Supplement material

Decontamination setup

In an exposure chamber of 10 m^3, 10 UV-C light sources (TUV 36W SLV/6, Philips SA, Netherlands) exhibiting a narrow emission peak at 254 nm (Figure A1) were mounted vertically in concentric circles (Figure A1). The outer circle, of about 150 cm in diameter, was made of seven light sources facing inwards. The inner circle was made of three lights sources facing outwards. The intermediate circle, of 80 cm in diameter, was constituted of a rotating metal grid, on which about 100 respirators can be hung simultaneously during the decontamination procedure. The surface of the chamber was of stainless steel and aluminium foils. The geometry of the setting and the reflective nature of the chamber surface ensured a multidirectional and homogenous irradiance of the respirators. The respirator irradiance at the intermediate grid, measured with a dosimeter (X1-3 with XD-45-HUV-4 detector, Gigahertz-Optik, GmbH, Munich, Germany), was of 0.25 mW/cm^2. After a preliminary drying in a laboratory oven at 70°C for 30 min, the respirators were irradiated for 4 minutes for each cycle, corresponding to a dose of 60 mJ/cm^2. FFP2 respirators (3M 6923 and 1862 respirators, 3M, Germany), either unused or used once, were treated with the decontamination procedure. Discarded respirators were collected in the front-line units from the Center for Primary Care and Public Health (Unisanté). They were worn, usually for 4 hours, by nurses or doctors during consultations and nasopharyngeal swabs in patients with SARS-CoV-2 symptoms.

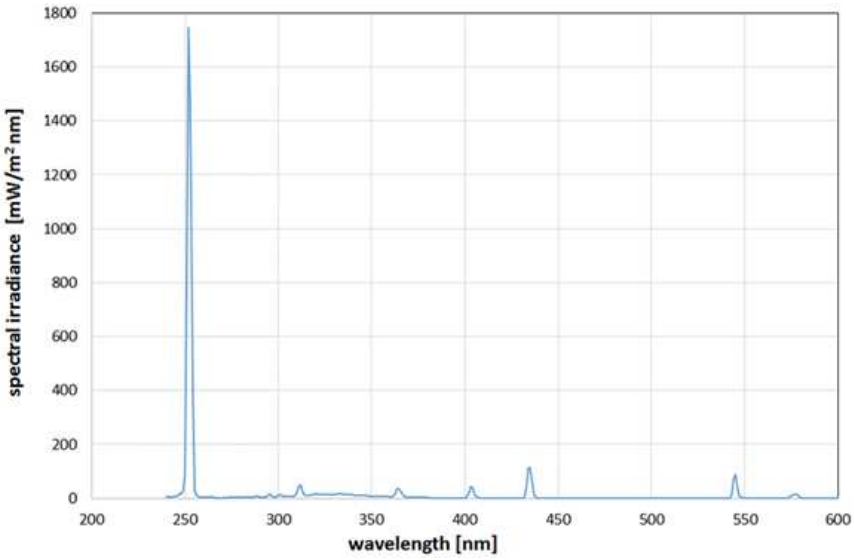

Figure A1. Emission spectrum of low pressure mercury UVGI lamp, reproduced courtesy of Schmid et al. (1)

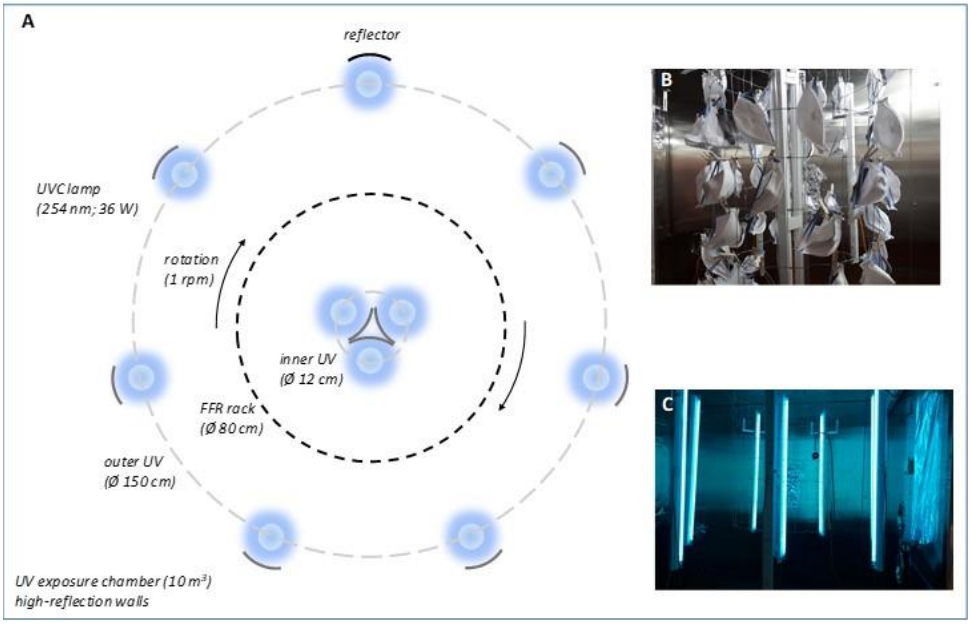

Figure A2. A) Top view schematic of the UV exposure chamber (not at scale); B) Photogram of used FFP2 respirators hung on the rotating rack prior to decontamination; C) Photogram of the treatment chamber during UV exposure.

Germicidal efficiency testing

Bacteriophages. The *S. aureus* lytic phage vB_HSa_2002 was isolated from sewage water collected at the Vidy wastewater treatment plant, Lausanne, Switzerland. It is a member of the Herelleviridae family of the Caudovirales order with a >140kb double-stranded genomic DNA.

The *S. aureus* lytic phage 66 (P66) has previously been kindly provided by Phagomed GmbH to G. Resch. This double-stranded DNA phage belongs to the Podoviridae family of the Caudovirales order and has a genome of >18kb in length (Genbank NC_007046).

For the purpose of the present study, both phages were amplified in batch cultures by mixing 1 mL of phage lysates with a 2L culture of the human *S. aureus* carriage strain Laus102 (i.e. production strain) previously collected at CHUV in the nasopharynx cavity of a healthy patient. After 3h incubation at 37°C and 200 rpm, the amplification mixtures were centrifuged twice at 4000g for 1h and supernatants filtered at 0.45µm after each centrifugation to remove remaining bacterial cells. The supernatants were further concentrated to 100mL and buffer exchanged against 2L of phosphate buffer saline (PBS) pH 7.4 using tangential flow filtration. The phage titers of the purified phage solutions were determined through classical diluted drop test assay at ca. 10^{10} PFU/mL and 10^{9} PFU/mL for phage vB_HSa_2002 and P66, respectively. The phage solutions were stored at 4°C until further use for FFP respirators contamination.

Contamination of FFP respirators and phage particles recovery

***Contamination*.** Twenty FFR were contaminated with eight 5µl droplets of either vB_HSa_2002 or P66 deposited within a 1.3 cm diameter circle on two different areas on the right and left side of a respirator. Thus, each area contained $4x10^{8}$ PFU or $4x10^{7}$ PFU when contaminated with vB_HSa_2002 or P66. FFR were dried at room temperature for 60 minutes.

***Decontamination*.** Twelve FFR were decontaminated using dry heat and UVGI and eight were not treated. After treatment, 1.3 cm diameter circular punches were collected separately in 2 ml of PBS

buffer pH 7.4 and agitated on a reciprocating shaker for 60 minutes. FFR extract solutions were stored at room temperature and processed within 2 h.

Determination of phage titers in the FFP respirators extract solutions. To evaluate the efficiency of the different decontamination treatment procedures, viable counts of vB_HSa_2002 and P66 in the FFR extract solutions were determined through diluted drop test assays. Briefly, 5µL of 10-times serially-diluted FFR extract solutions were deposited on the surface of solidified Tryptic Soy Broth (TSB) soft agar layers seeded with *S. aureus* indicator strain Laus102. After overnight incubation at 37°C, phage titers were determined by counting PFU on plates.

Germicidal efficiency tests conducted for dry heating alone

To evaluate the efficiency of the dry heating alone, seven respirators were contaminated with eight 5µl droplets vB_HSa_2002, applying the procedures already described for contamination and phage particle recovery and with an initial concentration of 3.80E +08. Four respirators were decontaminated by heating and seven were not treated. Results are summarized in Table A1.

		vB_HSa_2002	
		Phage titer [PFU/mL]	**Total amount of PFU/FFR**
Heat-treated (n=4)	Mean	0.00E+00	0.00E+00
	SD	0.00E+00	0.00E+00
Untreated (n=7)	mean	5.53E+06	1.11E+07
	SD	9.72E+06	1.94E+07

Table A1. Viable S. aureus phage particles measured on FFR with and without thermal drying

Filter aerosol penetration.

The penetration test is performed by measuring the differential number concentration of NaCl aerosol (11-307 nm) enabled to pass through the filter sample. Fine particle aerosol stream is generated from NaCl solution (0.6% w/v) using a Collison-type nebulizer (1-jet; flow rate: 1 L/min).

Aerosol dilution with dry air (1.5 L/min) ensures relative humidity control (45-50%). Each respirator sample is prepared (circular punch; 37 mm) and inserted in the filter cassette housing (Casella, UK) positioned on the aerosol line. Downstream, the particle number concentration is measured via scanning mobility particle sizer (SMPS; GRIMM Germany) in the size range 11 to 1082 nm. The penetration rate is calculated as the ratio between particle number concentration (average of three scans) measured alternatively through the respirator sample and the free-path, in the size range between 11 and 307 nm. For each tested respirator several samples are prepared and analysed (n≥3). Although the experimental setup does not strictly follow the method described in the standard EN 13273-7, in particular for air flow rates and filter sample dimensions, the final air velocity through the mask remains in the same order of magnitude (3,9 cm/s).

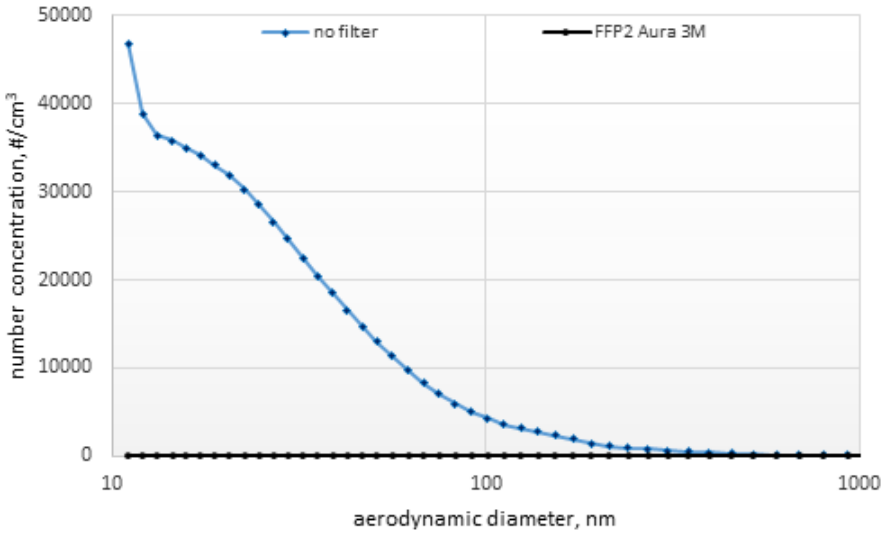

Figure A3, Size distribution of NaCl aerosol generated during filter particle penetration test and measured by Scanning Mobility Particle Sizer.

Observational and SEM analysis.

A 15mm circular punch was extracted from a disposable respirator (3M™ 06923+ Aura, FFP2). The core sample is composed of almost two layers including a hydrophobic layer on the outside and a fine fibers layer towards the face. Both layers, with and without treatment, were separately mounted on a carbon coated support and observed by scanning electron microscopy (SEM) with back-scattered detector at 15 kV and 600X magnification (Figure A4).

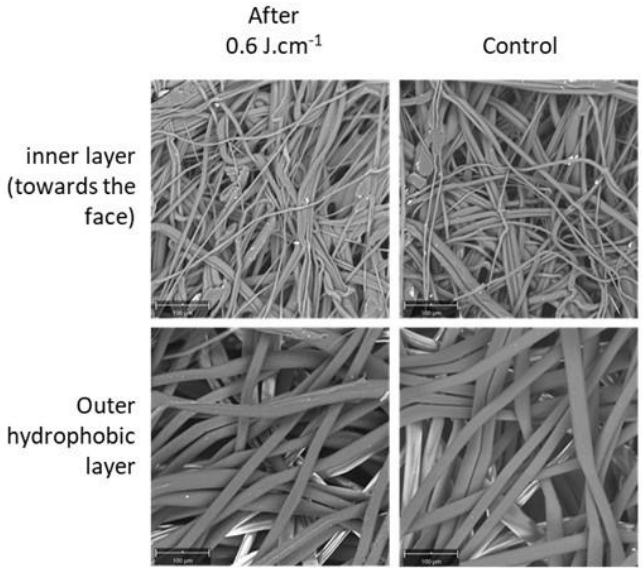

Figure A4. SEM-BSE of the two layers of the respirator, before and after UV-C exposure (image size: 450 x 450 µm).

Polymer melting properties

Melting behaviour was measured on 5-10mg samples extracted from the external layer of a disposable respirator (3M™ 06923+ Aura, FFP2) and subjected to a heating cycle of 10°C/minute in a DSC (TA Instruments DSC Q100) from 20 to 210°C. The melting behaviour exhibits two peaks which are characteristic of drawn PP filaments (2), and no significative difference is found between samples.

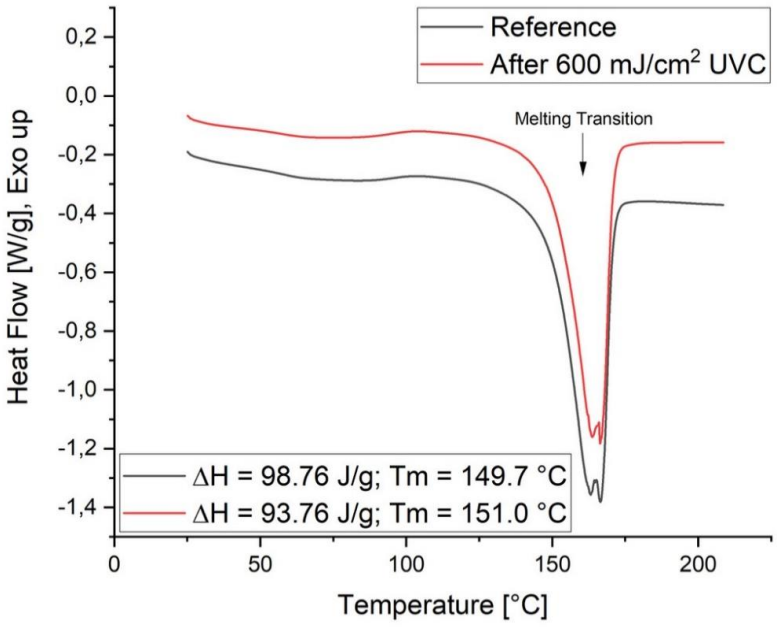

Figure A5: Heat flow behaviour of the external layer of the respirator, before and after 600 mJ/cm^2 UVC exposure.

Measurement of mechanical properties

Dog bone samples with a gauge length of 27mm and a width of 4mm were cut out of a disposable respirator (3M™ 06923+ Aura, FFP2), the layers were separated and each sample tested in a Zwick teachXpert-mobile testing machine with a 5kN load cell. For each sample the maximal force and the strain at failure were recorded. Due to the small quantity of samples (7 per condition) which was not sufficient to reach a statistical significance per layer and per position in the mask, the difference between the maximal force and the strain at break was calculated for all samples exposed at 600 mJ/cm^2 with respect to the reference samples, and averaged. Results exhibit a large scatter as expected for non-woven textiles and indicate a loss of 2%±18% in maximal force and 17%±27% in strain to failure, which represent a non-significant alteration of the layers mechanical performance.

Measurement of gas-phase ROS

Ambient ROS was collected using two impinging sets (5 mL milli-Q water; 0.5 L/min) placed on the mask rack prior and during one UV cycle. The quantitative analysis of air samples was achieved via the photonic detection system that combines multi-scattering absorbance enhancement and FOX assay (3). In brief, a fraction of the collection medium (300 µL) is inserted into the reaction vial containing FOX (700 µL) and positioned on the photonic instrument where the formation of coloured complexes in the presence of ROS is monitored (3 min; λ = 580 nm). Raw data (formation rate, s^{-1}) are converted into equivalent of $[H_2O_2]$ per collected air volume and expressed in $nmol/L_{air}$. Replicates were performed for each analysed sample (n≥4). ROS quantitative determination was performed at the same cabin ventilation rate as used during mask UV-treatment process.

Measurement of ozone

Direct reading instrument based on electrochemical detection of ozone (Aeroqual 500, measurement range 0 - 150 ppb, Aeroqual Inc., Auckland, New Zealand) was placed on the mask rack in the UV treatment cabin. Ambient ozone level was monitored for 10 min in the closed cabin prior to UV treatment (background data; n=11) and continued during ten consecutive UV-cycles (40 min; n=43). Ozone monitoring experiments were performed at the same cabin ventilation rate as used during mask UV-treatment process.

FTIR analysis

A sample of the inner layer (toward the face) of the respirator was exposed to UV-C radiation and periodically measured by FTIR (IRAffinity-1S Shimadzu) in absorbance mode with 2 cm^{-1} resolution (32 scans) with a control sample (not exposed to UVGI) as background scan. Nine levels of exposure were scanned with a cumulative UV-C dose from 0 to 0.6 $J.s^{-1}$. The carbonyl content variation was monitored using the peak height at 1700 cm^{-1} (carbonyl stretching peak) taking the value at 1600 cm^{-1} as a reference (figure 2).

References

1. Schmid J, Hoenes K, Rath M, Vatter P, Hessling M. UV-C inactivation of Legionella rubrilucens. GMS hygiene and infection control. 2017;12:Doc06. Epub 2017/04/30. doi: 10.3205/dgkh000291. PubMed PMID: 28451517; PubMed Central PMCID: PMCPMC5388836.
2. Abbasi Mahmoodabadi H, Haghighat Kish M, Aslanzadeh S. Photodegradation of partially oriented and drawn polypropylene filaments. Journal of Applied Polymer Science. 2018;135(7):45716. doi: 10.1002/app.45716.
3. Vernez D, Sauvain J-J, Laulagnet A, Otaño AP, Hopf NB, Batsungnoen K, et al. Airborne nano-TiO2 particles: An innate or environmentally-induced toxicity? Journal of Photochemistry and Photobiology A: Chemistry. 2017;343:119-25. doi: https://doi.org/10.1016/j.jphotochem.2017.04.022.