

Enveloped Virus Inactivation on Personal Protective Equipment by Exposure to Ozone

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Supplemental Information

Table S1. Materials used in assessments of virus inactivation, mechanical robustness, and filtration efficiency.

type	make and model	used for virus test?	used for mechanical test?
N95 respirator	3M, 8210	yes	yes
N95 respirator	3M, 8515	yes	yes
N95 respirator	Sperian, N1115 XL	yes	yes
N95 respirator	Sperian, N1125 S	yes	yes
KN95	ZKG9501	yes	yes
N95 respirator	Int'l Sourcing, NX95V	yes	yes
Tyvek gown	HDPE Dupont Tyvek	yes	yes
PAPR hood	3M Breathe Easy [®]	yes	no
cloth facemask	<i>unmarked</i>	yes	yes
Tyvek bunny suit	<i>unmarked</i>	yes	no

Table S2. Ozone treatment devices assessed.

Device	Volume (m ³)	Standard Time (m)	Standard [O ₃] (ppm)	Typical Humidity	O ₃ generator	Control Sensor, Logging Sensor
Global Ozone Decon-Zone 4201A Cabinet	0.53	16	20	ambient*	corona discharge	EcoSensor SM-7 0-20 ppm, recorded to SD card at 0.1 Hz
Global Ozone OT-100 Trailer	~30	< 99	≥ 20	ambient*	corona discharge	EcoSensor SM-6 0-20 ppm, recorded via USB O₃ Sensor at 1 Hz**
Zono SC 1 Cabinet	0.73	18	20	80%	deep UV	EcoSensor SM-7 0-50 ppm, recorded via USB O₃ Sensor at 1 Hz**
VirtuCLEAN 2.0 Waterless CPAP Cleaning Pouch	< 0.01	30	15-16	ambient*	unknown	No concentration readout. Recorded via USB O₃ Sensor at 1 Hz**

*not controlled

**[SPEC Sensors Digital O₃ Sensor \(DGS-O3 968-042\)](#)

Table S3. Characteristics of ozone, temperature, and humidity sensors used.

Sensor	Range (ppm)	Accuracy	Response Time (s)	Other parameters?
EcoSensors SM-7	0.3-20.0	greater of ±10% or ±0.03	< 60	temp, relative humidity
EcoSensors SM-7	0.3-50.0	greater of ±10% or ±0.2	< 60	temp, relative humidity
EcoSensors SM-6	0.8-50.0	greater of ±10% or ±0.2	< 60	temp, relative humidity
SPEC Sensors DGS-O3 968-042	0-5*	±15%	< 30	temp, relative humidity

* observed linearity to at least 45 ppm, as determined by comparison to response from SM-7

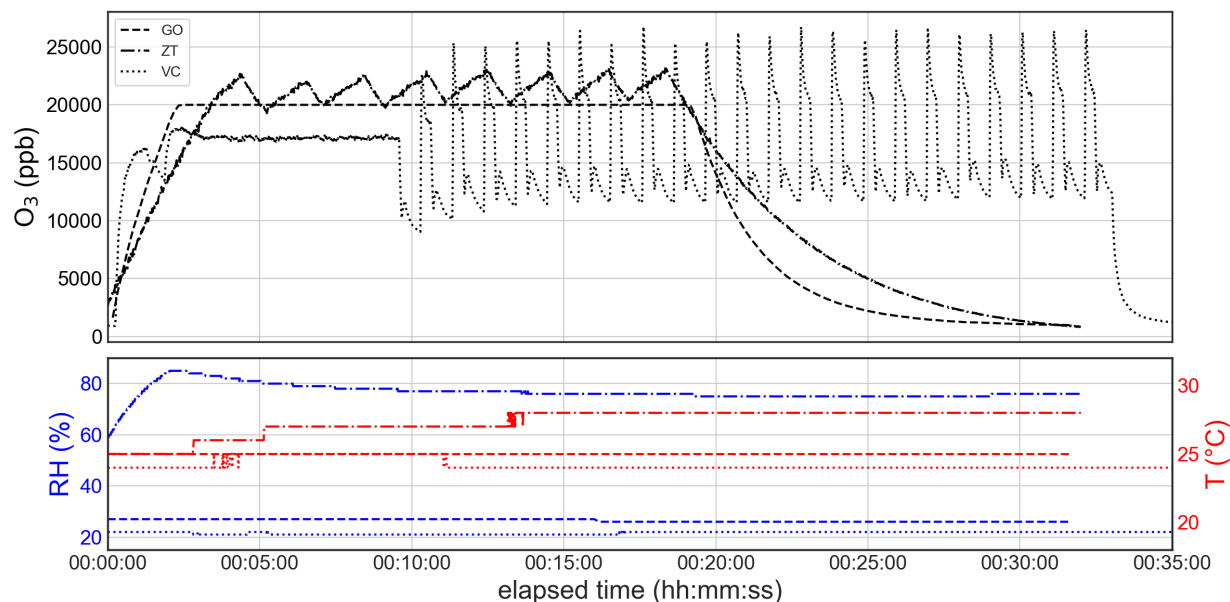


Figure S1. Comparison of ozone concentration, temperature, and humidity during a standard run cycle for each device. Line style convention for bottom plot follows from first plot. Also demonstrates these treatment devices do not exceed commonly recommended N95 respirator storage temperatures of < 30°C. GO = Global Ozone cabinet, ZT = Zono Technologies cabinet, VC = VirtuCLEAN portable PAP disinfection zippered pouch.

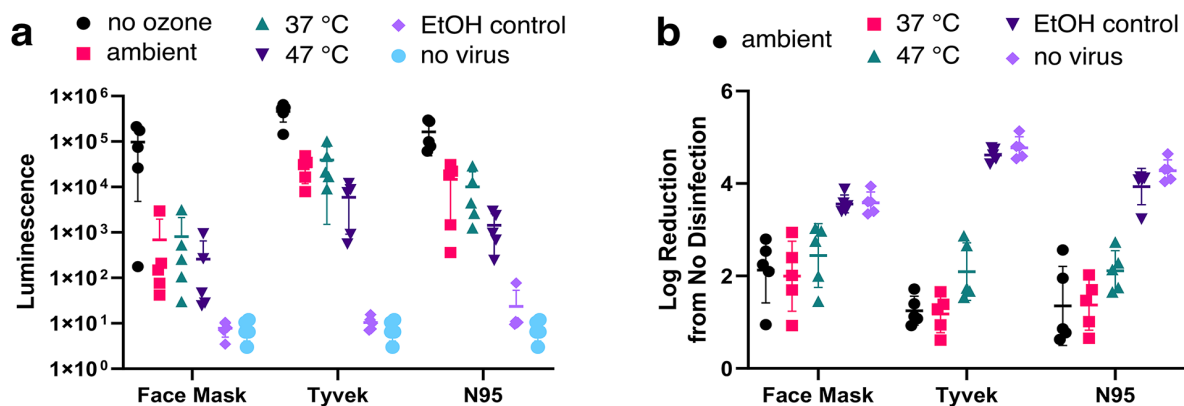


Figure S2. Inactivation of influenza A virus by ozone as a function of temperature, holding atmospheric moisture roughly constant. Here the data are displayed for illustrative purposes in terms of (a) observed luminescence from the NanoLuc assay and (b) reduction of viral infectivity derived from the data in panel (a). Approximate water vapor concentrations: ambient (25 °C), 14.3 g/m³ = 62% RH; 37 °C, 14.5 g/m³ = 33% RH; 45 °C, 17.7 g/m³ = 27% RH.

Table S4. Results of mechanical assessments.

item	make and model	exposure time (20 ppm)	observations of appearance and mechanical properties
N95 respirator	3M, 8210	320 m	no significant changes
N95 respirator	3M, 8515	160 m	No changes in respirator material, elastic bands failed at staple attachment
N95 respirator	Sperian, N1115 XL	320 m	No changes in respirator material, elastic bands failed at staple attachment
N95 respirator	Sperian, N1125 S	230 m	No changes in respirator material, elastic bands failed at staple attachment
N95 respirator	<i>KN95</i> , ZKG9501	160 m	no significant changes
N95 respirator	NX95V	160 m	No changes in respirator material, elastic bands failed at staple attachment
Surgical mask	<i>unmarked</i>	320 m	no significant changes
clear polycarbonate (face shield, goggles)	<i>unmarked</i>	160 m	no significant changes
Tyvek disposable gown	<i>unmarked</i>	160 m	no significant changes
Tyvek PAPR hood fabric	3M Breathe Easy®	160 m	no significant changes

Table S5. Results of particle filtration efficiency assessments.

Manufacturer	Model	Duration of ozone exposure	Control ^a	Result ^b
3M	8210	320 min	yes	pass
3M	8515	160 min	no	pass
Sperian	N1115 XL	320 min	yes	pass
Sperian	N1125 S	230 min	no	pass
KN95	ZKG9501	160 min	no	unknown ^c
International Sourcing	NX95V	160 min	no	unknown ^d
<i>unmarked</i>	surgical mask	320 min	yes	pass ^e

a) Filtration efficiency was not measured for the corresponding untreated sample. b) "Pass" denotes similar filtration efficiency compared to a corresponding control measurement, or filtration efficiency >95% for respirators lacking a control measurement. c) Filtration efficiency >89%; without comparison to a control sample, change due to ozone treatment could not be assessed. d) Filtration efficiency >92%; without comparison to a control sample, change due to ozone treatment could not be assessed. e) Filtration efficiency appears to be higher for the treated sample (reason unknown), but both untreated and treated samples have low overall filtration efficiency.



Figure S3. Example of strain-induced ozone damage (20 ppm, 30 minutes, 24°C, 38% RH) to bands separated from a Sperian N1125 respirator. (*Top*) Relaxed (not stretched) band underwent no visible damage and remained functional; (*bottom*) band tied off at 2.4 times its relaxed length during ozone exposure failed.

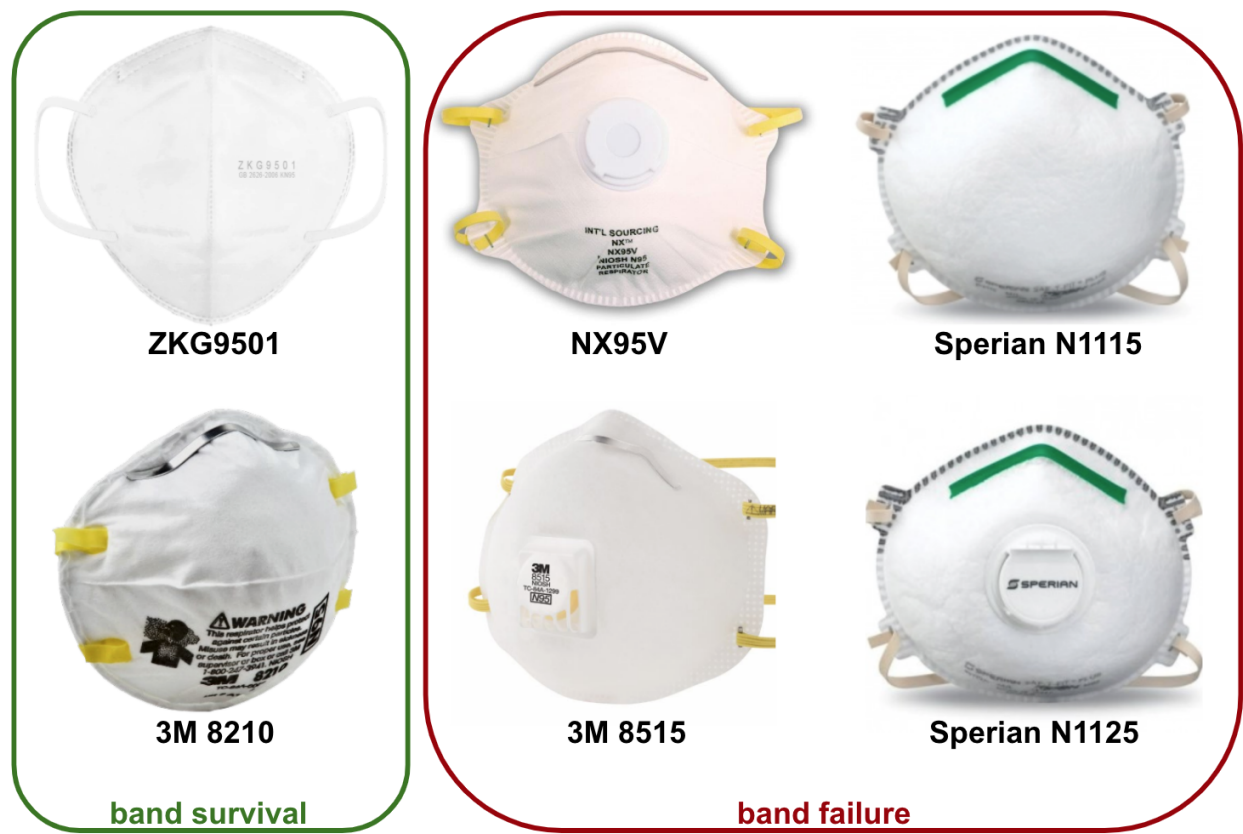


Figure S4. Respirators assessed for headband compatibility with ozone disinfection. All of the respirators with failed bands feature stapled attachments.

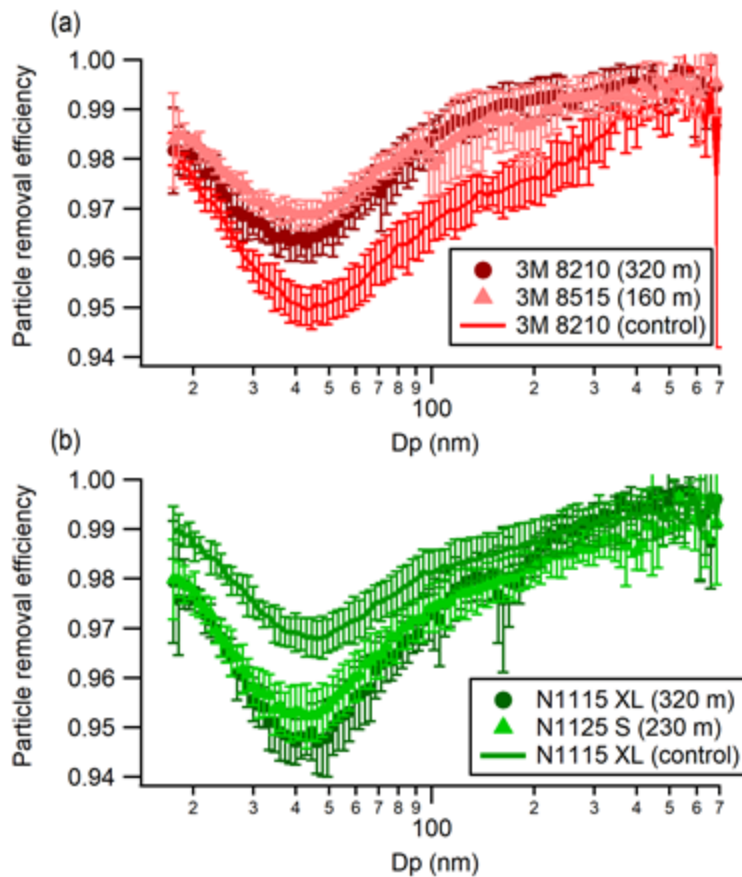


Figure S5. Particle filtration efficiency of untreated (control) and ozone-treated N95 respirators. Uncertainties are calculated from one standard deviation of aerosol volume concentration measured by the SMPS instrument. a) 3M 8210 and 8515 respirators. b) Sperial N1115 XL and N1125 S respirators.