An Eulerian Approach to Dilute Particulate Flow Simulations with Lattice Boltzmann Methods

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Inhalation of suspended airborne particulates can cause pulmonary diseases and other lethal illnesses. Although a correlation between particulate matter and the human mortality rate has been shown, the biological mechanism is not yet fully understood. To gain a deeper insight in the way particulate matter acts on the bronchial system a mathematical model has been developed and implemented to simulate non-steady particle flows. Here the fluid phase as well as the particle phase are computed by a Lattice Boltzmann Method, whereas for the latter an Advection Diffusion Equation (ADE) with a drag corrected flow field is solved. Furthermore, new outflow and no-slip boundary conditions for the ADE are developed. The advantage in contrast to a Lagragian approach is that the particle behavior is known on every point of the geometry, also the computational cost doesn't increase with the amount of particles to be considered.

Particles of different radii have been simulated in a model of a tracheobronchial tree. Main findings are that the escape rate is primarily dependent on the Stokes number and thus on the particle size. Particles with a Stokes number less than 0.01 can pass unhindered, while most particles with a Stokes number greater than 1 are captured. Finally, the escape rates are compared to results computed with an Lagrangian approach [1].

References

[1] de Vasconcelos, T. F., Sapoval, B., Andrade, J. S., Grotberg, J. B., Hu, Y., and Filoche, M. *Particle capture into the lung made simple?*, J. Appl. Physiol. 110, 6 (2011), 1664–73.