Supplemental information to "Quantification and characterization of manufactured nanomaterials shed from face masks"

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S1. Facemasks

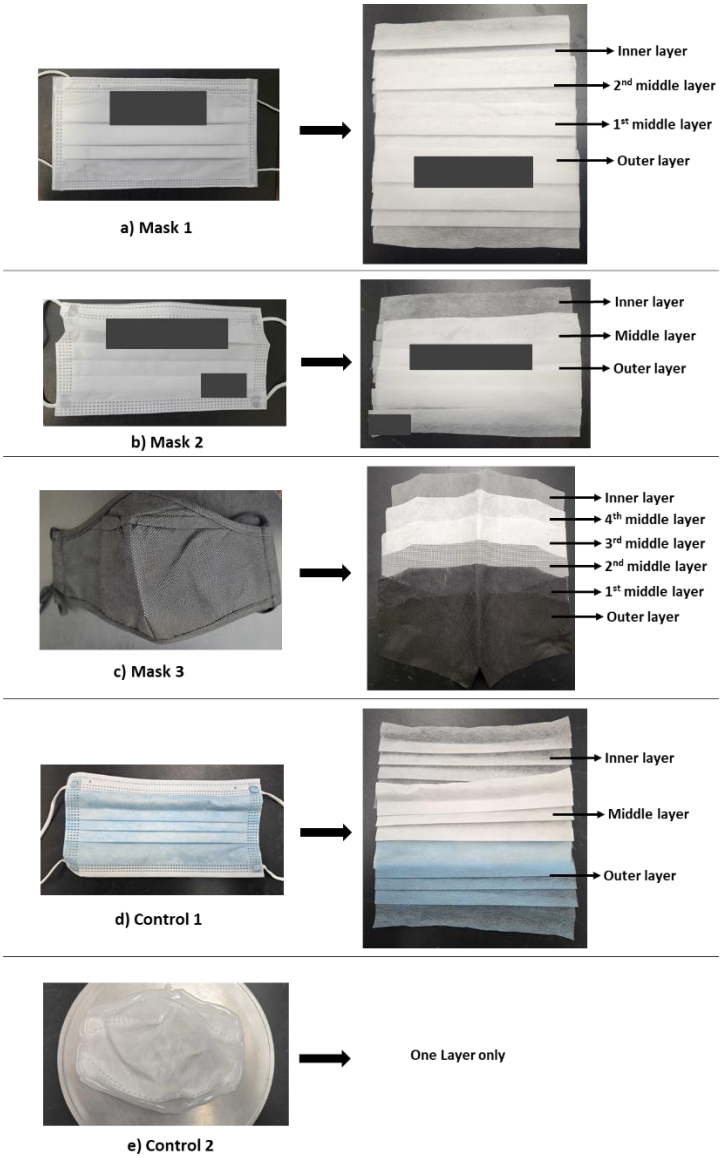

Figure S1: Description of the three facemasks and 2 controls selected. Mask 1 and 2 are disposable face masks made of 4 and 3 layers respectively, while Mask 3 is a reusable and washable face mask claimed to contain 5 layers. Control 1 is a surgical facemask made of 3 layers, while Control is composed of 1 layer only. For Mask 3, the composition of the outer layer was not disclosed by the manufacturer. Although Mask 3 is claimed to be composed on 5 layers, 6 layers were found when separating the facemask. Mask 1 and 2 claim to contain TiO_2, while Mask 3 was claimed to have been coated with titania and silver on the outer layer. No claim was associated with Control 1 and Control 2.

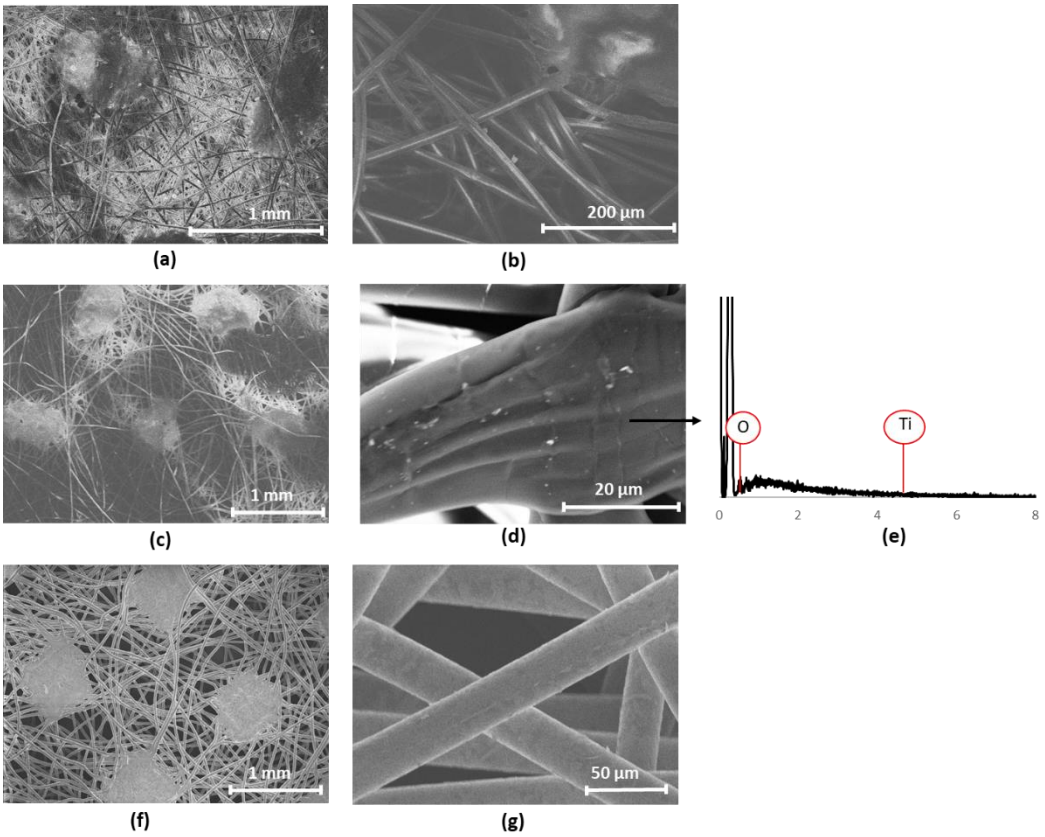

Figure S2: SEM images of the inner layer of (a) Mask 1, (c) Mask 2 and Mask 3 (f) with a higher magnification and EDX elemental map for Ti shown in (b), (d) and (g) respectively. The corresponding sum spectrum of the EDX elemental mapping is shown in (e) for Mask 2 only, where particles were observed on the inner layer.

S2. Validation of shedding experimental setup

In order to validate the experimental setup proposed to assess particle shedding, Control 2 facemask was used and separately loaded with sodium Chloride particles using an automated filter tester (8310, TSI Inc., USA) following the guidelines of the National Institute for Occupational Safety and Health (NIOSH) standard testing procedure [1]. This test procedure is used to determine the particle filtration efficiency of non-powered, air-purifying respirators. Loading was performed at 85 L/min for a duration of 56 minutes with a mass concentration of ~20 mg/m^3 resulting in a loading of approximately 80 mg. Although particle size distribution was not verified directly, green line media was used to ensure the filter tester would provide particles within the required range as outlined with the NIOSH standard procedure. Therefore, the particles loaded were assumed to have a geometric mean diameter (GMD) and geometric standard deviation (GSD) of 75 ± 20 nm and 1.8 respectively. Since the automated filter tester is equipped with photometers, calibrated to provide particle mass, we used the Hatch–Choate analysis [2, 3] to calculate the particle number concentration N_{conc} as follows:

$$N_{conc} = \frac{M_{conc}}{\frac{\pi \rho_{eff}}{6}\left[\mathrm{GMD}\ e^{1.5\,(\ln \mathrm{GSD})^2}\right]^3} \quad \text{(S1)}$$

where M_{conc} is the particle mass concentration expressed in mg/m^3, and ρ_{eff} represents the effective density of the NaCl particles. Assuming spherical particles, effective density can be taken as the material density of 2160 kg/m^3. Based on the following analysis, the total particle number N deposited onto the filter is estimated based on:

$$N_{loaded}=N_{conc}Qt \quad \text{(S2)}$$

where Q represents the loading flow rate and t the loading time.
A pristine unloaded Control 2 (here referred to as the negative (-) control) and the loaded Control 2 (here referred to as the (+) control) facemasks were tested consecutively in the experimental setup shown in Figure 2 with concurrent inline agitation. In both cases, the inside of the facemask (in contact with the skin) was facing the incoming airflow, opposite to the loading configuration.

Released particles detected by the downstream CPC are shown in Figure S3. As expected, no particles were detected with the negative control. When using the positive control, a burst of particles released from the facemask was detected within the first 5 minutes of the test run. Minimal particle concentration (10-70 #/cm^3) was observed for the remainder of the test run, resulting in an average particle concentration of approximately 200 #/cm^3.

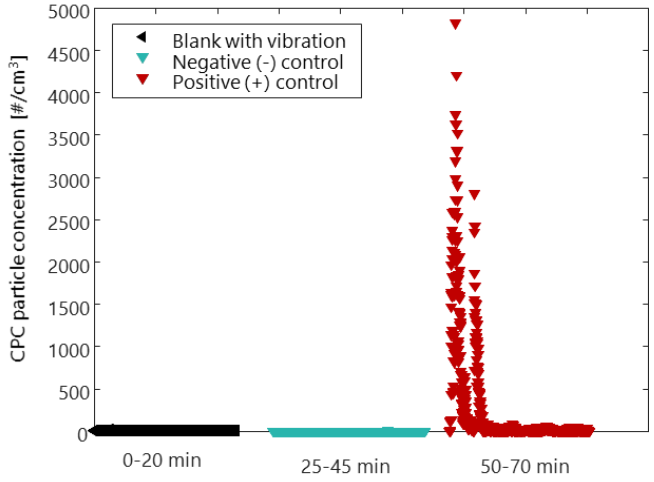

Figure S3: Number particle concentration measured using the downstream CPC for a blank plate, an unloaded Control 2 facemask (negative control) and an NaCl loaded Control 2 facemask (positive control). All tests were performed with inline agitation for a 20-minute period.

Similarly, applying, Eq. (S2), the total number of particles released from the loaded facemask can be calculated and used to determine the percent of resuspension as follows:

$$Resuspension\ (\%)=\frac{N_{loaded}}{N_{released}} \quad \text{(S3)}$$

In this validation study, although a burst of particles was released from Control 2, resuspension was found to be negligeable with a value of 0.00006% assuming a loaded particle size distribution with a GMD and GSD of 75 nm and 1.8 respectively.

S3. References

1. NIOSH. Determination of Particulate Filter Efficiency Level for N95 Series Filters Against Solid Particulates for Non-Powered, Air-Purifying Respirators, TEB-APR-STP-0059. 2019.
2. Hinds WC, Zhu Y. Aerosol technology: properties, behavior, and measurement of airborne particles: John Wiley & Sons; 2022.

3. Corbin JC, Smallwood GJ, Leroux ID, Norooz Oliaee J, Liu F, Sipkens TA, et al. Systematic experimental comparison of particle filtration efficiency test methods for commercial respirators and face masks. Scientific Reports. 2021;11(1):21979.