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The Definitive Guide to

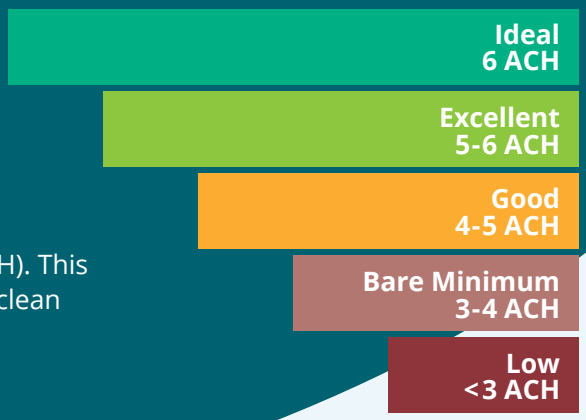
Improving Classroom Air Quality for COVID-19 Mitigation

Introduction

In classrooms across the country, air quality is an area of focus for COVID-19 risk mitigation. In October, the CDC updated its COVID-19 guidelines to acknowledge what many scientists and indoor air quality (IAQ) experts have suggested for months — airborne transmission of the novel coronavirus can occur in enclosed spaces. As a COVID-19 risk mitigation strategy, experts have established a target number of air changes per hour (ACH) for classrooms to help ensure the safety of students, teachers and staff during the pandemic. In this paper, we explain how schools can establish their benchmark ACH and discuss different approaches for boosting ACH to achieve recommended targets including supplemental in-room HEPA air cleaners.

Target Air Change Per Hour

The Harvard T.H. Chan School of Public Health recommends classrooms achieve at least **5 total air changes per hour** (ACH). This means that the air inside a classroom will be exchanged with clean air one time every 12 minutes.



There are two ways to achieve this ACH target:

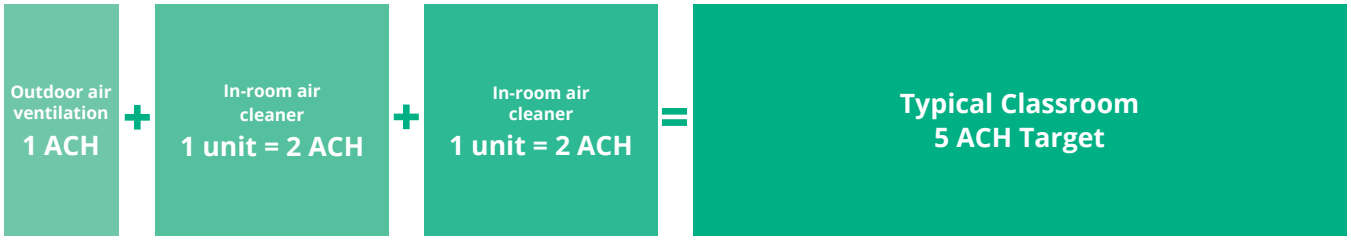
1) **Air changes from outdoor air ventilation** – can be mechanical (HVAC system) or natural (open windows or doors); or

2) **Air changes from recirculated air that is cleaned** – can be done by filtering air centrally by the HVAC system or using in-room fixed or portable HEPA air cleaners

These approaches can be additive, meaning that schools may rely on a combination of methods to achieve the target ACH in the classroom. For example, outdoor air ventilation of 1 ACH + air cleaning of 4 ACH = the target of 5 ACH.

One can also install multiple in-room air cleaners in a classroom to achieve a higher ACH. For example, installing 2 air cleaners, each with 2 ACH = 4 ACH total.

> ***"Standalone high efficiency particulate air (HEPA) filtering devices can be used to supplement outdoor air ventilation supplied through HVAC systems in order to achieve equivalent air exchange rates capable of significantly reducing infectious aerosol concentrations in workplaces and offices."***
>
> — American Industrial Hygiene Association, Reducing the Risk of COVID-19 Using Engineering Controls



What is an in-room air cleaner?

An in-room air cleaner is a device that is installed in a room or space independent of any HVAC system. In-room air cleaners pull air from the space, run the air through a series of filters, and send the air back into the space. In-room air cleaners may be fixed (e.g., ceiling mounted) or portable and go by many different names including portable, local or standalone air cleaners or purifiers, HEPA filters, and recirculation units.

In-room air cleaning devices provide additional air cleaning capacity on top of MERV13+ filters that may be installed on the main HVAC system. HVAC system filters with a rating less than MERV13 are not recommended for capturing the COVID-19 virus.

Note: Minimum Efficiency Reporting Values, or MERVs, report a filter's ability to capture particles between 0.3 and 10 microns. The higher the MERV rating on a filter, the fewer particles can pass through it.

How to Establish Your ACH Baseline

The design standard for minimum outdoor air ventilation in classrooms is approximately 3 ACH (slightly less for 5-8 year old students and slightly more for 9+ year old students), but many classrooms don't meet the minimum. In fact, research by the Harvard School of Public Health shows that a typical classroom has 1.5 ACH and many schools with poor ventilation have 1 ACH or less.

Harvard's 5 Step Guide to Checking Ventilation Rates in Classrooms can be used to calculate your ACH baseline. If a school is unsure of their current ACH, the Harvard guide recommends using 1 ACH.

How to Bridge the Gap to the Target ACH

If a school's baseline is well below 5 ACH, the first question might be, "Can't we just open the windows?" Opening windows can help increase air changes, but the amount of air that comes inside depends on outdoor winds, temperature gradients, and whether fans are used to exchange air. Additionally, when opening windows, schools need to consider outside noise and other environmental factors such as pollution and smoke as well as heating energy costs in colder months.

If a school has an HVAC system, cleaning of recirculated air may be achieved by installing high efficiency filters on the HVAC system. ASHRAE recommends MERV13 filters or higher for COVID-19 mitigation. If MERV13 filters cannot be installed due to HVAC system limitations, then ASHRAE recommends increasing the filtration to the maximum possible and supplementing with local HEPA filters.

ACH is calculated as cubic feet per minute (CFM) or airflow x 60 minutes / cubic feet for space. For recirculated air, CFM must be multiplied by the capture efficiency of the filter being used. 85% capture efficiency should be used for MERV13 filters. By definition, HEPA filters have 99.97% capture efficiency.

"Just opening a window is unreliable because of the dependence on other driving forces like pressure. Opening one window may not do anything for you. You may have air going out instead of coming in."

— Dr. William Bahnfleth, Chair, ASHRAE Epidemic Task Force, Professor of Architectural Engineering, Penn State

"Opening windows is not a panacea and doesn't mean we should not pursue other strategies."

— Dr. Joe Allen, Harvard T.H. Chan School of Public Health

How to Achieve 5 ACH in Each Classroom:

Is the space served by an HVAC system?

Yes

- Ensure required minimum outside air as per ASHRAE 62.1 (design standard for classrooms is ~3 ACH but actual often 1-1.5)
- If possible, install ≥MERV13 filters on the HVAC system for recirculated air (can add up to 6 ACH from recirculated air)
- Check if total ACH is ≥5 ACH
  - **Yes**
    - Perform required maintenance to ensure consistent performance
  - **No**
    - Supplement with in-room air cleaners to achieve ≥5 ACH
    - Perform required maintenance to ensure consistent performance

No

- If possible, open windows to increase ACH when winds and temperature gradients make possible (no reliable ACH)
- If possible, install window fans to force natural ventilation air changes (1-3 ACH may be possible if fans run continually)
- Install correct number of in-room air cleaners in a central location to achieve ≥5 ACH
- Perform required maintenance to ensure consistent performance

I Need a Supplemental In-Room Air Cleaner. What are My Options?

The good news is that solutions exist for schools to quickly and cost effectively boost their ACH. What's tricky, however, is that not all of these solutions are created equal. There are two types of in-room air cleaners: fixed and portable. Choosing the right solution for your school depends on whether you are looking for a long- or short-term fix for the problem and your budget parameters.

Fixed units, which are mounted to the wall or ceiling, are more expensive to install but are a permanent, long-term investment to not only help mitigate COVID-19 risks today, but also help reduce the risk of airborne viruses in years to come. On top of that, fixed units are proven to deliver better performance than portable units.

Portable units, which sit on the floor or any flat surface in the classroom, are often more affordable because they involve no installation costs. Just plug the cord into the wall to operate. However, portable units are more temporary and harder to track, take up valuable space in the classroom, are often loud and create distracting noise, present trip hazards from cords, are often lower powered (requiring multiple units in a typical classroom), and are not as effective due to their placement.

According to the CDC's **Guidelines for Environmental Infection Control in Health-Care Facilities (2003),** the effectiveness of the portable unit for particle removal is dependent on:

- the configuration of the room
- the furniture and persons in the room
- the placement of the units relative to the contents and layout of the room
- the location of the supply and exhaust registers or grilles

"With respect to air cleaners for airborne pathogens, there is a very clear hierarchy of performance. At the very top, we find ceiling-mounted filtration systems that allow for a very high level of control in specific areas because they are ducted and unobstructed by objects in a room. This is extremely important for issues like COVID-19, where aerosolized viruses can be removed at the source. The next level down is portable filters, which are 20-50% less effective than their ceiling mounted counterparts mainly due to challenges with placement in a space. Last is traditional central filtration systems, which force virus particles to travel a long distance prior to being removed."

— Raefer Wallis, Founder of RESET

Any restrictions of airflow from a portable unit can significantly compromise performance. This is why the CDC says,

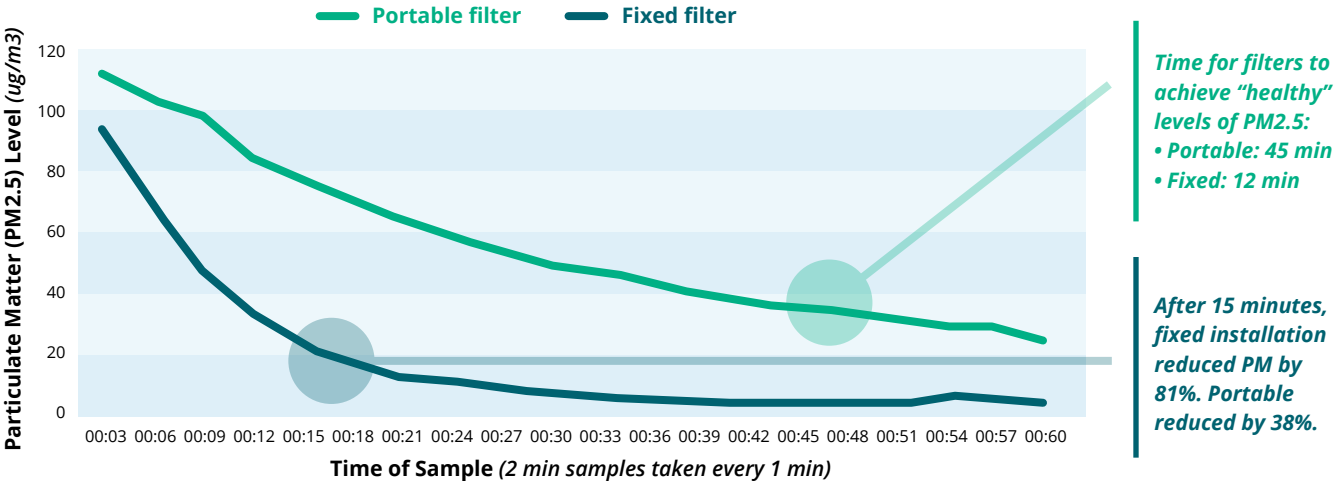
"Fixed recirculation systems are preferred to portable (free-standing) units because they can be installed with a higher degree of reliability…and the potential for short-circuiting of air is reduced as the distance between the air intake and exhaust is increased."

A report on air cleaning technologies by the Ontario Health Technology Assessment Series said that,

> ***"Because airflow patterns within a room affect the effectiveness of in-room air cleaners, fixed in-room air cleaning systems are preferable to portable ones, because they more reliably achieve adequate room air mixing and airflow patterns if installed properly."***

These findings are supported by side-by-side comparison testing between ceiling mounted and portable filters, which showed that ceiling mounted units clean the air more quickly and more effectively because of optimized air flow. The speed of air cleaning is important for schools where classes typically last around one hour. Having clean air only by the end of the class does not solve the COVID-19 risk mitigation problem at hand.

PM2.5 Levels Recorded Within 1 Hour



Based on testing by PureLiving Indoor Environmental Solutions

The above chart shows relative performance of a portable and fixed in-room air cleaner for fine inhalable particulate matter with diameters that are 2.5 micrometers and smaller (PM2.5), or 30 times smaller than the average human hair and smaller. The chart shows that ceiling mounted units can clean the air more quickly and more effectively because of optimized air flow.

Portable vs Fixed Air Cleaners

Portable	Fixed
Placement is key - may blow air across the breathing zone (not ideal)	Superior performance based on placement for optimal air flow
Can be easily removed from the space (good temporary solution)	Becomes part of the building infrastructure (good long-term solution)
Requires desk or floor space and power cords	More space efficient - does not require desk or floor space and no cords
Noise may be an issue - varies by model	Quieter than most portable units due to placement and ducting
Multiple units may be needed depending on space size	Higher powered than many portable filters (only 1 per classroom)
Less reliable performance because settings can be easily manipulated	More reliable performance with remote monitoring and control (some models)
No installation cost (just plug them in)	Typically requires a contractor to install, which adds cost
At scale, difficult to track units and manage filter replacements	Fixed units are easier assets to track and maintain

What's the Best Solution for You?

Fixed in-room ceiling mounted HEPA air cleaners are much more effective and work faster than portable HEPA filtration units. If a school chooses to use portable air cleaners, placing the unit(s) in the center of the classroom is the ideal location. If this is not possible, choose a location in which the flow out of the portable unit does not blow directly into occupants.

How Many In-Room Air Cleaners Are Needed?

The Portable Air Cleaner Calculator for Classrooms developed by the Harvard Healthy Buildings team and Dr. Shelly Miller at University of Colorado Boulder is a helpful tool to determine the number of in-room air cleaners needed for your classroom size to meet the 5 ACH target.

What about Noise Levels?

Sound is an important consideration for anything added to the classroom learning environment. If the in-room air cleaners are too loud at the optimal fan speed, there is a risk that teachers will turn them down or off or only run them in between classes, which defeats the purpose of having in-room air cleaners in the first place.

Standard	NC Level (NC)	Sound Level (dBa)
ANSI Standard S12.60	25	35
WELL Classroom	25-40	35-45

In the US, sound is described in NC (Noise Criterion) or dBa (A-weighted decibels). ANSI Standard S12.60 for Classroom Acoustics says the maximum level of background noise for an unoccupied, furnished classroom should be 35 dBa, which is equivalent to a NC rating of 25. The WELL standard recommends average dBa for classrooms of 35-45, which is equivalent to NC of 25-40.

When purchasing in-room air cleaners for classrooms, be sure to check the NC or dBa level for the unit at the fan speed necessary to achieve the target ACH. If multiple in-room air cleaners are required, then sound levels should be added together to get the total sound rating for the solution being considered.

Many in-room air cleaners exceed the recommended sound levels, so school administrators should look for the quietest options available while also considering performance in terms of ACH delivered.

Where the air cleaner is placed in the classroom also has an impact on whether noise from the unit will be a disruption. The closer the air cleaner is located to students, the more disruptive the sound from the air cleaner will be. A benefit of fixed units over portable devices is that fixed units can be mounted to the ceiling or installed in a ceiling plenum with duct work and sound attenuation that will make the air cleaner quieter and less disruptive.

A Note on Other Air Cleaning Technologies

There are many other air cleaning technologies on the market, including those using photocatalytic oxidation, photoelectrochemical oxidation, electrostatic precipitation, and various ionization technologies including bipolar ionization. In most cases, these products have not been tested by independent parties and/or lack test standards to assess their performance.

ASHRAE's Position Document on Filtration and Air Cleaning states, "At present, there is only significant evidence of health benefits for porous media particle filtration systems. For a few other technologies, there is evidence to suggest health benefits, but this evidence is not sufficient to formulate firm conclusions. A key position is that filtration and air-cleaning technologies are not recommended for use if they produce significant amounts of contaminants [such as ozone] that are known or expected to be harmful for health."

With respect to bipolar ionization, ASHRAE Building Readiness Guide adds, based on CDC feedback, "Relative to many other air cleaning or disinfection technologies, needlepoint bi-polar ionization has a less-documented track record in regard to cleaning/disinfecting large and fast volumes of moving air within heating, ventilation, and air conditioning (HVAC) systems. This is not to imply that the technology doesn't work as advertised, only that in the absence of an established body of evidence reflecting proven efficacy under as-used conditions, the technology is still considered by many to be an 'emerging technology'".

Next Steps:

A Buyer's Checklist for In-Room Air Cleaners

Once you have made the decision to purchase an in-room air cleaner, make sure it:

- ☐ Is HEPA rated (at least 99.97% efficient down to 0.3 microns)
- ☐ Delivers sufficient airflow (CFM) to achieve at least 5 ACH for the space intended (may require more than one in-room air cleaner in each classroom)
- ☐ Can be centrally located in the space for optimal effectiveness (ceiling mounted is ideal)
- ☐ Has acceptable sound levels (not more than 50 dBa) at the fan speed necessary to achieve the target ACH
- ☐ Has settings that cannot be easily manipulated by students or teachers to ensure reliable performance
- ☐ Will meet your needs during the current pandemic and future pandemics (long term solution)

Glossary of Terms

ACH: Air changes per hour. 1 ACH means the air inside a space is exchanged with clean air on average 1 time per hour. ACH is calculated as CFM x 60 minutes / cubic feet for space. For recirculated air, CFM must be multiplied by the capture efficiency of the filter being used.

ASHRAE: A globally recognized professional society of over 55,000 members that develops standards and recommendations for building operation. ASHRAE has established a Task Force to help deploy technical resources to address the challenges of the COVID-19 pandemic and possible future epidemics as it relates to the effects of heating, ventilation, and air-conditioning systems on disease transmission. More information can be found at https://www.ashrae.org/covid19.

CFM: Cubic feet per minute. Used to describe how much supply air (both outside air and recirculated air) is coming into a space.

HEPA: High efficiency particulate air. HEPA rated filters remove more than 99% of airborne particles regardless of the particle size.

MERV: Minimum efficiency reporting value. A rating that reflects the efficiency with which a filter can collect particles in different size ranges in a single pass. The higher the number, the better filtration a room will have. Many HVAC systems are built to run MERV8 filters that allow air to flow faster with less resistance. But this higher flow comes at a cost: They trap only 40% of particles in the 1-micron size. On the other hand, if the system can handle the resistance of a MERV13, the filtration is significantly improved. ASHRAE and other experts recommend at least MERV13, which has 85% efficiency or more for a 1-micron particle.

Ventilation Rate: The volume of outside air plus any recirculated indoor air that has been treated for the purpose of maintaining acceptable indoor air quality. Ventilation rates are defined in terms of cubic feet per minute (CFM).

Additional Resources:

Risk Reduction Strategies for Reopening Schools
Harvard T.H. Chan School of Public Health

5 Step Guide to Checking Ventilation Rates in Classrooms
Harvard T.H. Chan School of Public Health

Harvard-CU Boulder Portable Air Cleaner Calculator for Schools.v1.2
Harvard T. H. Chan School of Public Health

Reducing the Risk of COVID-19 Using Engineering Controls
American Industrial Hygiene Association

One Page Guidance for Reopening Schools
ASHRAE

Reopening Schools & Universities Guide
ASHRAE

About enVerid

enVerid helps buildings achieve ESG (Environmental, Social, and Governance), healthy building, and cost saving goals by improving indoor air quality while saving money and reducing energy consumption and carbon emissions. The companies porfolio of air filtration products remove particulate and microorganism contamination from indoor air without the significant cost of upgrading mechanical systems and increasing mechanical ventilation rates.

The **enVerid Air Purifier** is an in-room, ceiling-mounted True HEPA air cleaner with optional UVC lamps that captures 99.99% of viruses. It helps buildings cost-effectively boost air change rates four to five times an hour to meet industry recommended best practices to improve indoor air quality. Unlike temporary portable air filters that are noisy and distracting, use valuable floor space, present trip hazards from electrical cords, and are difficult to track and manage because they are easy to unplug and move, the enVerid Air Purifier is a permanent, optimally-placed solution that is quiet and easy to operate and manage at scale. Multiple health authorities including the CDC have stated that fixed recirculation systems such as the enVerid Air Purifier are preferred to portable filters because they can be installed with a higher degree of reliability and because they more reliably achieve adequate room air mixing and airflow patterns due to the distance between the supply and return grills.

To Learn More:

For additional questions about improving classroom air quality for COVID-19 mitigation, contact enVerid through your preferred channel.

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