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Predicting the Exposure Level of Airborne Contaminants in Occupational Settings via the Well-Mixed Room Model

Authors : Alireza Fallahfard, Ludwig Vinches, Stephane Halle

Abstract : In the workplace, the exposure level of airborne contaminants should be evaluated due to health and safety issues. It can be done by numerical models or experimental measurements, but the numerical approach can be useful when it is challenging to perform experiments. One of the simplest models is the well-mixed room (WMR) model, which has shown its usefulness to predict inhalation exposure in many situations. However, since the WMR is limited to gases and vapors, it cannot be used to predict exposure to aerosols. The main objective is to modify the WMR model to expand its application to exposure scenarios involving aerosols. To reach this objective, the standard WMR model has been modified to consider the deposition of particles by gravitational settling and Brownian and turbulent deposition. Three deposition models were implemented in the model. The time-dependent concentrations of airborne particles predicted by the model were compared to experimental results conducted in a 0.512 m3 chamber. Polystyrene particles of 1, 2, and 3 µm in aerodynamic diameter were generated with a nebulizer under two air changes per hour (ACH). The well-mixed condition and chamber ACH were determined by the tracer gas decay method. The mean friction velocity on the chamber surfaces as one of the input variables for the deposition models was determined by computational fluid dynamics (CFD) simulation. For the experimental procedure, the particles were generated until reaching the steady-state condition (emission period). Then generation stopped, and concentration measurements continued until reaching the background concentration (decay period). The results of the tracer gas decay tests revealed that the ACHs of the chamber were: 1.4 and 3.0, and the well-mixed condition was achieved. The CFD results showed the average mean friction velocity and their standard deviations for the lowest and highest ACH were (8.87 ± 0.36) ×10-2 m/s and (8.88 ± 0.38) ×10-2 m/s, respectively. The numerical results indicated the difference between the predicted deposition rates by the three deposition models was less than 2%. The experimental and numerical aerosol concentrations were compared in the emission period and decay period. In both periods, the prediction accuracy of the modified model improved in comparison with the classic WMR model. However, there is still a difference between the actual value and the predicted value. In the emission period, the modified WMR results closely follow the experimental data. However, the model significantly overestimates the experimental results during the decay period. This finding is mainly due to an underestimation of the deposition rate in the model and uncertainty related to measurement devices and particle size distribution. Comparing the experimental and numerical deposition rates revealed that the actual particle deposition rate is significant, but the deposition mechanisms considered in the model were ten times lower than the experimental value. Thus, particle deposition was significant and will affect the airborne concentration in occupational settings, and it should be considered in the airborne exposure prediction model. The role of other removal mechanisms should be investigated.

Keywords : aerosol, CFD, exposure assessment, occupational settings, well-mixed room model, zonal model
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