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Research Article

Using CO_2 to Determine Inhaled Contaminant Volumes and Blower Effectiveness in Several Types of Respirators

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This experiment was conducted to determine how much contaminant could be expected to be inhaled when overbreathing several different types of respirators. These included several tight-fitting and loose-fitting powered air-purifying respirators (PAPRs) and one air-purifying respirator (APR). CO_2 was used as a tracer gas in the ambient air, and several loose-and tight-fitting respirators were tested on the head form of a breathing machine. CO_2 concentration in the exhaled breath was monitored as well as CO_2 concentration in the ambient air. This concentration ratio was able to give a measurement of protection factor, not for the respirator necessarily, but for the wearer. Flow rates in the filter/blower inlet and breathing machine outlet were also monitored, so blower effectiveness (defined as the blower contribution to inhaled air) could also be determined. Wearer protection factors were found to range from 1.1 for the Racal AirMate loose-fitting PAPR to infinity for the 3M Hood, 3M Breath-Easy PAPR, and SE 400 breath-responsive PAPR. Inhaled contaminant volumes depended on tidal volume but ranged from 2.02 L to 0 L for the same respirators, respectively. Blower effectiveness was about 1.0 for tight-fitting APRs, 0.18 for the Racal, and greater than 1.0 for two of the loose-fitting PAPRs. With blower effectiveness greater than 1.0, some blower flow during the exhalation phase contributes to the subsequent inhalation. Results from this experiment point to different ways to measure respirator efficacy.

1. Introduction

Development of methods and the determination of inhaled volumes are important for the protection of wearers from airborne contaminants and assignment of minimal expected respirator protection factors [1]. Respirator protection factors are defined as contaminant concentration outside the facepiece divided by contaminant concentration inside the facepiece. These two concentrations are often measured by nondiscriminating particle counters that require a finite amount of time to reach a valid time-averaged measurement. Although this is a relatively simple measurement to make, it cannot be used accurately for rapidly changing particle counts. Particle count is also dependent upon placement within the facepiece, and sharp spatial discontinuities in contaminant concentrations may exist that lead to erroneous conclusions regarding representative facepiece concentrations.

Concentration ratio is only valid as a measure of protection factor as long as there are no particle sources or sinks in the system. It is known that the respiratory system is a source for moisture particles, and these can be counted along with particles of the challenge substance. Protection factors would, in this case, appear lower than they should. Deposition of particles within the respiratory system can also occur as air is inhaled, leading to apparent protection factors higher than they ought to be.

Respirator protection factors may only be an approximate indication of inspiration of contaminants by the wearer. That is because contaminants penetrating the respirator facepiece may not reach the mouth to be inhaled. A more direct indicator of protection afforded by the respirator is wearer protection factor, which we have defined as the concentration of contaminant inhaled divided by ambient concentration. The difference between this and conventional protection factor use is that contaminants inside the respirator facepiece,