CFD prediction of the spatial distribution of particulate matter deposition indoors

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The development of mathematical models for aerosol transport and deposition in the size range $0.1\mu m$ - $10\mu m$, associated with atmospheric pollution, has been largely motivated by health and indoor comfort concerns. Consequently, the main interest of this models has been the prediction of particle concentration in the free volume of rooms, and they are typically validated with measurements of decay rates in the centre of an experimental chamber [1]. However, in some environments such as museums, archives or historic houses, in which valuable objects are on display, the main interest is not only to know the suspended particle concentration but, especially, to know the fate of these particles, i. e. the deposition rates and the spatial distribution of deposition. [2].

Model description

A model for particle transport and deposition has been implemented in a commercial CFD code. The disperse and continuous phases are resolved following an Eulerian-Eulerian approach. Since the Stokes number is well below 1, one-way coupling is assumed for the velocity fields. Following a comparison of turbulence models, the $k-\varepsilon$ has been chosen as the most suitable. The diffusive and convective terms of particle conservation equations have been modified to account for different phenomena. The diffusive term includes Brownian diffusion and turbulent diffusivity. The convective term adds a vertical component to the velocity field which describes gravitational settling. The semi-empirical deposition equations developed by Lai and Nazaroff [3], which are functions of the Schmidt number and require the wall shear stress as an input, have been implemented as boundary conditions for the particle concentration field. Their solution has been extended to surfaces with arbitrary face angles.

Validation

Since our main interest is in the spatial distribution of deposition, validation requires a comparison of the computational results with deposition values obtained at different points in a space. Published experiments offering data with such characteristics [4] have been simulated, and the numerical results have shown good agreement with experimental values. Figures 1 and 2, as an example, show the simulated distribution of deposition in the floor of a room after an accidental release of 5 g of particles with a normally distributed size, which corresponds with the reported experimental values. An on-going monitoring campaign involving monitoring of deposition and of suspended concentration will allow for validation of the model with a full-scale case study, enabling it to be used as a predictive tool for spatial distribution of deposition in indoor environments.

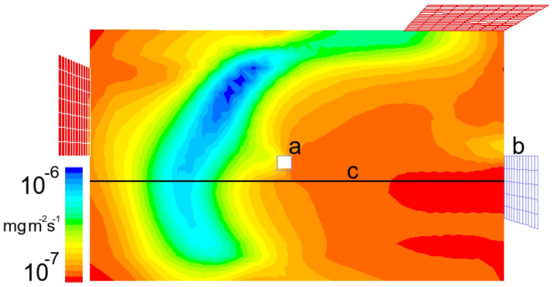

Figure 1: Instant deposition flux on the floor. $t = 100\ s$, inlet velocity, $v = 0.6\ m/s$, (a) is the particle inlet, which emits particles vertically, (b) is the air inlet and (c) is the line used to produce Figure 2.

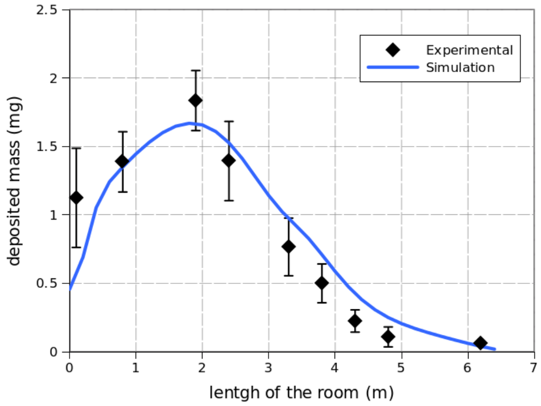

Figure 2: Experimental and simulated total deposited mass along the central line (c) 90 minutes after the release. Experimental values adapted from [2].

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