Document developed by the Environmental Health Committee and does not represent an ASHRAE Society position.

Environmental Health Committee (EHC) Emerging Issue Brief

Increased Awareness of Health Impacts of Indoor $PM_{2.5}$ and Need for Particulate Matter Control in Occupied Spaces

1. What is the issue?

The impact of exposure to airborne particles on human health has been recognized for millennia.[1] As we spend more of our time indoors (up to 90% of lifetime for some populations[2]), exposure to and control of airborne particles indoors becomes increasingly important. The aggregate harm done to the population in the indoor environment, measured in Disability Adjusted Life Years (DALY) is dominated by exposure to particulate matter (PM); no other contaminant comes within a factor of five.[3] Fine particles 2.5µm or less in diameter (PM2.5) have increased short- and long-term adverse health effects because they penetrate more deeply into the respiratory system. Research continues into the health effects of ultrafine particles and nanoparticles.[4] [5] Airborne pathogens such as SARS-CoV-2 are transmitted by respiratory aerosols that are predominantly fine particles.[6] [7] [8] [9] [10]

People are exposed to harmful concentrations of particles both outdoors[11] and indoors.[12] There are issues of wildfires in several locations[13] [14] and crop burning in some countries.[15] Although outdoor pollution migrates indoors[16], particles from indoor sources[17] dominate personal exposure for many people. World Health Organization (WHO) air quality guideline levels for PM_{10} (45 µg/m^3 24-hour, 15 µg/m^3 annual) and $PM_{2.5}$ (15 µg/m^3 24-hour, 5 µg/m^3 annual) are more stringent than US EPA and States' requirements for PM[18] [19].

Despite the increased awareness of negative health impacts, indoor PM2.5 sources and levels have remained largely unaddressed in standards and codes, with the exception of health care facilities. For media filters of the type usually installed in building HVAC equipment, current model codes only regulate smoke generation from filters if ignited.[20] [21] [22]ASHRAE standards for non-healthcare buildings contain requirements for filters to protect some HVAC equipment; only when outdoor PM levels exceed national limits is outdoor air filtration required to protect occupant health in non-residential occupancies. Some building types often lack effective filtering, notably senior living facilities that are not governed by more stringent healthcare facility requirements. Certain recirculation HVAC systems that are becoming more popular[23] (e.g., selected VRF cassettes) cannot easily accommodate filters that are effective in removing small particles[24] and are being applied where they influence more vulnerable populations.

2. What does this mean for ASHRAE?

ASHRAE Standards define acceptable indoor air quality (62.1, 62.2)[25] [26]and particle filter performance (52.2)[27]. However, they do not provide comprehensive guidance for when and where filtration should be used to achieve acceptable indoor air quality and what level is required, unless outdoor PM10 or PM2.5 exceed national standards. For more than four decades, ASHRAE ventilation standards for non-healthcare facilities adopted a definition of *acceptable indoor air quality* that requires that there be *no known contaminants at harmful concentrations*.[28] Because we now know more about the health harms of $PM_{2.5}$, target concentrations for indoor air should be included in ASHRAE Standards.

Cost-benefit analyses that consider the impact on human health of $PM_{2.5}$ control find air cleaning to be highly cost-effective.[29] [30] The convergence of higher health benefits of small particle filtration combined with the decreasing costs of filtering small particles makes this an opportune time to establish health-based requirements for $PM_{2.5}$ in occupied spaces.

The ASHRAE Epidemic Task Force's widely adopted recommendation to achieve MERV-13 or better levels of filtration for infectious aerosol exposure reduction[31] highlights a significant leadership opportunity for ASHRAE to improve indoor air quality at all times of building and its HVAC system operation. California's Title 24-2019 had already increased filtration requirements (MERV-13 for outdoor and return air in all building types).[32] Other organizations requiring or recommending improved filtration as a new baseline include the General Services Administration for all US federal buildings[33], the White House National COVID-19 Preparedness Plan[34] and *Clean Air in Buildings Challenge*[35], and UK building regulations.[36] These new requirements differ in their levels of prescribed filtration performance, type of air to be filtered (outdoor, recirculation), applicable systems, and operation conditions (normal, pandemic, wildfire). A comprehensive, consistent, and flexible approach is needed, and ASHRAE is best positioned to create the framework for reducing indoor environmental exposures to $PM_{2.5}$.

3. What Actions Should ASHRAE Consider?

ASHRAE consensus standards committees should consider the following actions:

- Require control of indoor particle concentrations to 24-hour and annual levels, in standards for acceptable indoor air quality (62.1, 62.2), for all building types and across all climatic conditions.
- Require commissioning of filtration and air cleaning systems in the commissioning section of applicable standards.

ASHRAE should consider the following actions:

- Propose changes to the model building codes to require capacities for minimum filtration of particles, particularly in spaces where occupants are more vulnerable, like long term care facilities, schools, and prisons. These capacities may be required for both outdoor air filtration and indoor air recirculation and infiltration.
- Incorporate cost-benefit analysis in development of standards and guidance that takes into consideration the health impacts of $PM_{2.5}$ exposure
- Establish global outdoor air quality design data, analogous to climatic design data, to provide a standardized starting point for design professionals.
- Formulate recommendations to building owners and policy makers regarding retrofits of existing buildings to meet new particle concentration guidance.

- Provide information about the benefits of operating filtration systems in buildings to our allies who operate and maintain buildings and to the public for their dwellings.

References

[1] Meiklejohn, A., "Pneumoconiosis", *Postgraduate Medical Journal*, December 1949, https://pmj.bmj.com/content/postgradmedj/25/290/599.full.pdf

[2] Klepis, N., Nelson, W., Ott, W. et al. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Sci Environ Epidemiol 11, 231–252 (2001). https://doi.org/10.1038/sj.jea.7500165

[3] Logue, J. M. et al., "A Method to Estimate the Chronic Health Impact of Air Pollutants in U.S. Residences," *Environ Health Perspect* 120:216–222 (2012). https://ehp.niehs.nih.gov/doi/10.1289/ehp.1104035

[4] EPA, "Integrated Science Assessment for Particulate Matter", December 2019, https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=539935

[5] "*Health Risks of Indoor Exposure to Particulate Matter: Workshop Summary*", National Academies Press, 2016, http://nap.edu/23531

[6] "Getting to and Sustaining the Next Normal – A Roadmap for Living with COVID" Rockefeller Foundation, March 2022, https://www.rockefellerfoundation.org/wp-content/uploads/2022/03/Getting-to-and-Sustaining-the-Next-Normal-A-Roadmap-for-Living-with-Covid-Report-Final.pdf

[7] Morawska, L., et al., "How can airborne transmission of COVID-19 be minimized?" Environment International 142 (2020) 105832, https://www.sciencedirect.com/science/article/pii/S0160412020317876?via%3Dihub

[8] Johnson, G.R., et al., "Modality of human expired aerosol size distributions," *Journal of Aerosol Science*, 42:12 December 2011, pp 839-851, https://www.sciencedirect.com/science/article/abs/pii/S0021850211001200?via%3Dihub

[9] Adenaiye, O.O. et al., "Infectious Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) in Exhaled Aerosols and Efficacy of Masks During Early Mild Infection" *Clinical Infectious Diseases*, 14 September 2021, https://doi.org/10.1093/cid/ciab797

[10] Milton, D.K., Fabian, M.P., Cowling, B.J., Grantham, M.L. and McDevitt, J.J., 2013. Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. *PLoS pathogens*, *9*(3), p.e1003205.

[11] Southerland, V.A., et al., "Global urban temporal trends in fine particulate matter ($PM_{2.5}$) and attributable health burdens: estimates from global data sets," *Lancet Planet Health* 2022; 6:e139-46, https://www.thelancet.com/action/showPdf?pii=S2542-5196%2821%2900350-8

[12] Morawska, L et al., "Airborne particles in indoor environment of homes schools, offices and aged care facilities: The main routes of exposure" Environment International 108 (2017) 75-83, https://www.sciencedirect.com/science/article/pii/S0160412017306840?via%3Dihub

[13] "How Does Marshall Fire Smoke Affect Indoor, Outdoor Air Quality?", CIRES. January 13, 2022, https://cires.colorado.edu/news/how-does-marshall-fire-smoke-affect-indoor-outdoor-air-quality

[14] "Ontario forest fires burned record area of land this summer as they displaced First Nations in northwest" CBC News, November 10, 2021 https://www.cbc.ca/news/canada/thunder-bay/record-breaking-ontario-forest-fire-season-1.6242422

[15] "Open agricultural burning" Climate & Clean Air Coalition accessed 3/26/22 https://www.ccacoalition.org/en/activity/open-agricultural-burning

[16] Tham, K. W., Parshetti, G. K., Balasubramanian, R., Sekhar, C., & Cheong, D. K. W. (2018). Mitigating particulate matter exposure in naturally ventilated buildings during haze episodes. BUILDING AND ENVIRONMENT, 128, 96-106. doi:1016/j.buildenv.2017.11.036

[17] Mendell, A.Y., et al. "Particulate matter concentrations in social housing", *Sustainable Cities and Society*, January 2022, https://doi.org/10.1016/j.scs.2021.103503

[18] *WHO global air quality guidelines*, Geneva: World Health Organization, 2021, https://apps.who.int/iris/handle/10665/345329

[19] EPA Green Book, https://www.epa.gov/green-book

[20] 2018 International Mechanical Code (IMC), Section 605 Air Filters, https://codes.iccsafe.org/content/IMC2018P4/chapter-6-duct-systems

[21] 2018 Uniform Mechanical Code (UMC), Section 311.2 Air Filters, https://up.codes/viewer/nevada/umc-2018/chapter/3/general-regulations#311.2

[22] Underwriters Laboratory, UL 900 Standard for Air Filter Units https://standardscatalog.ul.com/ProductDetail.aspx?productId=UL900
[23] https://www.prnewswire.com/news-releases/the-worldwide-ductless-heating--cooling-systems-industry-is-expected-to-reach-145-billion-by-2026-301492733.html
[24] Lu, J. et al., "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020", *Emerging Infectious Diseases* 2020 Jul; 26(7): 1628-1631, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7323555/
[25] ANSI/ASHRAE Standard 62.1-2019 Ventilation for Acceptable Indoor Air Quality, ASHRAE, Atlanta, GA
[26] ANSI/ASHRAE Standard 62.2-2019 Ventilation and Acceptable Indoor Air Quality in Residential Buildings, ASHRAE, Atlanta, GA
[27] ANSI/ASHRAE Standard 52.2-2017 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size, ASHRAE, Atlanta, GA
[28] ASHRAE Standard 62-1981 Ventilation for Acceptable Indoor Air Quality, ASHRAE, Atlanta, GA
[29] Montgomery, J.F. et al., "Financial implications of modifications to building filtration systems" *Building and Environment* 85 (2015) 17-28,
[30] Fisk, W.J., "Health benefits of particle filtration" Indoor Air 2013; 23:357-368 https://onlinelibrary.wiley.com/doi/10.1111/ina.12036
[31] ASHRAE Epidemic Task Force, *Core Recommendations for Reducing Airborne Infectious Aerosol Exposure,"* October 2021. https://www.ashrae.org/file%20library/technical%20resources/covid-19/core-recommendations-for-reducing-airborne-infectious-aerosol-exposure.pdf
[32] California Energy Commission, 2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings https://www.energy.ca.gov/sites/default/files/2021-06/CEC-400-2018-020-CMF_0.pdf
[33] P100 Facilities Standards for the Public Buildings Service, US General Services Administration, October 2021: https://www.gsa.gov/cdnstatic/P100%202021%20v1.pdf
[34] *National COVID-19 Preparedness Plan*, March 2022, US White House. https://www.whitehouse.gov/wp-content/uploads/2022/03/NAT-COVID-19-PREPAREDNESS-PLAN.pdf
[35] Nelson, A., "Let's Clear the Air on COVID," White House Office of Science and Technology blog, 2022 Mar 23, https://www.whitehouse.gov/ostp/news-updates/2022/03/23/lets-clear-the-air-on-covid/
[36] The Building Regulations 2010, Ventilation, Document F, Volume 2: Buildings other than dwellings. UK Government: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1057371/ADF2.pdf

Other Resources

Getting to and Sustaining the Next Normal: A Roadmap for Living with COVID, March 2022. The Rockefeller Foundation. https://www.rockefellerfoundation.org/wp-content/uploads/2022/03/Getting-to-and-Sustaining-the-Next-Normal-A-Roadmap-for-Living-with-Covid-Report-Final.pdf

National Academy of Engineering 2022. Indoor Exposure to Fine Particulate Matter and Practical Mitigation Approaches: Proceedings of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/26331.

Owen, K. and Kerr, C. "What You Can and Can't Do With ASHRAE Standard 52.2" *ASHRAE Journal*, December 2020.

Stephens, B., T. Brennan, L. Harriman, "Selecting Ventilation Air Filters to Reduce PM2.5 of Outdoor Origin," *ASHRAE Journal*, September 2016; 12-20.

Authors

Hoy Bohanon
Bill Bahnfleth
Chandra Sekhar
Luke Leung
Meghan McNulty
Kathleen Owen
Marwa Zaatari
Max Sherman
Junjing Yang
Wane Baker

April 25, 2022