Improved modeling of the near-range atmospheric dispersion by the use of CFD

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Abstract

An essential part of the nuclear emergency planning is the estimation of the external dose to the general public after the accidental release of radioactive gases. This is in particular important to be able to take effective countermeasures. Although Gaussian models are frequently used to assess the pollutant dispersion, they are known to have a limited accuracy close to the source or in situations with complex air flow. The aim of this PhD project is to improve the modeling and assess the radiation dose in these situations by the use of Computational Fluid Dynamics (CFD). Here, we report on three aspects that have been studied during the first two years of the project i.e. performing time-averaged dispersion simulations, transient dispersion simulations, and assessing the gamma dose rate.

We use an Eulerian approach to simulate the pollutant dispersion from a stack release over an open field under neutral atmospheric stratification. The evolution of the concentration is formulated as a three-dimensional convection-diffusion problem. The wind field is obtained from a CFD simulation of the atmospheric boundary layers, either using a Reynolds-Averaged Navier-Stokes (RANS) turbulence modeling or using a Large Eddy Simulation (LES) approach. With the RANS approach, a time-average concentration field is obtained. We have shown that for this type of approach a significant increase in accuracy over the existing Gaussian models is obtained when the wind direction fluctuations are properly included in the simulations. The LES approach produces a transient wind field which allows to study the dynamic behaviour of the plume.

Finally, we coupled the CFD model to a gamma dose rate model. This allows to perform a gamma dose assessment, based on the simulated concentration field from the CFD simulation, both under steady state as well as transient conditions. The coupled model is applied to the dispersion of the unstable isotopes Argon-41 and Xenon-133 in an open field. These simulations clearly visualize the significant difference in behaviour of the local concentration and local dose rate.

As a next step in the project, the coupled model will be applied to an existing site to allow for model validation. In addition, model reduction techniques will be studied and applied to reduce the required computational time as an initial step in the preparation of an operational monitoring system.