Validation of a CFD Study of Particle Distribution in Nuclear Workplace

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Abstract

In nuclear work environments where contaminated materials are handled there is always a possibility of accidental airborne releases of toxic or radioactive substances in form of aerosols and gases. This requires to safety professionals and engineers to design effective warning systems and countermeasures to minimize a worker's risk. Understanding the air flow patterns and aerosol trajectories in ventilated rooms can provide key information for determining where to place early warning and monitoring instruments, and how to minimize hazardous materials in the worker's breathing zone. The dispersion within rooms can be influenced by complex interactions between numerous variables, but especially ventilation design and room furnishings. In fact, the assumption of a well-mixed condition of room air and particles could fail because perfect mixing is difficult to obtain. In order to accurately design a healthy indoor environment, it is important to consider spatial distributions of particles.

The experimental benchmark studied the dependence of ventilation rate on aerosol dispersion within a room that was designed to approximate a plutonium laboratory (glove box). Two ventilations rates and three different release locations were studied.

In particular, with the numerical simulations, they have been firstly evaluated the capabilities of the numerical model to reproduce the available experimental data and secondly the optimized positioning of continuous air monitoring to obtain a quickly and good sensitive response.

The 3D simulations have been performed with COMSOL Multiphysics® (Heat Transfer and Particle Tracing Modules). The simulations are based on the following segregated steps: fluid flow study (single-phase incompressible turbulent k-eps-wall function) and time dependent transport of particles (Lagrangian approach). The trajectories of particles in the flow field are simulated including such effects as inertia, drag and gravity force and turbulent diffusion. In all cases studied the particle size distribution is considered monodisperse with a diameter ranged of 0.5 μm. Particle deposition rate is neglected, and particles are hence removed only by the ventilation system. This investigation uses the discrete random walk (DRW) model to simulate the stochastic velocity fluctuations in the airflow. The DRW model assumes that the fluctuating velocities follow a Gaussian probability distribution.

Although the overall computational cost is considerable, the numerical results agree well

with associated experimental data. The development of this work has allowed us to obtain useful indications for the design of a Continuous Air Monitoring sampling layout.

Reference

[1] J. Whicker, P. Wasiolek, Influence of Room Geometry and Ventilation Rate on Airflow and Aerosol Dispersion: Implication for Worker Protection, Health Physics, Vol. 82(1), p. 52 (2002)
[2] J. Whicker, J. Rodgers, A Quantitative Method for Optimized Placement of Continuous Air Monitors, Health Physics, Vol. 85(5), p. 599 (2003)
[3] J. Whicker, J. Rodgers, Evaluation of Continuous Air Monitor Placement in a Plutonium Facility, Health Physics, Vol. 72(5), p. 734 (1997)
[4] S. Konecni, J. Whicker, Computational Modeling and Experimental Characterization of Indoor Aerosol Transport, Proceedings of ASME FEDSM (2002)
[5] Z. Zhang, Q. Chen, Experimental Measurements and Numerical Simulations of Particle Transport and Distribution in Ventilated Rooms, Atmospheric Environment, Vol. 40(18), p. 3396 (2006)

Figures used in the abstract

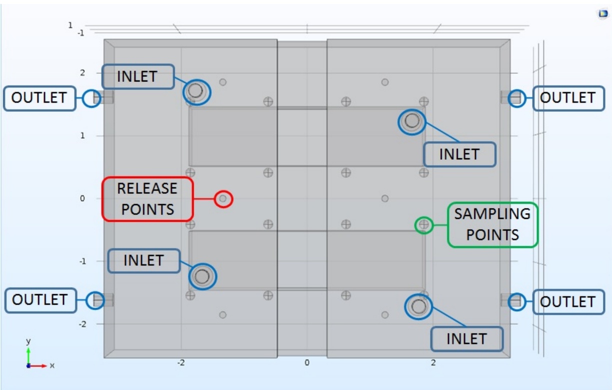

Figure 1: Experimental benchmark: plan view.

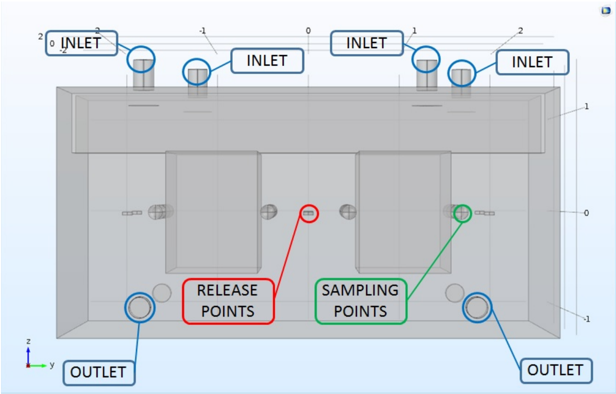

Figure 2: Experimental benchmark: section view.

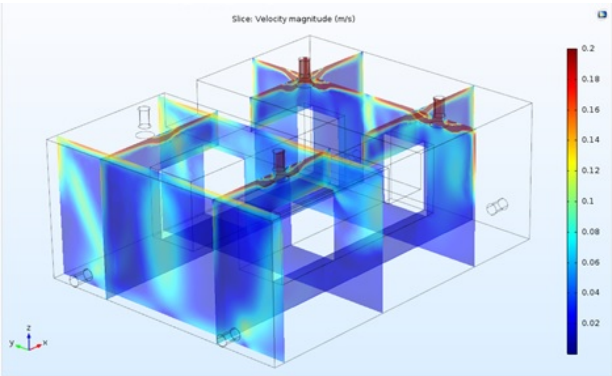

Figure 3: Computed ventilation velocity field.

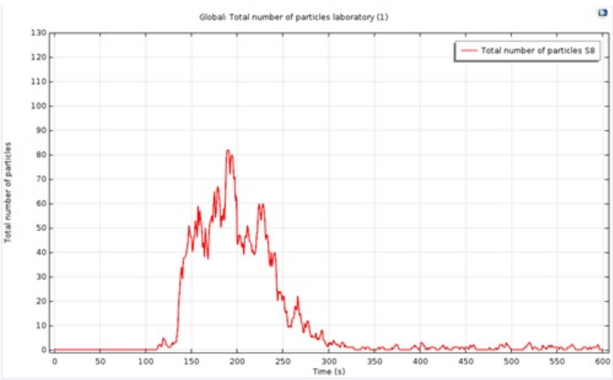

Figure 4: Particle concentration at a sampling location as function of time.