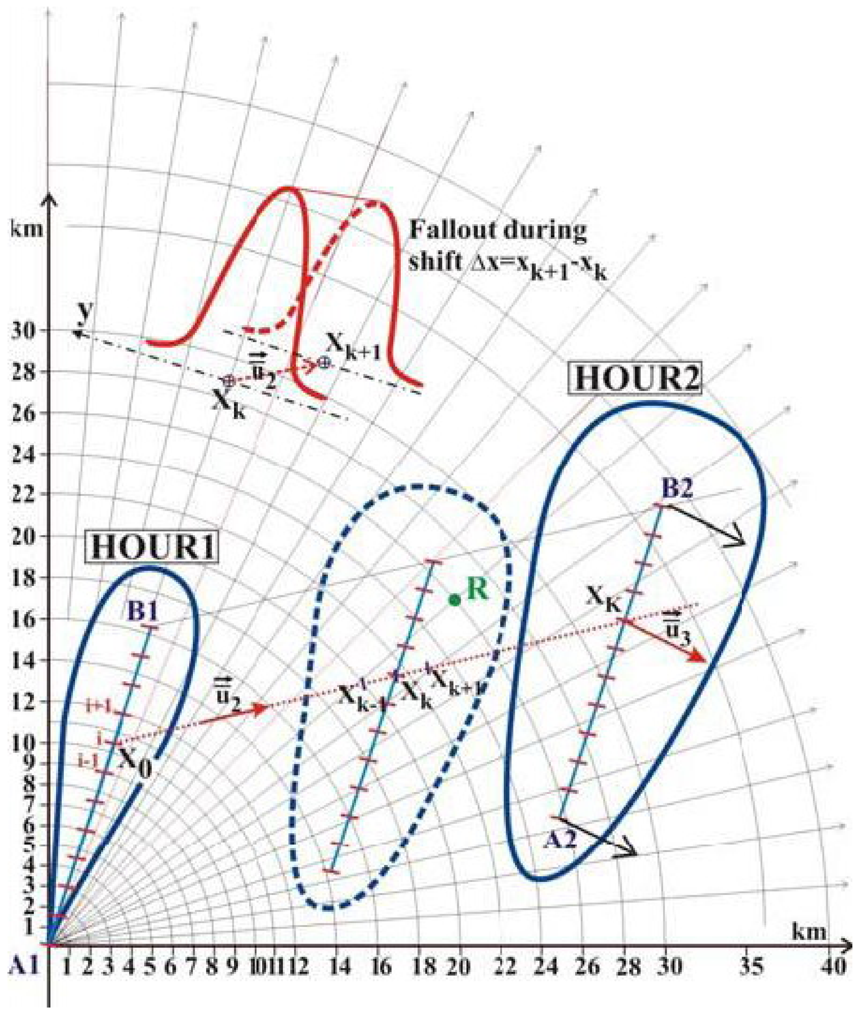

Figure 1. Segmented Gaussian plume approach for modeling of discharges propagation in atmosphere.

Deterministic estimation of radiological burden of population

Estimation of radiological impact includes various combinations of irradiation pathways and time horizons, age categories and organ or tissues. Radiological consequences of accident are calculated according to doses of irradiation using dose coefficients (factors) based on the latest ICRP recommendations.

Irradiation doses in early stage According to pathways are distinguished external irradiation from cloudshine and groundshine and internal irradiation due to inhalation of contaminated air. The doses fields are generated in each node of polar calculation grid.

Irradiation doses in late stage of accident It stands for long-term doses from groundshine and committed doses from inhalation of resuspended radioactive material and from ingestion due to consumption of contaminated foodstaffs during time consumption interval from day of fallout.

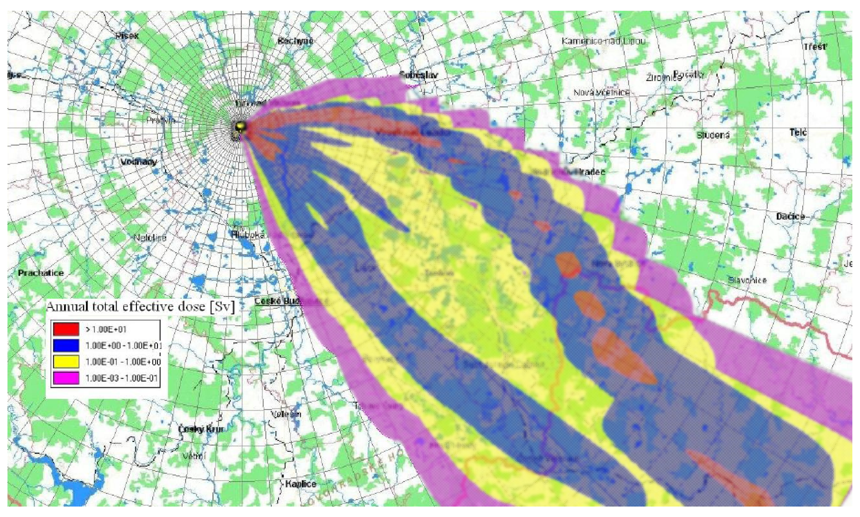

Figure 2. Total annual effective dose for adults [Sv] in the first year of release. Scenario from Austrian-Czech exercise: STEP IIb (MELK process). Source term ST2 for severe LOCA accident with fuel melting, meteorological forecast for June 28,2002, 00 UTM. Conservative "*Local production* × *Local consumption*" ingestion scheme.

Comment on probabilistic version of the HARP code

A special emphasis in further development is laid on proper treatment of types of input parameter fluctuations in sense of differentiation between variability and uncertainty. Uncertainties arise mainly due to inherent stochastic character of some input data, partial ignorance of model description or lack of knowledge regarding the true model formulation. Relevant uncertainty groups for input parameters of ADM, FCM and dose model DOS have been formulated. The first application of probabilistic concept of HARP is presented in [5]. The probability approach enables:

1. Progress from deterministic simplification of consequence assessment toward probabilistic approach. Resulting endpoint fields are modeled as random and then much better informative output data is generated in addition to the deterministic best estimate (expected) single values. Then, the answers on consequence assessment questions can be formulated on probabilistic fundamentals.
2. More detailed investigation of error structure of the model predictions is carried out in [4]. It enabled to compute covariance matrices of the model error. It also represents inevitable requirement for transition to the statistical assimilation techniques that can improve the posterior model predictions on the basis of optimal blending of prior model forecast with real observations incoming from terrain. The latter problem is beeing solved in UTIA.

Architecture of HARP system

Several cooperating subsystems for interactive input of "hot data" and on-line access to actual meteorological forecasts and radiation monitoring network represent user-friendly environment for staff training and analysis of alternative scenarios.

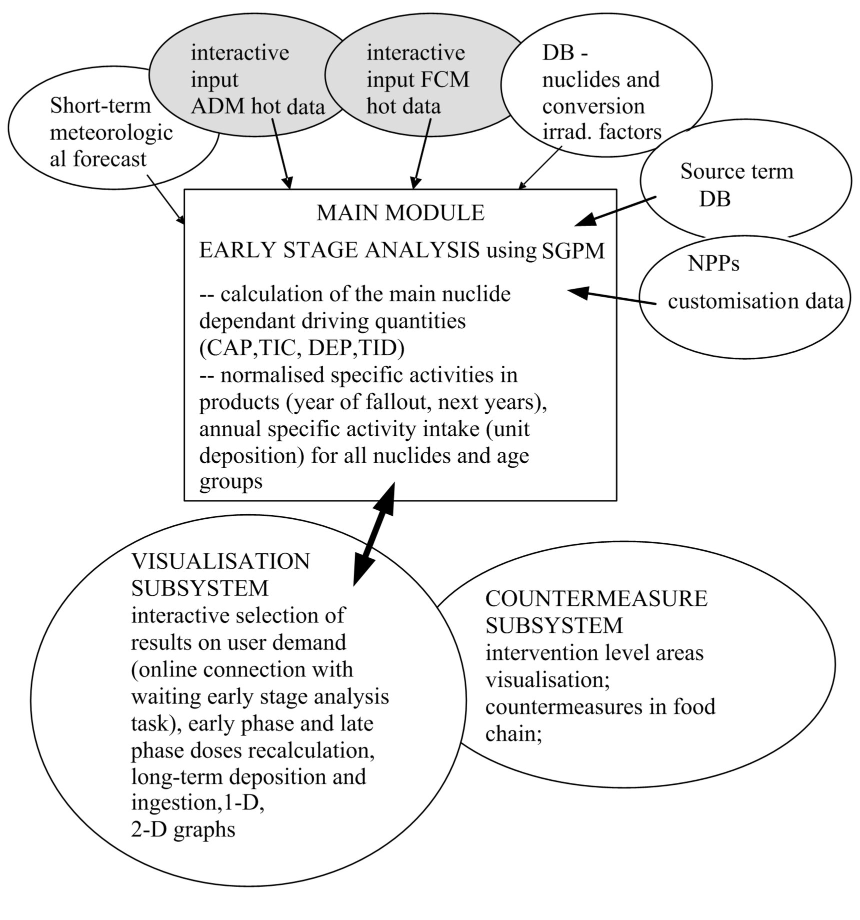

Figure 3. Architecture of HARP system.

Architecture of the system complies with requirements for transparent communication among particular subsystems providing user-friendly interactive environment. The system offers various alternative options of input parameters definition of the release scenarios in their atmospheric, deposition, ingestion and dose parts. For that reason the software product can serve as a training tool enabling responsible staff to improve their knowledge and preparedness in decision making during nuclear emergency situations. From general viewpoint, the system offers fast, robust and easy tool for decision support under stress emergency situations including simulation of effects of various countermeasure actions launched in early phase of release.

Associated vizualization subsystem offers wide range of graphical tools including 1-D graphs for comparison of multiple end-point quantities and 2-D vizualization of results on the proper scalable map background.

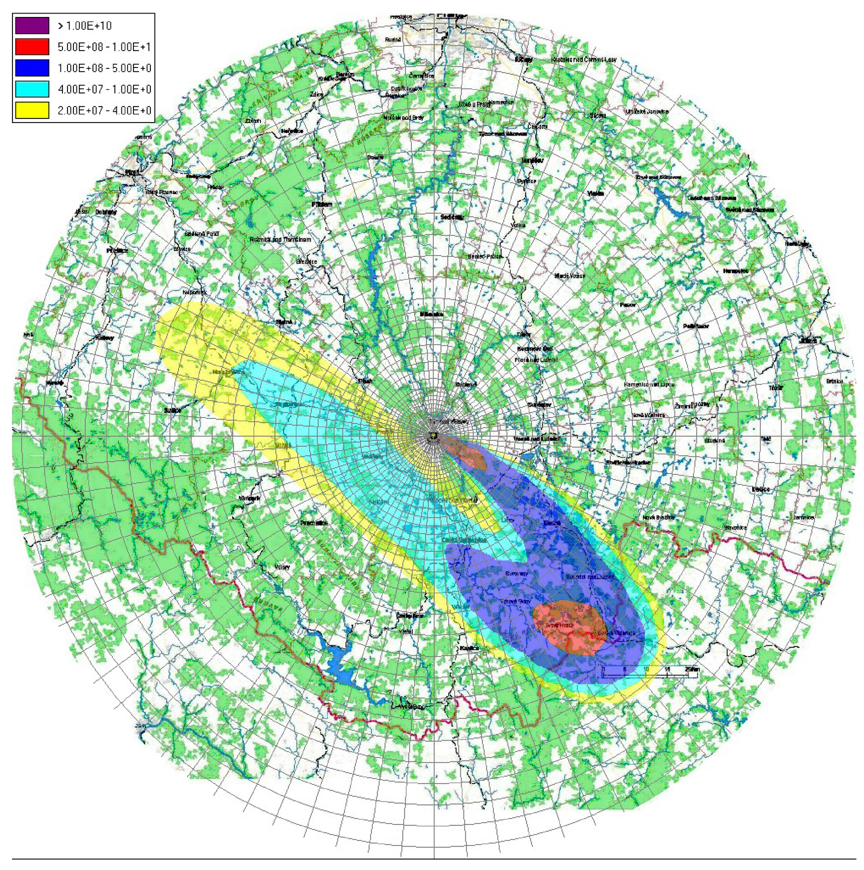

Figure 4. Deposited activity of I131 after 32 hours after the release beginning at 12.00 UTM on Feb. 22, 2007. After 8 hours the wind direction changed to nearly opposite orientation (the forecast confirmed by latter measurements).

Tools for countermeasure support

Early stage of accident From the point of view of urgent countermeasures in early stage of accident the prime significance insists in description of as correct as possible prediction of the plume spreading in consecutive hours. It enables to emergency staff to make a decision about countermeasure introduction (iodine prophylaxis, sheltering, relocation) in a certain heavily impacted areas predicted by the model (eg. from position of plume in *Fig. 5*).

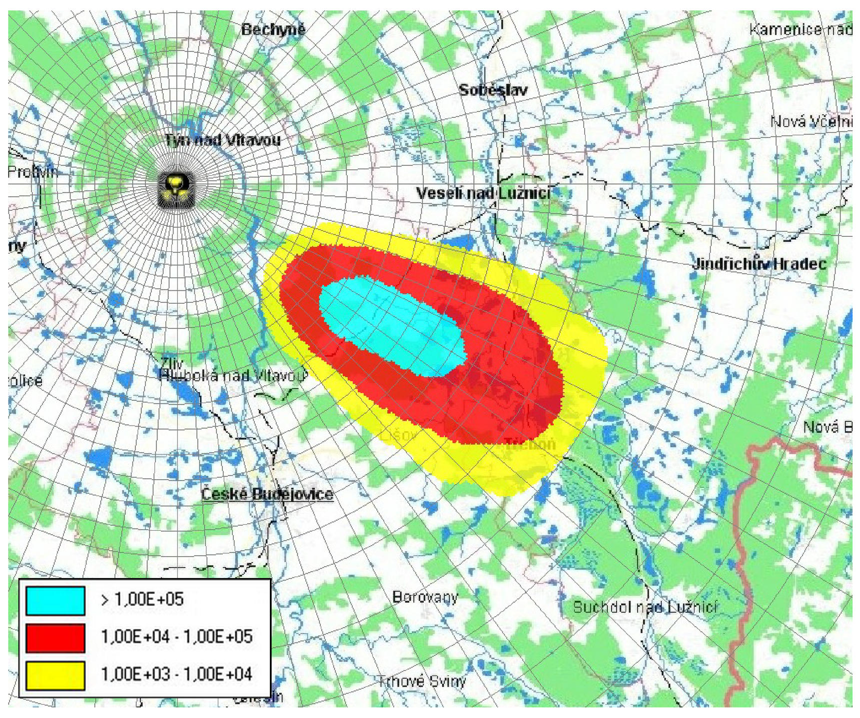

Figure 5. Near-ground activity concentration of I131 in air just after 2nd hour after release beginning $[Bq \cdot m^{-3}]$.

Late stage of an accident Wide range of options is provided. There exist three ways how to utilize HARP system as a tool for countermeasure effectiveness assessment:

- Variations of long-term output quantities can be displayed in 2-D representation
- Foodbans effects
- Effect of modification(s) of arbitrary parameter(s) of ingestion model

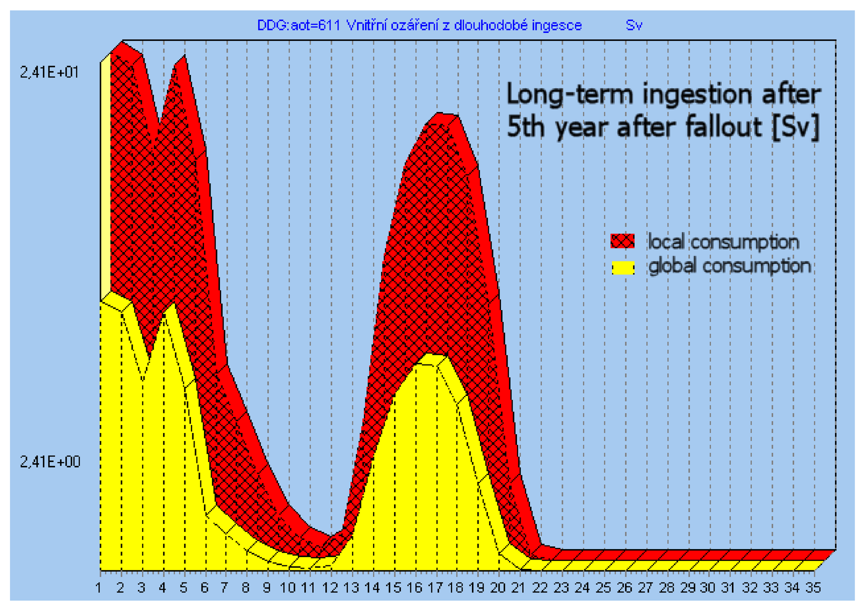

Figure 6. Committed ingestion dose for adults averted due to foodbans in consumption (reduced global consumption with regard to conservative "*Local productuion* × *Local consumption*"). Vizualization of values in East direction - see scenario in *Fig. 2*.

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References

[1] W. Raskob ed., A. Kerekes, A. Dvorzak, O. Slavik, ..., and P. Pecha. Documentation on INCO working programs: Review of the adequacy of the present foodchain and dose calculations and collection of the data required for each radioecological region and their integration. In *RODOS (WG3) TN(99)-40, 2000.*

[2] S. R. Hanna, G. A. Briggs, and R. P. Hosker Jr. *Handbook on Atmospheric Diffusion*. 1982. DOE/TIC-11223 (DE82002045).

[3] J. Päsler-Sauer. Description of the atmospheric dispersion model ATSTEP. In *RODOS(WG2), 2000.*

[4] P. Pecha and R. Hofman. Integration of data assimilation subsystem into environmental model of harmful substances propagation. In *Harmo11 - 11th Internal Conf. Cambridge, paper No. H11-069, 2007.*

[5] P. Pecha and E. Pechova. Modeling of random activity concentration fields in air ... In *HARMO10 10th Internal Conf. Sissi (Crete)Greece, H10-146, 17-20 October 2005.*

[6] S. Thykier-Nielsen, S. Deme, and T. Mikkelsen. Description of the atmospheric dispersion module RIMPUFF. In *RODOS(WG2)-TN(98)-02, April 1999.*