Supplementary Information

Collection Efficiency of Airborne Fibers on Nylon Mesh Screens with Different Pore Sizes and Configurations

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S1. Aerodynamic diameter definition for fibers based on Cox's expressions

The aerodynamic diameter of a fiber is defined with expressions Cox (Cox, 1970) derived for a cylinder in motion parallel ($d_{a,||}$) and perpendicular ($d_{a,\perp}$) to the long axis:

$$d_{a,\perp} = d_f \left\{\frac{9\rho}{8\rho_0}[\ln(2\beta) + 0.193]\right\}^{1/2}, \quad \text{(S1)}$$

$$d_{a,||} = d_f \left\{\frac{9\rho}{4\rho_0}[\ln(2\beta) - 0.807]\right\}^{1/2}, \quad \text{(S2)}$$

where d_f is the fiber diameter, β is the aspect ratio of a cylinder (fiber length/fiber diameter; i.e., L/d_f), ρ is the fiber material density (we assume a value of 2.5 g cm^{-3} for glass fibers), and ρ_0 is the unit density (1 g cm^{-3}).

According to Cox's expressions, aerodynamic diameter of a fiber depends on fiber density, fiber length and diameter though the aspect ratio, and fiber orientation in the flow. Because the orientation of the particles is constantly changing due to Brownian rotation (Fuchs, 1964), the average aerodynamic diameter from the above equations is used ($1/3d_{a,||} + 2/3d_{a,\perp}$; $d_{a,\perp}$ is preferred during gravitational acceleration (Fuchs, 1964; Baron and Willeke, 2001.).

Previous studies (Griffiths and Vaughan, 1986; Griffiths et al., 1984; Ku et al., 2014) showed that the Cox expressions overestimate the APS measured aerodynamic diameter and that a quantitative prediction of the measured aerodynamic diameter for fibers, on the basis of their measured physical dimensions, is somewhat uncertain. Discrepancy between theoretically estimated and experimentally measured aerodynamic diameters of fibers has been reported by previous researchers (Morigi et al., 1999; Prodi et al., 1982; Griffin and Vaughan, 1986). This disagreement for fibers was suspected due to fiber orientation in the APS and other spectrometer (Timbrell, 1972; Griffiths et al., 1984). Despite this lack of quantitative understanding, the aerodynamic diameter measured by the APS is still a useful measure, allowing us to compare the fiber characteristics (screen collection efficiency) of different aerosol streams. In our study, we used just the APS measured aerodynamic diameter to obtain collection efficiency, but did not measure the fiber diameter and aspect ratio for Cox's expression to calculate the theoretical aerodynamic diameter.

S2. Relation between aerodynamic diameter and fiber length

To see relation between aerodynamic diameter and fiber length, we calculated the aerodynamic diameter as a function of fiber length with a fixed fiber diameter using the Cox's expressions (Eqs [1] & [2] above). Figure S3 shows that aerodynamic diameter increases with increasing fiber length for given fiber diameter (d_f) (i.e., 0.5, 1.0 & 2.0 µm). According to Fig. S3, the fiber with fiber diameter of 1.0 µm has aerodynamic diameter in the range of 1.5 – 5.0 µm as fiber length increases from 1 up to 100 µm. Interestingly, aerodynamic diameter increases faster for up to 20 µm length while it increases more slowly for fibers with length larger than 20 µm.

Considering the glass fibers used in this study have broad length and diameter distributions, one aerodynamic diameter may have different combination of fiber lengths and diameters.

To see if the APS-measured data in our study would be predicted by the Cox's expressions, we compared the APS-measured and Cox's estimated aerodynamic size distributions for 60 µm screen. Cox's data were obtained from fiber length and diameter measured by SEM. Fig. S4 shows those two distributions seems to be somewhat similar although Cox's estimated aerodynamic diameters overestimate the APS-measured aerodynamic diameters, which is reported by previous studies (Griffiths and Vaughan, 1986; Griffiths et al., 1984; Ku et al., 2014) probably because fiber orientation is unknown in the APS. Based on this, the Cox's expressions may predict approximately the aerodynamic diameter for fibers and estimate the relationship between fiber length and aerodynamic diameter.

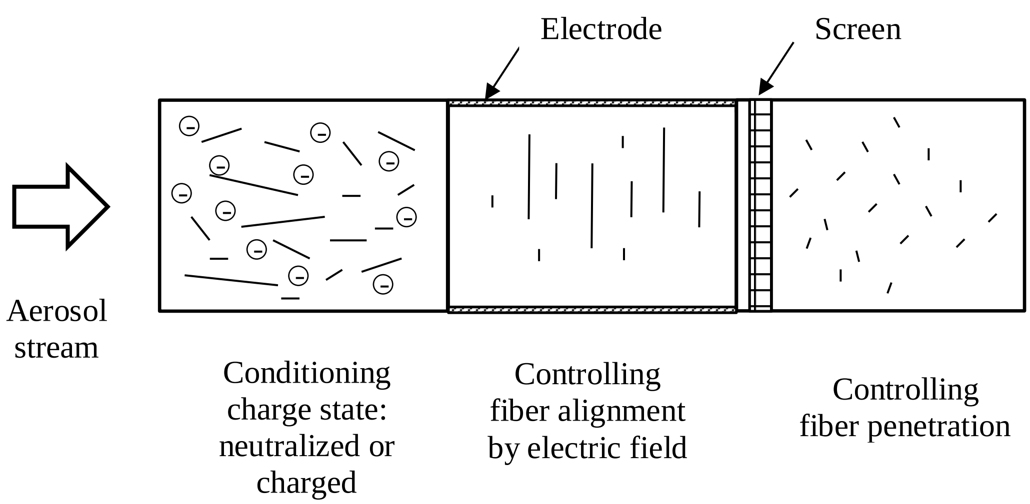

Fig. S1. Schematic diagram on overall concept for using a screen as collection media of long fibers from an aerosol stream.

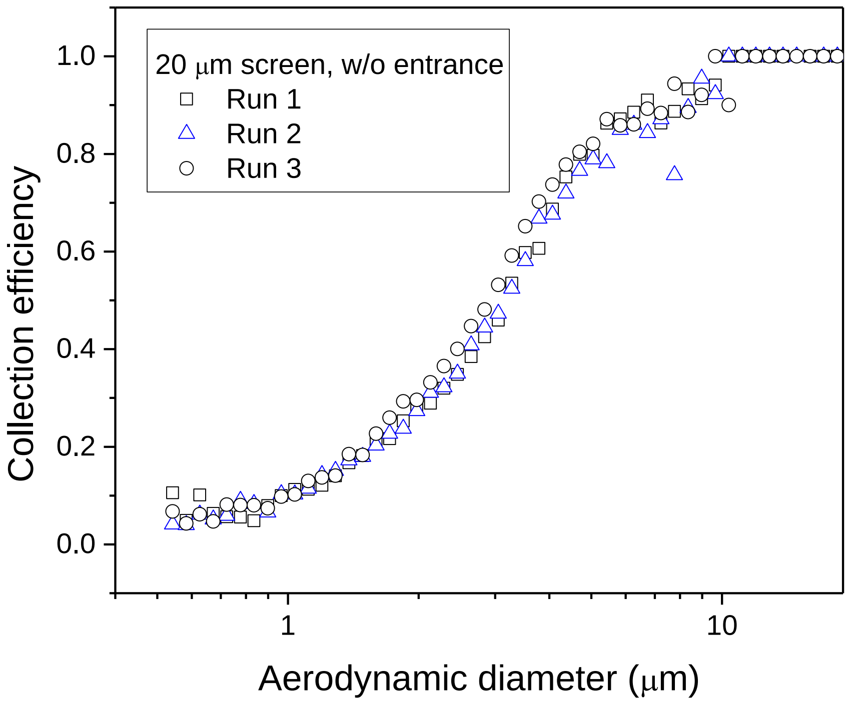

Fig. S2. Collection efficiency of 20 μm screen for the first three consecutive runs under the same condition.

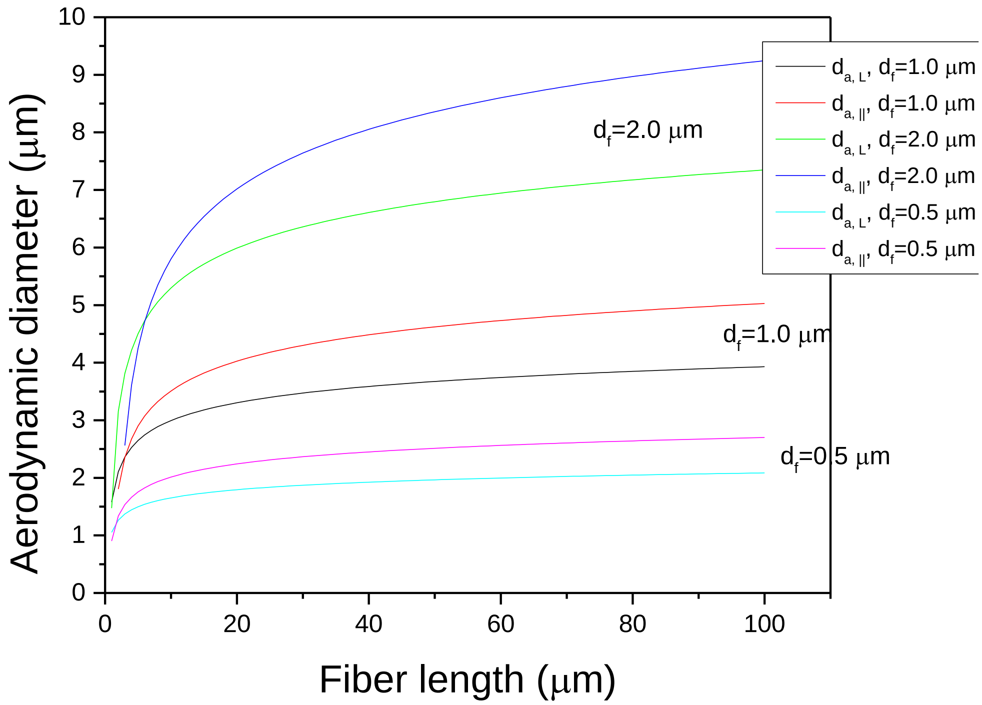

Fig. S3. Calculated aerodynamic diameter as a function of fiber length for a given fiber diameter (i.e., 0.5, 1.0 & 2.0 μm) based on Cox's expressions (Cox, 1970). $d_{a,L}$ and $d_{a,\parallel}$ are aerodynamic diameters for a fiber in motion perpendicular and parallel to the long axis, respectively.

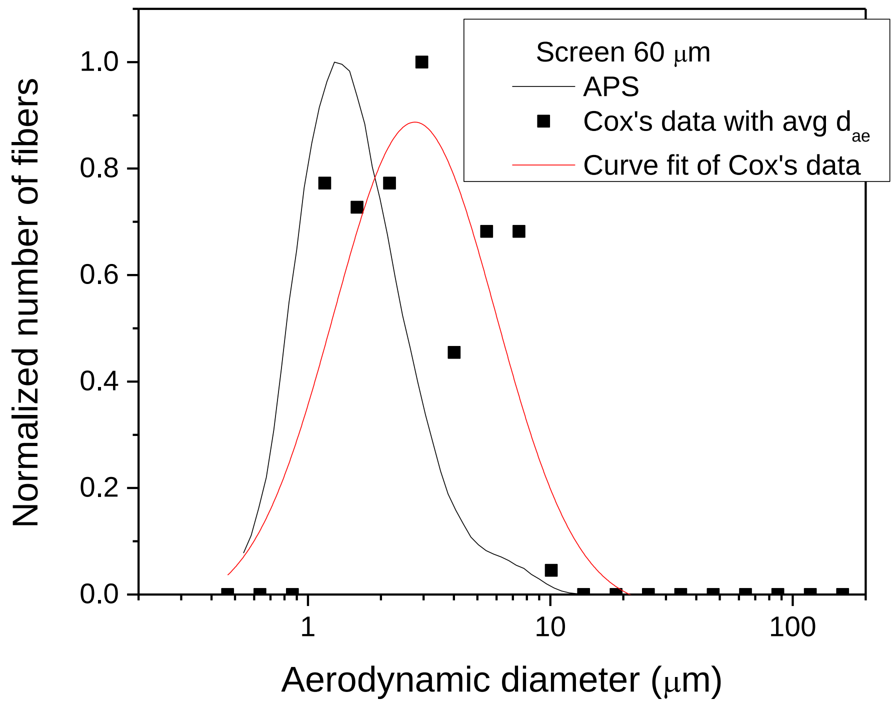

Fig. S4. Comparison between APS-measured and Cox's estimated aerodynamic size distributions of fibers penetrating 60 μm screen. Cox's data were obtained from fibers collected on a filter whose lengths and diameters were measured by SEM.

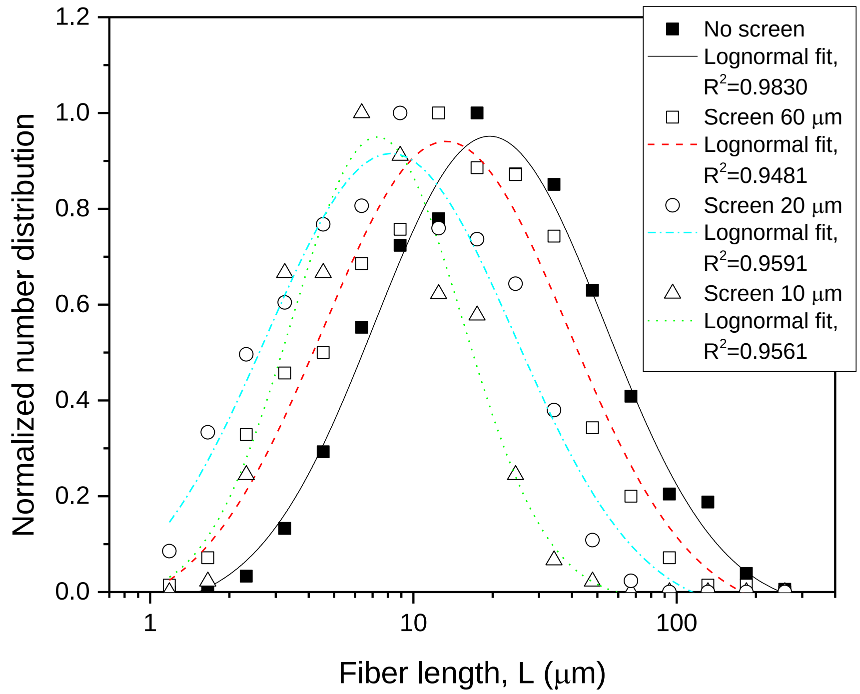

Fig. S5. Length distributions of fibers collected on filters and analyzed by an optical phase contrast microscope for no screen and screens 10, 20 & 60 μm.

References

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