PERFORMANCE OF N99 AND N95 FILTERING-FACEPIECE RESPIRATORS AGAINST VIRUSES & ULTRAFINE PARTICLES

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<table>
<thead>
<tr>
<th>BACKGROUND</th>
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<tbody>
<tr>
<td>- Filtration certification: 42 CFR 84.181</td>
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<td>- Filtering-facepiece respirators (FFRs)</td>
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<td>- Certification: aids in selection of appropriate RP</td>
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BACKGROUND

Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks?

Anna Balazy, MSc, Mika Toivola, PhD, Atin Adhikari, PhD, Satheesh K. Sivasubramani, PhD, Tiina Reponen, PhD, and Sergey A. Grinshpun, PhD

Cincinnati, Ohio, and Warsaw, Poland

Protection of the human respiratory system is a growing issue in occupational hygiene. Particles of 1–100 nm are probably the major emerging issue in occupational hygiene. The performance of two models of N95 half masks was evaluated at two inhalation flow rates protocol. The aerosol concentration was monitored using a Wide-Range Particle Spectrometer, and the N-series respirators were NIOSH 42 CFR 84 certified. The targeted particle sizes ranged from 0.003 to 300 nm. The results indicate that the nanoparticle penetrations may exceed the 5% threshold, particularly for particles in the range of 0.3–0.5 mm, at a flow rate of 40 L/min. The analysis revealed that the efficiency of the respirators was below 95% at these particle sizes. The particles were detected in the particle size range of 10 to 80 nm. Results: The results indicate that the penetration of viruses through the N95 respirators can exceed an expected level of 5%. As anticipated, the test respiratory protection devices were investigated using MS2 virus (a noninfectious simulant of several pathogens). The viruses were detected in the particle size range of 10 to 80 nm. Conclusion: The N95 filtering face piece respirators may not provide the expected protection level against small viruses. Some surgical masks may let a significant fraction of airborne viruses penetrate through their filters, providing very low protection against aerosolized infectious agents in the size range of 10 to 80 nm. It should be noted that the surgical masks are primarily designed to protect the environment from the wearer, whereas the respirators are supposed to protect the wearer from the environment. (Ann Occup Hyg 2006;40:51-7)
PURPOSE

- Place Balazy studies in context
- Broaden literature on FFR
- Compare N95 and N99
- Incorporate quality factor, $q_f$
METHODS

- Two models N99 and one N95 FFRs
- Inert and biological challenge aerosols
- Filter penetration ($P$), quality factor ($q_f$)
- $\sim 20 - 500$ nm

Compare N99, N95
Compare inert, biological
METHODS

Filtration study
Leakage not assessed

Flow rates = 30, 85, 150 l/min

Recorded: \( \sim d_p = 20 \text{ nm} - 0.5 \text{ \mu m} \)

Diagram by Takeshi Honda
METHODS

\[ P = \frac{C_{\text{down}}}{C_{\text{up}}} \times 100\% \]

\( P = \) count penetration, percent
\( C = \) count concentration

*Lower is better*

\[ q_F = \frac{\ln\left(\frac{1}{P}\right)}{\Delta p} \]

g\( q_F = \) filter quality factor
\( P = \) count penetration, fraction
\( \Delta p = \) pressure drop (mm \( H_2O \))

*Higher is better*

Inert aerosol
 METHODS

- **NaCl** N95, N99
- **MS2 bacteriophage** N95, N99
- **Bacillus subtilis bacteriophage** N95
- **Enterobacteriophage T4** N95

Diagram of T4 phage by Mike D. Jones, Creative Commons License
RESULTS - NaCl

Filter quality, $q_f$ (1/mm H$_2$O)

Penetration, $P$ (%)

PARTICLE SIZE $\mu$m

N99 - A

N99 - B

N95 - A

[Graphs showing data for N99-A, N99-B, and N95-A]
RESULTS – MS2

PARTICLE SIZE (µm)

N99 - A

N99 - B

N95 - A

Penetration, P (%)

30, 85 l/min data from Balazy et al. 2006a
RESULTS – *b.s. phage, T4*

**Bacillus subtilis phage**
- Both N95 - A

**T4 phage**
RESULTS - comparison

Penetration, P (%)

NaCl challenge
100 nm

ANOVA, p = 0.69
RESULTS - comparison

MS2 challenge
20 - 90 nm

Penetration, P (%)

ANOVA, p = 0.46
RESULTS - comparison

NaCl and MS2 aerosol challenge
20 - 90 nm

N99 - A
NaCl
MS2 phage

N99 - B

N95 - A

Penetration, P (%)

p = 0.09
p = 0.79
p = 0.30
RESULTS - comparison

**NaCl**, b.s.-phage, T4-phage

20 - 200 nm

- NaCl
- *b.s.* phage
- **T4** phage

Penetration, P (%)

- **p = 0.006**
- **p = 0.03**

All N95 - A
OBSERVATIONS & CONCLUSIONS

- Most-penetrating particle size < 100 nm
- Viral aerosol $P \leq$ inert aerosol $P$
- N99 may not be superior to N95 at filtering ultrafine aerosols
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