Respirator Filter Collection Efficiency of Biological Aerosols: A Review

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Objective

- Review recent literature that demonstrates that NIOSH-approved respirator filters
  - Filter biological aerosols similarly to non-biological aerosols.
  - Perform as certified when challenged with biological aerosols.

Theory

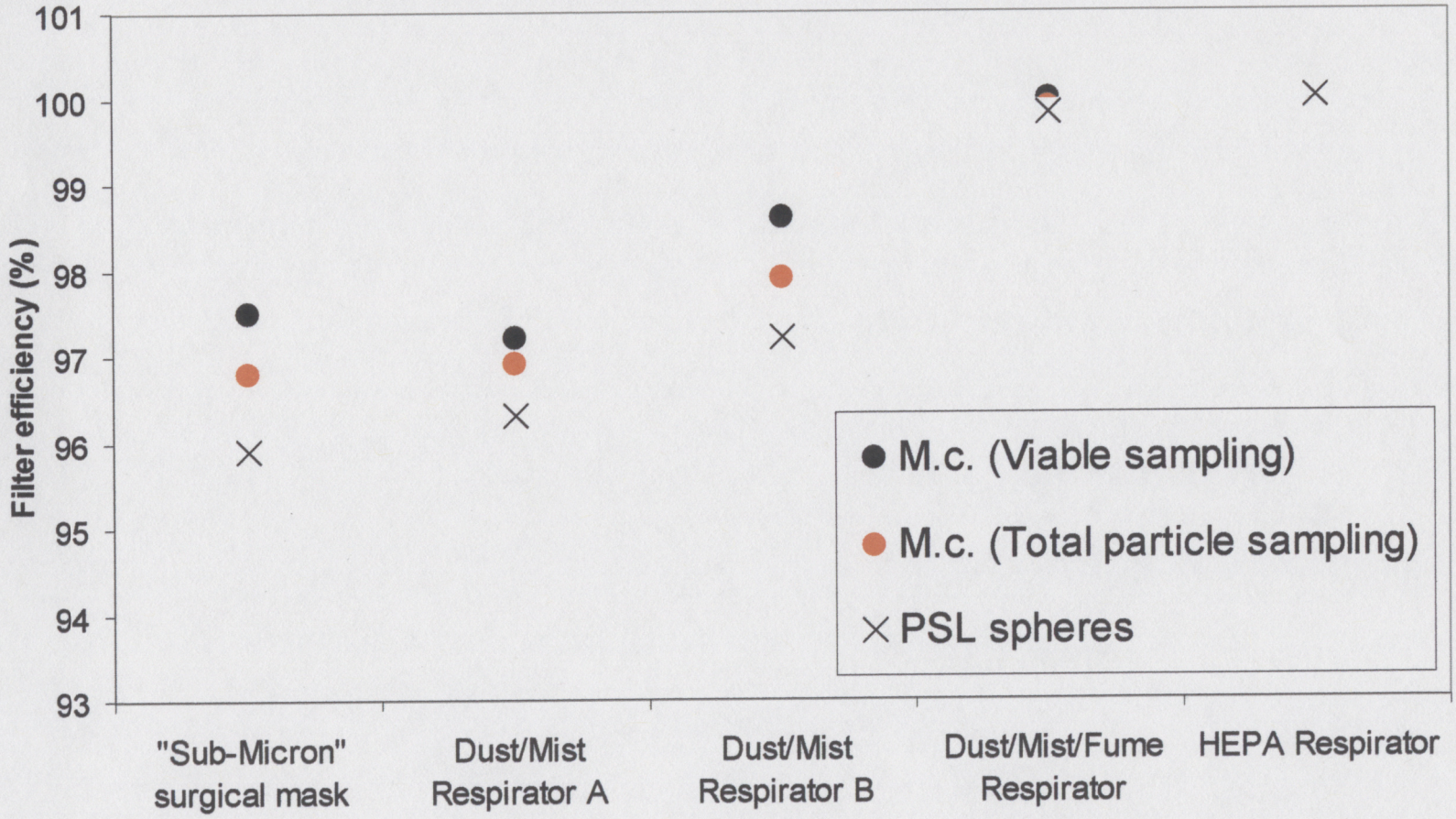
- Current aerosol and filtration theory are based on the physical parameters (size, shape, density) of a particle and do not incorporate viability or biological nature of the particle

- Hinds, 1982. Aerosol technology; Properties, behavior and measurement of airborne particles. Pp.164-186.

Chen et al., 1994

- Challenged filters with *Mycobacterium chelonae abscesses* (*M.c.*) (surrogate for TB, measured avg. d_{ae} = 0.7 μm) and polystyrene latex (PSL) spheres (0.8 μm)
- Evaluated 4 filtering facepiece respirators utilizing electrostatic media, including HE filters
- All NIOSH-approved respirator filters performed as expected
- Respirator filter penetration can be accurately predicted by filter challenge with PSL spheres of a representative size.
- Am. J. Infect. Control 22:65-74; 1994

Mean efficiency of masks and respirators challenged with *M.c*. bacteria and PSL spheres (Chen et al., 1994)



Brosseau et al., 1997

- Challenged filters with *Mycobacterium abscesses* (*M.a.*) (surrogate for TB, 0.7 μm)
- 45 & 85 LPM, 30 & 70% RH
- Filters preconditioned for 24 hr at 85% RH
- Tested both purely mechanical filters and those incorporating electrostatic media
- When challenged with *M.a.* all filters performed as expected for their class.
- Appl. Occup. Environ. Hyg. 12(6):435-445; 1997

McCullough et al., 1997

- Challenged filters with
  - *Mycobacterium abscesses* (*M.a.*) (0.7 μm), rod
  - *Staphlococcus epidermidis* (S.e.) (0.87 μm), sphere
  - *Bacillus subtilis* spores (B.s.) (0.88 μm), rod/sphere
  - PSL spheres (0.55 μm)
- Evaluated a mix of purely mechanical and electrostatic filters
- Testing conducted at 45 & 85 LPM, 30 & 70% RH
- For NIOSH-approved filters, filtration efficiency was as expected for the certified filter performance.
- A change in flow affected penetration of all particles similarly.

McCullough et al., 1997

- Rod-shaped particles are less penetrating than the equivalent spherical particle, when the two have the same calculated aerodynamic diameter.
- Linear regression analysis demonstrated that filter penetration of PSL spheres predicted filter penetration of the biological aerosols, $R^2 = 0.951$
- If testing biological aerosols, total particle sampling (as opposed to viable sampling) is appropriate for determining bioaerosol penetration.
- Non-biological aerosols are good predictors of biological aerosol filtration behavior.
- Ann. occup. Hyg. 41(6):677-690; 1997.

Qian et al., 1998

- Challenged N95 filters (electrostatic) with
  - *Bacillus subtilis* avg. d_{ae} = 0.8μm
  - *Bacillus megatherum* avg. d_{ae} = 1.2 μm
  - NaCl particles and PSL
- 32 & 85 LPM
- Filter efficiency >99.5% when challenged with the biological aerosols, this is expected result based on particle size
- Respirators performed as certified when challenged with biological aerosols
- Filtration efficiency determined with PSL sphere and salt particles predictive of bioaerosol efficiency
- AIHA Journal 59:128-132; 1998

Willeke et al, 1996

- Challenged a surgical mask and dust/mist respirator (utilizing electrostatic media) with
  - *Streptococcus salvarius*, sphere, 0.8-1.0 μm
  - *Pseudomonas fluorescens*, rod, 0.8 μm
  - *Bacillus alcalophilus*, rod, 0.7-0.9μm x 3-4 μm
  - *Bacillus megatherium*, rod, 1.2 μm
  - Corn oil aerosol, 0.1 - 10 μm

- Tested at 16, 32, 50, 80 LPM

Willeke et al., 1996

- Penetration of spherical corn-oil particles and equivalently-sized spherical bacteria is similar
- Spherical particles are consistently more penetrating than rod-shaped particles with equivalent aerodynamic diameter over a range of particle sizes
- AIHA Journal 57:348-355; 1996

Conclusions 1

- Experiments published in peer reviewed literature have demonstrated that there is no difference in the filtration of biological aerosols and non-biological aerosols
  - Brosseau et al., 1997; Chen et al., 1994; McCullough et al., 1997; Qian et al., 1998; Willeke et al., 1996.
- Evaluations conducted over a range of test conditions (flow, humidity), biological species, filter type and filters with varying filter media.

Conclusions 2

- When aerosol generation and sampling are conducted properly, bioaerosol samplers can be replaced by direct reading aerosol monitors to increase reproducibility and ease of testing and decrease cost and variability
- Further, non-biological particles with the same size, shape, and density are appropriate surrogates for biological aerosols.

Conclusions 3

- Since current certification test methodologies utilize the most penetrating particles, they appear to be appropriate tests for predicting the filtration behavior of both biological and non-biological aerosols.

References

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