Supporting Information for

Hydration of Hydrophilic Cloth Face Masks Enhances the Filtration of Nanoparticles

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Supplemental Results
Homemade masks of 100 % cotton were worn by authors and mass measurements were made as a function of time worn, see Figure S11. Initial mass of masks was ≈ 13.5 g. The results show a rapid initial increase in mask mass, followed by a slow increase in mass with time worn.

**Figure S1.** Increase in the mass of cloth face coverings from water uptake as a function of time worn (min) for three 100 % cotton masks by 2 individuals. Mask #1 (black circles), mask #2, (red squares), Mask #3 (green triangles).

**Figure S2.** Filtration efficiency (FE, %) as a function of particle mobility diameter ($D_m$) for 100 % cotton at 0 % RH (gray circles), 55 % RH (black circles), 99 % RH (red circles), Uncertainties (1σ) in FE are ± 5 %.
Detailed $\Delta P$ results.
The $FE$ and $\Delta P$ at a $D_m$ of 300 nm was measured continuously for all samples. Data is shown for all 100 % cotton and synthetic samples in Fig. S3. Cotton sample show a change in $FE$ and $\Delta P$ with exposure to ambient RH. The $FE$ and $\Delta P$ was indepdent of RH for synthetic samples.

![Figure S3.](image)

**Figure S3.** a) $FE$ at $D_m = 303$ nm as a function of time (s) at $<10 \%$ RH for samples exposed to 99% RH for 12 hours for and b) $\Delta D_p$ as a function of time (s) all 100% cotton samples. c) $FE$ at $D_m = 303$ nm as a function of time (s) at $<10 \%$ RH for samples exposed to 99% RH for 12 hours for and d) $\Delta D_p$ as a function of time (s) all synthetic samples.
**H$_2$O uptake results.**

**Table S1.** Percent (%) H$_2$O uptake by mass of fabric samples exposed to 99 % RH for 12 hours, $FE$ at $D_m$ of 303 nm of humidified (humid) and under ambient conditions (55 % RH) and % change between 99 % RH and 55% RH. 1σ uncertainty in $FE$ is 5 %. *Sample names correspond to those used in (Zangmeister, et al. 2020).*

| Sample                                    | % Mass H$_2$O Uptake (%) | $FE$ 99% RH (%) | $FE$ 55% RH (%) | % $FE$ Change (%) |
|-------------------------------------------|--------------------------|-----------------|-----------------|-------------------|
| Cotton flannel 1                          | 9.3                      | 44.8            | 31.0            | 44.7              |
| Cotton flannel 7                          | 9.7                      | 21.5            | 15.7            | 37.0              |
| Cotton flannel 8                          | 7.7                      | 15.5            | 11.5            | 34.2              |
| Cotton 10* - yellow (flannel)             | 10.4                     | 36.4            | 25.3            | 43.7              |
| Cotton 10 - brown                         | 8.7                      | 27.0            | 18.7            | 44.4              |
| Cotton 10 - green                         | 8.5                      | 38.9            | 27.4            | 41.8              |
| Cotton flannel 13                         | 7.9                      | 24.1            | 16.8            | 43.6              |
| Cotton flannel 17                         | 9.0                      | 32.0            | 24.0            | 33.6              |
| Cotton flannel 19                         | 7.0                      | 12.7            | 10.1            | 26.3              |
| Cotton single gauze                       | 9.0                      | 11.5            | 9.5             | 21.4              |
| Cotton 13*                                | 11.0                     | 22.2            | 20.7            | 7.3               |
| Wool flannel 5                            | 11.9                     | 19.9            | 13.4            | 48.2              |
| Poly/Cotton blend 2*                      | 6.2                      | 7.9             | 6.6             | 18.8              |
| Rayon*                                    | 32.2                     | 11.7            | 7.4             | 58.0              |
| Polyester 3*                              | 0.4                      | 15.0            | 14.8            | 1.7               |
| Polyester 5*                              | 0.6                      | 17.5            | 17.4            | 0.5               |
| Polyester 4*                              | 3.5                      | 19.6            | 20.0            | -1.8              |
| Synthetic blend 2*                        | 0.8                      | 20.4            | 20.5            | -0.2              |
| Nylon*                                    | 3.9                      | 5.6             | 5.8             | -3.4              |
| Surgical mask 2*                          | 1.3                      | 30.8            | 30.5            | 1.0               |
| N95*                                      | 0.4                      | 99.9            | 99.9            | 0.0               |
RH effect on fiber thickness.
The $D_f$ of rayon samples were measured after exposure to high and at ambient $RH$. Rayon was chosen because it had the highest measured H$_2$O uptake. A total of 24 fibers were measured and increased on average 14.7 % $\pm$ 11.5 % ($1\sigma$), see Fig. S4. Assuming cylindrical fibers, this results in a 32.8 % $\pm$ 27.1 % increase in fiber diameter.

**Figure S4.** Transmitted light microscopy of a rayon fiber imaged before and after hydration. a) A selected rayon fiber (among 24 monitored fibers) at ambient relative humidity (45%) with a mean initial apparent diameter $D_f = 14.2$ mm. b) same fiber imaged after 4.25 hours at $> 90\%$ relative humidity with a mean final apparent diameter $D_f = 15.1$ mm.
Flow rate affect on $\Delta P$ and $FE$.

The impact of flow rate (face velocity) was modelled to better understand its affect on $\Delta P$ and $FE$ as a function of $D_m$ ($FE$ curve shape). The experimental face velocity in the measurements detailed in this study was 0.064 m/s and the material parameters for Cotton 10 were modelled. The face velocity was varied and the $FE$ was calculated as a function of $D_m$, see Fig. S5a. Varying face velocity through the filter changes the $FE$ and changing the shape of the $FE$ curve, and the Dm of the most penetrating particle size (MPPS), see Fig. S5b, shifting the MPPS to smaller $D_m$ with increasing face velocity. The $\Delta P$ increases linearly with face velocity, see Fig. S5d. Using a $D_m$ of 300 for reference, the $FE$ initially rapidly decreases with face velocity until the face velocity is 0.52 m/s, and increases linearly with flow velocity. The $FE$ at 300 nm is nearly 40% higher at the highest modelled flow velocity of 8.3 m/s when compared to a flow velocity used in this study.

Figure S5. a) Calculated $FE$ as a function of $D_m$ and face velocity. b) $FE$ at 300 nm, c) MPPS (nm), and $\Delta P$ (Pa) as a function of face velocity.
Figure S6. Measured $FE$ as a function of Time (s) for 305 nm ammonium sulfate, KCl, and SiO$_2$ spheres and dry NaCl. Change in color denotes transition from humidified to ambient fabric.
**NaCl growth as a function of $D_m$ and RH.**

Table S2. Equilibrium $D_m$ as function of RH using Eq. S11.

| RH (%) | 86   | 88   | 90   | 92   | 94   | 96   | 98   | 98.5 | 99  |
|--------|------|------|------|------|------|------|------|------|-----|
| $D_m$ ambient (nm) | 50   | 108  | 112  | 116  | 123  | 132  | 146  | 173  | 184 | 201 |
|        | 61   | 132  | 137  | 143  | 151  | 162  | 180  | 216  | 232 | 255 |
|        | 75   | 163  | 169  | 177  | 187  | 201  | 225  | 272  | 293 | 324 |
|        | 91   | 198  | 206  | 215  | 228  | 246  | 276  | 336  | 363 | 404 |
|        | 111  | 242  | 252  | 264  | 279  | 302  | 339  | 416  | 452 | 505 |
|        | 136  | 298  | 309  | 324  | 344  | 372  | 419  | 517  | 562 | 631 |
|        | 166  | 364  | 378  | 396  | 421  | 456  | 515  | 637  | 696 | 784 |
|        | 203  | 445  | 463  | 486  | 516  | 560  | 633  | 787  | 860 | 972 |
|        | 248  | 545  | 567  | 594  | 632  | 686  | 777  | 968  | 1060| 1202|
|        | 303  | 666  | 693  | 727  | 773  | 841  | 953  | 1190 | 1305| 1483|
|        | 370  | 814  | 847  | 889  | 946  | 1029 | 1167 | 1461 | 1604| 1826|
|        | 452  | 995  | 1035 | 1087 | 1156 | 1259 | 1429 | 1792 | 1969| 2245|
|        | 553  | 1218 | 1267 | 1331 | 1416 | 1542 | 1751 | 2200 | 2419| 2762|
|        | 675  | 1487 | 1548 | 1625 | 1730 | 1884 | 2141 | 2693 | 2963| 3386|
|        | 825  | 1818 | 1893 | 1988 | 2116 | 2305 | 2621 | 3299 | 3632| 4154|

**Fluid flow imaging.**

Fluid flow imaging was used as a second, independent method to visualize the flow of droplets through fabric samples.$^{S1}$ High-speed videos of air pulses laden with aqueous 1% glycerol droplets were collected for 2-layer fabric samples sealed to the end of a 5.08 cm inner diameter PVC pipe. Data were acquired for 100% cotton and 100% polyester samples equilibrated at ambient RH and high RH, representing the extremes of the measured FE change shown in Fig. 1a in the main body of the manuscript. The imaged aqueous droplets had a geometric mean diameter and geometric standard deviation of 3.41 $\mu$m and 1.47. This is a larger particle size than those measured in the data shown in Figure 1 and Table 1, and similar in size and distribution of human exhalation.$^{S2-3}$
**Figure S7.** Droplet size distribution for flow visualization data
Figure S8. Flow visualization of 100 % cotton and 100 % polyester equilibrated at high and ambient RH. Flow is from left to right, and the material is visible as a vertical line on the left edge of each still image. a) Still images from fluid flow visualization experiments of fabric covered pipe of 100 % cotton at ambient RH. Scale bar represent 1 cm. b) Same as a) but equilibrated for 12 h at high RH. c) Pipe covered with 100 % polyester, equilibrated at ambient RH. d) Same as c) but equilibrated for 12 h at high RH. e) Normalized pixel intensity as a function of time (s) after pulse initiation for samples equilibrated at ambient RH (solid) and high RH (dashed) for cotton (black) and polyester (red). Shaded regions of ambient cotton represent the 1σ uncertainty of multiple experiments.
Videos were taken of each sample and still images near the peak droplet intensity from each sample are shown in Figure S7a to S7d. Both samples equilibrated at ambient RH show visually higher signal, corresponding to the scattered light intensity from a larger volume fraction of transmitted droplets, when compared to samples equilibrated at high RH. This is consistent with the quantitative trends in the measured FE for smaller particles. The scattered signal intensity of the 100 % polyester sample was 33 % higher when compared to 100 % cotton measured under the same conditions, also consistent with the lower measured FE of synthetic materials. A plot of the measured pixel intensity vs. time after pulse initiation (Fig. S7e) highlights the impact of exposure of each fabric to high RH and supports above stated observations. Using this analysis, samples equilibrated at high RH had 75 % ± 22 % and 29 % ± 6 % (1σ) lower intensity for 100 % cotton and 100 % polyester, respectively, when compared to the same samples equilibrated at ambient RH.
Supplemental Methods.

Fabrics.

**Table S3.** List of fabrics measured, their fiber content, yarn count, and source information. *Samples were previously reported in (Zangmeister et al. 2020). Yarn count determined is by summing the total number of yarns per cm in the warp and weft directions.*

| Sample               | Fiber Type               | Yarn Count (yarns cm$^{-2}$) | Product Source (may not be primary manufacturer) |
|----------------------|--------------------------|------------------------------|--------------------------------------------------|
| Cotton flannel 1     | 100 % Cotton             | 60                           | Benartex                                         |
| Cotton flannel 7     | 100 % Cotton             | 60                           | Spasilk                                          |
| Cotton flannel 8     | 100 % Cotton             | 60                           | Tom Bihn                                         |
| Cotton 10* - yellow  | 100 % Cotton             | 60                           | Dit Dot Flannel by Jason Yenter                  |
| Cotton 10 - brown    | 100 % Cotton             | 60                           |                                                  |
| Cotton 10 - green    | 100 % Cotton             | 60                           |                                                  |
| Cotton flannel 13    | 100 % Cotton             | 60                           | Pinzon                                           |
| Cotton flannel 17    | 100 % Cotton             | 60                           | Kaufman                                          |
| Cotton flannel 19    | 100 % Cotton             | 60                           | Tom Bihn                                         |
| Cotton single gauze  | 100 % Cotton             | 30                           | Zsedrut                                          |
| Cotton 13*           | 100 % Cotton             | 240                          | Cozeri                                           |
| Wool flannel 5       | 100% Wool                | 40                           | Heritage Products                                |
| Polyester/Cotton blend 2* | 65% polyester/35% cotton | 60                           | Tom Bihn                                         |
| Rayon*               | Rayon                    | 60                           | Joann Fabrics                                    |
| Polyester 3*         | 100 % Polyester          | 60                           | Joann Fabrics                                    |
| Polyester 5*         | 100 % Polyester          | 90                           | Joann Fabrics                                    |
| Polyester 4*         | 100 % Polyester          | 60                           | Joann Fabrics                                    |
| Synthetic blend 2*   |                          | 80                           | MicronOne/CleanBrands                            |
| Nylon*               | 100 % Nylon              | 50                           | Joann Fabrics                                    |
| Surgical mask*       | Polypropylene            | n/a                          | Hyland                                           |
| N95*                 | Polypropylene            | n/a                          | 3M                                               |
Regain and Water Transport Properties of Measured Fibers.

*Standard Moisture Regain* is the mass % of H$_2$O in an oven dry material at 21°C and 65% relative humidity (% RH). Fabrics with higher regain values are more absorbent and those with lower values are less absorbent. The amount of water uptake by a fiber is dictated by the type and number of polar groups on the surface of a fiber and its physical structure. These polar groups attract and aid in the retention of atmospheric water through hydrogen bonding. *Cotton* and *rayon* have relatively high moisture regains (between 7% and 11% for cotton and 11% and 12.5% for rayon) because they contain a large concentration of very polar hydroxyl groups on their surfaces - a feature common of cellulose based fibers. Hydroxyls are also present for *wool* along with other polar groups such as amides and carbocyclic acids. These functional groups are components of the keratin cross-linked proteins that make up wool fibers. *Wool* is reported to have a standard regain of 13%, but can go as high as 30 %. *Nylon* fabrics usually have lower regain values because their surface functional groups are amides, which are less polar than hydroxyls. *Polyesters* usually have no polar functional groups and, therefore, have very low regain values near 0.4 %. The regain value of polyester can be increased by the addition of special processing steps during fiber/yarn production. Polyesters are usually better at *wicking*, which is the ability of fibers to transport water across their surface, than fibers that more readily absorb water (e.g. cotton).

*Fiber structure* is another important factor to how fibers uptake and retain water. Natural fibers such as cotton and wool have multiple layers (i.e. walls) and irregular surfaces (e.g. convoluted for cotton and scaled for wool). The irregular structure of cotton is due to it containing both crystalline (straight) and amorphous (curved) molecular chain sections that can span nm to μm lengths. This feature impacts the fiber’s regain as water uptake and transport into the fiber occurs predominately at the amorphous sections of the cotton where water can more easily penetrate the cellular walls. Once water has penetrated the walls it can be moved through the fiber via the hollow lumen core, pushing apart lightly hydrogen bonded regions of the amorphous cellulose and causing the fiber to swell. Water transport in wool follows a different mechanism as wool is a bicomponent fiber, with one component being more hydrophilic than the other. The outer protective scales of wool are hydrophobic, with water penetration occurring only at gaps or damage points between the scales. Once water breaks this barrier it is attracted to the hydrophilic components of the cortex, where it will be absorbed, causing the fiber to swell.

In contrast to natural fibers, synthetic fibers such as polyester and nylon are mono-structured, have regular or repeating surfaces, and either have solid cores or a set-dimension. However, it is their low concentration or lack of polar functional groups that dictates their hydrophobic properties. One major exception to this is rayon, which is a cellulosic synthetic fiber. The cellulose chemistry of this fiber type means it has polar surface hydroxyls, often at a concentration higher than cotton and wool. However, as it is commercially synthesized (i.e. regenerated), it does not have a layered structure like cotton or wool. Rather it is often a solid structure with a circular shape and has lengthwise striations that give it a high surface area. During rayon synthesis the native cellulose structure is destroyed, and the polymer chains are rejoined in new packing configurations to promote different fiber properties such as absorbency, heat retention, and durability.
Filtration efficiency.

![Diagram](image)

**Figure S9:** Block diagram for the filtration efficiency experiments. Connections between flows are shown for measurement. Abbreviations: condensation particle counter (CPC), differential mobility analyzer (DMA stainless steel flow splitter (S) and precision needle valve (V). $N_U =$ upstream particle concentration, $N_D =$ downstream particle concentration.

Flow visualization.
A flow system was assembled to aid in visualization of H$_2$O droplets penetrating these fabrics. The assembly consisted of a 5.08 cm inner diameter straight-walled PVC pipe and a custom mounting flange. The flange was constructed to mount and lock fabric samples to the pipe terminus and provided a seal to minimize gaps or leaks. Flexible tubing connected the pipe system to a custom in-line fog generator that consisted of a cotton plug (soaked in an aqueous solution of 1 % glycerin) wrapped with 20-gauge nichrome wire, see Fig S13 for an experimental schematic in the Supporting Information. A 12 V DC, 2 A power supply was used to pass current through the wire which created a dense plume of fog droplets. The particle size distribution of these droplets was measured with an Aerodynamic Particle Sizer (APS, Model 3321) as shown in Fig. S6. A solid-state timer (model TMM-0999M, Ametek.com) was used to pulse current into the fog generator for 2 seconds and provided a repeatable plume of fog droplets for each visualization experiment.

A custom flow system was located upstream of the fog generator and pipe mounting flange. Compressed air passed through a shutoff valve and pressure regulator, and then into a 1.75 L accumulator. A solenoid valve (SMCpneumativs.com, model VX2220) and a solid-state timer controlled the timing of the air pulse. When the solenoid was activated, air exited the accumulator and passed through a needle valve that governed the flow rate of the exhalation. This air stream entered a second 1.75 L accumulator which widened the pulse width of the flow exiting the first accumulator. Air then flowed past the in-line fog generator and then to the mounted fabric samples. A hot-wire anemometer (OMEGA.com, model FMA-905) was used to monitor velocity and flow rate.
Video data was collected with a high-speed camera (Photron.com, NOVA S9) at 125 frames per s. Triggering of the system was enabled via manual control box that fired the solenoid valve and also triggered image acquisition of the high-speed camera. The duration of each pulsed experiment was 3.25 s and images were collected with a high-speed camera at 125 frames per s. Precise control over the air pressure, flow rate, and pulse timing and image acquisition enabled complete control over the expiratory flow rate, face velocity and topography of this flow system. The face velocity used was set at 60 cm per s.

![Diagram](image)

**Figure S10.** Schematic for flow visualization experiment. V = shutoff valve, FVC = flow control valve, SV = solenoid valve

**Change in local RH with H₂O desorption from fabric sample.**
The release of H₂O from fabric samples into the air raises the RH in the air volume. The RH of the airstream was 10 % ± 5 %, or containing 2.31 mg of H₂O per L of air at 25 °C. Assuming complete loss of 10 mg of H₂O over the 180 sec experimental window at a flow rate of 1.5 liters per minute (2.25 liters total volume), as shown in Fig. 1b, it is expected the RH would increase up to a maximum of 29% RH, lower than the deliquescence point of NaCl of 74 % RH.

**Calculation of filtration properties.**
Eq S1 – S10 and Eq. 2 were used to calculate and report filtration properties of as a function of \( D_f \), \( \alpha \), and \( L. Ku \) and \( Pe \) represent the Kuwabara number and Peclet number, respectively. \( d_p \) is the particle diameter. \( Stk \) is the Stokes number. \( D \) represents the diffusion coefficient.

Number,

\[
E_D = 2.9Ku^{-1/3}Pe^{-2/3} \quad (S1)
\]

\[
E_R = \frac{1 + R}{2Ku} \left[ 2\ln(1 + R) - 1 + \alpha + \left( \frac{1}{1 + R} \right)^2 \times \left( 1 - \frac{\alpha}{2} \right) - \frac{\alpha}{2} (1 + R)^2 \right] \quad (S2)
\]

\[
E_I = \frac{Stk}{(2Ku)^2} \left[ (29.6 - 28\alpha^{0.62})R^2 - 27.5R^{2.8} \right] \quad (S3)
\]
\[ Pe = \frac{D_f U}{D} \quad \text{(S4)} \]

\[ Ku = -0.5 \ln \alpha - 0.75 + \alpha - 0.25 \alpha^2 \quad \text{(S5)} \]

\[ D = \frac{kTc}{5\pi \eta D_p} \quad \text{(S6)} \]

\[ C = 1 + \frac{\lambda}{D_p} \left[ 2.33 + 0.966 \exp \left( -0.499 \frac{D_p}{\lambda} \right) \right] \quad \text{(S7)} \]

\[ R = \frac{D_p}{D_f} \quad \text{(S8)} \]

\[ Stk = \frac{\rho_p D_p^2 C U}{18\eta D_f} \quad \text{(S9)} \]

\[ \Delta P = \frac{\eta UL}{D_f^2} \left[ 64 \alpha^{1.5} (1 + 56 \alpha^2) \right] \quad \text{(S10)} \]

**Calculation of NaCl growth as a function of \( D_m \) and \( RH \).**

Equilibrium particle diameters for NaCl aerosol at high \( RH \) were calculated using the thermodynamic growth model developed in Radney.\textsuperscript{S9} For hydrated particles, the equilibrium \( D_m \) can be calculated from the Kelvin equation

\[ \left( \frac{RH}{100a_w} \right) = \exp \left( \frac{\gamma (MW)}{D_m \rho RT} \right) \quad \text{(S11)} \]

where \( a_w, \gamma, MW, D_m, \rho, R \) and \( T \) are the activity of water in the particle, the particle surface tension (J m\(^{-2}\)), molecular weight of water (18.02 g mol\(^{-1}\)), the physical diameter of the particle (nm), particle density, ideal gas constant (8.314 J K\(^{-1}\)) and temperature (K), respectively. Values \( a_w \) and \( \rho \) were calculated from the parameterizations of Tang with \( \gamma \) determined similarly from Dutcher.\textsuperscript{S10- S11}

References
S1. Staymates, M., Flow visualization of an n95 respirator with and without an exhalation valve using schlieren imaging and light scattering. *Physics of Fluids* **2020**, *32*, 111703.
S2. Papineni, R. S.; Rosenthal, F. S., The size distribution of droplets in the exhaled breath of healthy human subjects. *Journal of Aerosol Medicine* **1997**, *10*, 105-116.
S3. Morawska, L.; Johnson, G. R.; Ristovski, Z. D.; Hargreaves, M.; Mengersen, K.; Corbett, S.; Chao, C. Y. H.; Li, Y.; Katoshevski, D., Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *Journal of Aerosol Science* **2009**, *40*, 256-269.
S4. Kadolph, S. J.; Marcketti, S. B., *Textiles*. 12th ed.; Pearson: Boston, MA, 2016.
S5. Hearle, J. W. S., *Cotton: Science and technology*. The Textile Institute, CRC Press: Cambridge England, 2007.
S6. Erdogan, U. H.; Seki, Y.; Selli, F., *Wool fibres*. "Handbook of natural fibres". Woodhead Publishing: 2020.
S7. Hearle, J. W. S.; Morton, W. E., *Physical properties of textile fibres*. Elsevier: 2008.
S8. Perel, J., An x-ray study of regain-dependent deformations in cotton crystallites. *Journal of the Textile Institute* **1990**, *81*, 241-244.
S9. Radney, J. G. Development of a nephelometry camera and humidity controlled cavity ring-down transmissometer for the measurement of aerosol optical properties. Dissertation, Portland State University, Portland, OR, 2012.
S10. Dutcher, C. S.; Wexler, A. S.; Clegg, S. L., Surface tensions of inorganic multicomponent aqueous electrolyte solutions and melts. *The Journal of Physical Chemistry A* **2010**, *114*, 12216-12230.
S11. Tang, I. N., Chemical and size effects of hygroscopic aerosols on light scattering coefficients. *J. Geophys. Res.* **1996**, *101*, 19245-19250.