Characterization Testing of a Personal Air Purification Device in Removal of Aerosolized SARS-CoV-2

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Introduction

The threat of COVID-19 infection and high rate of transmission, associated with severe illness, and fatalities, has created a severe threat to health care personnel, first responders, and general populations worldwide. This pandemic has brought about a need for rapid development of effective methods to remove SARS-CoV-2 virus from the air. Here we describe the characterization of a personal air purification (PAP) device in its efficiency in removing aerosolized SARS-CoV-2. The device is designed to provide breathable air to the user. The device is pocket sized and incorporates replaceable filters, built in fan flow, and rechargeable power supplies. A single-pass aerosol system was fabricated to evaluate the device's ability to remove SARS-CoV-2 bio-aerosols. The bio-aerosols were collected both upstream and downstream of the device and assayed via $TCID_{50}$ to quantify its efficacy.

Aerosol Testing Description

Testing was conducted to evaluate the efficacy of the PAP device in removal of aerosolized SARS-CoV-2. All testing was conducted in a Biological Class 3 safety cabinet in a high containment Biosafety Level 3 (BSL-3) laboratory at MRIGlobal. The aerosol test system consisted of an aerosol flow tube with nebulizer adaptation, aerosol dilution air regulation and control, exhaust flow regulation, system pressure monitoring, and aerosol samplers. System flow rates were monitored using calibrated digital mass flow meters and controllers with HEPA filter conditioned supply air.

The PAP device was positioned with the air inlet sealed in a flow tube adapter facing the aerosol challenge flow stream. The air purifier exhaust was connected to air supply tubing that was adapted to a downstream aerosol system manifold.

As air is pulled into the PAP device, the air is filtered and then exits the device through a supplied flow tube for delivery to the user. The aerosol test system was fabricated out of two inch diameter sanitary stainless steel flow tube assembly for leak-free adaptation of the PAP device flow inlet and the purified air exhaust tubing. Aerosol generation was provided with an air assist Collison 6 jet nebulizer operated at a supply pressure of 26 psi for all tests. Additional flow controlled dilution air was provided to supply sufficient volumetric flows for device operation and sampling systems. Viral aerosol samples were collected continuously throughout each test using AGI-30 impingers (Ace Glass Inc.) filled with 20 ml of DMEM/F12 (Gibco). The impingers sampled simultaneously at upstream and downstream locations throughout the entirety of each test.

An Aerodynamic Particle Sizer (APS) model 3321 (TSI Inc.) was also used to sample aerosol challenges to evaluate aerosol characteristics at upstream and downstream locations of the PAP device. The APS samples at a continuous flow rate of one liter per minute, and has a dynamic particle size measurement range of 0.3 to 20µm. The APS provides mass median aerodynamic diameter ("MMAD"), geometric standard deviation ("GSD"), total sample aerosol mass (mg/cc), and aerosol particle counts (#/cc).

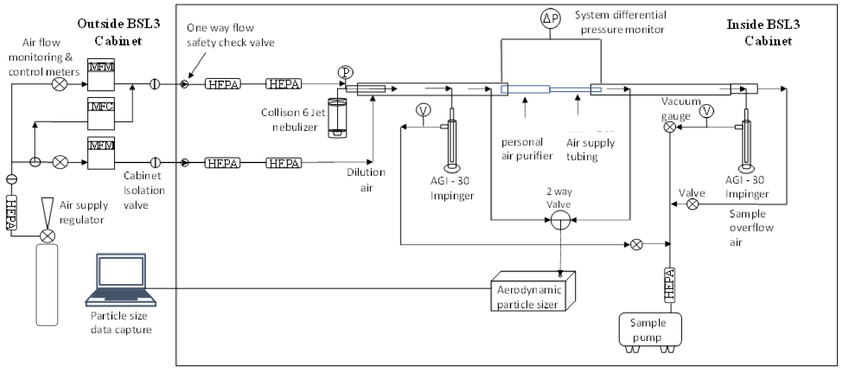
For each test, bio-aerosol challenge flows were continuously maintained at 39.5 to 40 L/min for ten minutes. This flow rate range provided adequate volumetric flow to satisfy the device operation requirements as well as additional aerosol sample flow rates. Supply flows and exhaust flows of the test system were controlled and equilibrated in the range of negative 0.1 to positive 0.1 inches of water column for each test. This near ambient pressure operating condition ensured operation that closely replicates a personal use environment.

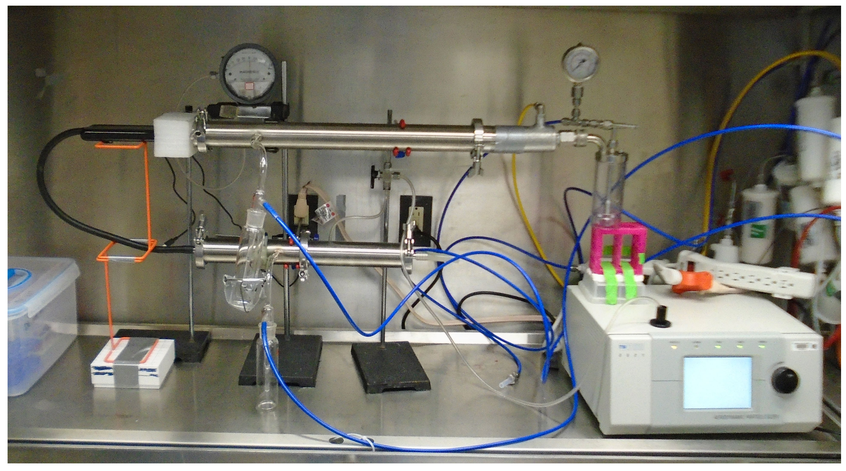
Following each test, collected upstream and downstream impinger samples were analyzed via a $TCID_{50}$ assay for viral concentration and the calculation of the PAP device's efficacy in collection/removal of SARS-CoV-2 aerosols.

$TCID_{50}$ Methods and Materials

Impinger samples were diluted 1:10 down a 24-well plate in DMEM/F12 to assess the TCID50 of the samples. These dilutions were incubated approximately 45 minutes, after which DMEM/F12 supplemented with 5% FBS was added to cells to feed them for the next four to five days. This incubation period allowed the virus to adsorb to cells without interference from FBS.

Aerosol Test System





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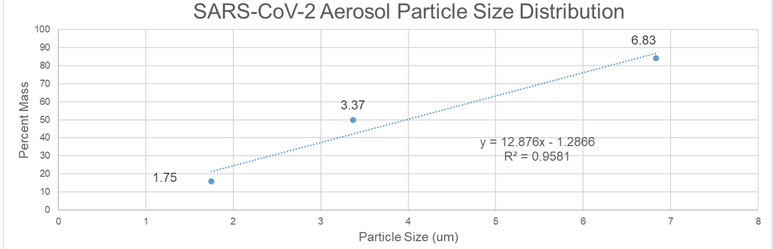
Results

Sample Type	Sample Name	TCID50/mL	Log10 TCID50/mL	Average TCID50/mL	Average Log10 TCID50/mL	Log Reduction	Percent Log Reduction
Downstream	Down T1	7.01E+00	0.85	3.52E+01	1.38	2.45	99.65%
	Down T2	2.85E+01	1.46				
	Down T3	7.01E+01	1.85				
Upstream	Up T1	4.14E+03	3.62	7.42E+03	3.84		
	Up T2	7.01E+03	3.85				
	Up T3	1.11E+04	4.05				
Stock Titer	20211007KS	4.22E+06	6.63				

APS Results	Particle Counts		Mass Conc. (mg/m³)		Diameter (µm)	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
T1	1732319	58347	11.7	0.0931	3.53	1.62
	1694716	88758	11.5	0.147	3.46	1.66
	1683070	195132	11.5	0.434	3.47	1.69
T2	1751264	95317	12.2	0.170	3.59	1.51
	1731891	136717	12.3	0.262	3.47	1.60
	1720340	220753	12.3	0.498	3.51	1.86
T3	1761898	88863	12.8	0.168	3.67	1.46
	1739025	150842	12.8	0.312	3.62	1.56
	1725306	233471	12.6	0.557	3.55	1.81
Average	1726648	140911	12.2	0.294	3.54	1.64
% Reduction	91.84		97.59		N/A	



Conclusions

- The PAP device had an effective average reduction of viable airborne virus of 2.45 log (99.65%).
- Particle counts were reduced by 91.84%.
- Particle mass concentration was reduced by 97.59%.
- The particle size maintained a linear distribution with an R^2 of 0.9581.
- The efficacy observed in testing indicates that this device or others like it could be a valuable addition to the landscape of consumer PPE.