

Respiratory Protection Against Nanoparticles

Samy Rengasamy and Ron Shaffer

**National Personal Protective Technology Lab
Research Branch
Pittsburgh, PA 15236**



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NPPTL Mission . . .

To prevent work-related illness and injury by ensuring the development, certification, deployment, and use of personal protective equipment and fully integrated, intelligent ensembles.



This will be accomplished through the advancement and application of personal protective technology standards.



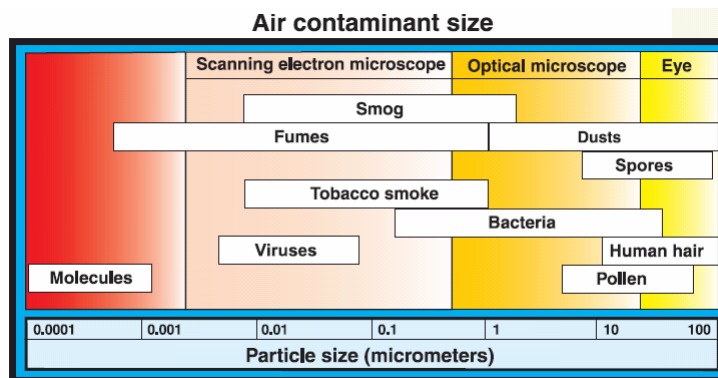
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What are Nanoparticles?

Nanoparticles are particles having a diameter between 1 and 100 nm (0.001-0.1 μm)



Adapted from: Guidance for Filtration and Air-Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, or Radiological Attacks, DHHS (NIOSH) Publication No. 2003-136.



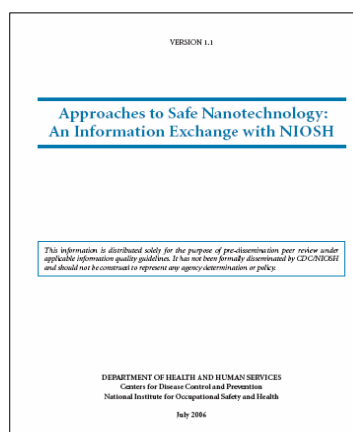
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Nanoparticles – Health Concerns

- Chemistry and surface property influence nanoparticle toxicity
- Pulmonary inflammation and lung tumors in animal models
- Nanoparticles may be deposited in the airways and translocated to other organs



<http://www.cdc.gov/niosh/topics/nanotech/>

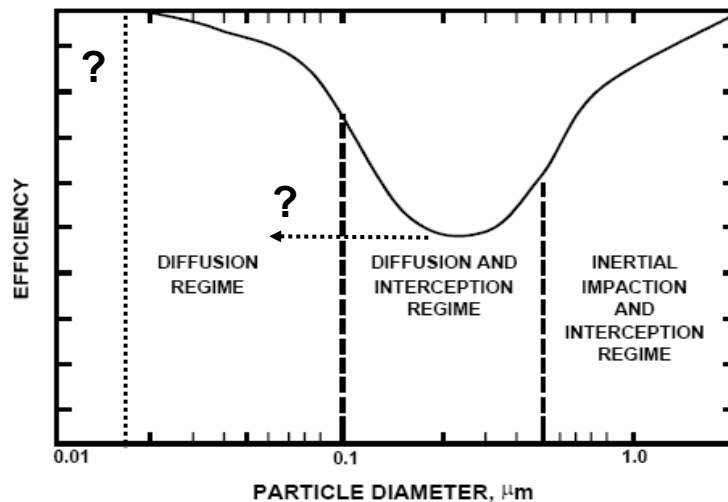


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Filtration Theory



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Previous Studies (> 20 nm Particles)

- Balazy et al., Manikin-based performance evaluation of N95 filtering facepiece respirators challenged with nanoparticles. *Ann Occup Hyg* 50:259-269, 2006
- Balazy et al., Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? *AJIC* 34:51-57, 2006
- Key Points:
 - Two N95 respirator models were tested with NaCl or MS2 particles using a manikin-based protocol at 85 L/min flow rate
 - MPPS was in the 50 nm range
 - Penetration of monodisperse challenges of 30-70 nm particles exceeded 5% penetration for one of the models tested
- Further investigation is warranted



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Previous Studies (< 20 nm Particles)

- NIOSH contract to the Univ. Minnesota
- Kim et al., Experimental study of nanoparticles penetration through commercial filter media. J Nanoparticle Research 9:117-125, 2007
- Key Points:
 - H&V Fiberglass and electret filter media were tested against 3 nm - 20 nm silver particles
 - Penetration decreased with decreasing particle diameter down to 3 nm
 - No evidence for thermal rebound of nanoparticles down to 3 nm size
- Further investigation of nanoparticle (<20 nm) penetration for respirators is important



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Objectives

- Better understand nanoparticle penetration through NIOSH approved N95 filtering facepiece respirators
- Compare NaCl particle penetrations using two test methods
 - Monodisperse (20 nm - 400 nm)
 - Polydisperse (similar to NIOSH certification test)



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Monodisperse NaCl Aerosol Penetration

- NaCl particles are size distributed by an SMPS electrostatic classifier (TSI 3160 Particle Penetration Tester)
- Upstream and downstream particle concentrations are measured by Condensation Particle Counters
- Particle penetration measured at 85 L/min flow rate
- Particle penetration is determined based on particle number



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Polydisperse NaCl Aerosol Penetration

- Polydisperse aerosol particle penetration is measured by an Automated Filter Tester (TSI 8130)
 - NaCl particles with a count median diameter (CMD) of $0.075 \pm 0.020 \mu\text{m}$ and a geometric standard deviation (GSD) of less than 1.86
 - 95% of the particles in the range of 22–259 nm
 - Particle penetration measured at 85 L/min flow rate
- Particle penetration is measured by a forward light scattering photometer. The scattering light flux is proportional to particle $(\text{mass})^2$ or $(\text{diameter})^6$



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Experimental Design

- 5 models of commercially available NIOSH approved N95 filtering facepiece respirators
- 5-10 samples of each model were tested for monodisperse aerosol tests (TSI 3160)
- 10 samples of each model were tested for the polydisperse aerosol tests (TSI 8130)
- Initial penetration levels (no loading)
- No preconditioning at high humidity



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Data Analysis

- Calculate average penetration levels, standard deviation and 95% confidence intervals for each model and test method
- ANOVA: significance of particle penetration data (particle sizes and test methods)
- T-test: compare average penetration level for each model and test method with the 5% penetration level used for N95 respirator certification
- Correlation analysis between polydisperse aerosol test results and 40 nm monodisperse aerosol test results

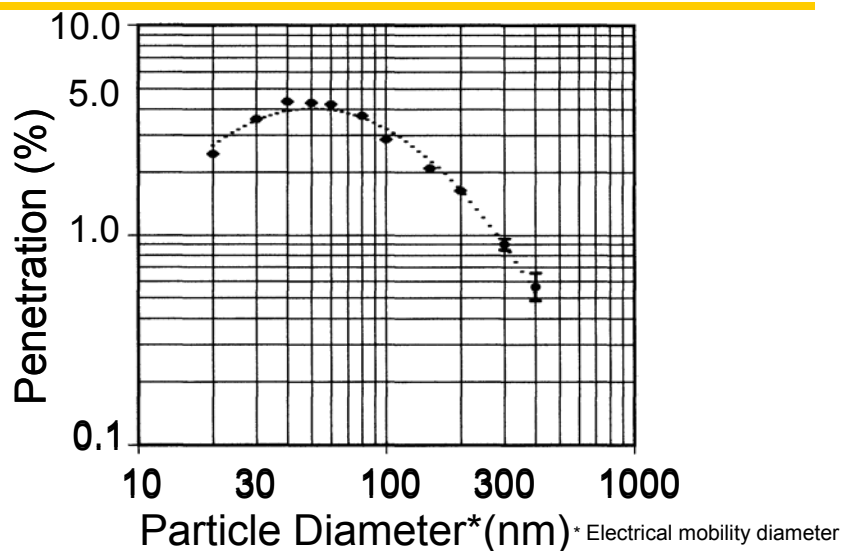


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Typical Particle Penetrations for an N95 Respirator

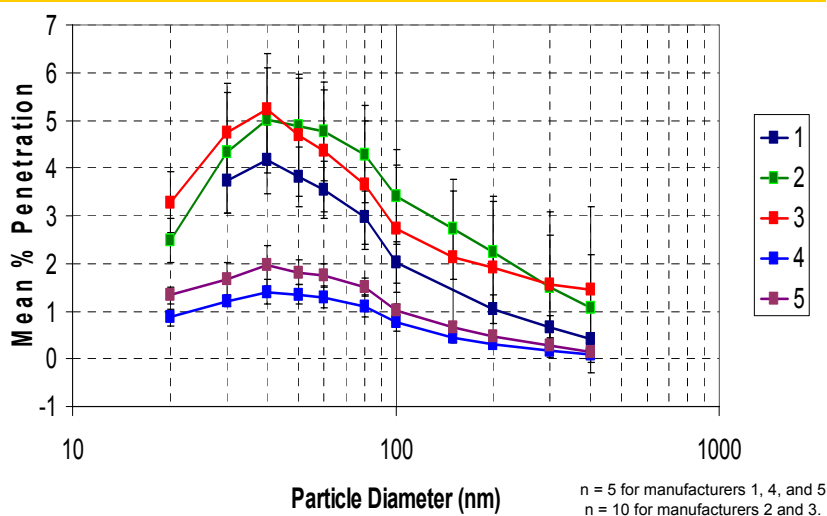


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Particle Penetration for N95 Respirator Models

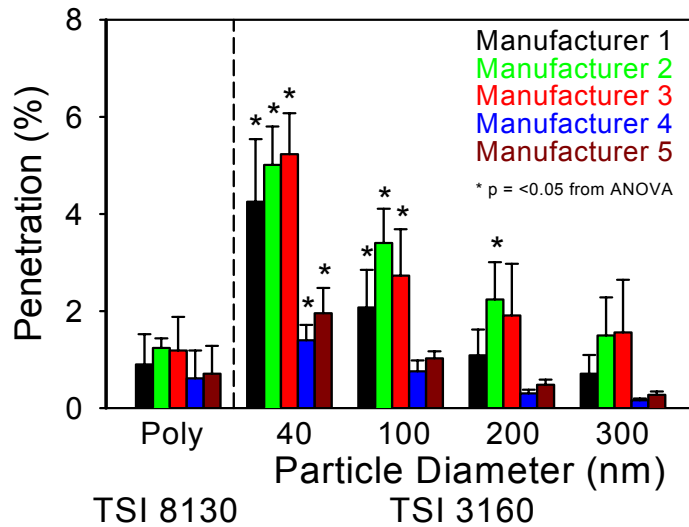


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Polydisperse and Monodisperse Aerosol Penetrations

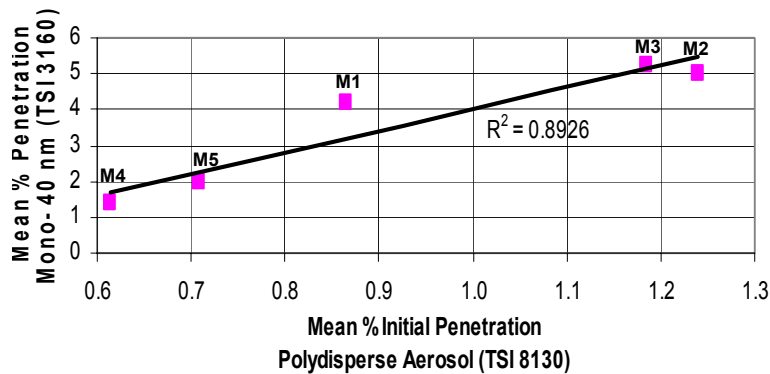


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Correlation of Polydisperse and 40 nm Monodisperse Aerosol Penetrations



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Filtration Efficiency for Nanoparticles below 20 nm size

- Silver nanoparticles 4-30 nm diameter
- Generated at 950°C in a furnace
- Particle size selected by an SMPS nano-differential mobility analyzer
- Monodisperse aerosol penetrations measured at 85 L/min flow rate

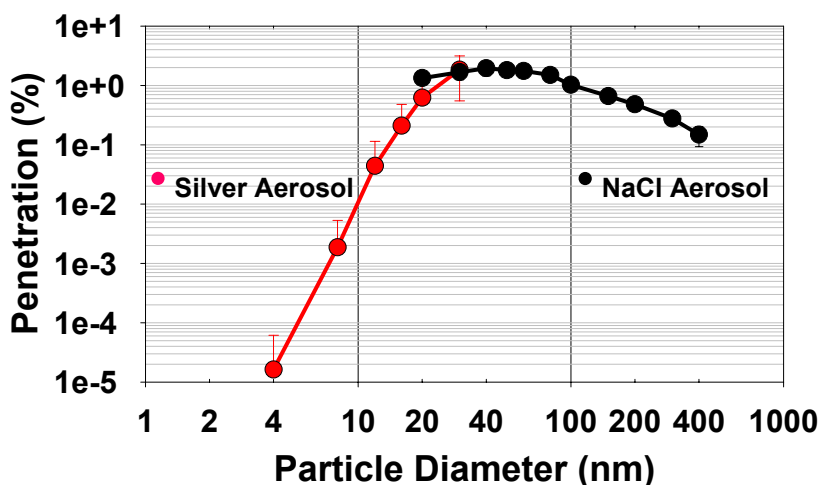


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Monodisperse Aerosol Penetrations 4 nm - 400 nm



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Respiratory Protection

- Filtration Efficiency
- Face Seal Leakage
- Protection Factor



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Assigned Protection Factor (APF)

- Reflects the level of protection that a functioning respirator would be expected to provide a population of properly fitted users
- An APF of 10 of a respirator means that a user could expect to inhale no more than one tenth of the airborne contaminant



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Assigned Protection Factor

- **Air Purifying**

Filtering Facepiece	-----	10
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Full-Facepiece	-----	50
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- **Powered Air Purifying (PAPR)**

Half-Mask	-----	50
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Full-Facepiece	-----	1000
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- **Supplied Air (SAR)**

Full-Facepiece - continuous flow mode	-----	1,000
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- **SCBA**

Full-Facepiece - Positive pressure mode	-----	10,000
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Conclusions

- Data support the single-fiber filtration theory
- MPPS was in the 40 nm diameter range
- The average 40 nm monodisperse particle penetration exceeded 5% level for 2 of the 5 models tested, but were not statistically significant
- Polydisperse aerosol test provides a consistent rank-ordering of the filtration performance of N95 respirators against 40 nm monodisperse nanoparticles
- NIOSH-approved N95 respirators provide expected levels of protection when properly fitted



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Thank You

