S1. Empirical correlation for filtration efficiency

The macroscopic property of the filter penetration is related to the single-fiber efficiency $E_{\Sigma}$ (a microscopic property) using the following equation [1]:

$$ P = \exp \left( \frac{-4\alpha t E_{\Sigma}}{\pi d_f} \right) $$

(S-1)

where $\alpha$ and $t$ are filter solidity and thickness, respectively, for a monodisperse fiber diameter $d_f$. $E_{\Sigma}$ is total single-fiber efficiency, calculated by combining each of the mechanical single fiber efficiencies. The accuracy is most valid for small values of the component efficiencies:

$$ E_{\Sigma} = E_R + E_I + E_D + E_{DR} + E_G $$

(S-2)

$E_R$ = collection by interception, $E_I$ = collection by impaction, $E_D$ = collection by diffusion, $E_{DR}$ = interaction term to account for enhanced collection due to interception of the diffusing particles, $E_G$ = collection by gravitational settling.

Interception occurs when a particle follows a gas streamline that happens to come within one particle radius of the surface of a fiber. $E_R$ is given by

$$ E_R = \frac{(1 - \alpha)R^2}{Ku(1 + R)} $$

(S-3)

$R$, also called the interception ratio, is the ratio of particle to fiber diameter. $Ku$ is the Kuwabara number (see main text for details).

$E_I$ represents collection by inertial impaction of a particle on a fiber. Because of its inertia, a particle collected by this mechanism is unable to adjust quickly enough to the abruptly changing streamlines near the fiber and crosses those streamlines to hit the fiber

$$ E_I = \frac{(St)\gamma}{2Ku^2} $$

(S-4)
where \( St_k = \frac{\rho_p d_p^2 C_c v_f}{18 \mu d_f} \) is the Stokes number, \( \rho_p \) and \( d_p \) are the density and diameter of the aerosol particle, \( \mu \) is the dynamic viscosity of the air, \( C_c \) is the Cunningham slip factor and \( v_f \) is the face velocity. Stokes number is the ratio of the stop distance (or distance a particle would penetrate into a stagnant gas before stopping) to a characteristic length scale of the flow and can be considered as a measure of the inertia of the particle. \( J \) is an empirical function of solidity and the interception ratio. \( J \) is given by

\[
J = \left(29.6 - 28 \alpha^{0.62}\right) R^2 - 27.5 R^{2.8} \quad \text{for } R < 0.4 \tag{S-5}
\]

There is no simple equation for \( J \) when \( R > 0.4 \). For approximate analysis, a value of \( J = 2 \) for \( R > 0.4 \) can be used [1]. This change in assumption regarding \( J \) is responsible for the discontinuities sometimes observed in the plots of theoretical penetration distribution function versus particle diameter (\( d_p \)).

\( E_D \) is the collection due to Brownian motion of small particles, which causes them to diffuse to the particle surface.

\[
E_D = 2 Pe^{-2/3} \tag{S-5}
\]

where \( Pe = d_f v_f / D \) is the dimensionless Peclet number, defined as the ratio of the rate of advection of a physical quantity by the flow to the rate of diffusion of the same quantity driven by an appropriate gradient, and \( D \) is the particle diffusion coefficient. \( E_D \) is the only mechanism that increases as particle diameter decreases.

It is necessary to include an interaction term that accounts for enhanced collection due to interception of the diffusing particles or \( E_{DR} \):

\[
E_{DR} = \frac{1.24 R^{2/3}}{(KuPe)^{1/2}} \tag{S-6}
\]

\( E_G \) is the gravitational settling of the particles and is often negligibly small for sub-micrometer particles:

\[
E_G = \frac{St_k d_f g}{v_f^2} (1 + R) \tag{S-7}
\]

where and ‘\( g \)’ is acceleration due to gravity.
S2. Loading characteristic of all filters using solid and liquid aerosol

For each filter, the pressure drop was measured as a function of time up to 10 min under constant volumetric flow of 2 LPM. The pressure drop $\Delta p$ was normalized by the pressure drop ($\Delta p_0$) for particle free air flow (values provided in legend of Figure 9) and plotted versus time. Figure S1 and S2 shows these two plots for NaCl and DEHS aerosol. The derivative $d(\Delta p/\Delta p_0)/dt$ was estimated at each time point using a 3-point formula.
Figure S1: The loading curve of tested filters (a) NaCl aerosol (S1) (b) DEHS aerosol (S2). The pressure drop $\Delta p$ was normalized by the pressure drop ($\Delta p_0$) for particle free air flow (values provided in legend of Figure 9) and plotted against time. $\Delta p_0$ (kPa) values for the several filters were: 11CA, 2.8; 15CA, 1.7; 17CA, 1.7; GF, 3.4; 17CA_NP, 0.2; MFc, 0.15.
References