EVALUATING THE PERFORMANCE OF VENTILATION SYSTEM FILTERS FOR FILTRATION OF PARTICLES SMALLER THAN 300 NM

Evaluating the Performance of Ventilation System Filters for Filtration of Particles Smaller Than 300 nm

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Ultrafine particles, or nano-sized particles (100 nm or smaller) found in many workplaces can be toxic. However, for general ventilation, Standard 52.2-2017 does not evaluate particles that small. Researchers developed a measurement procedure to evaluate the performance of filters used in ventilation systems for filtration of particles smaller than 300 nm, including ultrafine particles.

Researchers Clothilde Brochot and Ali Bahloul talked with *ASHRAE Journal* about this work, which appeared in a recent issue of *Science and Technology for the Built Environment*.

1. Why is it important to explore this topic now?

For an idea of how small nano-sized particles are, consider that a sheet of paper is about 100,000 namometers thick.

Nano-sized particles that are generated by manufacturing processes, e.g., welding, combustion, vapour deposition synthesis or gaseous phase processes, are found in the indoor air of many workplaces. Companies have become aware of the toxicity of these particles, whose diameter is less than 100 nanometers (compare that to a sheet of paper, which is about 100,000 nanometers thick). Indeed, studies have already shown that these nanometric particles, due to their very high specific surface area, have an increased biological activity for the same mass, leading to a higher toxicity than particles with the same chemical composition but that are larger in size.[1,2]

However, for general ventilation, the current standard, ANSI/ASHRAE Standard 52.2-2017, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*, limits the evaluation of filtration efficiency to particles between 0.3 µm (300 nm) and 10.0 µm (10,000 nm) in size. The most penetrating particle size (MPPS) is the particle size that is least captured by the filter, i.e., the filter efficiency is minimum for this particle size. MPPS is commonly accepted at 300 nm, so Standard 52.2-2017 does not attempt to measure efficiency below this particle size. Although MPPS for purely mechanical filters (and media) with low filtration velocities has been observed around 300 nm, the scientific literature refers to a size range from 100 nm to 300 nm. Moreover, it has been shown that the test conditions (medium characteristics, filtration velocity, etc.) have an effect on the MPPS.[3]

The main objective of this research was to develop a measurement procedure to evaluate the performance of filters used in ventilation systems for filtration of particles smaller than 300 nm, including ultrafine (nano-sized) particles. To do this, the research team designed and validated a test bench and then developed a measurement procedure to determine the mechanical filter performance. This project, which results from an agreement between IRSST (Institut de recherche Robert-Sauvé en santé et en sécurité du travail) and Concordia University, is the first step in the creation of a laboratory on particle filtration.

2. Why is it important to explore this topic now?

According to the World Health Organization (WHO), 90% of the world's population lives in an area with air that is unhealthy to breathe.[4]
Both natural and human contributions such as transportation, industry and energy production, waste management, household energy use, agricultural practices, natural dust and forest fires are responsible for this degradation in air quality. They also lead to nonreversible health problems such as respiratory or cardiac diseases. These are mainly related to exposure to fine particulate matter ($PM_{2.5}$, particles with an aerodynamic diameter of less than 2.5 micrometers), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2).[4]

More specifically, in the context of workplaces, exposures to gases, vapors, particles and/or their mixtures are frequent. These exposures are generally limited in time but intense. They are due to the presence and use of different products or materials in large quantities, all in a generally closed or semi-closed environment. Moreover, as nanotechnologies are becoming more and more popular in many work environments (automotive, aerospace, transportation, etc.), workers' exposure to these nanometric materials is growing.

In most of these situations, the reduction of gaseous or particulate contaminants through the use of ventilation systems is the most practical solution to implement. Filtration is a simple and effective means of capturing particles of various sizes. It is one of the tools used in the field of occupational health and safety to control exposure to ultrafine particles and nanoparticles, both in restricted or specific work areas and in general or specific ventilation systems.

In addition, filtration is also one of the measures promoted to reduce exposure to COVID-19 throughout the world. Indeed, when used with other CDC-recommended best practices (including social distancing, hygiene and barrier face covering), filtration can be part of a plan to reduce the potential of indoor airborne transmission of COVID-19. Although ventilation is not the most critical element in reducing the risk of COVID-19 transmission, it could still play a role. EPA, ASHRAE and CDC suggest, among other things, to increase outdoor air ventilation, to use predominantly MERV 13 filters or the highest level achievable in the HVAC unit, and to limit air leakage inside.[5–9]

3. What lessons, facts and/or guidance can an engineer working in the field take away from this research?

The performance measurements carried out during this study, on five filters in particular, are presented and discussed.[10]
The results clearly show an increase in efficiency as the particle diameter decreases below 100 nm. They also show that the MPPS is always higher than 100 nm. The measured MPPS range varies between filters: it is above 150 nm for the tested filters classified as MERV 8 and in the range 200 nm to 350 nm for the tested filter classified as MERV 14. The data thus show that the 150 nm to 500 nm range gives a better estimate of the MPPS, in contrast to the fixed size of 300 nm. However, the efficiency measurements at 300 nm and MPPS are equivalent for the tested mechanical filters (MERV 8 and MERV 14) and at the velocity used.

In conclusion, our results are in good agreement with the classical filtration theory for mechanical media and with the few previous experimental measurements on media and filters. The data show that, under the conditions tested, the mechanical filters show a higher efficiency in the nanometric range than that measured at MPPS.

Therefore, in the case of reducing the airborne contamination of COVID-19, the authorities' recommendations to replace the original filters (typically MERV 6 or MERV 8) in buildings (houses, schools, etc.) with MERV 13 filters or higher (as long as it is supported by the system) will increase the filtration performance of ventilation systems. However, it should be noted, that the efficiency of the filter tested in the laboratory is different from that of the filter used in an HVAC system.[11]

4. How can this research further the industry's knowledge on this topic?

The originality of this work lies in obtaining reproducible efficiency measurements as a function of particle size, using an approach with nanometric and polydisperse particles. The first results, which were promising, have already shown that the data are in good agreement with the MPPS theory. One can wonder if similar results would be found for higher velocities or for electrostatic filters. The setup developed during this project can now be used to answer these questions.

In the context of workplaces, the reduction of particulate contaminants is mainly achieved through use of ventilation systems. The workers' exposure to nanometric materials thus seems effectively reduced by the use of these mechanical filters. However, the question remains as to what is the acceptable performance value for filters that would protect workers in the case of nanoparticle exposure.

5. Were there any surprises or unforeseen challenges for you when preparing this research?

In this study, particular attention was paid to the calibration of the setup. In the context of nanometric particles, this calibration required a substantial amount of work, whether for homogeneity, stability, repeatability and aerosol concentration in the nanometric range.
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Although the laboratory has substantial expertise in the case of respiratory protective device efficiency measurements against nanoscale particles, the challenge is bigger in the case of ventilation filters and nanoparticles setups. This task was successfully completed and the efficiency of ventilation filters with respect to particles in the nanometer range was measured.

References:

1. CDC. 2009. “Approaches to safe nanotechnology—managing the health and safety concerns associated with engineered nanomaterials.” Publication No. 2009–125. Centers for Disease Control and Prevention.

2. Ostiguy, C., M. Debia, B. Roberge, A. Dufresne. 2014. “Nanomaterials: best practices for nanomaterial risk management in the workplace (2nd ed.) (Report R-899).” IRSST.

3. Brochot C., P. Abdolghader, F. Haghighat, A. Bahloul. 2020. "Développement d'une procédure d'évaluation de la performance de filtres de ventilation pour des particules de taille inférieure à 300 nm, incluant les nanoparticules (Report R-1107)." IRSST (English version soon available).

4. WHO. 2019. “Healthy Wnvironments for Healthier Populations: Why Do They Matter, and What Can We Do?” World Health Organization.

5. Schoen L.J. 2020. “Guidance for Building Operations During the COVID-19 Pandemic.”
ASHRAE Journal
(5):72–74.

6. ASHRAE. 2020. “ASHRAE Position Document on Infectious Aerosols.” ASHRAE. https://tinyurl.com/dkzfxf48

7. ASHRAE. 2021. “Core Recommendations for Reducing Airborne Infectious Aerosol Exposure.” ASHRAE. https://tinyurl.com/2m9bmtd7

8. CDC. 2021. “Ventilation in Buildings.” Centers for Disease Control and Prevention. Updated March 23. https://tinyurl.com/4e4tdy8w

9. EPA. 2021. “Air cleaners, HVAC filters, and coronavirus (COVID-19).” Environmental Protection Agency. https://tinyurl.com/r9rbymbh

10. Brochot C., P. Abdolghader, F. Haghighat, A. Bahloul. 2020 “Performance of mechanical filters used in general ventilation against nanoparticles.”
Science and Technology for the Built Environment
26(10):1387–1396.

11. Avalny, M., J.A. Siegel. 2020. “In-situ effectiveness of residential HVAC filters.”
Indoor Air
30(1):156–166.

12. Abdolghader P., C. Brochot, F. Haghighat, A. Bahloul. 2019. “Procedure to measure the penetration of one mechanical filter for nanoparticles—validation by comparison.”
Measurement
147:106840.


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