Technical Report #2020-0
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Laboratory Testing for Respirators, Masks, and Filter Media

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Supplier:

Executive Summary

As with multiple aerosol science and engineering laboratories around the world, our laboratory aims to aid in the COVID-19 healthcare crisis by providing particle filtration testing for new mask and respirator designs. Our goal is to help researchers and manufacturers by testing their filters and mask designs to aid in product development before they are ready for official testing and distribution. As such, our goal is to relieve pressure from official certifying labs and to provide more feedback to manufacturers to aid in their product design. This report documents the results for one respirator sample as to its filtration efficiency and inhalation resistance, according to the methods detailed in the methods section of this report. Results are summarized below:

Sample ID	Average Filtration Efficiency (± standard deviation)		Average Inhalation Resistance (± standard deviation)
	In terms of total particle mass	In terms of total particle number	
2020-002-002	95% ± 1%	96% ± 1%	18.6 ± 0.2 mm H_2O

1. Introduction

Due to the Coronavirus Disease (COVID-19) global pandemic and healthcare crisis, there is an urgent need to manufacture, test, and supply respirators and masks to healthcare providers, essential workers, and to the general population. As with multiple aerosol science and engineering laboratories around the world, our laboratory aims to aid in the COVID-19 health care crisis by providing particle filtration testing for new mask and respirator designs. Our goal is to help researchers and manufacturers by testing their filters and mask designs to aid in product development before they are ready for official testing and distribution. As such, our goal is to relieve pressure from official certifying labs and to provide more feedback to manufacturers to aid in their product design.

2. Testing Methods

Our laboratory has adapted from the NIOSH testing procedures for filtration efficiency (TEB-APR-STP-0059-508)[1] and inhalation resistance (TEB-APR-STP-0007-508),[2] to the extent possible using our research-grade particle sizing instrumentation. Similar tests to what we are performing are also reported in the scientific literature.[3] A detailed list of testing procedures follows:

Sample pre-conditioning

Respirators, masks, and filter material are pre-conditioned at 85 ± 5% relative humidity and 38 ± 2.5 °C for 25 ± 1 hours. After conditioning, filters are either tested immediately or sealed in a gas-tight container and tested within 10 hours.

Aerosol generation

A solution of 10% by weight of ammonium sulfate [$(NH_4)_2SO_4$] in deionized water is prepared and placed in a Collison-type atomizer, operated at ~32 psi to generate an aerosol with a median diameter of 0.075 ± 0.020 micrometer. The aerosol stream passes through a diffusion dryer to remove excess water and an X-ray neutralizer to neutralize electrical surface charge before being injected into a 38 m^3 testing chamber.

Sample fixture

For respirator and mask testing, the sample is placed on a foam human headform and taped to seal any potential gaps between the respirator/mask and headform. A total flow rate of 15 LPM is passed through the sample to be tested and supplied to the particle sizing instrumentation: a Scanning Mobility Particle Sizer (TSI Inc.), measuring particles 11- 514 nm in electrical mobility diameter, and an Aerodynamic Particle Sizer (TSI Inc.), measuring particles 0.54 - 18.3 μm in aerodynamic diameter.

Test duration

The test encompasses 234 min of total particle loading during a ~6-hour test, leading to ~0.2 mg particle loading. During this period, particle concentrations in the testing chamber and downstream of the sampling material are measured multiple times in order to provide a filtration efficiency over time.

Accordance to NIOSH procedures
This filtration efficiency test is not performed in complete accordance with the NIOSH N95 filtration efficiency procedure. Please see Table 1, in the Appendix of this report, for details on which steps are in accordance to the NIOSH procedure.

Inhalation resistance
The test for the determination of inhalation resistance is performed according to NIOSH procedure TEB-APR-STP-0007-508, which states: “The resistance for non-powered, air-purifying particulate respirators upon initial inhalation shall not exceed 35 mm water-column height.”

3. Results

Sample description
Sample ID: 2020-002-002

Filtration efficiency over time
As a function of particle number:

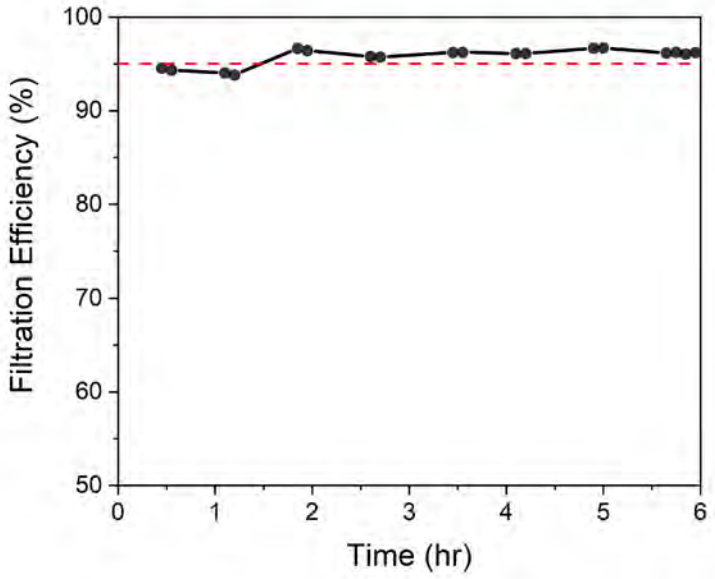

Figure 1. Filtration efficiency calculated using total particle number concentration over time.

As a function of particle mass:

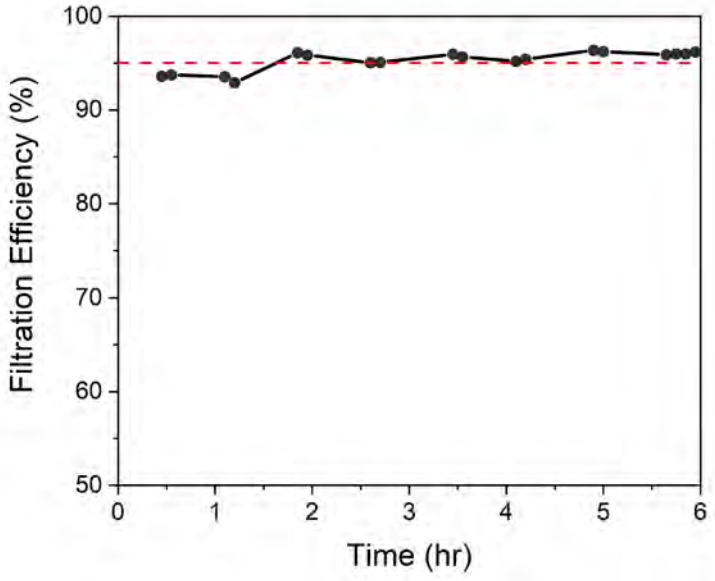

Figure 2. Filtration efficiency calculated using total particle mass concertation over time.

Size-resolved filtration efficiency

As a function of particle number:

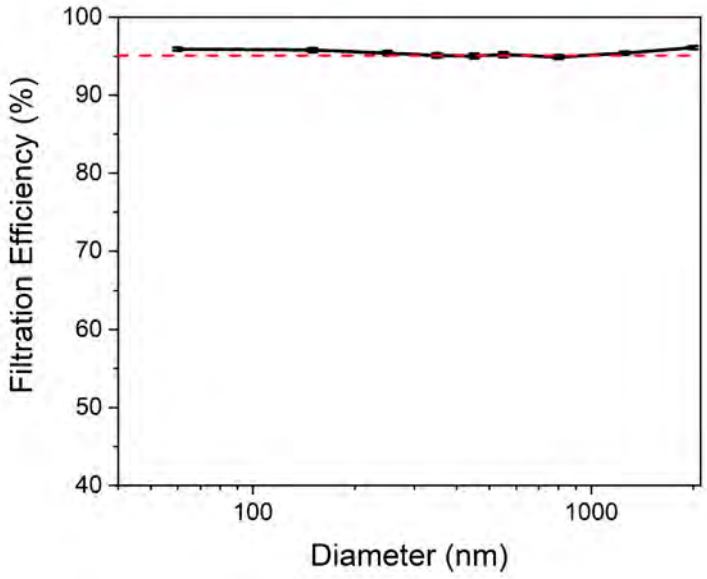

Figure 3. Size-resolved filtration efficiency calculated as a function of particle number distribution. The whiskers represent standard error (N=16).

As a function of particle mass:

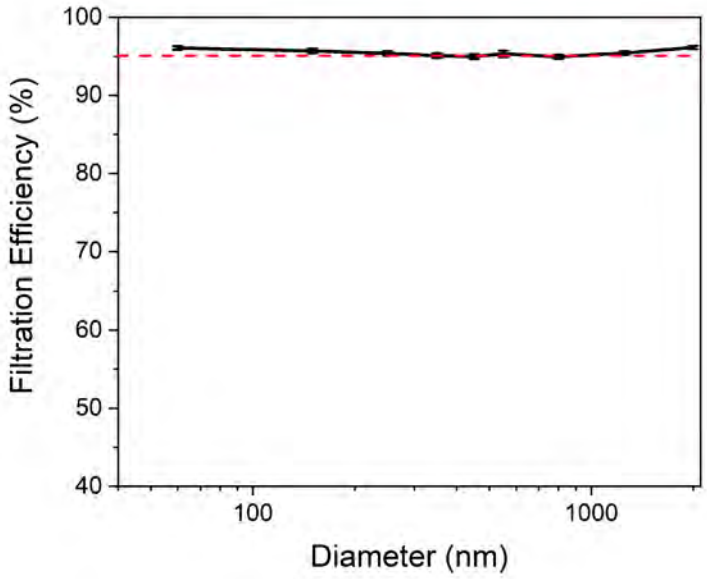

Figure 4. Size-resolved filtration efficiency calculated as a function of particle mass distribution. The whiskers represent standard error (N=16).

Inhalation resistance

Total inhalation resistance = 18.6 ± 0.2 mm H_2O. Does not exceed the limit of 35 mm.

4. References

(1) NIOSH. *Determination of Particulate Filter Efficiency Level for N95 Series Filters against Solid Particulates for Non-Powered, Air-Purifying Respirators Standard Testing Procedure (STP).*; TEB-APR-STP-0059; Pittsburgh, MA, 2019.

(2) NIOSH. *Determination of Inhalation Resistance Test, Air-Purifying Respirators. Standard Testing Procedure (STP).*; TEB-APR-STP-0007; Pittsburgh, MA, 2019.

(3) Konda, A.; Prakash, A.; Moss, G. A.; Schmoldt, M.; Grant, G. D.; Guha, S. Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks. *ACS Nano* **2020**. https://doi.org/10.1021/acsnano.0c03252.

(4) EPA. Exposure Factors Handbook. EPA 2011.

Appendix

Table 1. Compliance according to NIOSH filtration efficiency testing procedure.

Procedure/Material	Following NIOSH N95 filtration efficiency procedure?	Details/comments
Pre-conditioning	YES	The NIOSH procedure states: “Respirator filters will be preconditioned at 85 ± 5% relative humidity and 38 ± 2.5 °C for 25 ± 1 hours. After conditioning, filters shall be sealed in a gas tight container and tested within 10 hours.”
Aerosol material	NO	The NIOSH procedure describes the use of sodium chloride (NaCl, table salt). We use ammonium sulfate to protect our laboratory instrumentation from rust. Results are unlikely to be affected by this substitution.
Aerosol size (0.075 ± 0.020 micrometer)	YES	The NIOSH procedure states: “The particle size distribution will be a count median diameter of 0.075 ± 0.020 micrometer and a geometric standard deviation not exceeding 1.86.”
Test flow rate	NO	The NIOSH procedure states: “single air purifying respirator filters will be tested at a challenge flow rate of 85 ± 4 Lpm.” Our test flow rate is 15 l/min, which is comparable to the flow rate of human breath at light intensity activity level for most of the age groups.[4]
Aerosol mass loading	NO	The NIOSH procedure describes that filters will be loaded until 200 ± 5 mg loading is reached. At our testing flow rate of 15 l/min, this would take an amount of time that is impractical. Instead, we are performing tests for 6 hours to simulate an average work day.
Testing temperature and relative humidity	YES	The NIOSH procedure describes testing at 25 ± 5 °C and a relative humidity of 30 ± 10%. Our testing chamber is kept at ~22 °C and ~37%.