Study

UNIVERSITY OF CINCINNATI

How to increase the protection factor provided by existing facepiece respirators against airborne viruses: A Novel Approach

Introduction

Adverse health effects associated with airborne particles, including microbial and non-microbial aeroallergens, have recently gained considerable attention, especially due to increased reporting of respiratory symptoms in some occupational and residential indoor environments. The latest outbreaks of emerging diseases and the threat of bioterrorism have added some fuel to the problem. Although the transmission routes for some emerging diseases are still to be identified (e.g., SARS), many virus-induced health effects are known to be spread in the aerosol phase. Reducing the concentration of inhaled airborne particulates should reduce the risk of infection, as the number of cases among susceptible population is proportional to the average concentration of infectious droplet nuclei in a room and the probability that the particles will be inhaled. There is a special demand to increase the efficiency of existing respiratory protection devices, which otherwise may not provide an adequate protection against aerosol agents.

Responding to this demand, we have developed and tested a new concept that allows to drastically enhance the protection factor provided by conventional facepiece filter respirators against submicron airborne particles (e.g., viruses). The concept is based on the continuous emission of unipolar electric ions in the vicinity of a respirator.

Methods

The new concept was tested in a non-ventilated indoor chamber (24.3 m3). An R95 respirator (3M 8247, 3M Company, St. Paul, MN, USA) was sealed to a manikin with silicone and petroleum jelly and connected to a breathing machine that operated at a constant air flow rate of 30 L/min. (inhalation). Prior to the start of data collection, leak tests (between the mask and the face of the manikin) were conducted with a bubble producing liquid (Trubble Bubble, New Jersey Meter Co., Paterson, NJ, USA). This experimental design allowed us to evaluate the enhancement effect of continuous emission of unipolar electric ions on the protection provided by the respirator filter (assuming that the particle penetration through the leaks was negligible). The viral-size particles (mid-point aerodynamic size da = 0.04-0.20 µm) were aerosolized into the chamber using a smoke generator. An Electrical Low Pressure Impactor (ELPI, TSI Inc./ Dekati Ltd, St. Paul, MN, USA) was used to determine the concentration and aerodynamic particle size distribution in real-time. Aerosol sampling from outside and inside the respirator was alternated. Sampling lines and flow rates were identical upand down-stream of the ELPI. The time resolution was adjusted to 10 seconds. The respirator protection factor was determined as a ratio of the measured aerosol concentrations outside (COUT) and inside (CIN) the respirator in 3 min. increments during a period of 12 min. The set-up is schematically presented in Figure 1. The background tests were performed in the absence of air ion emission. Then, a unipolar ion emitter (VI-3500*, Wein Products Inc., Los Angeles, CA, USA) was turned on at 20 cm from the respirator, and the protection factor was determined in 3 min. increments during 12 min. of its operation. The emitter was characterized by measuring the air ion density at 1 m from the emission point using an Air Ion Counter (AlphaLab Inc., Salt Lake City, UT, USA). In addition, to the manikin-based experiments with a sealed respirator, human subject testing was also performed. In this phase of testing, the same model R95 filtering facepiece was worn by a test subject who was previously fit tested to this respirator using a TSI model 8020 Portacount (TSI, Inc). The fit testing protocol included standard head and breathing maneuvers required in the U.S. (normal and deep breathing, moving the face and the body left and right and up and down, talking, etc.).

Results

The protection factor measured with the respirator sealed on the manikin face was 73±6.0. We expected that it would exceed 20 since the R95 device should have at least 95% collection efficiency in the worst-case scenario. The emitter characterization tests showed that the density of negative air ions in the chamber increased rapidly, once it was turned on. It reached (1.340±0.037)x106 cm·3 during 5 sec., remained approximately at that level during a 30 min. continuous ion emission, and dropped to the initial level within 3 min. after it was turned off. Therefore, it was concluded that the experiments with respirators in the presence of the emitter were conducted at a constant air ionization level.

It is seen that the respirator protection increased to 512±65 (enhancement of 7) as a result of a 3 min. ion emission in the vicinity of the respirator. Further ionization did not significantly change the enhancement of the respirator performance (p= 0.06). It is believed that since the particles and the filter fibers charged unipolarly by the ions, the repelling forces decreased the particle flow toward the filter. This reduced the number of particles that could potentially penetrate through the mask and be inhaled. The protection (fit) factors of the R95 respirator measured on the human subject ranged from 110 to 278, depending on the breathing procedure, with an average of 152, when no air ion emission was introduced. When the ion emitter was turned on, the fit factors ranged from 311 to 1380, with an average of 611, showing a 4-fold enhancement. The data suggest that faceseal leakage may somewhat reduce, but not eliminate, the effectiveness of respirator performance enhancement achieved due to the unipolar ion emission.

Conclusion

Continuous unipolar ion emission in the vicinity of a filtering facepiece respirator has the potential to drastically enhance performance against virus-size aerosol particles.

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