

The present study was designed to expand our knowledge of filtration efficiency for ultrafine particles. Two models of N95 FFPs available from different manufacturers were tested under cyclic and constant flow. Both models were sealed to a manikin's face and challenged with ultrafine polystyrene latex particles (25, 65, and 99 nm) at four flow rates (15, 30, 85, and 135 L min<sup>-1</sup>). Each of the four constant flows used in this study were compared with an equivalent cyclic flow having the same mean inspiratory flow (MIF) rate. (Defined as the ratio of the tidal inspiratory volume to the inspiratory duration, MIF is conventionally accepted as a cyclic-flow regime comparator and analog for constant flow.) At relatively low rates (15 and 30 L min<sup>-1</sup>), cyclic flow produced higher penetration values than an equivalent constant flow. In contrast, no statistically significant difference was found at 85 L min<sup>-1</sup>. At 135 L min<sup>-1</sup>, a reverse tendency was observed so that the penetration of ultrafine particles was higher under constant flow conditions. The findings are attributed to a complex interaction of different filtration mechanisms and can be explained using advanced filtration theory. We conclude that respirator filter testing conducted at constant flow may under- or overestimate the particle penetration under cyclic flow conditions.

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### Filtration Efficiency of Filtering Facepiece Respirators Approved Per 30 CFR 11 and 42 CFR Part 84

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This study evaluated the filtration efficiency of filter media from five similar filtering facepiece respirator models manufactured between 1984 and 2007. The filter media was designed to meet either 30 CFR 11 or 42 CFR 84 performance criteria. The research was conducted in an active coal mine. Airborne particles were collected on filters inside and outside the facepieces, and analyzed gravimetrically. Neither a statistical nor a practical difference was found between the respirators, either for filtration efficiency of "total dust" or for respirable dust. Although the filtration tests for 30 CFR Part 11 and 42 CFR Part 84 had different laboratory test parameters for certification, the filtration efficiency demonstrated in an active coal mine showed no differences. Because the regulations governing fit did not change when 42 CFR 84 was promulgated, a change in respirator performance provided the coal miner would not be expected as a result of this regulation change.

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### A Realistic Method for Testing Antimicrobial Respirator Efficacy

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In this presentation, we will describe 3M's novel microbiology test method for evaluating the antimicrobial effectiveness of filtering facepiece respirators and masks. Current antimicrobial claims are often based on tests using the American Association of Textile Chemists and Colorists (AATCC) Method 100, "Assessment of Antibacterial Finishes on Textile Materials." The AATCC Method 100 was designed for garments and not for respirators and facemasks. This new test method was designed to

more closely simulate large droplets splashing directly onto the surface of a respirator (or mask) or its component layers. NIOSH-approved respirators, as well as nonapproved facemasks that claim to be antimicrobial, were evaluated by both the AATCC Method 100 and this new test method. The antimicrobial performance measured by the new test method was significantly different than that determined by AATCC Method 100. Because this new method more closely simulates the temperature, humidity, and time exposure conditions when wearing a respirator or mask, it is more appropriate than AATCC 100 for evaluating antimicrobial claims on respirators or masks targeted for the health care market.

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### Toluene Adsorption on Various Types of Activated Carbon Fibers

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Activated carbon fiber (ACF) has been demonstrated to be a good adsorbent for the removal of organic vapors in air. ACF has a large surface area and high absorption capacity when compared with granular activated carbon (GAC) commonly used in respiratory protection devices. ACF is an attractive alternative adsorbent to GAC because of its ease of handling, light weight, and dropping cost. ACF may offer the potential for short-term respiratory protection for first responders and emergency personnel. This study compared the critical bed depths and adsorption capacities for toluene among GAC and ACF of different forms and surface areas. GAC and ACF in cloth (ACFC) and felt (ACFF) forms were challenged in stainless steel chambers with a constant concentration of 500 ppm toluene via conditioned air at 25°C, 50% RH, and constant airflow (7 LPM). Breakthrough data were obtained for each adsorbent using gas chromatography with flame ionization detector. The surface areas of each adsorbent were determined using a physisorption analyzer. The results showed that the critical bed depth of GAC is 275% higher than the average of ACFC but is 55% lower than the average of ACFF. The adsorption capacity of GAC (with surface area of 1800 m<sup>2</sup>/g) at 50% breakthrough is 25% higher than the average of ACF with surface area of 1000 m<sup>2</sup>/g, while the rest of ACF with surface area of 1500 m<sup>2</sup>/g and higher have 40% higher adsorption capacities than GAC. ACFC with higher surface area has the smallest critical bed depth and highest adsorption capacity, which makes it a good adsorbent for thinner and lighter respirators. It was concluded that ACF has great potential for application in respiratory protection considering its higher adsorption capacity and lower critical bed depth, in addition to its advantages over GAC, particularly for ACF with higher surface area.

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### Estimating Reusability of OV Air-Purifying Respirator Cartridges

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Reuse of organic vapor air-purifying respirator cartridges provides economic and energy savings. However, OSHA and European regulatory standards as well as manufacturers' guidance discourage reuse, presumably due to a lack of quantitative ob-

jective information. To address these knowledge gaps, storage and reuse data were collected in laboratory studies and mathematical modeling of these data was performed. Two important parameters obtained from the breakthrough curves - midpoint time (related to adsorption capacity) and midpoint slope (related to adsorption rate) - were found to be unchanged during storage. A third parameter, immediate breakthrough upon reuse (IBUR), was also determined to be significant. The all-humidity MultiVapor model (developed previously by the authors and available for download at the NIOSH website) can be used to estimate maximum IBUR, which depends on many factors, including time of first use. Calibrated with experimental measurements, MultiVapor can also provide intermediate IBUR estimates, which are very dependent on the vapor identity and first-use loading. Such estimates, with appropriate safety factors, can help industrial hygienists make informed reusability decisions.

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### Determination of Service Life Using Models: Impact of Underlying Adsorption Physics

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When data is unavailable to support determination of service life to satisfy the requirements of OSHA 1910.134, one must turn to breakthrough models. Application of these models, whether obtained from the open literature, NIOSH, or manufacturers must be done with an appreciation of the underlying adsorption physics that characterize the conditions being evaluated. A universal breakthrough model, predictive or descriptive, that accurately models service life for all chemical compounds, sorbent materials, and conditions does not exist. In this presentation, we will examine models currently in open literature with respect to their limitations and capabilities. We will describe the basic physics of adsorption that control breakthrough, and ultimately, service life. These include adsorption equilibrium, mass transport, and reaction kinetics. We will explore conditions that adversely impact the accuracy of breakthrough models, and then recommend how to properly apply these models to real-world conditions.

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### Evaluation of Procedures and Controls Used in Chemical Challenge Respirator Test Methods Using ClO<sub>2</sub>, Tear Gas, and Other Difficult Species

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While several U.S. and international laboratories engage in chemical challenge testing of air-purifying respirators, few test methods are published except for NIOSH Standard Test Procedures (STPs) and standards published by governments and international bodies. While NIOSH test methods are excellent and instructive, they normally include a statement of procedures as practiced by NIOSH without expounding on principles or providing allowable options with respect to procedures followed. Other national and international standards tend to include fewer details than NIOSH procedures, allowing discretion to knowledgeable practitioners, but providing little instructions for those

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