Improving Ventilation Performance in Response to the Pandemic

Andrew Persily and Jeffrey A. Siegel

Andrew Persily is a fellow, Building Energy and Environment Division, US National Institute of Standards and Technology. Jeffrey Siegel is a professor, Department of Civil and Mineral Engineering, University of Toronto.

In response to the covid-19 pandemic and in recognition of the importance of airborne disease transmission, there have been multiple calls to ensure adequate building ventilation, in some cases recommending increased ventilation rates (ASHRAE 2021; CDC 2021; REHVA 2021; WHO 2021). The cited organizations stress that ventilation is one element of a layered approach to managing the risk of airborne disease transmission; other measures include handwashing, face masks, vaccination, and distancing.

Introduction

The importance of ventilation has been recognized for as long as people have occupied buildings (e.g., Beecher and Stowe 1869; Janssen 1999; Klauss et al. 1970; Wargocki 2021), with increased interest driven recently by the pandemic, climate change, and other issues. This increased attention to ventilation is a positive step given the well-established connection of ventilation to indoor air quality (IAQ) and to the health, comfort, and performance of building occupants (ASHRAE 2020). However, in pursuing efforts to address ventilation it is important to understand that potential changes in ventilation depend on the specific building being considered, its existing ventilation and space conditioning systems, the local climate, and outdoor pollutant levels, among other factors.

In this article we use the term "ventilation" broadly to include outdoor air and exhaust ventilation, heating and cooling, humidification and dehumidification, and contaminant removal using filtration and other technologies. This usage is consistent with ASHRAE Standard 62.1, which defines ventilation as "the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space" (ASHRAE 2019a). Note that this definition does not mention outdoor air delivery. Some people think of ventilation exclusively as outdoor air delivery, while others think of it as air supply to an occupied space without reference to the amount of outdoor air it might contain. It is therefore essential to identify the specific airflow of interest when discussing ventilation.

Approaches to Improving Ventilation

Given the impact of ventilation rates on airborne infectious disease transmission, improving ventilation is clearly important (Morawska et al. 2021; WHO 2021). However, it is essential that such efforts recognize the large amount of variation between buildings and their ventilation systems, which directly relate to what can and should be done in a given building.

One of the first things to consider before modifying ventilation in a particular building is how jt is ventilated: Is there a mechanical system that brings outdoor air into the building and distributes it to the occupied spaces? What kind of system is it (e.g., central or local)? How much outdoor air does the system provide? How is the outdoor air intake rate controlled and can it be modulated?

Is the building naturally ventilated? If so, does it have a natural ventilation system with openings and other components sized and located based on engineering principles? Or does it simply have operable windows? Is the building ventilated primarily by uncontrolled infiltration and exfiltration through unintentional leaks in the building envelope? All buildings, even very tight ones, generally have significant rates of outdoor air entry via envelope infiltration driven by weather conditions and the operation of building equipment (e.g., local exhausts). While infiltration will dilute internally generated air contaminants, including infectious aerosols, it is uncontrolled, unfiltered, and unconditioned and can degrade IAQ and increase energy requirements.

Other key system attributes include the level of particle and gas-phase pollutant removal, the ability to improve filtration (which is sometimes space- or fan-capacity constrained), and the capacity to condition (heat and cool) additional outdoor air.

The impacts of these attributes on ventilation performance and the ability to reduce the risk of airborne disease transmission are system specific. For example, calls to increase outdoor air intake must recognize that many systems, including the forced-air space conditioning systems used in most US homes, do not bring any outdoor air into a building. In fact, some systems (e.g., baseboard and radiator heating) have no air distribution at all. Newer homes are more likely to have outdoor air intake than older ones, but the fraction of US dwellings with mechanical outdoor air intake is very small.

Even in systems that bring outdoor air into the building, increasing the outdoor air ventilation rate may not be possible given existing duct sizes and configurations, fan and space conditioning capacities, and control limitations. The outdoor air ventilation rate in a naturally ventilated building is determined by wind and indoor-outdoor temperature differences as well as the size and position of ventilation openings.

Many pandemic-motivated recommendations suggest opening windows to increase natural ventilation (e.g., REHVA 2021), but this can affect comfort, energy, security, safety, moisture, and IAQ (if outdoor air quality is poor). In addition, the ventilation associated with open windows is hard to predict in terms of its magnitude and direction (inward or outward). The intent here is not to suggest that opening windows is not an option but rather that these factors can impact the benefits of doing so.

In considering various approaches to ventilation, it is critical to also consider how the air is distributed within the space, bearing in mind that ventilation is most effective when air is supplied to the occupant’s breathing zone and indoor-generated pollutants are removed near their source. Some ventilation approaches may lead to uncontrolled and potentially undesirable airflow and contaminant transport in the building.

Pandemic-Aware Ventilation

Implementing recommendations to increase outdoor air rates and/or improve filtration may not be possible with existing systems in some buildings. But ventilation system performance can be improved in almost all buildings by inspecting the system and ensuring that its components are in place and functional. These efforts should also verify that the system is operating as intended per its design and that the design is still relevant to the current building usage and occupancy.

Buildings, especially nonresidential buildings, are generally commissioned before occupancy to ensure that the various systems are properly installed and functioning. In the case of ventilation systems, this process (commonly referred to as testing and balancing) is required by ASHRAE Standard 62.1 and is a cornerstone of ventilation system maintenance. However, over time, systems can degrade as sensors go out of calibration, dampers break or get stuck, filters become clogged and other inevitable events occur. Such changes will result in the system not operating as intended in terms of outdoor air intake rates and other aspects of system performance, contributing to both poor IAQ and increased energy consumption.

An additional consideration is that building and space use often changes over time, leading to different ventilation requirements. Too often these changes in space usage and occupancy are not accompanied by modifications to the ventilation system in response to the new conditions. For these reasons, a common recommendation in response to the pandemic is to verify that the system is operating as intended and that it is consistent with current space use (ASHRAE 2021).

Along the same lines, systems require operations and maintenance (O&M), which includes periodic inspections of system components, filter changes, sensor calibration and other actions. ASHRAE Standard 62.1 includes O&M schedules for nonresidential buildings.

<u>Carbon Dioxide Monitoring</u>
There have been many proposals to monitor indoor CO_2 concentrations to better manage ventilation, and many such measurement programs have been put in place. CO_2 monitoring can be a useful tool for obtaining information about ventilation rates but requires knowledge of how indoor CO_2 concentrations relate to ventilation, sensor calibration and maintenance, careful measurement procedures, and recognition that infectious aerosols behave very differently from CO_2 molecules. Nevertheless, measuring CO_2 concentrations over time can indicate whether the system is providing the expected outdoor air ventilation rates.

This topic merits more discussion than space allows; ASHRAE (2022) recently published a *Position Document on Indoor Carbon Dioxide* that addresses this topic and includes cautions on the application of indoor CO_2 monitoring.

<u>Standards</u>
In addition to recommendations to enhance ventilation, there have been calls to revise ventilation standards to address airborne disease transmission (Morawska et al. 2021). Standards such as ASHRAE 62.1 and 62.2 (ASHRAE 2019a,b) and CEN 16798-1 (2019) focus primarily on the control of odor and irritation, but health impacts are a factor in their requirements (Persily 2015). While these standards do not address airborne infection control directly, the topic was discussed in developing Standard 62.1.

Discussions and actions to revise these standards are certainly merited, but the organizations and committees responsible for those standards need to define and justify new ventilation rates and other requirements. Some have proposed specific ventilation requirements for infection control (e.g., Li et al. 2021), recognizing the need to consider not just outdoor air ventilation but also "effective" ventilation rates provided by filtered recirculated air and other removal mechanisms. To support these changes, there is a compelling need for research that quantitatively establishes the benefits of ventilation in the context of specific infectious diseases.

Conclusion

Ventilation has a fundamental role in managing airborne infectious disease transmission in the context of a broader layered approach. But before making changes to the way a building is ventilated, one must understand how the ventilation system design and operation and other building features may impact infectious disease transmission. Understanding the system and ensuring that reliable ventilation is provided are great first steps for infection control, improved IAQ, and energy efficiency.

References

ASHRAE [American Society of Heating, Refrigerating and Air-Conditioning Engineers]. 2019a. ANSI/ASHRAE Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality. Peachtree Corners GA.

ASHRAE. 2019b. ANSI/ASHRAE Standard 62.2-2019, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. Peachtree Corners GA.

ASHRAE. 2020. Position Document on Indoor Air Quality. Peachtree Corners GA.

ASHRAE Epidemic Task Force. 2021. ASHRAE Building Readiness Guide. Peachtree Corners GA.

ASHRAE. 2022. Position Document on Indoor Carbon Dioxide. Peachtree Corners GA.

Beecher CE, Stowe HB. 1869. The American Woman's Home: Or, Principles of Domestic Science; Being a Guide to the Formation and Maintenance of Economical, Healthful, Beautiful, and Christian Homes. New York: J.B. Ford and Company. Available at https://lccn.loc.gov/07035680.

CDC [Centers for Disease Control and Prevention]. 2021. COVID-19, Ventilation in Buildings. Atlanta.

CEN [European Committee for Standardization]. 2019. EN 16798-1:2019: Energy performance of buildings – Ventilation for buildings, Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Brussels.

Janssen JE. 1999. The history of ventilation and temperature control. ASHRAE Journal 41(10):47–52.

Klauss AK, Tull RH, Roots LM, Pfafflin JR. 1970. History of the changing concepts in ventilation requirements. ASHRAE Journal 12:51–55.

Li Y, Cheng P, Jia W. 2021. Poor ventilation worsens short-range airborne transmission of respiratory infection. Indoor Air 32(1):e12946.

Morawska L, Allen J, Bahnfleth W, Bluyssen PM, Boerstra A, Buonanno G, Cao J, Dancer SJ, Floto A, Franchimon F, and 29 others. 2021. A paradigm shift to combat indoor respiratory infection. Science 372(6543):689–92.

Parhizkar H, Mahic A, Van Den Wymelenberg KG. 2022. Toward incorporating numeric disease transmission risk in energy codes and ventilation standards. The Bridge 52(3):XX–XX.

Persily A. 2015. Challenges in developing ventilation and indoor air quality standards: The story of ASHRAE Standard 62. Building and Environment 91:61–69.

REHVA [Federation of European Heating, Ventilation and Air Conditioning Associations]. 2021. REHVA COVID19 Guidance, Version 4.1. Ixelles, Belgium.

Srebric J, Milton DK. 2022. Active air interventions. The Bridge 52(3):XX–XX.

Wargocki P. 2021. What we know and should know about ventilation. REHVA Journal 58 (2):5–13.

WHO [World Health Organization]. 2021. Roadmap to Improve and Ensure Good Indoor Ventilation in the Context of COVID-19. Geneva.