Penetration of Combustion Aerosol Particles through an N95 FFR Respirator Filter

S.A. Grinshpun, X. He, J.Y. Kim, T. Reponen

Center for Health-Related Aerosol Studies, University of Cincinnati, Cincinnati, Ohio, USA

Keywords: filter, respirator, combustion aerosol
Presenting author email: sergey.grinshpun@uc.edu

Smoke generated from a fire consists primarily of ultrafine particles.(1) Exposure to combustion aerosols may cause various adverse health outcomes, including respiratory problems and impairment of cardiovascular function.(2-4) The Filtering Facepiece Respirators (FFRs), including N95-certified ones [filter efficiency ≥95%, i.e. penetration <5%, according to the National Institute for Occupational Safety and Health (NIOSH)] are commonly used for protecting the wearers from various aerosol exposures, including smoke. The filter performance of these respirators is usually determined using conventional aerosol challenges such as charge-equilibrated NaCl particles.(5) However, it has not been examined how well the data obtained with these challenges represent the actual protection offered by an N95 FFR filter against combustion aerosols.

The objective of this study was to evaluate the penetration of combustion particles of different sizes through an N95 FFR filter under different flow rates and exposure time conditions and compare the data to the corresponding penetration values obtained using the charge-equilibrated NaCl particles. The study was carried out using the University of Cincinnati's Respirator Evaluation Facility. The tested N95 FFRs were fully sealed on a breathing manikin and challenged with a specific aerosol being evaluated. First, we used NaCl particles generated by a Particle Generator (TSI Inc.) and passed through a Kr^{85} particle equilibrator. A constant inhalation flow (Q = 15, 30, 55, and 85 L/min) was established, and the aerosol concentrations inside (C_{in}) and outside (C_{out}) of the respirator were measured size-selectively with a Nanoparticle Spectrometer (PMS Inc.) at time points of 0, 30, 60 and 90 minutes. The filter penetration was calculated as C_{in}/C_{out}. Second, the same respirator was exposed to one of the three combustion aerosols generated by burning a specific material being tested. The experiments were performed with plastic, wood and paper. The first measurement (time t=0) was conducted after 15 minutes of active burning to allow the aerosol system to stabilize.

The experimental results showed that penetration curves produced with both NaCl and combustion aerosols did not change dramatically during the 90-min exposure period. Additionally, the most penetrating particle size (MPPS) for both NaCl and combustion aerosols was found to be in a range from 30 to 40 nm, suggesting that the MPPS was not significantly affected by the characteristics of a challenge aerosol.

It was found that the combustion particles might penetrate the respirator filter more readily than the NaCl challenge particles. This was especially pronounced for plastic aerosol with a particle sizes below 100 nm. Under some conditions, the penetration exceeded 5%, which is not expected for an N95 respirator filter. This finding can be partially attributed to the influence of highly charged combustion particles on the pre-charged filter media fibers, which may inhibit the efficiency of the filter. The other explanation involves the combustion-originated vapors that may condense on the electret filter material and thus affect its properties.

Overall, the results suggest that the performance data obtained with the well-established NaCl aerosol challenge may not accurately predict (and rather overestimate) the protection level provided by the N95 respirator filters against combustion aerosol particles.

The outcomes of this pilot study call for a more extensive investigation of the interaction between the combustion aerosol particles and different filter materials using a study design that is capable of accounting for various aerosol properties and filter characteristics. The data will be useful in an effort to enhance the present NIOSH respirator testing and certification program.

This research was funded by the NIOSH Targeted Research Training Program and Pilot Research Project Training Program (University of Cincinnati, Education and Research Center, Grant T42/OH008432-07). The authors also acknowledge support from the U.S. Defense Threat Reduction Agency (DTRA).

REFERENCES:

1. Baxter, C.S., C.S. Ross, T. Fabian, J.L. Borgerson, J. Shawon, P.D. Gandhi et al.: Ultrafine Particle Exposure During Fire Suppression-Is It an Important Contributory Factor for Coronary Heart Disease in Firefighters? J. Occup. Environ. Med. 52(8): 791-796 (2010).
2. Peters, A., H.E. Wichmann, T. Tuch, J. Heinrich, and J. Heyder: Respiratory Effects are Associated with the Number of Ultrafine Particles. Am. J. Respir. Crit. Care Med. 155(4): 1376-1383 (1997).
3. Schwartz, J., D.W. Dockery, and L.M. Neas: Is Daily Mortality Associated Specifically with Fine Particles? J. Air Waste Manag. Assoc. 46(10): 927-939 (1996).
4. Timonen, K.L., E. Vanninen, J. de Hartog, A. Ibald-Mulli, B. Brunekreef, D.R. Gold et al.: Effects of Ultrafine and Fine Particulate and Gaseous air Pollution on Cardiac Autonomic Control in Subjects with Coronary Artery Disease: The ULTRA Study. J. Expos. Sci. Environ. Epidemiol. 16(4): 332-341 (2005).
5. NIOSH. National Institute for Occupational Safety and Health. US DHHS, Public Health Service. "Respiratory Protective Devices; Final Rules and Notices" Federal Register 60:110, pp 30335-30393 1995.