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A new approach for assessing aerosol inhalation dose in confined spaces

Introduction

Inhalation of aerosols has a direct effect on health and is a critical factor in exposure assessment. Experimental approaches to determining inhalation dose are limited due to technical challenges and ethical concerns regarding human participation. As a result, alternative methods have been developed. One common approach involves simplified estimations, while another uses breathing thermal manikins (BTMs) to simulate human respiration. However, these methods have limitations: simplified approaches do not account for breathing dynamics, and BTMs cannot replicate physiological changes and fluctuations.

This study presents an experimental methodology for measuring inhalation dose that overcomes these limitations by involving human participants. This approach considers variations in the breathing cycle and their effects on aerosol dispersion. The methodology is designed to pose no health risks and is suitable for real-world applications. An experimental setup was built in a controlled environment to validate the method. Inhalation doses were measured under different airflow conditions, and the aerosol protection factor was calculated for each scenario to assess reductions in exposure based on indoor ventilation.

Methodology

The methodology involves aerosolizing a magnesium-water solution, where the water evaporates, leaving magnesium particles that follow airflow patterns. These aerosols are collected by individuals positioned at different locations within the room. Collection occurs via removable filters placed inside breathing masks. The magnesium content is extracted from the filters and analyzed using inductively coupled plasma mass spectrometry (ICP-MS), which also detects other elements to identify potential contaminants.

Three airflow conditions were tested: (1) No forced ventilation; (2) Forced ventilation with an axial fan to enhance turbulent mixing; and (3) Forced ventilation with an air purifier for aerosol removal. Each scenario included five sets of four experiments conducted at distances of 0.5, 1, 2, and 3 meters from the aerosol source, plus a control to measure background levels.

Results

The inhalation dose results obtained via ICP-MS and the protection factor (PF), which quantifies exposure reduction between conditions, were used to evaluate dose variations across scenarios. The results indicate that in the absence of ventilation, inhalation dose decreases with distance from the aerosol source. When forced ventilation is introduced, the overall inhalation dose is lower and less affected by distance.

Protection factors increase with distance, particularly in the scenario without ventilation, where the dose at 3 meters is significantly lower than at 0.5 meters. When comparing ventilation scenarios, forced airflow is most effective at close range, with the air purifier offering the highest level of protection at short distances. However, its efficiency decreases as distance increases, suggesting that airflow dynamics play a crucial role in aerosol exposure.

Conclusions

A methodology for measuring inhalation dose using real human participants has been developed and validated. This approach extends beyond controlled laboratory conditions and can be applied to everyday environments. The study highlights the impact of distance and ventilation on aerosol exposure. Results show that while distance from the aerosol source reduces exposure, forced ventilation and air purification significantly enhance protection, particularly at close range. This methodology provides valuable insights for assessing aerosol exposure and improving indoor air quality strategies.

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