

# POST-PANDEMIC VENTILATION GUIDANCE



November 2023 Fall Workshop  
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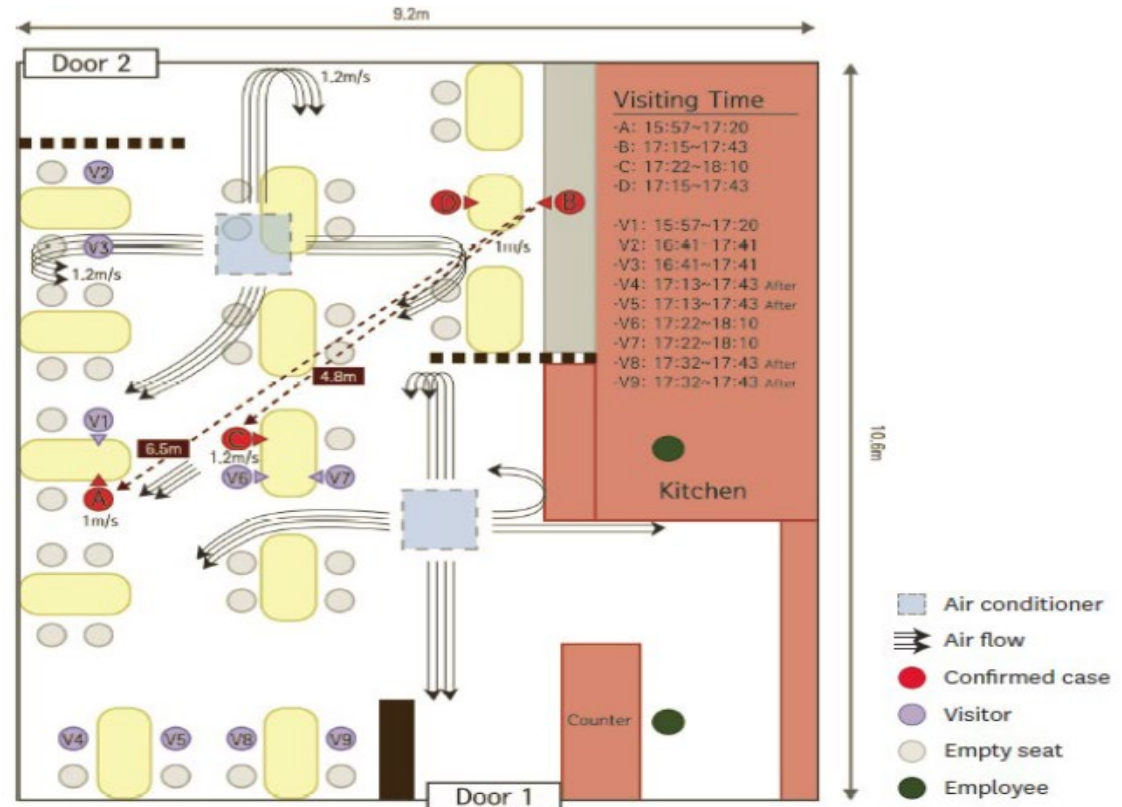
# Outline

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- What We Learned from the Pandemic
- Ventilation Guidance
  - Overview and Definitions
  - Ventilation Standards
  - Ventilation Guidance Specifics
    - Dilution
    - Filtration
    - Additive Technologies
    - Key Ventilation Reminders
- ASHRAE 241 Guidance Overview
- Resources

# What We Have Learned

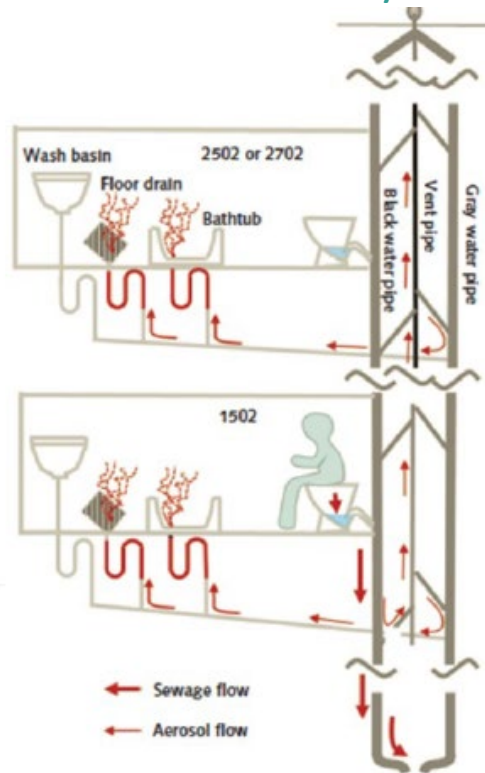
Infectious viral particles are carried in air streams



Kwon, K.S., et al., 2020. Evidence of long-distance droplet transmission of SARS-CoV-2 by direct air flow in a restaurant in Korea. *Journal of Korean medical science*, 35(46). <https://doi.org/10.3346/jkms.2020.35.e415>

# What We Have Learned

Transmission of viral aerosols may occur through plumbing



Kang, M., et. al. 2020 Probable evidence of faecal aerosol transmission of SARS-CoV-2 in a High-Rise Building. *Ann Intern Med.* doi:10.7326/M20-0928

## Three families involved

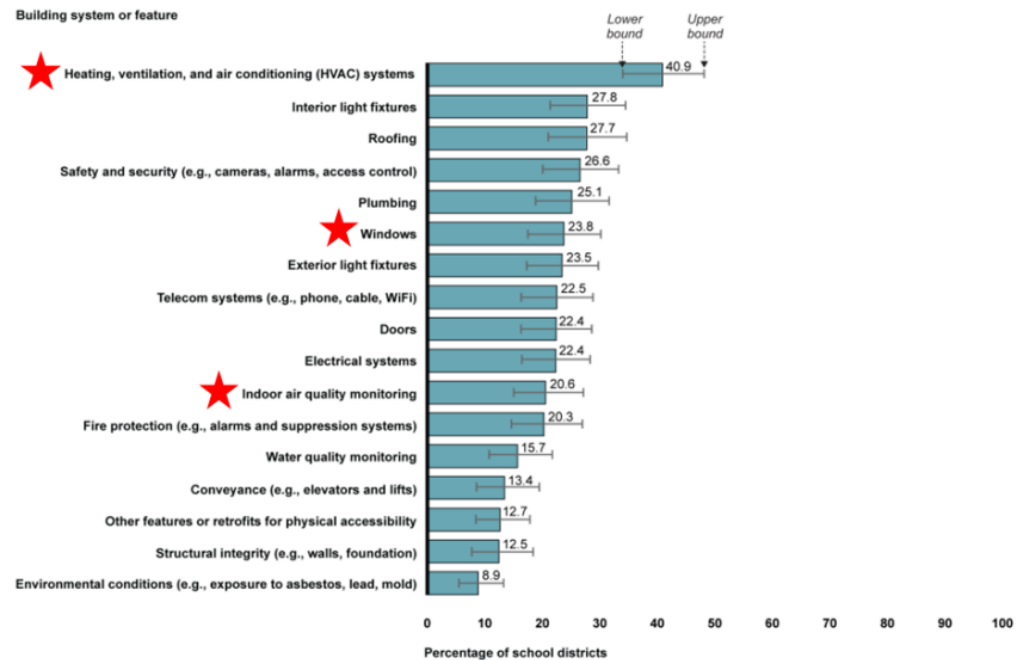
- First family had history of infection after travel to Wuhan
- Two other families later infected had no travel history or other known exposures
- The families lived in 3 vertically aligned flats connected by drainage pipes

# What We Have Learned

## School Maintenance Was A Problem Before COVID

- ▶ General Accountability Office study on condition of US schools (June 2020)
- ▶ Maintenance or replacement needs
  - ▶ HVAC - #1
  - ▶ Windows - #6
  - ▶ IAQ monitoring #11
- ▶ Poor maintenance impacts IAQ and energy use, increases infection risk

Figure 2: Estimated Percentage of School Districts in Which at Least Half the Schools Need Updates or Replacements of Key Building Systems or Features



<https://www.gao.gov/assets/710/707374.pdf>

# What We Have Learned

## Spread of illness in schools historically didn't address ventilation

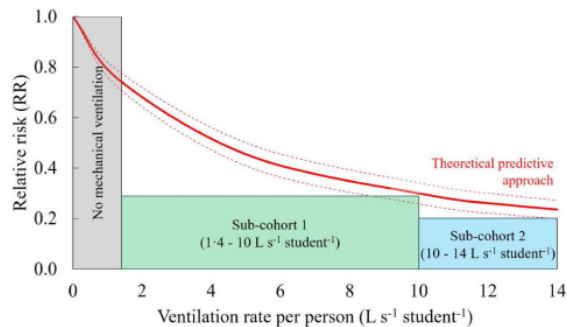
- Get available vaccinations
- Stay home if you are sick
- Cough into your sleeve
- Wash your hands frequently



## Ventilation is important

### Italian schools study

- 10,000+ classrooms
- 316 retrofitted with mechanical ventilation
- Covid infection rates 80% lower in mechanically ventilated classrooms with 10 – 14 L/s-pers
- 12-15% reduction per unit of ventilation



### Increasing ventilation reduces SARS-CoV-2 airborne transmission in schools: a retrospective cohort study in Italy's Marche region

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Preprint - <https://arxiv.org/abs/2207.02678>

# Ventilation Guidance

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- Overview and Definitions
- Ventilation Standards
- Ventilation Guidance Specifics
  - Dilution
  - Filtration
  - Other Air Cleaning Technology
  - Key Ventilation Reminders

# Ventilation Guidance

## Overview

- Post-pandemic guidance has held to same key ventilation recommendations
- Both CDC and DOH guidance now address mitigating the spread of respiratory aerosols (no longer COVID-specific documents)
- ASHRAE has developed guidance to address preparedness for future pandemic conditions



# Ventilation Guidance

## Definitions

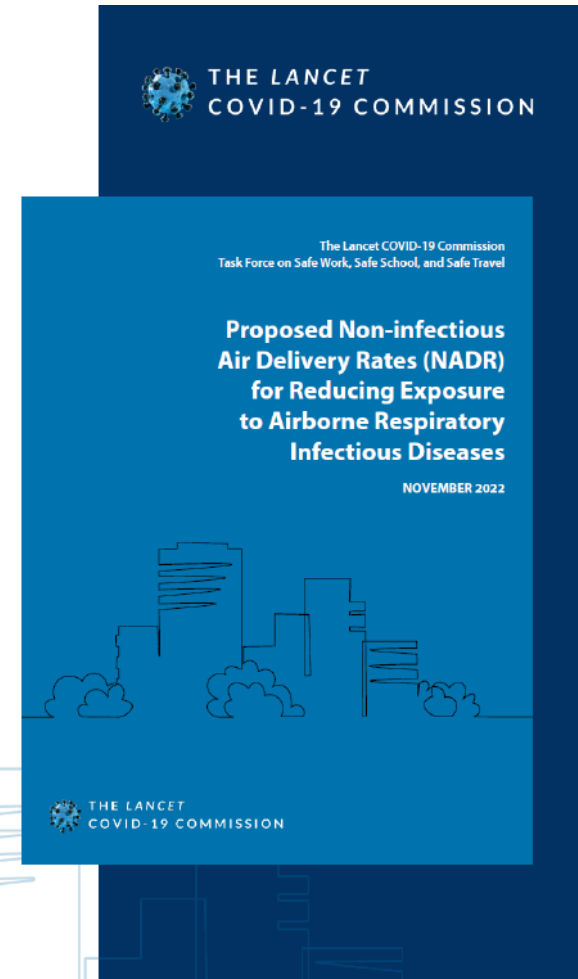
- **ACH- Air changes per hour**  
The number of times an hour that the entire volume of air in a room is replaced
- **ACHe- Air change per hour equivalents**  
The number of air changes per hour of *pathogen-free air* provided by technologies other than basic air supply and exhaust from an air handling unit  
Some examples: HEPA filtration units; GUV
- **NADR –**  
Non-infectious Air Delivery Rate. Same concept as air change equivalents.

# More on ACHe/NADR

TABLE 1.  
**Proposed Non-infectious Air Delivery Rates (NADR) for Reducing Exposure to Airborne Respiratory Diseases;**  
**The Lancet COVID-19 Commission Task Force on Safe School, Safe Work, and Safe Travel**

	Volumetric flow rate per volume		Volumetric flow rate per floor area		
	ACHe	cfm/person	L/s/person	cfm/ft <sup>2</sup>	L/s/m <sup>2</sup>
Good	4	21	10	0.75 + ASHRAE minimum outdoor air ventilation	3.8 + ASHRAE minimum outdoor air ventilation
Better	6	30	14	1.0 + ASHRAE minimum outdoor air ventilation	5.1 + ASHRAE minimum outdoor air ventilation
Best	>6	>30	>14	>1.0 + ASHRAE minimum outdoor air ventilation	>5.1 + ASHRAE minimum outdoor air ventilation

To read the full report, visit:  
[covid19commission.org/safe-work-travel](https://covid19commission.org/safe-work-travel)



# More on ACHe/NADR

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## What ACHe Does and Does Not Address:

- Focus is on removing infectious aerosols; side benefit of particulate removal depending on the mitigation strategy adopted
- Does not focus on control of odors, CO<sub>2</sub> levels, or other indoor air quality parameters (i.e., less focus on dilution ventilation)

**DOH guidance retains focus on the importance of providing dilution ventilation and filtration, emphasizing need for providing as much outside air as possible.**

# Ventilation Standards

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## Dilution Minimum Standards for Schools

### ASHRAE 62.1

- 15 cfm/person of air
- 17 cfm/person of air for science labs (directly exhausted, but supply can be recirculated from non-lab/shop areas)
- 19 cfm/person of air for art and wood/metal shops (directly exhausted, but supply can be recirculated from non-lab/shop areas)

### SBOH School Rule WAC 246-366-080 Ventilation

- All rooms used by students or staff shall be kept reasonably free of all objectionable odor, excessive heat or condensation
- All sources producing air contaminants of public health importance shall be controlled by the provision and maintenance of local mechanical exhaust ventilation systems as approved by the health officer.

# Ventilation Standards

## Minimum Standards Compared to Literature (cfm/person)

	<u>ASHRAE 62.1</u>	<u>LBL</u>	<u>Lancet NADR</u>
Minimum	15		
Good		20	21
Better			30
Best			>30

Notes:

LBL: [Lawrence Berkeley National Labs Indoor Air Quality Scientific Finding Resource Bank  
https://www.iaqscience.lbl.gov/performance-summary](https://www.iaqscience.lbl.gov/performance-summary)

NADR: Non-Infectious Air Delivery Rate: <https://covid19commission.org/safe-work-travel>

# Ventilation Guidance

## Dilution

### Improving Dilution in Building with Central HVAC System

#### Have HVAC System Inspected and Balanced

A preliminary building survey conducted by the GSA on 1756 air handling units identified some of the following issues:

- Outside air dampers were not working correctly
- Filters needed changing, or were not seated correctly
- Building Automation System (BAS) was not operating correctly
- Demand control system was not disabled
- Heating/cooling coils were dirty/damaged

System should deliver 5-6 air changes per hour

Reduce recirculation of indoor air, maximize outdoor air

# Ventilation Guidance

## Dilution

Monitor CO<sub>2</sub> as an indicator of appropriate dilution

- CO<sub>2</sub> concentration is affected by both inside and outside factors
- Goal is to keep CO<sub>2</sub> below 700-800 if possible

# Ventilation Guidance

## Dilution

### Improving Dilution Ventilation in Building without Central HVAC, or Limited Central HVAC

- Open windows and doors to create a cross draft. Even a few inches helps



- Reduce occupancy in areas where opening windows and doors isn't an option
- Use fans to increase the effectiveness of open windows.
- Avoid blowing respiratory aerosols from one person to another.



# Ventilation Guidance

## Dilution

### Other Important Practices to Improve Dilution Ventilation

- Inspect and maintain local exhaust ventilation in restrooms, kitchens, and laboratories
- Increase exhaust ventilation in restrooms above code minimums
- Ventilate building 1 hour prior to start of class and continue until 2 hours following custodial activities after school.

# Ventilation Guidance

## Dilution

- Work with building engineers or HVAC specialists to generate air movement that goes from clean-to-less clean spaces

Nurse's Exam Room

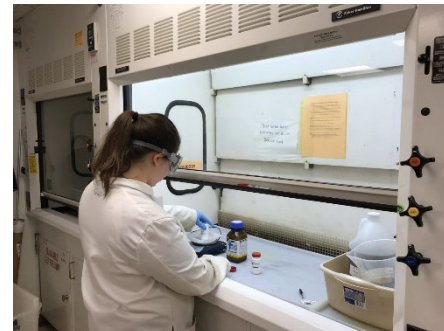
Negative pressure



Laboratories

Art and Shop Rooms

Local exhaust and enclosures



# Ventilation Guidance

## Filtration

### Filtration within a building HVAC System

- Minimum of MERV 13 for Outside Air and Recirculated Air  
(A coarser filter at the intake can prolong the life of the MERV13 filter)
- MERV 13 filters with deeper pleats that reduce air resistance are available

# Ventilation Guidance

## Filtration

### Why MERV 13 Filters?

ASHRAE Epidemic Task Force estimate of viral load capture by typical MERV rated filters

Accounts for particle size and assumed distribution of virus in particles

MERV Rating (Based on 52.2-2017)	Filter Droplet Nuclei Efficiency
4	16%
5	24%
6	28%
7	36%
8	49%
9	54%
10	57%
11	67%
12	77%
13	86%
14	93%
15	94%
16	97%

Typically present →

Recommended →

[ashrae.org/covid19](https://www.ashrae.org/covid19) – Building Readiness guidance

# Ventilation Guidance

## Filtration

### Filtering Within a Room

Look at Portable HEPA filtration Units

- Prioritize common areas
- Prioritize high risk areas
  - Sensitive students
  - High aerosol-generating areas

Advantages of Portable HEPA Units


- They can be sized to a room
- Some available for \$200



# Ventilation Guidance

## Filtration

### Filtration Within A Room

 National Institute of Environmental Health Sciences  
Worker Training Program

### Selection and Use of Portable Air Cleaners to Protect Workers from Exposure to SARS-CoV-2

This fact sheet provides guidance to help employers, building operators, and union officials select and use portable air cleaners to remove virus-contaminated air in indoor spaces.

#### Overview

Ventilation and filtration are important to prevent transmission of COVID-19. SARS-CoV-2, the virus that causes COVID-19, is mainly spread through inhalation of virus-contaminated air when an infected person speaks, laughs, coughs, sings, or sneezes. Physical distancing alone will not prevent the build-up of viral particles in a room or workspace (Figure 1).

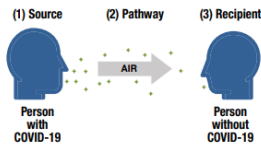


Figure 1. For transmission to occur via tiny airborne particles, three things are necessary: source, pathway, and recipient.<sup>1</sup>

Approximately 40% of people who are infectious are asymptomatic (no symptoms) or presymptomatic (before symptoms begin) and may contaminate air unknowingly. Work settings with inadequate ventilation and/or those that require people to be close together for extended periods of time, increase the risk of COVID-19 transmission. The illustration at right outlines the recommended steps to improve ventilation in buildings (Figure 2).

<sup>1</sup> Based on an image from the Center for Infectious Disease Research and Policy. <https://www.cidrap.umn.edu/covid-19/preparedness-and-response/protecting-essential-workers>

The Centers for Disease Control and Prevention defines close contact as within 6 feet of a person for 15 minutes or more during a 24-hour period. Wearing a cloth or surgical mask, while helpful, cannot be relied upon to prevent the spread of COVID-19.



Figure 2. Illustration of the order in which to consider improvements to ventilation in buildings.<sup>2</sup>

<sup>2</sup> Source, Jones et al, 2020. Schools for Health, Risk Reduction Strategies for Reopening Schools. Harvard Healthy Buildings Program.

**Key point:** If feasible, increase outside air and filtration in the building's mechanical ventilation system. If this can't be done or is insufficient, **then** consider using portable air cleaning units.

Source: [https://tools.niehs.nih.gov/wetp/public/hasl\\_get\\_blob.cfm?ID=13021](https://tools.niehs.nih.gov/wetp/public/hasl_get_blob.cfm?ID=13021)

# Ventilation Guidance

## HEPA Unit Selection

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- Look for one that does **NOT** have additional features such as UV lights, ionizers, electrostatic precipitators, plasma, etc. (nothing additive).
- Look for a noise rating of 45 decibels or less with other equipment running.
- You may need more than one unit for your room
- Look for Association of Home Appliance Manufacturer (AHAM) Certification- this is a third-party certifying organization that verifies unit function

# Ventilation Guidance

## HEPA Unit Placement and Maintenance

- Do not place next to corners, doorways, curtains, walls, or furniture
- Units should be about 3 feet away from obstructions
- Place away from open windows (units are meant to filter air from inside, not outside)
- Have a filter replacement schedule that is easy to follow and based on the manufacturer's recommendations
- Ensure good fit of filters in the frame during maintenance

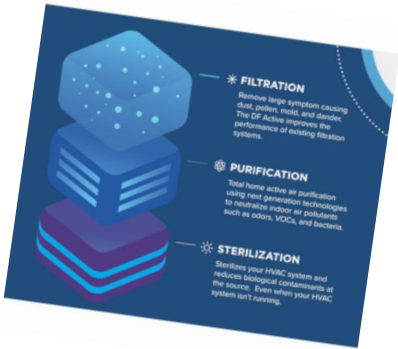


# Ventilation Guidance Additive Technologies

## A Note of Warning



<https://ultraviolet.com/ultraviolet-air-ozone-generator/>



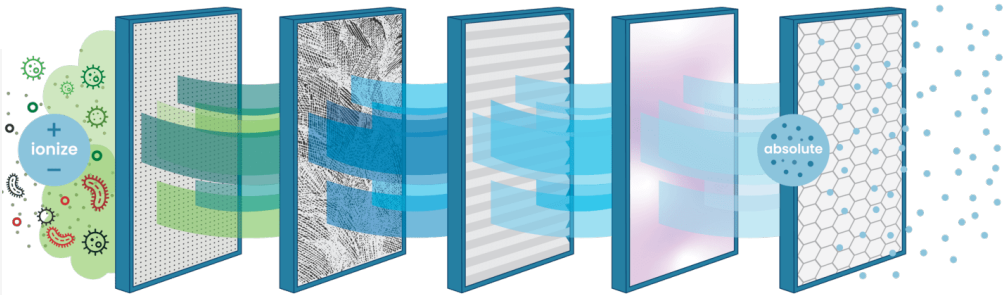
### Stage 1 Of 5: Negative Ionization & Pre-Filter

ionize

Negative ionization attracts air particulate & clumps them together for easier capture during the filtration process.

clumps particles

Clumps together small particles



<https://www.sanalifewellness.com/air-purifier-technologies/multi-stage-air-filtration>

### Stage 4 Of 5: Photocatalytic UV-C (PCO Technology)



UV-C light activated by a titanium dioxide catalyst results in the removal of viruses & bacteria.



Bacteria, mildew, & mold spores (airborne)



Viruses (airborne viral particles)



Airborne microorganisms

# Ventilation Guidance

## Additive Technologies

**EPA and others have investigated a wide variety of additive air cleaning technologies**

### **Some of the Concerns:**

- Generation of other airborne contaminants of concern (secondary contaminants)
  - Volatile Organic Compounds
  - Reactive intermediates such as hydroxyl radicals
  - Particulate matter
  - Ozone
  
- Non-standardized testing procedures for effectiveness of the technologies
  
- Manufacturer testing does not consider secondary contaminants

# Ventilation Guidance Additive Technologies

## Literature Review of Electronic Air Cleaners (CARB White Paper, 2023)

- **Reviewed operating principles of electronic cleaners**
  - Ion generators (unipolar/bipolar needlepoint ionization, corona discharge, plasma generator)
  - Electrostatic precipitators
  - Photocatalytic oxidation (dry hydrogen technology)
  - Ultraviolet Germicidal Irradiation
  - Hypochlorous acid
  - Nano-confined catalytic oxidation
- **Identified reactive compounds and chemical byproducts associated with use**
- **Identified adverse health effects associated with these compounds and byproducts**

<https://ww2.arb.ca.gov/sites/default/files/202309/CARB%20White%20Paper%20Final.pdf>

# Ventilation Guidance Additive Technologies

## Literature Review Findings

- **Identified byproducts that are of clear health concern:**
  - Ozone (respiratory tract inflammation, asthma aggravation)
  - Formaldehyde (carcinogen and respiratory irritant)
  - Ultrafine particles (pulmonary inflammation, blood pressure changes, asthma aggravation)
  - These compounds are an indicator of general byproduct production; other compounds have been identified.
- **Safety regulations only exist for ozone**
- **Risk versus benefits of electronic air cleaners have been inadequately studied**

# Ventilation Guidance Additive Technologies

## Literature Review Findings

### White Paper Conclusion:

Only use mechanical filtration technology or devices compliant with UL 2998 (less than 5 ppb ozone emission)

# Ventilation Guidance

## Key Reminders

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- **Periodic Testing and Balancing is Important**
  - Done by certified HVAC contractor
  - Done after any system modification
- **Conduct Timely Preventive Maintenance**
  - Should be on a set schedule
- **Conduct Periodic Visual Inspections**
  - Air handling unit-inside and outside
  - Inside rooms

# Ventilation Guidance

## Key Reminders

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### Preventive Maintenance Is Important!!



When filter changes aren't timely

- Lack of air flow/IAQ complaints
- Harder to pull air through them
- HVAC fans can burn out

Changing filters is cheaper than replacing fans!

When fan belts break:

- Fan doesn't work- lack of air flow
- IAQ complaints
- Lack of confidence in maintenance



# Ventilation Guidance

## Key Reminders

- **Look at Air Intake**
  - Is it near a source of air pollution?
    - Above an exhaust vent?
    - Below the roof and next to a parking garage?
  - Is there mold growth?
    - Check for excessive mold growth on roof near intake





# Ventilation Guidance

## Key Reminders

### Look Inside Air Handling Unit - Proper Installation of Filters is Critical

Is filter seated properly in frame

Look for cracks in seams-  
places for air to bypass filter



# Ventilation Guidance

## Key Reminders

### Other Places to Look Inside the Air Handling Unit

- Look at Coils



- Look for standing water, rust, and mold in drain pan



# Ventilation Guidance

## Key Reminders

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### Inspections Inside of Rooms



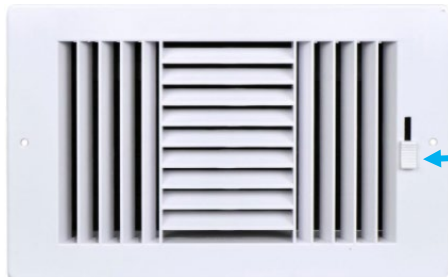
- Are you blocking ceiling diffusers?
- Is furniture blocking wall diffusers?

# Ventilation Guidance

## Key Reminders

### Inspections Inside of Rooms

Are return grills blocked/dirty?



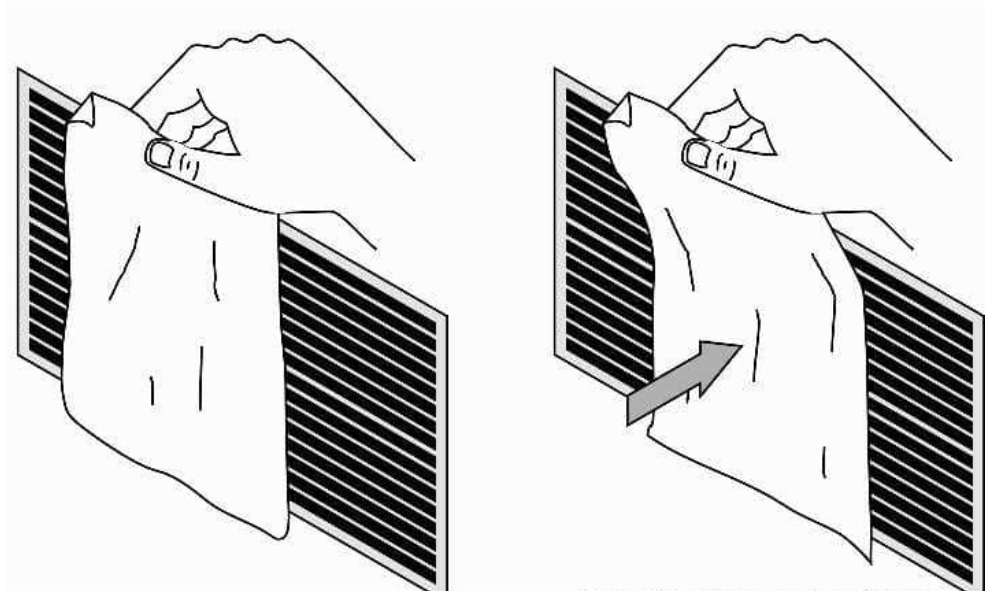
Is adjustable damper closed?

# Ventilation Guidance

## Key Reminders

### Inspections Inside of Rooms

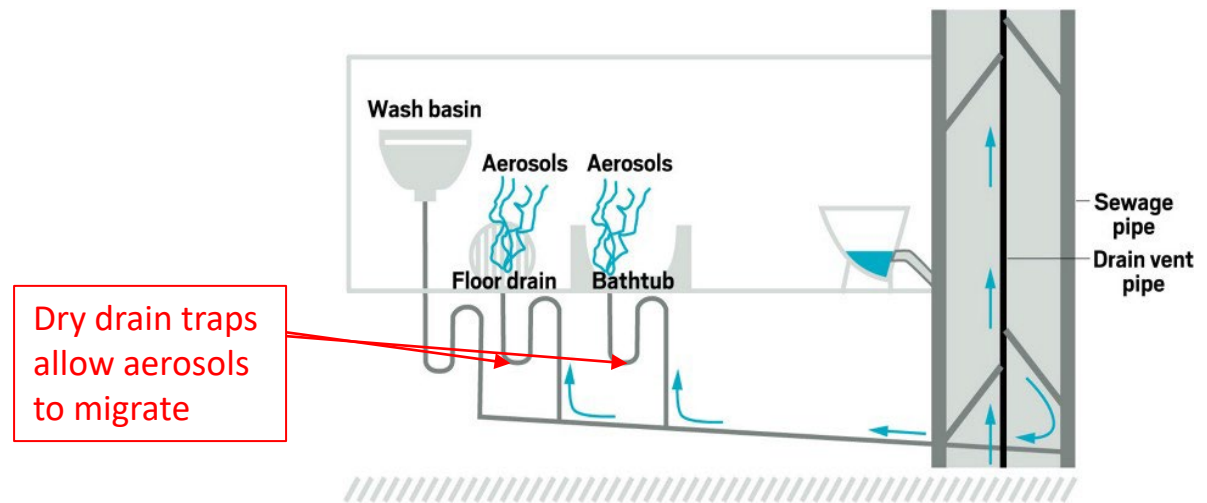
Can you detect air movement? (tissue test)



# Ventilation Guidance

## Key Reminders

- Maintain relative humidity between 40 and 60 percent
- Keep restroom exhaust fan ON at all times when building is occupied.
- Keep water in drain traps



# Ventilation Guidance Summary

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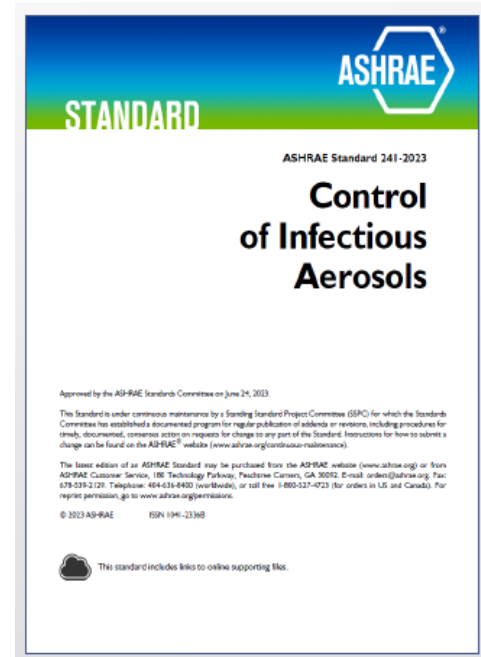
- Have ventilation system checked and balanced by an HVAC engineer
- Provide MERV 13 filtration on HVAC system
- Open windows and doors to the extent possible to enhance dilution
- Increase outside air
- Consider CO<sub>2</sub> monitoring
- Supplement with portable HEPA filters if necessary
- Conduct periodic inspections of indoor environment
- NO additive technologies such as ozone, electrostatic precipitators, ionizers, negative ion air purifiers

# ASHRAE Standard 241

## Control of Infectious Aerosols

### Overview

- Establishes minimum requirements for control of infectious aerosols to reduce risk of disease transmission
- Created to complete and codify ASHRAE Epidemic Task Force Guidance
- Created to lay foundation for readiness for next pandemic condition





# ASHRAE Standard 241

## Control of Infectious Aerosols

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### Scope

- Addresses long range (>1.5 meter from infector) infection risk
- As a prerequisite a facility must comply with the applicable version of the standard (ASHRAE 62.1, 62.2, or 170- or other approved jurisdiction standard). These standards set minimum requirements for outdoor air and filtration.
- Does NOT establish overall requirements for acceptable indoor air quality

# ASHRAE Standard 241

## Control of Infectious Aerosols

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### Definitions

**Infectious Aerosol:** Airborne particles containing active pathogens capable of causing infection

**Infectious Risk Management Mode (IRMM):** The mode of operation in which measures are implemented to reduce the level of infectious aerosols

**Building Readiness Plan (BRP):** A plan that documents the controls that a facility will use to achieve the infectious aerosol reduction goals

**Equivalent Clean Airflow (ECA):** The flow rate of pathogen-free air (same concept as ACHe and NADR)

# ASHRAE Standard 241

## Control of Infectious Aerosols

### Comparing ASHRAE Standard 62.1 to 241 for Classrooms

	<u>ASHRAE 62.1</u>	<u>ASHRAE 241</u>
cfm/person	15	40 (ECA)
air changes/hour	3	10.5

# ASHRAE Standard 241

## Control of Infectious Aerosols

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### How Does ASHRAE 241 Achieve these Ventilation Rates?

- Considers contribution of removal of infectious aerosols by means other than outside air dilution.
- Provides equations for calculating the additional clean air provided by other technologies
  - Filtration
  - Other additive technologies\* (discussed previously)
- Provides appendix outlining procedure to test effectiveness of additive technologies

*\*Has interesting caveat stating that mentioning of these technologies does not imply endorsement.*

# ASHRAE Standard 241

## Control of Infectious Aerosols

### Some concerns with this Standard:

- Criteria for switching to Infectious Risk Management Mode (IRMM) are not included- leaving that to Public Health or other Entities
- Does not consider indoor air quality concerns other than particulate
- Mentions air cleaning technologies that are still being evaluated for safety
- Increased ventilation rates will only be applicable when IRMM status is determined.

### Current Status of this Standard:

- Has not been incorporated into building codes yet
- Waiting for ANSI approval/certification of technology testing appendix

# Resources

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[Ventilation and Air Quality for Reducing Transmission of Airborne Illnesses \(wa.gov\)](#)

[CDC Guidance: Ventilation in Buildings](#)

[Lancet COVID-19 Commission Task Force: NADR for Reducing Exposure to Airborne Respiratory Infectious Diseases](#)

[EPA Clean Air Buildings Challenge](#)

# Questions??

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Thank you

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