

# Ventilation for Coronavirus in the Workplace

What workers need to  
know and what they can  
do



People's  
CDC

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# Table of Contents

## What Workers Need to Know

|   |         |
|---|---------|
| Air Quality Matters                                   | page 3  |
| Types of Ventilation System                           | page 6  |
| What About Windows?                                   | page 7  |
| HVAC systems may be poorly designed and/or maintained | page 8  |
| Do-it-yourself filtration units                       | page 10 |

## What Workers Can Do

|                 |         |
|-----------------|---------|
| Recommendations | page 11 |
|-----------------|---------|

## Appendices

|  |         |
|--|---------|
| Diagram of HVAC and Unit Ventilators   | page 19 |
| Actual Ventilation numbers: How much filtration? How many air changes? How much outside air? How do you measure airflow? | page 20 |
| The Corsi/Rosenthal DIY Air Purifier Design- to use or not to use?   | page 26 |
| What to look for on a walk through and what to ask   | page 31 |

## References

page 34

## Notes

page 36

## Air quality matters

Air quality is an important piece of the puzzle for protecting the health of people at their workplace. The purpose of a ventilation system is to provide clean air at a comfortable temperature and humidity. A broken or inadequate ventilation system can result in air that is polluted and/or at uncomfortable temperatures and humidity. People experiencing poor air quality know (and many studies have confirmed) that poor air quality has consequences for worker health (Ref 1) as well as for performance and productivity (for example, Ref 2). But indoor air quality and ventilation are more important than ever during the pandemic for two reasons: 1) infected building occupants are the source of pollution, and 2) some of the particles containing virus are much smaller than most pollutants and require higher quality filters and more fresh air to dilute them than most pollutants.

Note, this article does not apply to workplaces with special contaminant issues, such as healthcare settings and industrial or manufacturing workplaces that use or generate toxic pollutants. It is focused on other workplaces, such as offices or retail locations. Of course in any workplaces in which employees are in the presence of many other people—coworkers or customers—ventilation is not enough to protect workers from potentially infected people. High quality masks, social distancing and vaccinations/boosters are also essential protective measures.

Ventilation can help in two ways: **diluting** the virus with fresh air flowing through the room and **filtering** the air. Indoor air may contain many more pollutants than the Coronavirus, including indoor sources, such as asbestos, mold, dust from renovation and cleaning supplies, as well as outdoor sources, such as pesticides used on the grounds, pollutants from vehicles, wildfire smoke and construction debris. This article is addressing primarily the virus—and any future respiratory viruses. If ventilation is upgraded to address the virus, it will address other pollutants as well.

We now know that social distancing is not enough to protect people from the virus – the CDC recommendation for social distancing of 6 feet was based on early confusion about how the virus moves in air. While it is true that large virus-containing droplets do fall to the floor on average within about 6 feet from an infected person, they can be projected much further (Ref 3). Later it became clear that much smaller droplets, called aerosols, are produced just by breathing (and more are produced by talking, laughing or singing). The aerosols are so lightweight that they don't fall to the ground. Rather, they can float in the air for hours (Ref 4), unless diluted with outside air or trapped in a filter. In addition, a 2021 study showed that the smallest aerosols contain the greatest amount of viruses (Ref 5). That makes both filtration and dilution with fresh air more important than ever.

## Types of ventilation systems

Many buildings have a heating, ventilation and air conditioning (HVAC) system that delivers air to rooms all over a building via ducts. The HVAC system is supposed to filter, heat or cool the air and control humidity before blowing air into rooms. Some percentage of the air delivered should be clean outside air, and some may be recirculated room air. It is very important that as large as possible a percentage of that air be outside air.

Other buildings may have a heating/air conditioning unit in each room, or a combination of HVAC and room units. Individual room units vary widely. They may or may not admit outside air, and they may or may not have filters other than a bit of foam to keep dust out of the heating coils, similar to what you find in your home air conditioner. Similarly, window air conditioning units don't have filtration and don't admit outside air. None of the above mentioned units control humidity. Thus only an HVAC system truly provides ventilation. This article will address HVAC systems only, because there are too wide a variety of room units to address. (See **Appendix 1** for a diagram of an HVAC system)

## What about windows?

In buildings which lack an HVAC system, you hear a lot that opening windows is a quick fix solution. They can help by providing fresh air, but they are a limited solution and ***never* should be relied upon by themselves for ventilation** for COVID. The primary reason is that they do not provide filtration. Several additional reasons include: they can only be used if outdoor temperatures are moderate, and their effectiveness depends on weather conditions, such as wind; if a building is located on a street with heavy traffic or other pollution sources, opening windows may bring in pollution and noise; if the windows lack screens mosquitoes may enter, which could be a public health concern in some areas.

If windows can be used, best practices are discussed in the **Recommendations** section. Best use of windows provides *dilution* with outside air, but not filtration. That is why **open windows should be used in conjunction with portable high efficiency particulate air (HEPA) air purifiers.**

Bear in mind that the International Mechanical Code requires all occupied spaces be served by natural or mechanical ventilation that includes providing outside air (Ref 6). Sometimes rooms are “created” where they were not intended to be (like basements or supply closets), and thus have no ventilation, but these should not be occupied work spaces.

HVAC systems may be poorly designed and/or maintained

A properly designed and properly functioning HVAC system both filters air and dilutes pollutants, and provides heating/cooling and humidity control. But poor design, operation issues and/or lack of maintenance are common.

Common design issues include:

- Demand-control ventilation that automatically reduces the rate at which outdoor air is pulled into a building, often in response to temperature control or carbon dioxide monitors in ventilated rooms.<sup>1</sup>
- Outdoor air intakes are sometimes too close to exhaust outlets (from the HVAC, plumbing, kitchen, toilets or labs) or to other pollutant sources and draw exhaust or other pollutants in with the outside air.
- HVAC system can't handle filters that capture virus-containing particles.

Common operational issues include:

- Filters don't fit tightly and may allow air to bypass them.
- Reducing outside air when the weather is very hot or cold, in order to reduce heating and cooling costs. Outside air dampers may be closed entirely, especially in cold weather when they may need to be closed *only in the coldest hours* to prevent pipes from freezing. Some buildings don't have enough personnel to monitor the dampers.
- Finally, HVAC systems, like any mechanical systems, must be kept clean and in working order. Some employers do not budget enough to pay for skilled personnel or maintenance costs.

## Do-it-yourself filtration units are a last resort with many drawbacks

Some scientists have developed a DIY unit created by taping together filters in a box formation with one face of the box a fan.

Building managers should instead add filtration in the form of professionally designed and tested portable units with HEPA (high efficiency particulate air) filters. HEPA filters capture virtually all viral particles, whereas the DIY unit can capture as little as 50% of the most hazardous aerosols; because they are not enclosed, replacing filters may be hazardous, labor intensive and expensive. (Please see Appendix 3 for details on problems with DIY units.)

Here are some steps to improve ventilation in a workplace. Note, whenever the word “you” appears, it is referring to you as a group, because, as you know, it’s hard to win any changes as an individual!

- Educate yourself about good ventilation by reading this document and related references.
- Learn about the status of ventilation in your building. You can request a walkthrough of the building to learn more. If your building has an HVAC system, ask for a meeting with whoever maintains and operates the HVAC system. These individuals typically have titles such as building manager, building mechanic, service manager, furnace operator, or building engineer.
- **Appendix 4** lists what you can look for on a walkthrough and questions to ask at a meeting.
- Using the Recommendations below as a guide, prioritize the improvements you want, get more people together, and present your priorities to your employer.

## Recommendations

1. All occupied spaces should be provided with portable air purifying units with HEPA (high efficiency particulate air) filters. Only if an HVAC can use HEPA filters (which very few can) *or* provide at least 6 air changes per hour of 100% outside air, are the HEPA air purifying units not needed. (See **Appendix 2** for details on filters and air changes.)
2. Seek to maintain relative humidity between 40 and 60%, which may reduce the potential for airborne viral transmission.
3. Inspect and maintain exhaust ventilation systems in areas such as kitchens, cooking areas, etc. Operate these systems any time these spaces are occupied. Operating them even when the specific space is not occupied will increase overall ventilation within the occupied building.
4. Ensure that restrooms are under negative pressure—that is, air always flows into the restroom and is exhausted to the outside of the building. The exhaust fan should be on all the time. Be sure airflow into the restroom does not interfere with the ventilation of adjacent spaces.

5. Ensure that any free-standing fans or air purifying units are not blowing air from one person's breathing zone directly into the breathing zones of other persons nearby. Having the purifying unit blow upwards accomplishes this.

## **6. Buildings with HVAC Systems**

A) Ensure that the HVAC system is working as designed. Ensure that the HVAC system complies with or exceeds appropriate codes, standards, guidelines, and supplier instructions.

B) The Ventilation System in combination with HEPA air purifiers must provide 6 air exchanges per hour of outside air plus HEPA-filtered air to be effective at reducing the spread of the Coronavirus by aerosols produced by an infected person. Note that many engineers calculate air changes to include all the outside air plus recirculated air. But that's not what you need to know. Be sure to ask the rate of outside air plus HEPA-filtered air!

C) Disconnect from the HVAC system any device that operates the fan or outdoor air louvers in response to CO2 levels or temperature. Instead, operate outdoor air louvers manually or remotely. Alternatively, it may be possible to set the louvers to deliver a set minimum of outside air.

D) In buildings where the HVAC fan operation can be controlled at the thermostat, set the fan to the “on” position instead of “auto,” to operate the fan continuously, even when heating or cooling is not required.

Ensure that the ventilation system brings in as much outdoor air as the HVAC system will safely allow.

E) Ensure that the HVAC system uses the highest efficiency filters the system can handle (MERV 13 or higher, if possible). The outside air setting should compensate for having MERV 13-16 filters, by adding 20 to 40% outside air, preferably 40%.

If HEPA filters are used, outside air can be set at 20% for comfort.

F) Ensure that filters are sealed in place using tape, clamps, gasket or other methods, to prevent contaminated air from leaking around the filter, and test for air leaking around them.

G) Start the ventilation system at nominal speed at least 2 hours before the building usage time and switch to lower speed 2 hours after the building usage time. This will help flush any contaminants before and after occupants enter the building (Ref 8).

H) Ensure that the HVAC system is checked, inspected, cleaned, and maintained on a regularly scheduled basis. System performance (for example, airflow rates) should be checked regularly. Filters should be changed about every 3 months. For further guidance, consult ASHRAE's May 2021 Epidemic Task Force document, found in Ref 8.

I) Consider checking airflow regularly, perhaps weekly, either by occupants using the tissue test or by facilities personnel. (The tissue test means holding a tissue in front of an intake vent to see if the air blows the tissue away from the vent, or an exhaust return to see if the tissue is sucked toward the return). If handheld CO<sub>2</sub> monitors are used, consider that they cannot prove good HVAC function: Since CO<sub>2</sub> is produced by room occupants, a low reading may reflect few people in the room, rather than good HVAC function. Airflow measurements are a much more reliable measure of HVAC function.

J) Ensure that air supply and return louvers in the rooms, as well as outdoor air intake louvers are open, clean, and operating properly.

K) Take steps to ensure that outdoor air sources are not located near sources of contamination, including exhaust from the HVAC, kitchens, toilets or labs, stored chemicals or very dirty areas.

## 7. For Buildings relying on windows

A) Ensure that windows alone are not relied upon as the sole source of ventilation. **Windows should be used in conjunction with portable HEPA air purifiers.**

B) Consider how best to use windows to contribute to ventilation.

C) When windows are used for ventilation, they are most useful if two windows on two different walls are used, providing cross ventilation.

Similarly, opening a window and a door on an opposite wall can improve circulation (depending on whether the door opens into a space with clean, circulating air).

D) If a room has windows on only one wall, you can experiment with different arrangements of intake fans (blowing into the room) and exhaust fans (blowing out). Opening two windows at a distance from each other and providing an intake fan in one and an exhaust fan in the other is sometimes recommended. But they can easily short circuit each other—circulate air between the fans and not the room. You could check this with tissues to see where air is flowing. Or you could open two windows, and put an exhaust fan in one, and allow outside air to be drawn into the other. If there is an open door in the room that might draw unclean air into the room, as for example, from a bathroom or lab with a malfunctioning exhaust fan, it might be better to put an intake fan in one window.

E) If you're using pedestal or free-standing fans to increase circulation within the room, be sure to avoid blowing air from the face area of one student toward the face area of another student.

F) If windows are jammed or designed not to open, ventilation must be achieved with one or more portable air purifiers with HEPA filters. If possible, consider repairs that allow windows to open.

## 8. Avoid hazardous air cleaning methods.

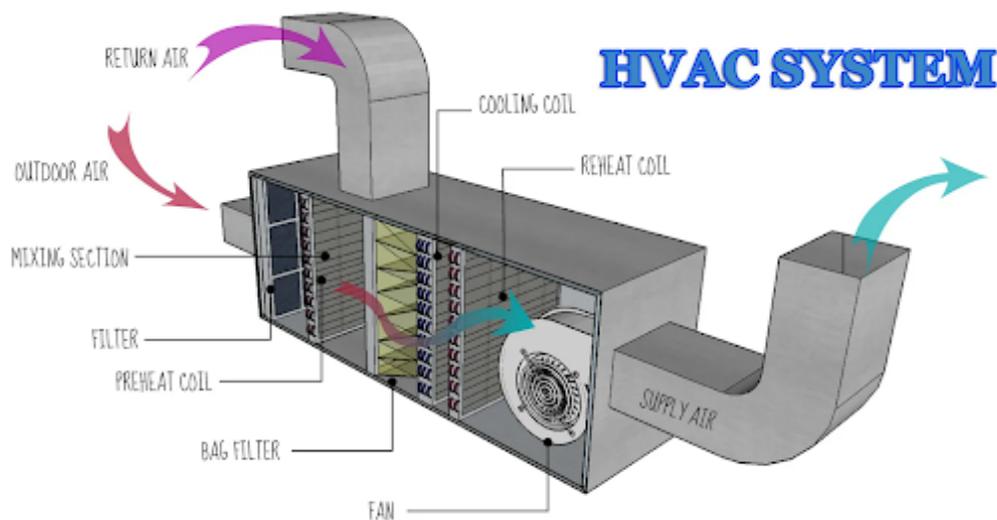
Employers should use only proven technologies for improving indoor air quality: appropriate ventilation and HEPA filtration. They should not use chemical foggers or any "air cleaner" other than filtration. Nor should they use unproven technologies such as ozone generators, ionization, plasma, and air disinfection with chemical foggers and sprays. The effect of these disinfection methods has not been tested and may be ineffective and/or detrimental to health. The primary aim for improving air quality should be to remove contaminants and impurities from the air and not to introduce new hazardous substances into the air.

**9. Avoid barriers as a protection measure.** Some employers put up barriers between employees to reduce the spread of infection. However, if you consider that aerosols containing COVID behave like smoke—they will find a route over the top, under and around barriers. You would need floor-to-ceiling barriers to prevent this. But even that is not a good idea, because *any* barrier is likely to interfere with the ventilation system and reduce its effectiveness in replacing contaminated air.

## Appendix 1

### Diagram of HVAC System

Below is a diagram of the basic elements of an HVAC system. The air handling unit takes in a mixture of room (return) air and outside air and passes it through a filter. There are louvers somewhere on the outside air and recirculated air ducts which govern the proportion of each entering the mixing section. Then a fan sends the mixed, filtered air through heating/cooling coils and out to the rooms to be ventilated. Note the HVAC in this picture has a bag filter, not a MERV 13 or higher filter recommended for virus protection.



## Appendix 2

**Actual ventilation numbers: How much filtration? How many air changes? How much outside air? And how do you measure airflow?**

### What filters should be used?

Filters are rated on their ability to capture particles by a system called MERV, or minimum efficiency reporting value, on a scale of 1 to 20. The higher the MERV rating, the better the particle capture. Ideally, HVAC systems would use MERV 17 filters, which are equivalent to HEPA, or high efficiency particulate air filters. However, HVAC systems may not be capable of using that level filter. In that case, the administration should use a minimum of MERV 13 filters, if the HVAC system can accommodate them. They remove 50-85% of particles in the virus size range. (HEPA or MERV 17 filters remove 99.97% of particles in that range.)

## Appendix 2 (cont)

### How many air changes (ACH) are needed in a room?

Engineers use air changes per hour, or ACH, to measure the amount of clean air (in the case of virus, this means outside air plus HEPA-filtered air) flowing through a space. If a room is 20 ft wide, 30 ft deep and 8 feet high, the total volume of the room is  $20 \times 30 \times 8$ , or 4800 cubic feet. One ACH would mean 4800 cubic feet of air supplied to the room per hour.

So how many ACH are enough? The group which creates ventilation guidelines respected throughout the country is ASHRAE, the American Society of Heating, Refrigeration and Air-conditioning Engineers. As of August, 2021, ASHRAE recommends for places that may contain viruses, 6 to 12 ACH. The two groups which provide guidelines for workplace ventilation, the American Industrial Hygiene Association, AIHA, and the American Conference of Governmental Industrial Hygienists, ACGIH, both say that at least 6 ACH is needed to control bioaerosols (tiny airborne particles containing viruses, or other plant or animal matter).<sup>2</sup>

## Appendix 2 (cont)

### How much outside air or HEPA-filtered air is needed?

The volume of clean air needed in a room is the sum of outside air (unmixed with recirculated room air) and air delivered by portable HEPA air purifier units in the room. To calculate how much is needed, we use CADR, or clean air delivery rate. This is just the room volume X the desired ACH. For the room described above and 6 ACH, the CADR is

$$4800 \text{ cubic feet} \times 6 \text{ ACH} = 30,800 \text{ cubic feet per hour}$$

Another way to look at outside air is to consider what percentage of the delivered air should be outside air, and then consider how long it will take each MERV rated filter to change the air:

1. AIR CHANGES PER HOUR (ACH). The minimum ACH should be 6, which can at best provide a replacement (purge) of 99% of the air in the room in 46 minutes. The more ACH, the better. An ACH of 12, for example, can at best provide a purge in 23 minutes. (Note: purge time depends on how well air coming in is mixed with air already in the room.)

## Appendix 2 (cont)

2. FILTER GRADE (MERV RATING). The minimum grade of filter should be a MERV 13 with the MERV 17 (HEPA) being ideal. (If the system will not operate with a MERV 13, the only options are to run the system at 100% outdoor air or supplement with HEPA air purifiers.)

3. THE PERCENTAGE OF OUTDOOR AIR. The percentage of fresh air should be as high as possible with minimums in the following table:

**Suggested minimum outside air (OA) at 6 ACH<sup>3</sup>**

| MRV#      | Minimum OA |
|-----------|------------|
| 17 (HEPA) | 20%        |
| 16        | 25%        |
| 15        | 30%        |
| 14        | 35%        |
| 13        | 40%        |
| <13       | 100%*      |

\*Resetting the HVAC system's fresh air intake to 100% will improve protection but can raise heating and cooling costs unsustainably. Even then, the system must provide at least 6 ACH to provide adequate protection. If the HVAC system cannot deliver 100% outside air, or cannot deliver at least 6 ACH of outside air, then HEPA filtered air purifiers are necessary in the classrooms and other occupied spaces. Unit ventilators, even when set for 100% outside air, are not powerful enough to deliver 6 ACH. They deliver 1 to 2.5 ACH, so they too must be supplemented with HEPA filtered air purifiers.

## Appendix 2 (cont)

### Summary recommendations

- Filters MERV 13-17
- Highest percent of outside air possible from HVAC system and unit ventilators, ideally conforming to the table above of MERV/Minimum OA
- Minimum of 6 Air Changes per Hour (ACH), counting only HEPA-filtered and outside air

### A note on measuring airflow

Airflow from a diffuser should be measured with an instrument called a **balometer**, which covers the diffuser with a sort of tent, and measures all the air coming through. It looks like this:



## Appendix 2 (cont)

Request the engineers conduct a study of airflow in rooms served by an HVAC. The data sheet can look like this:

| Room # | Room vol cubic feet | Supply air design, CFM | Actual Supply Air CFM | OA CFM | %OA to room | Min required ACH | Atual ACH of OA |
|--------|---------------------|------------------------|-----------------------|--------|-------------|------------------|-----------------|
| Room 1 | 23,142              | 3,150                  | 3,188                 | 956    | 30%         | 6.00             | 2.5             |
| Room 2 | 11,306              | 2,900                  | 2,944                 | 677    | 23%         | 6.00             | 3.6             |

CFM = cubic feet per minute

OA = outside air

**Note:** The ACH of outside air is very low. There is no point in calculating the ACH base on supply air, because most of the supply air is recirculated. For example, in Rehearsal room 1, only 30% is outside air, so 70% is recirculated from the room, and can't be considered part of an air change.

## Appendix 3

### **The Corsi/Rosenthal DIY Air Purifier Design—to use or not to use?**

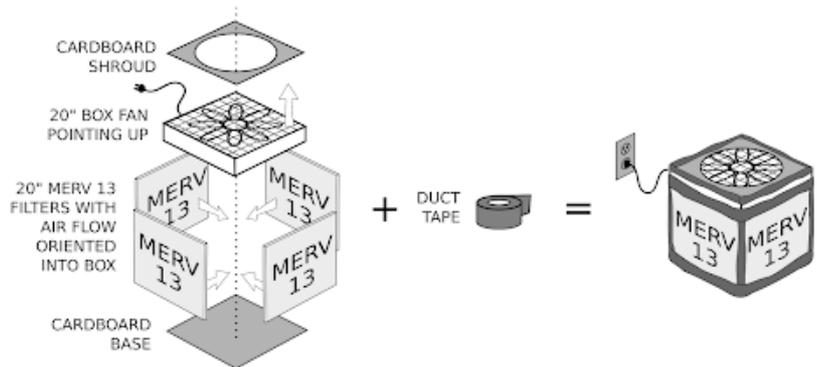
Corsi/Rosenthal boxes have gotten a lot of press as an affordable alternative to HEPA air purifying units where resources are limited. We do not recommend it for the reasons described below, and we urge building occupants to push hard for commercial HEPA units.

**Here's what the designers say (in a Twitter thread, [Ref 11](#))**

Several researchers and practitioners, working together and in parallel, have come up with a design for an in-room air purifier which can remove a significant amount of COVID-19 virus from the air. The design involves making a 'box' out of four 20" MERV-13 (or HEPA) filters (the 'sides' of the box), a 20" box fan (the 'top' of the box), and a cardboard (the 'bottom' of the box'). Air flows in through the filter sides, removing particulates of the sizes that can transport COVID-19 particles, and then flows out through the fan at the top.

These devices can be built from parts that cost less than \$100 USD, without any special tools.

## Appendix 3 (cont)



### Here are reasons *not* to use these DIY units

Below, are listed a summary of all the reasons that this system should not be used. This list may make it easier for readers to facilitate a discussion with employers and experts who advocate its use.

#1. **MERV 13 CAPTURE EFFICIENCY.** The MERV 13 filter captures only some of the aerosols in the size range of 0.3 to 3 microns in diameter (Ref 12)<sup>4</sup>. These particles are the most hazardous because 1) they stay airborne the longest, 2) they have a much higher virus load than larger particles (Ref 5) and 3) medical data and an animal study have shown that these smaller particles are also associated with more severe disease, presumably because the small particles deposit deep in the lung (the alveoli) (Ref 13). HEPA filters capture virtually all of the aerosols in that hazardous size range.

## Appendix 3 (cont)

#2. CONTAMINATED FILTERS. If there is an infected person in the room, the filter will capture the larger particles and some of the smaller virus-containing particles. However these particles are now captured on, and in, the MERV 13 filters. Unlike commercial air purifiers whose filters are inside the unit, a person who touches or who moves a DIY purifier will physically contact these filters. Filters are a reservoir for all sorts of particulate contaminants besides virus-containing particles. They may house, for example, dust, mold, allergens, asbestos, or lead dust. Any of these contaminants may be dislodged and shed into the air when the DIY air purifiers are moved around, touched, bumped into, etc. While no study has demonstrated the seriousness of the risk from such shedding, it is something to bear in mind.

#3. CHANGING CONTAMINATED FILTERS. The person breaking down the box and rebuilding the DIY air purifier may be handling four contaminated filters every 3 to 6 months, and thus may be exposed to multiple contaminants. Here are some precautions: The person should carefully bag the whole device in the room and take it outside, while wearing protective equipment. (ASHRAE recommends N95 respirators, eye protection—safety glasses, goggles, or face shields—and disposable gloves). They should then take the unit apart and dispose of the filters and tape in a bag, seal the bag and dispose of it outside. Then they can dispose of the gloves and respirator, thoroughly wipe down the fan.<sup>5</sup>

## Appendix 3 (cont)

#4. TIME AND COST. Time must be spent periodically breaking down the old air purifier, disposing of these filters, and constructing a new one from four unused MERV 13 filters and a lot of tape. The cost of a commercial HEPA air purifier and its filter replacement should be compared to the time and money to replace four MERV 13 filters.

#5. VARIABILITY OF THE FANS. There is no data on the variability of the output of the box fans themselves. These are inexpensive, mass-produced, often imported units that are unlikely to be uniform in output unless each individual unit is tested.

#6. THE CADR OF THE DIY PURIFIER MAY BE UNRELIABLE. The Corsi/Rosenthal box is a recent invention and continues to be developed and studied. Early measurements used an anemometer to measure/calculate CADR, rather than the appropriate tool, a balometer (see Appendix 2). A very recent study (Ref 23) measured the rate of particle removal, which is a better measure of efficacy. The study found the CR boxes had a high rate of particle clearance, but with many serious omissions and other problems in their presentation that make it impossible to evaluate their results. As of this writing, that study is the only peer reviewed study of CR box efficacy in the literature.

## Appendix 3 (cont)

### CONCLUSION

Buy properly manufactured and tested HEPA filter units, appropriately sized for the room they will be used in. These will capture virus-containing particles safely inside the unit and their contaminated filter can be removed and replaced with minimum contact.

## Appendix 4

### What to look for on a walkthrough and what to ask

#### Exterior of the building

1. View the outside air intakes of HVAC system(s) and note if they are close to exhaust (plumbing, kitchen, toilet, labs), or other sources of contaminants or excessive dirt, and clear of obstructions, debris or covers.
2. If there are individual room heating/cooling units, check the outside wall behind each of them to see if there is an opening, and if possible, to see if the outside air louvers are open. If you have access to chemical smoke tubes use them. If not, just use a piece of tissue, to see if air is entering the intakes (if air is entering, the tissue will be sucked against the louvers).

#### Interior of the building

Most of what you need to know about the ventilation system you will need to ask about, using the guide below. However there are a few things you can check yourself.

1. If there is an HVAC system, look at all supply and return louvers (also known as registers, grilles, and vents) to see if they are clean, open and operable. Check with a piece of tissue whether air is flowing into the room through supply vents and out of the room through returns when the system is on.
2. Check whether bathrooms, kitchens and labs are at negative pressure. This means that airflow is inward through the doors, and that windows are closed. You can check this with a tissue.

## Appendix 4 (cont)

### Document your walkthrough

Keep good documentation of your walkthroughs, correlating your findings to a map or spreadsheet, so that if certain areas are consistently not functioning properly, those areas can be more frequently checked in the future.

### Questions for HVAC and unit ventilator engineers and operators

1. Describe the building's ventilation: what buildings have an HVAC system and which rooms does it serve? Where are room ventilation units used, and are windows ever used for ventilation?
2. For HVAC systems:
  - a. What MERV filters are used? (Should be 13 or as high as HVAC can handle)
  - b. Outside air:
    - i. What percent of delivered air is from outside? (Should be as high as possible, 100% is desirable, but may drive heating and cooling costs too high). Can you verify this with an engineering report?
    - ii. Is it a demand system, that is, is it varied according to inside and/or outside temperature or indoor carbon dioxide levels? Demand or trigger systems should be disabled.
    - iii. How many air changes per hour (ACH) of **outside air plus HEPA-filtered air** are provided by the HVAC system? (should be at least 6 ACH)

## Appendix 4 (cont)

- c. Is regular cleaning, inspection and maintenance performed? How often? Is it in compliance with ANSI/ASHRAE 180-2018, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems (Ref 15)? Can you provide us with your preventive maintenance plan?
- d. How often are filters changed?
- e. Has a check been carried out to make sure the filters are sealed into place to prevent leaks of air around them?
- f. Are all supply and return louvers (also known as registers, grilles, and vents) open, operable, and is air flowing through them when the system is on?
- g. Is the relative humidity in the building maintained at 40 to 60%?
- h. Is ventilation operated at low speed for 2 hours before the building is occupied and for 2 hours after people have left?
- i. Are you willing to do an airflow study using a balometer? (show the sample Airflow Data Sheet in Appendix 2)

1. US Environmental Protection Agency (EPA), **Introduction to Indoor Air Quality**  
<https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality>
2. Harvard School of Public Health, **Office air quality may affect employees' cognition, productivity**, 2021  
<https://www.hsph.harvard.edu/news/press-releases/office-air-quality-may-affect-employees-cognition-productivity/>
3. Issakhov, et al, **A numerical assessment of social distancing of preventing airborne transmission of COVID-19 during different breathing and coughing processes**  
<https://www.nature.com/articles/s41598-021-88645-2>
4. Wang, C. *et al*, Science vol 373, No. 6558, Aug 27, 2021  
**Airborne transmission of respiratory viruses**  
<https://www.science.org/doi/10.1126/science.abd9149>
5. K.K. Coleman, et al, **Viral Load of SARS-CoV-2 in Respiratory Aerosols Emitted by COVID-19 Patients while Breathing, Talking, and Singing**, Clin Infec Disease, August 2021,  
<https://pubmed.ncbi.nlm.nih.gov/34358292/>
6. 2018 **International Mechanical Code (IMC)**, chapter 4 Ventilation  
<https://codes.iccsafe.org/content/IMC2018P4/chapter-4-ventilation>
7. Centers for Disease Control and Prevention, **Ventilation in Buildings**, summary of recent changes, June, 2021 <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>
8. ASHRAE Epidemic Task Force on Building Readiness, Updated 5-17-2022  
<https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf>
9. The AIHA released **Recommendations on Reducing Risk of COVID-19 Using Engineering Controls**, on Sept 9, 2020, which recommends 6-12 ACH <https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/Guidance-Documents/Reducing-the-Risk-of-COVID-19-using-Engineering-Controls-Guidance-Document.pdf>
10. American Conference of Governmental Industrial Hygienists (ACGIH), and the Industrial Ventilation Committee of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), **White Paper: Ventilation for Industrial Settings during the COVID-19 Pandemic**, July 2021, found in ACHIG document, COVID-19 References,  
<https://www.acgih.org/covid19/>

11. An informal collection of information, references and Tweets,  
<https://edgecollective.io/airbox/>
12. MERV/ASHRAE 52.2 Vs ISO 16890 Efficiency Charts,  
<https://www.energysmartfilters.com/merv-ashrae-52-2-vs-iso-16890-efficiency-charts/>
13. C.C. Wang, et al, Airborne transmission of respiratory viruses, *Science*, August, 2021,  
<https://www.science.org/doi/10.1126/science.abd9149>
14. R. Dal Porto, et al, **Characterizing the performance of a do-it-yourself (DIY) box fan air filter**, *Aerosol Science and Technology*, April 2022,  
<https://www.tandfonline.com/doi/pdf/10.1080/02786826.2022.2054674>
15. ANSI/ASHRAE 180-2018, **Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems**  
[https://www.ashrae.org/File%20Library/Technical%20Resources/Bookstore/previews\\_2016639\\_pre.pdf](https://www.ashrae.org/File%20Library/Technical%20Resources/Bookstore/previews_2016639_pre.pdf)

1. Carbon dioxide (CO<sub>2</sub>) is a gas we exhale. As it builds up, it can be harmful itself, and the buildup also indicates that other pollutants—including the Coronavirus—are building up too. Problems with CO<sub>2</sub> monitors connected to an HVAC include: they are expensive and require expertise to set up and maintain; and they are often in a fixed location which is unlikely to read the CO<sub>2</sub> level representative of where the people in the room are. CDC recommends using a (cheaper) hand-held CO<sub>2</sub> monitor to check HVAC performance in many rooms ([Ref 7](#)). CO<sub>2</sub> levels should not exceed 800 PPM, but 600 PPM is preferable. However, since CO<sub>2</sub> is produced by room occupants, a low reading may reflect few people in the room, rather than good HVAC function. Airflow measurements are a much more reliable measure of HVAC function.

2. The guidance document from ASHRAE in use for decades, **ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality**, recommends 5 ACH for schools. However, this document and this recommendation were not designed to control bioaerosols, e.g. virus particles. Thus we need to turn to recent guidance documents from the two industrial hygiene groups offering guidance on workplace ventilation on controlling bioaerosols during the pandemic: [Refs 8, 9, and 10](#)

3. These recommendations were first developed by industrial hygiene expert, Monona Rossol, and adopted in 2020 by the Screen Actors Guild–American Federation of Television and Radio Artists (SAG-AFTRA), published in their October 2020 ACTS FACTS, and were later adopted by other unions.

4. This comparison of MERV and International Standards Institute data from April 7, 2021 points out that the ASHRAE 52.2 chart of capture efficiency for the MERV 13 is  $\geq 50\%$  in the particle size range of 0.3 to 1 micron and  $\geq 85\%$  of 1 to 3 micron particles. COVID virus aerosols fall in both those ranges.

5. The ASHRAE- ACGIH White Paper, **Ventilation for Industrial Settings during the COVID-19 Pandemic**, (in [Ref 9](#)) suggests: “While we did not identify any studies that suggest re-aerosolization of SARS-CoV-2 particles from filters is likely, it is best to be prudent and take precautions. Wearing an N95 or higher respirator, gloves, and safety glasses or goggles is recommended.”