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ARTICLE

Overview of WP4: extension of atmospheric dispersion and consequence modelling in Decision Support Systems

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Abstract – The activities that have been carried out within the frame of Working Package 4 of PREPARE project, entitled “Extension of atmospheric dispersion and consequence modelling in Decision Support Systems (DSSs)” can be grouped under the following themes: (1) Source term (quantity and time variation of release rate of radionuclides from a nuclear accident) estimation based on optimal combination of atmospheric dispersion modelling with measurements through simple and more advanced computational methods integrated within operational DSSs. (2) Implementation of physicochemical properties of radionuclides emitted as particulate matter in computational modules of DSSs that simulate their environmental transport from deposition to mobility in soil and estimate the resulting radiation doses. (3) Extension/update of existing DSSs in the area of atmospheric dispersion on the basis of recent experiences, technological advances and users' requirements. In conclusion, the new features that have been developed regarding atmospheric dispersion and consequence modelling in the frame of PREPARE project, have substantially increased the capabilities of operational DSSs, and have also revealed directions for future research and development.

Keywords: source term estimation / inverse modelling / particulate matter / atmospheric dispersion / deposition / Decision Support Systems

1 Introduction

The aims of Working Package 4 of PREPARE project have been to extend and to update the capabilities of atmospheric dispersion and consequence modelling in existing and widely used Decision Support Systems (DSSs) for nuclear emergencies, such as RODOS and ARGOS, on the basis of latest experiences, like the Fukushima accident, and technological advances that have become available. Therefore the WP4 has addressed the following issues that were – when the project started – either handled in a non-satisfactory way or not handled at all by the DSSs and meanwhile their importance was recognized by the operational, regulatory and scientific communities:

– Computational methods for estimating the emissions of radionuclides (“source term”) from accidental releases using measurements and atmospheric dispersion modelling have been further developed and integrated in DSSs. Simple and more advanced source-term estimation methods have been reviewed, evaluated, further extended in terms of operational capabilities, tested, and integrated or are ready for immediate integration in DSSs.
– Physicochemical properties of radionuclides emitted as particulate matter during nuclear or radiological accidents have been reviewed and computational modules of DSSs have been accordingly extended to model environmental mobility of radionuclides in particulate form and calculate the related radiation doses in a more accurate way.
– Atmospheric dispersion modules of DSSs have been extended and updated of on the basis of recent experiences, technological advances and requests by the users' community.

In the following sections of the paper, the above accomplishments will be briefly presented. For further details, the reader is referred to the corresponding PREPARE technical reports.

2 Source term estimation

Given the difficulties of estimating the emitted quantities of radionuclides (“source term”) for an ongoing or recent accidental release, as experienced both in the Chernobyl and Fukushima accidents, and at the same time the high importance of the source term for the subsequent prognosis (and associated uncertainties) of consequences, source term estimation has been a major task in WP4. Both a simple and a more advanced computational method for source term estimation combining measurements, such as gamma dose rate in air, and dispersion modelling have been further developed, tested and integrated in DSSs (Kovalets *et al.*, 2014c).

The simpler method utilizes measurements in the vicinity of the NPP (“at the fence”) and sensitivity curves of gamma dose rates at the monitoring positions, pre-calculated for a number of important selected parameters (wind speed, atmospheric stability, height of the release, thermal energy, dimensions of the reactor building, etc.) considering their uncertainties too. The mean value and the error band of the total released activity are calculated through a statistical method. Pre-calculated values of nuclides ratios for specific accident scenarios are used initially, and can be replaced later by measured values, if available (Duran *et al.*, 2013; Duran and Duranova, 2014).

The more advanced method is based on variational principles and in particular on the minimization of a cost function formulated from the differences between measurements and model-calculated values plus the differences between first-guess ("background") and analysed source term. Observations and model error covariance matrices are included in the cost function. The method utilizes measurements at any distances from the source. "Source-receptor functions" (SRFs) are calculated (currently calculated by a Lagrangian puff/particle dispersion model) at the receptor positions for the specific source location and the particular atmospheric conditions. For the minimization a system of linear equations is solved. The method can calculate time-varying and multi-nuclide releases. Nuclide ratios are taken into account as additional linear equations, weighted by error variances that allow controlling of how strongly the ratios values are imposed (Kovalets *et al.*, 2013, 2014a, 2014b).

3 Modelling for radionuclides in particulate form

This activity in WP4 created the capabilities to consider the physicochemical properties of emitted radioactive particles (such as the distribution of particle sizes and their solubility) in the prognostic modules of DSSs, depending on the type and conditions of the nuclear accident. The characteristics of aerosols released to the atmosphere under different conditions have been reviewed, based on experimental observations. The accident scenarios considered in the database of JRODOS DSS have been grouped according to the particles release conditions. As a result a summary of properties of particles (size distribution, density and solubility) released to the atmosphere following different types of nuclear/radiological accidents has been compiled (Andersson *et al.*, 2013).

The most important radionuclides for consideration regarding particle releases from the different types of nuclear accidents have been identified concluding that a number of radionuclides are only released in the form of fuel particles. From the observations collected after nuclear accidents and from experimental measurements a fuel particle size distribution has been proposed to be used in prognostic modelling in DSSs in the absence of or prior to actual assessment of the case-specific particle size distribution. The atmospheric dispersion modules of DSSs have been extended to perform dry and wet deposition calculations taking into account a more detailed size distribution and density of aerosols than previously, following the recommendations of Andersson (2015a).

To further study the mobility of radioactive particles deposited in urban areas, experiments for dry and wet deposition of selected nuclides on selected urban surface and for weathering have been performed (Brown and Charnock, 2013). Recommendations for taking into account in European DSSs the presence of contaminants as low-solubility particles (fuel segments) in modelling post-deposition migration and decontamination in urban areas (ERMIN model) and in agricultural products (AGRICP) following a major NPP accident have been formulated (Andersson, 2015b). Following these recommendations the ERMIN model has been updated (Charnock, 2016a, 2016b).

4 Extension of capabilities of atmospheric dispersion modules

In order to enhance the effectiveness and operational applicability of the atmospheric dispersion modules in DSSs, exploiting available technological capabilities and to satisfy the requirements of the users' community, several modifications and updates have been performed in the Lagrangian puffs/particles model DIPCOT in JRODOS, such as parallelization of the code leading to an overall gain in elapsed time of 74% for a computation with a large number of particles on a 8-processor machine in comparison to a fully sequential run. This update improves the applicability of Lagrangian particle dispersion models for long-lasting releases. Furthermore modelling of eight mother–daughter nuclide chains have been implemented in JRODOS-integrated DIPCOT, as well as the capability of simulating multiple emission sources simultaneously.

Another part of the activities within this task of WP4 concerned extensions and improvements of the Eulerian dispersion model EEMEP that are needed for its application in the ARGOS DSS. In particular it was concluded that the improvements should include a better parameterization of the source terms for nuclear accident and explosion in the Eulerian framework, as well as a better and more detailed parameterization of dry and wet deposition processes (Klein and Bartnicki, 2014).

5 Conclusions

WP4 of project PREPARE has addressed the following issues that were recognized as important by the operational, regulatory and scientific communities, based on the recent experiences from nuclear accidents: (1) source term estimation using measurements of environmental variables and dispersion model prognoses, (2) more detailed modelling of environmental mobility of radionuclides in particulate form, (3) extension of capabilities of atmospheric dispersion models. The new features that have been developed regarding atmospheric dispersion and consequence modelling in the frame of PREPARE project, have substantially increased the capabilities of operational DSSs, and have also revealed directions for future research and development, such as the assessment of uncertainties in the various stages and components of the above procedures.

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