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CFD simulations of transport of atmospheric aerosols and nanoparticles in models of human respiratory system

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Numerical simulations of transport of atmospheric aerosols and nanoparticles in models of various parts of human respiratory system are performed using the Navier-Stokes equations in continuum regime and slip/transitional flow regime. Although the primary interest of this investigation is the study and understanding of aerosol transport in human respiratory system, the computational modeling and analysis of the entire system is currently not feasible because of extreme complexity of airflow in the nasal cavities, oral and bronchial airways of the respiratory system. Because of geometric complexity of pathways, the flow field features include turbulent jet-like flow, recirculating flow, secondary flow (Dean's flow), vortical flows, large pressure drops etc. Such complex flows generated in nasal cavities and oral airways eventually propagate into the tracheobronchial airways. In order to make the problem tractable, simple rigid models of nasal cavities, oral and bronchial airways are considered; fluid/structure interactions are neglected. CFD modeling results show that essential features of the flow fields in these passages can be captured; however the proper formulation and implementation of boundary conditions is critical in obtaining accurate solutions. We assume that aerosols are spherical, non-interacting and mono-disperse, and deposit upon contact with the airway surface. These dilute particle suspensions are modeled with the Euler-Lagrange approach for micron size particles and in the Euler-Euler framework for nanoparticles. The results show that micron size particles deposit non-uniformly with high concentrations while the nanoparticles almost coat the airway surfaces. Although preliminary, these simulation studies have implications in assessing the detrimental health effects in the case of inhaled toxic nanoparticles. The variations in several parameters employed in the models such as the geometric features (which can be individual-specific), the inhaling/exhaling patterns, particle distributions (from micron to nanoscale), boundary conditions etc. can significantly affect the particle deposition in the respiratory system pathways.

Biography

Ramesh Agarwal received Ph.D. from Stanford University in 1975 and post-doctoral training at NASA Ames Research Center in 1976. From 1976 to 1994, he was the Program Director and McDonnell Douglas Fellow at McDonnell Douglas Research Laboratories in St. Louis. From 1994 to 2001, he was the Sam Bloomfield Distinguished Professor and Executive Director of National Institute for Aviation Research at Wichita State University in Wichita, KS. He is currently the William Palm Professor of Engineering at Washington University in St. Louis. He is the author/co-author of nearly 150 archival papers and over 300 conference papers. He is on the editorial board of more than 20 journals.

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