Numerical Simulation of Fiber Deposition Behavior in an Air-Liquid Interface Exposure System

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Specifying the relevant in-vitro dose (RID) is crucial to determine the dose-response relationship of inhalable aerosols in Air-Liquid Interface (ALI) exposure systems. As the result of using new composite materials such as carbon fiber reinforced plastics, determining the deposition behavior of non-spherical objects such as fibers is fundamental.

These elongated objects are characterized by their aspect ratio β, which describes the length-to-diameter ratio of non-spherical objects. The aspect ratio β is used to calculate the dynamic shape factor X. This shape factor quantifies the difference in particle-gas interaction of spherical to prolate ellipsoids (Fuchs, 1964).

For the numerical simulation of particle transport within the exposure system, gravitational force, drag force and Brownian force, which models diffusion are considered. The simulation of fibers is achieved by implementing the shape factor X into the calculation of the drag force. Simulations are performed for fiber diameters ranging from some nanometers to a few microns with aspect ratios between 1 and 20. These dimensions include so-called WHO-fibers, which meet the criteria of the World Health Organization (WHO) for potential health risks. Model validation is conducted through comparison with experimental data.

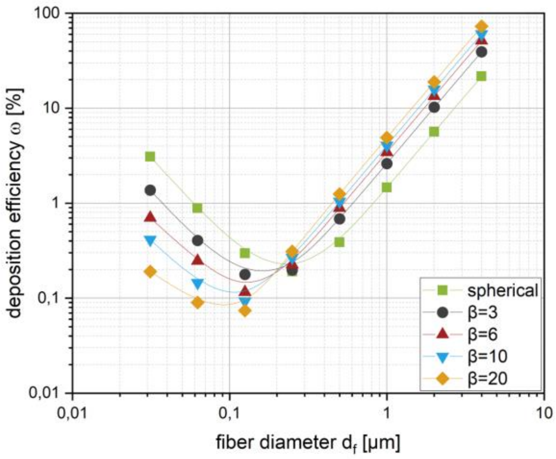

Figure 1. Comparison of numerical data of deposition efficiencies for different aspect ratios of carbon fibers in the ALI exposure chamber as a function of the fiber diameter.

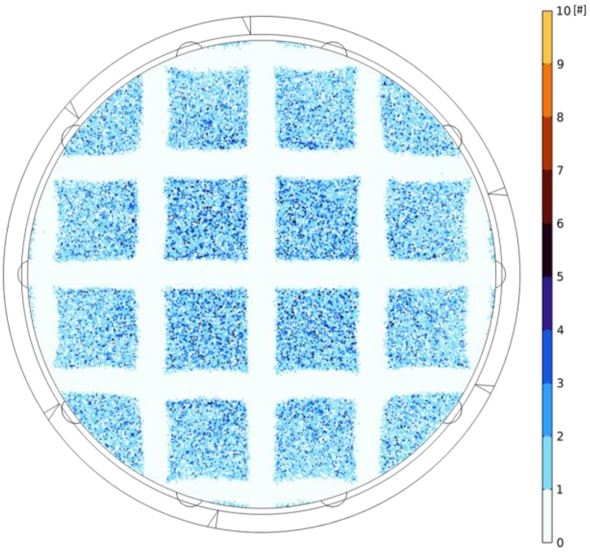

Figure 2. Distribution of particle deposition locations on the deposition surface in the ALI exposure chamber under impact of an electrical field.

This study includes the numerical simulation of particle deposition efficiency in different exposure chamber geometries as a function of fiber diameter and length. The results of investigating the influence of the shape factor on the deposition efficiency are shown (Fig. 1) and the deposition locations of the particles are analyzed. Furthermore, results for electrical field induced deposition will be presented and discussed for selected fiber geometries (Fig. 2).

Fuchs, N.A. (1964). The Mechanics of Aerosols. Pergamon Pr.: Oxford.