AIR FILTER TOOLKIT

AN OVERVIEW AND INSTRUCTION MANUAL

WE ACT FOR ENVIRONMENTAL JUSTICE

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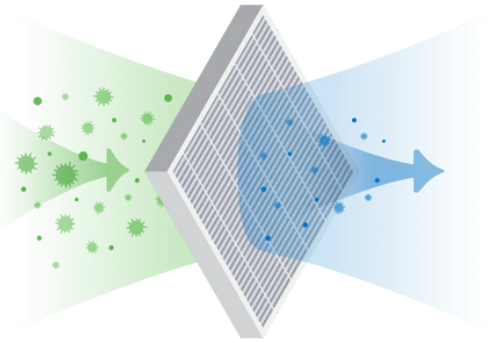
AIR FILTERS: OVERVIEW

WHAT IS AN AIR FILTER?

An air filter is a device that removes particles, pollutants, and microorganisms that are harmful to health and the environment from the air. This includes dust, dirt, smoke, viruses, mold, bacteria, toxic gases, and odors, depending on the type of filter that is used. These pollutants can cause or aggravate allergies, respiratory illnesses, and skin disorders.

HOW DOES AN AIR FILTER WORK?

Air filters work by pulling uncleaned air through a synthetic, mesh, paper, or metal filter with microscopic openings. This filter traps particles that are larger than the microscopic openings and pushes clean air out. Think about these filters as similar to face masks that block harmful particles throughout a whole room.



Air filters are measured with the Minimum Efficiency Reporting Value (MERV) scale. The ratings range from MERV 1 to 16. A higher number means smaller particles can be filtered out, including particles between 0.3 to 10 micrometers.

The EPA recommends that 35% of a home's air is cleaned per hour to maintain good indoor air quality and protect residents' health. This means that depending on the size of the room or home that you are trying to keep clean, the type and size of the air filter you use will change.

AIR FILTERS: OVERVIEW

WHY A DIY AIR FILTER?

Commercial air filters cost between $100 to $300. This means they are not accessible to everyone, especially if you want multiple throughout your home. DIY air filters are less expensive, relatively easy to make, and perform similarly to commercial air filters. This makes them a good lower-cost alternative. However, if you are particularly sensitive to air pollution in your everyday life, you may want to consider purchasing a commercial air filter instead of creating a DIY air filter because they will be less effective than commercial ones for everyday use.

DIY air filters work similarly to commercial air filters and can be a good lower-cost alternative. They pull uncleaned air through filters that catch dust, pollen, smoke, and viruses. The reason that it is important to use a filter that is MERV 13 rated is that these filters catch smaller particles found in wildfire smoke and COVID-19 viral particles.

DIY air filters have similar clean air delivery rates (CADR) and energy efficiency as commercial air filters. They do not replace other parts of a comprehensive indoor air quality strategy and should be used with other strategies like ventilation. The efficacy of DIY air cleaners depends on the size of a space, the activities that take place there, how often it is cleaned, and the materials used to make the filter.

AIR FILTERS: OVERVIEW

COMMERCIAL AIR FILTERS

If you would prefer to purchase a small commercial air filter rather than create your own DIY air filter, click here to see a list of recommended air filters. It is best to purchase a mechanical air filter (with HEPA or MERV-13 filters) as opposed to an electronic air filter (a product using terms such as ionizer, electrostatic precipitator, plasma, photocatalytic oxidation, hydroxyl generator, or UV light). Electronic air filters can produce byproducts that harm people's health.

At this time, there are no government programs that directly offset the cost of residential air purifiers. In specific situations, you may be able to get your health insurance to cover the cost of an air purifier. If you have a letter of medical necessity from your healthcare provider, you could be reimbursed by your HSA or FSA for the cost of an air purifier. Medicare will not cover the cost of air purifiers unless it is categorized as direct medical equipment.

HOW TO CHOOSE THE BEST DIY AIR FILTER DESIGN FOR YOUR SPACE

According to the EPA and ASHRAE's recommendations, a room should have 0.35 air changes per hour. This means that every hour, 35% of the air in a room should be cleaned by an air filter to maintain healthy indoor air quality.

Air changes per hour can also be referred to as the Clean Air Delivery Rate (CADR). The CADR is measured by the cubic feet per minute of clean air delivered. Depending on the size of your room, the design and number of air filters that you use will change. Having a certain air exchange rate/number of air changes per hour is important because it will remove pollutants, bacteria, viruses, mold, dust, and other harmful particles from the air in a standard manner that can be regulated.

AIR FILTERS: OVERVIEW

Portable Air Cleaner Sizing for Particle Removal						
Room area (square feet)	100	200	300	400	500	600
Minimum CADR (cfm)	65	130	195	260	325	390

Note this chart is for estimation purposes. The CADRs are calculated based on an 8-foot ceiling. If you have higher ceilings, you may want to select a portable air cleaner with a higher CADR.

Image Credit: EPA Indoor Environments Division, 2018.

A basic design of a 1x1 air filter using a box fan, 1" MERV 13 filter, and duct tape to seal the edges has an estimated CADR of 111.2 ± 1.3 CFM. According to the EPA's scale, this would be enough to provide air cleaning to a 200 square foot room, around the size of a bedroom that could fit a queen sized bed.

Using this same 1x1 design but adding a shroud increases CADR to around 155.68 CFM.* Similarly, changing the MERV 13 filter from 1" to 4" version will increase CADR to an estimated 136.78 CFM. Both of these adjustments would slightly increase the size of a room that the air filter would clean to closer to 250 square feet.

A 4x1 air filter built using a box fan, 4 1" MERV 13 filters, duct tape, and a shroud, has an estimated CADR of 290.23 CFM. According to the EPA's scale, this would be enough to clean the air of around a 450 square foot room. This is the size of a studio apartment or a small one bedroom apartment.

Modifying either of these designs by increasing the thickness of the filters, speed of the fan, and addition of a shroud, explained below, will increase the CADR and the size of the room that they can be used in as a result. If you would like to calculate the CADR of your air filter, use a calculator to do so here.

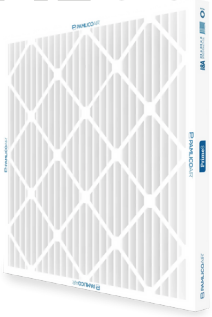
*A shroud is made out of cardboard or duct tape and is added to the air filter on the opposite side as the filter. It covers the corners of the fan so that air that has already been cleaned is not pulled back in by the blades of the fan. This closes gaps in the design and increases efficiency of the air filter. See the diagram in the *Building a 4x1 Air Filter* section for an example of a shroud.

DIY AIR FILTERS: INSTRUCTIONS

HOW TO MAKE A DIY AIR FILTER

DIY air filters can be made in different ways depending on the number, thickness, and orientation of the filters and fans that are used.

BUILDING A 1X1 AIR FILTER (200 SQ. FT)



Supplies for 1x1 Air Filter ~$40

- 1 20x20 inch MERV 13 air filter
- 1 20x20 inch box fan (2012 or older model)
- Duct tape or bungee cord
- Scissors or x acto knife
- Cardboard (optional)
- Pencil/marker/pen (optional)

Instructions for 1x1 Air Filter

1. Attach the air filter to the back of the fan with duct tape or a bungee cord.
2. Make sure air is being pulled through the filter through the back of the fan, and pushed out the other side into the room.
    a. To increase the efficacy of your filter, create a shroud out of cardboard or duct tape that covers the edges of the box fan (see “A” in the photo below). Cut a 20x20 square of cardboard with a large hole in the center out and duct tape the edges, or create a shroud entirely made of duct tape. Place the shroud on the side of the fan without the filter.
3. Replace the filter when it is dirty.

Click here for a video tutorial

DIY AIR FILTERS: INSTRUCTIONS

BUILDING A 4X1 AIR FILTER (450 SQ. FT)

Supplies for Corsi-Rosenthal 4x1 Air Filter ~$70

- 4 20x20 inch MERV 13 air filters
- 1 20x20 inch box fan (2012 or older model)
- Duct tape
- Scissors or x acto knife
- Cardboard
- Pen/marker/pencil

Instructions for Corsi-Rosenthal 4x1 Air Filter

1. Cut one 20x20 inch piece of cardboard and four cardboard corners.
2. Tape 4 MERV 13 air filters together with the air flow arrows pointing inwards to create a box. Seal the edges of the box with tape.
3. Tape the four cardboard corners on the inner corners of the box, creating a shroud.
4. Flip the box over and tape the 20x20 inch cardboard square to the bottom of the box, covering each side with tape.
5. Place the box fan on the top of the cube with the four cardboard corners and tape the gaps around its edges. Make sure that the air is being pulled through the filters and the fan is pushing it back into the room, cleaned.
6. Replace the filters when they are dirty.

Click here for a video tutorial

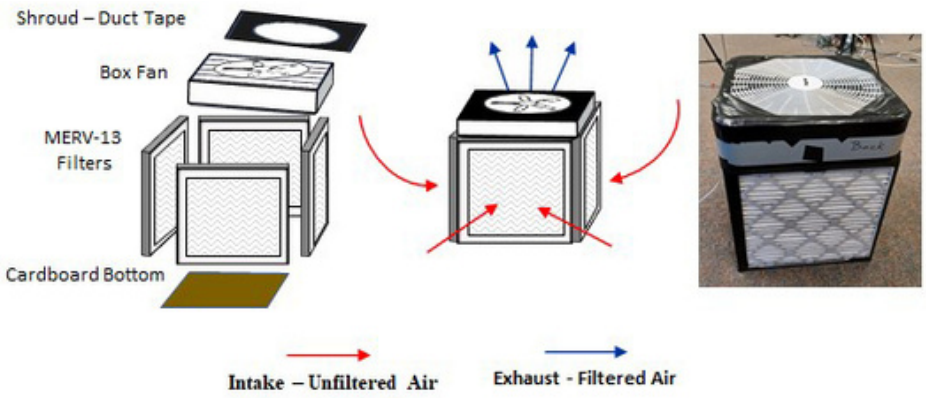


Image Credit: The National Institute for Occupational Safety and Health, 2023.

FREQUENTLY ASKED QUESTIONS

DIY AIR FILTERS AND WILDFIRE SMOKE

Many nonprofits and government organizations recommend that community members use DIY air filters during wildfire events. Studies about their efficacy and safety compared to commercial air filters are still in process. The EPA is collaborating with researchers to study both their safety in terms of fire hazard risk and the efficacy of these air filters in wildfire events.

REDUCING WILDFIRE SMOKE EXPOSURE

Some published literature, the beginnings of EPA testing, and anecdotal reports say that these DIY air filters are effective in removing particles with smoke from the air. Their CADR is similar to many small commercial air cleaners. Depending on the design, fan speed, and fan type, DIY air filters' CADRs range from 49 to 825 Cubic Feet Per Minute (CFM). Commercial air filters generally have a CADR of around 300 CFM. More in-depth EPA testing around this is currently being conducted. There are expected to be full results coming in 2023 or 2024. At this time the EPA does not recommend routine use of DIY air filters instead of commercially available ones.

FIRE SAFETY

Studies about the safety of DIY filters done by the EPA show that there is little fire risk if the box fan that is used was made in 2012 or later. This is because these have built-in safety features. The filter should be changed when dirty and fans should avoid being blocked. However, when tests were conducted with both sides of the fan blocked and the DIY air filter was run continuously for 7 hours there were no fires, which suggests that the fire risk is not extreme. Regardless, DIY air filters should still be closely monitored and turned off when no one is home.

FREQUENTLY ASKED QUESTIONS

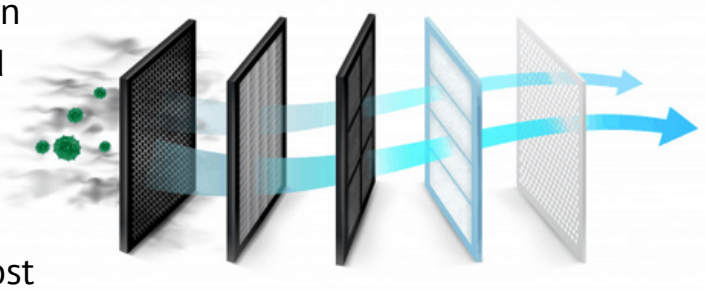
DIY AIR FILTERS' EFFICACY

A study from the EPA's first round of testing has been published. Tests of a box fan with one MERV 13-rated filter showed a CADR of 111.2 ± 1.3 CFM. By increasing the fan speed, type, filter thickness, or number of filters, the CADR will change. Tests have shown that by using a shroud CADR increases by 40%, using a 4" MERV 13 filter increases CADR by 123%, using two filters in a wedge shape increases CADR by 137%, and using four filters in a Corsi-Rosenthal box increases the CADR by 261%. Changing the air filter design by changing these aspects as opposed to using multiple means that the cost and noise level are not impacted.

Tests during the study found that a Corsi-Rosenthal box costs $0.18 per unit of clean air, then the wedge design costs $0.21/CADR, and the single filter design with a 4" MERV 13 filter is $0.29/CADR. All of these designs have a much lower initial cost than a commercial air cleaner.

COVID-19 TRANSMISSION

Because COVID-19 spreads through aerosols, particles, or liquid droplets that are suspended in the air, filtering that air can decrease the spread of the disease. Similarly, with wildfire smoke, filters with microscopic openings trap harmful particles and release the air back into the room, cleaned. Creating DIY air filters is a good low-cost way to decrease COVID-19 transmission.



WHICH AIR FILTERS DECREASE COVID-19 TRANSMISSION

Not all air filters decrease particles containing viruses; for a filter to do this it must be able to filter particles that are 0.1-1 micrometers. This means that you should look for a filter that is rated MERV 13 or higher, state that they remove 99.99% of particles that are as small as 0.3 um, or are High Efficiency Particulate Air (HEPA) filters.

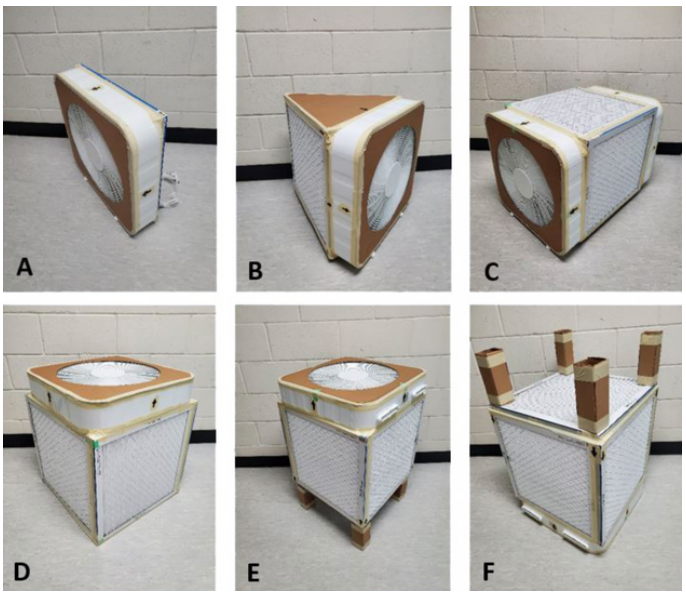
While the use of DIY air filters cannot eliminate COVID-19 transmission, it can decrease the probability of an infection. Using DIY air filters combined with masking, vaccines, and social distancing further decrease the risk of infection. When there is an active COVID-19 case in your home, using a DIY air filter in combination with these other options can decrease the probability of further infection. In everyday life, your air filter should be placed in a room where you all spend the most time unless there is someone who is particularly susceptible to COVID-19. In this case, the filter should be placed in their room.

Image Credit: Green Ductors, 2020.

STUDIES OF DIY AIR FILTERS AND COVID-19 TRANSMISSION

Studies have shown that DIY air filters can reduce aerosol exposure by 73%. This depends on the filter thickness, design, and fan airflow. Studies done by the CDC of DIY filters without masks being used led to exposure to COVID-19 particles decreasing from 59% to 78%. When there was universal masking and no air filters were running, exposure was reduced by 75%. A combination of universal masking and DIY air filters led to relative exposure being reduced by 88% when 1" filters were used and the fan was on low, and by 94% when 2" filters were used and the fan was on high.

Using two filtration units instead of one can lead to better results as well specifically when using air filters to combat COVID-19. Tests showed that using one DIY air filter changed the airflow pattern in the room, meaning that while some people in the room would have lower exposure, this setup could lead to higher exposure for others. Using two filtration units makes the airflow less dependent on one point in the room. This means that the aerosol distribution will be more constant throughout the space.



A) One filter and one fan (1×1 design); **B)** Two filters and one fan (2×1 or "wedge" design); **C)** Three filters and two fans (3×2 design); **D)** Four filters and one fan (4×1 or Corsi-Rosenthal box); **E)** Five filters and one fan (5×1 design) with supports to elevate the device; **F)** Bottom view of 5×1 design showing the fifth filter and improvised cardboard legs. Black arrows show the direction of airflow and all units feature a cardboard shroud taped to the front of the fan. *Image Credit: Molly Mastel, BCCDC.*

REFERENCES

1. Industrial Quick Search. Industrial Quick Search. [cited 2023 Jul 11]. Air Filters: What Is It? How Does It Work? Types, Uses. Available from: https://www.iqsdirectory.com/articles/air-filter.html
2. US EPA O. US Environmental Protection Agency. 2019 [cited 2023 Jul 13]. How much ventilation do I need in my home to improve indoor air quality? Available from: https://origin-aws-www.epa.gov/indoor-air-quality-iaq/how-much-ventilation-do-i-need-my-home-improve-indoor-air-quality
3. Eykelbosh A. Do-it-yourself (DIY) air cleaners: Evidence on effectiveness and considerations for safe operation.
4. Heffman T. The Best Air Purifier. The New York Times [Internet]. 2023 Jun 30 [cited 2023 Aug 8]; Available from: https://www.nytimes.com/wirecutter/reviews/best-air-purifier/
5. Regional Asthma Management and Prevention. [cited 2023 Jul 11] How to Choose a Safe & Effective Air Cleaner. \
6. Petkevich D. Fair Square Medicare. 2022 [cited 2023 Jul 17]. Does Medicare Cover Air Purifiers? Available from: https://www.fairsquaremedicare.com/articles/does-medicare-cover-air-purifiers
7. Vaniman [Internet]. [cited 2023 Aug 8]. Air Changes per Hour (ACH & ACPH) Calculator Tool - CFM (Cubic Feet per Minute). Available from: https://www.vaniman.com/air-changes-per-hour-calculator/
8. DIY Ecology: Breathe better by easily making a clean air fan [Internet]. 2020 [cited 2023 Jun 13]. Available from: https://www.youtube.com/watch?v=ujUFj2G9_-Y
9. How to build a Corsi Rosenthal Box [Internet]. 2022 [cited 2023 Aug 8]. Available from: https://www.youtube.com/watch?v=CXa8auzKx9Y
10. US EPA O. US Environmental Protection Agency. 2021 [cited 2023 Jun 13]. Research on DIY Air Cleaners to Reduce Wildfire Smoke Indoors. Available from: https://www.epa.gov/air-research/research-diy-air-cleaners-reduce-wildfire-smoke-indoors
11. US EPA O. US Environmental Protection Agency. 2018 [cited 2023 Jun 13]. Wildfires and Indoor Air Quality (IAQ). Available from: https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq
12. Davis A, Black M. An Evaluation of DIY Air Filtration. Chemical Insights: Underwriter Laboratories. 2021 Jun;1–17.
13. Holder AL, Halliday HS, Virtaranta L. Impact of do-it-yourself air cleaner design on the reduction of simulated wildfire smoke in a controlled chamber environment. Indoor Air. 2022;32(11):e13163.
14. Derk R, Coyle J, Lindsley W, Blachere F, Lemons A, Service S, et al. The Effectiveness of DIY Air Filtration Units [Internet]. Centers for Disease Control. 2023 [cited 2023 Jun 29]. Available from: https://blogs.cdc.gov/niosh-science-blog/2023/02/03/diy-filtration/