1.26 VALIDATION AND COMPARISON OF DISPERSION MODELS OF RTARC DSS

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INTRODUCTION

RTARC DSS (Real Time Accident Release Consequences – Decision Support System) is a computer code developed at the VÚJE Trnava, Inc. (*Stubna, M. et al, 1993*). The code calculations include atmospheric transport and diffusion, dose assessment, evaluation and displaying of the affected zones, evaluation of the early health effects, concentration and dose rate time dependence in the selected sites etc. The simulation of the protective measures (sheltering, iodine administration) is involved.

The aim of this paper is to present the process of validation of the RTARC dispersion models. RTARC includes models for calculations of release for very short (Method Monte Carlo - MEMOC), short (Gaussian Straight-Line Model) and long distances (Puff Trajectory Model - PTM). Validation of the code RTARC was performed using the results of comparisons and experiments summarized in the Table 1.

Table 1. Experiments and comparisons in the process of validation of the system RTARC

Experiments or comparison	distance	model
Wind tunnel experiments (Universität der Bundeshwer, München)	Area of NPP	Method Monte Carlo
INEL (Idaho National Engineering Laboratory) multi tracer atmospheric experiment	short/medium distances	Gaussian model and PTM
Model Validation Kit	short distances	Gaussian model
STEP II.b 'Realistic Case Studies'	long distances	PTM
ENSEMBLE comparison	long distances	PTM

THE STRUCTURE OF RTARC

Accident assessment is the base for intervention in an appropriate and timely manner and for mitigation of the effects of the accident. RTARC is a computer code developed to calculate and predict atmospheric transportation and off-site radiological consequences in the event of a nuclear accident or radiological emergency during the early phase. The code is used by nuclear facilities for basic emergency response planning and preparedness, real time dose projection and dispersion calculations during an accident, and for post-accident analysis.

RTARC incorporates three types of atmospheric transport and diffusion models for:

- Very short distances (area of NPP) – model Monte Carlo of Lagrangian particles which serves for teledosimetric system, backward estimate or assimilation of source term data with use bootstrap resampling procedure
- Short distances (from area of NPP up to 40 km) – straight-line Gaussian puff or plume dispersion model, which use meteodata from single meteostation at the site of NPP
- Long distances (area of Europe) – PTM is Lagrangian dispersion model which uses the same input data as Gaussian model (inventory of reactor, predefined source term, dose factors etc.), except of meteorological data (NWP data for all Europe).

BRIEFLY DESCRIPTION OF MODELS

MEMOC model

A 3D statistical Monte Carlo atmospheric dispersion model in vicinity of the reactor building, cooling towers etc. has been developed. Trajectories of the particles are calculated using mass consistent flow model. The turbulence characteristics for the stream are modelled and are adjusted in the wake and cavity region of the buildings. Time-integrated concentration (TIC) field is calculated in the fixed 3D grid (MEMOC). For the purpose of estimation of the source term the dose rates are calculated using the cell-integrated dose model.

Module MEMOC for the calculation of TIC field consists of the following parts: calculation of the particle trajectories with the modelling of the random velocities, which are generated by the computer as white noise; calculation of the form and turbulent characteristics in the cavity and wake region of the buildings. Output data from MEMOC model serve as input data for the backward estimation of the source term.

Straight-line Gaussian model

RTARC uses Gaussian plume dispersion model. Conservative approach is applied in RTARC, it means that doses are calculated from the concentrations at certain height of the plume axis. The code enables prediction of radiation situation. Predefined source terms based on accident scenarios are implemented in RTARC.

The task of RTARC dispersion model is to calculate space- and time-dependent air and ground concentrations of radionuclides, which represent the core inventory of the VVER type reactors. Dispersion model simulates buoyant and mechanical plume rise, reflection of plume on the ground and mixing layer, dry and wet deposition, radioactive decay, influence of geometric size of source and influence of surface roughness at the wind profile and vertical diffusion parameter. Horizontal and vertical diffusion parameters are calculated according to the Hosker scheme.

Puff Trajectory Model

PTM is Lagrangian dispersion model, which carries on the Gaussian calculations. The model uses numerical method of finite differences for vertical diffusion description. Lateral diffusion is modeled by Heffter’s sigma parameter. Model allows calculation of up to 100 nuclides of the reactor inventory and uses the same database of source terms as Gaussian model.

Category of stability and mixing height are calculated using prognoses data (from system ALADIN). Trajectories of puffs starts from the source every hour. PTM provides following types of results: time integrated concentration, dry and wet deposition, doses from cloud, doses from deposition and doses from inhalation.

RESULTS OF VALIDATION AND COMPARISON

Wind tunnel experiment

The model MEMOC has been validated in wind tunnel simulation of the dispersion of radionuclides released from the reactor building of the NPP Mochovce, Slovak Republic (hilly terrain) and NPP Temelin, Czech Republic (flat terrain) in collaboration with the Universitat der Bundeswehr, München, Germany (*Duran, J. et al, 1998*).

For the wind tunnel simulation it was assumed that the emission source is placed on the top of that reactor building; the source area is nearly momentum free; the source emissions are non-buoyant and; the cooling towers are passive and without any flow inside. The investigation was dealing with the generation of a boundary layer flow inside the wind tunnel with free stream velocities of U_∞ = 4.5 m/s and U_∞ = 9.0 m/s and a neutrally stratified atmospheric boundary layer flow. Lateral and vertical concentration profiles were measured in the wake of NPP Mochovce up to distances of 5.8 km for four wind directions and for two wind speeds.

The qualitative comparisons of observed and predicted concentrations on the space over the area of NPP indicate that module MEMOC can yield reasonable good results. Fields of observed and predicted concentrations have a similar geometric form and concentrations values correspond in order of one magnitude.

INEL experiment

Six tracers were released simultaneously over three-hour period and sampled at various downwind distances. A detailed description of the experiment has been given by Clements (*W.E. Clements, 1979*). The tracers were released near ground level and sampled on arcs at 3, 50 and 90 km downwind. The experiment was conducted during persistent southwest flow. Tower turbulence measurements indicated very unstable conditions. For purpose of validation was selected 3-hour release of tracer SF_6 and 15-hour release of ^{85}Kr from the stack the height of 76 m.

TIC at the distances of 3, 50 and 90 km was simulated by the Gaussian straight-line model and PTM. Measured concentrations were compared with the calculated values for the following variants: with or without the effect of wind shear; using different values of vertical parameter of diffusion K; using different types of horizontal parameter diffusion; using different values of the vertical profile of wind speed.

Two basic outcomes arise from results of comparison (*J. Duran, 1998*): Gaussian model and PTM ‘slightly’ overestimates (in order of one magnitude); for the short and medium distances is very important effect of the vertical shear of wind direction.

Model Validation Kit

The ‘Manno Validation Kit’ (MVK) is a collection of three experimental data sets from Kincaid, Copenhagen, Lillestrom and supplementary Indianopolis experimental campaigns. The validation of the RTARC dispersion model (*J. Duran, 2001*) has been performed on the basis of the maximum arc-wise concentrations using the Bootstrap resampling procedure. Validation was performed for the short-range distances.

The maximum observed concentrations at each arc was compared with the estimated maximum concentrations at same arc. The model evaluation contains: 1) quantitative statistical model evaluation, 2) scientific evaluation of residual plots and 3) estimation of model uncertainty components (roughness length, class stability).

From a statistical point of view the overall performance of the model is comparable to other models that have been applied on the ‘MVK’ fields experiments, where all the dispersion models face difficulties due to the stochastic nature of observations. The results of validation have shown that the outputs of the Gaussian dispersion model are very sensitive to the accurate estimation of the roughness length and that model exhibits a tendency to underestimate the measured concentrations.

STEP II.b "Realistic Case Studies"

In the framework of STEP II.b "Realistic Case Studies" (*Road Map – Item 7a, 2004*) different codes performed dispersion and dose calculations based on realistic meteorological cases were compared to the historical input data (prognostic or diagnostic data). The objective of STEP II.b was to compare the weather modeling, the radionuclide air concentrations, ground deposition and foodstuff contamination in real time and/or posterior in the relevant parts of Europe following a hypothetical accident at the location of Temelin NPP. The calculations were performed using a wide range of models and real cases of weather situations.

Differences in the results of TAMOS and FLEXPART calculations, presented by the Austrian side, are mainly due to differences in the chosen input/output grid. The Czech side compared the long-range models RODOS/MATCH and RTARC/PTM. As in the case of the Austrian results, the differences are caused by different dispersion model parameters and the size of the evaluated grid.

An important conclusion of the model/code comparison is that the advantage of Euler models (such as RODOS/MATCH) lies in conservative determination of contaminated areas, whereas the advantage of Lagrangian models (TAMOS, FLEXPART, PTM, etc.) lies in a relatively reliable estimation of dosimetric quantities.

Different meteorological input data (prognostic data from ECMWF and ALADIN) are considered to be the main source of differences in the results of the dispersion and dose calculations.

ENSEMBLE comparison

The ENSEMBLE exercises (EC 5th framework program) offer an international platform for the intercomparison of real-time long-range emergency response dispersion forecasts. Calculated concentration and deposition fields are sent to the EC JRC in Ispra for evaluation and procedure development. Results of intercomparison are put out on the ENSEMBLE website. VUJE Trnava, Inc. takes a part in the ENSEMBLE exercise #10 with the results of the dispersion model PTM and meteorological data from model ALADIN.

CONCLUSIONS

The results of validation and comparison show that the outputs of the RTARC dispersion models are slightly overestimated in the most cases. This property suits of the claims on the conservative estimations, which is proposed in the all DSS models.

In case of:

- source term backward estimation it is necessary to continue with the process of MEMOC model quantity validation and improvement (more accurate model of wind field and turbulent characteristic).
- Gaussian model for short distances it is necessary to continue with validation in the additional experiments, whereas not only maximal concentration values should be validated, but also geometrical form and dimensions of the contaminated area (data needed for the process of countermeasures implementation decision).
- PTM it is necessary to continue with comparison in the framework of ENSEMBLE project, pertinently to make comparison with the results of such experiments as for example ETEX1 and ETEX2. Similarly, as in the case of Gaussian model it is necessary to continue with validation of dimensions of the contaminated area too.

- all three dispersion models it is necessary to make sensitivity analysis of model parameter and uncertainty analysis of input data. Outputs of these works is development of simplified version of particular dispersion models, which should offer also information about uncertainty level (e. g. 5 and 95 % confidence limit) of such output parameters as dimensions of contaminated areas, values of doses etc.

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