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Do-it-yourself (DIY) air cleaners: Evidence on effectiveness and considerations for safe operation

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Key Messages

- A review of academic and technical literature showed that do-it-yourself (DIY) air cleaners performed similarly to commercial portable air cleaners in terms of clean air delivery rate (CADR) and energy efficiency under controlled conditions. However, DIY devices were much more cost efficient that commercially available air cleaners. Both types of devices generated >50 dB of noise.
- Field evaluations of DIY air cleaners have found they were effective in homes and schools, but there are no long-term studies. There is also a lack of user engagement to understand whether DIY devices are used properly and consistently.
- The “best” DIY design will depend on the space to be cleaned, the activities carried out, space available, noise disruption, and other factors. Because CADR can vary substantially depending on material quality, it may be useful to evaluate DIY air cleaner effectiveness post-construction using low-cost particulate matter sensors indoors and outdoors.
- DIY air cleaners made with newer model fans are unlikely to pose a fire or burn risk, but should be kept clear of obstructions and operated with common sense precautions. The filters should be changed when soiled; duration of filter lifespan will vary with use and conditions.
- Portable air cleaners are only part of a comprehensive indoor air quality strategy. They do not replace the need for ventilation and should be used in conjunction with other appropriate health protective measures.

Introduction

Portable air cleaners are filtration-based devices that remove particulate matter (PM) from indoor air. Due to the COVID-19 pandemic and the increasing impacts of wildfire smoke, portable air cleaners have become an important tool for public health protection.[1-4] Most commercial portable air cleaners use high-efficiency particulate air (HEPA) filters[5] that can remove up to 99.97% of particles in the 0.3 to 1.0 micrometer (µm) size range. This range includes viruses, such as SARS-CoV-2 (which causes COVID-19), and the very small particles in air pollution, which are associated with numerous negative health effects. Portable air cleaners can be used to reduce PM exposure in several different contexts, such as:

- During cold and flu season to reduce the presence of respiratory pathogens;
- During wildfire events to remove smoke that gets indoors;
- During allergy season to reduce exposure to pollen indoors;
- During the rest of the year to reduce exposure to pollutants and allergens that are continuously generated indoors (emissions from cooking and wood-burning stoves, mould, animal dander, etc.) and infiltrate from the outdoors (traffic exhaust, residential woodsmoke, dust, etc.).

Portable air cleaners have the added benefits in that they are scalable, can be implemented quickly when needed, do not require costly renovations or permits, and are relatively inexpensive. There are many commercial air cleaners on the market with different properties, but a good quality unit typically costs less than $500.

Portable air cleaners are most effective when they have a clean air delivery rate (CADR) that is appropriate for the air volume of the space they are intended to clean. However, occupants often underestimate the size and capacity of air cleaner(s) required to treat a given space. As a rule of thumb, the Association of Home Appliance Manufacturers (AHAM) recommends purchasing an air cleaner with a CADR (in cubic feet per minute or cfm) that is at least two-thirds of the floor area for rooms with a standard ceiling height of 8 feet.[6] For example, a typical classroom (~1000 ft^2) would need a total CADR of 0.66 × 1000 or 666 cfm, which would likely require 2–3 portable air cleaners to achieve. Given that commercial units clean the air at a unit cost of approximately $0.71 to $2.66 per CADR,[7] it is easy to see that relying on commercial units may be prohibitively expensive in many contexts.

This barrier has led to the development of do-it-yourself (DIY) air cleaner designs made from easily sourced, relatively low-cost materials. Part of the cost-savings comes from the use of furnace filters with a minimum efficiency reporting value (MERV) of 13 or greater,[5] rather than a more expensive HEPA filter (MERV-17 or greater), as in commercial units. Although MERV-13 filters are not as efficient at removing the smallest particles on a single pass through the filter, a significant reduction can still be achieved by increasing the number of times the same volume of air passes through the filter. However, there is limited publicly available information about the effectiveness of DIY units in terms of their CADR and other important parameters such as noise and energy efficiency.

The purpose of this document is to review the evidence on DIY air cleaner effectiveness, cost effectiveness, energy efficiency and noise compared with commercially available units. This document also gathers resources to assist in building and implementing DIY air cleaners and describes other considerations that might be relevant to deploying these devices in real-world settings. It is intended to assist people with their decision-making regarding the potential use of DIY air cleaners in both residential and nonresidential settings.

Methodology

The scholarly and grey literature were searched for studies specifically examining the effectiveness of "do-it-yourself (DIY)" or improvised air cleaners. Additional key words related to construction materials (e.g., MERV-13 filters, box fans) were also included, as well as exposures of interest (e.g., PM, wildfire smoke, pathogens, viruses). A full list of keywords is presented in **Appendix A.** The academic literature was searched using the Ebscohost databases (includes Medline, Cinahl, Academic Search Complete, ERIC, etc.), Scopus (Elsevier), and Google Scholar. All relevant English-language results were collected without time delimitation. Additional references were added via forward and backward chaining of those search results and supplemental searches, as necessary. A full list of results is available upon request.

Studies were selected for review if they evaluated DIY air cleaners with respect to effectiveness (CADR), PM removal, energy efficiency, noise or other factors impacting use, either in experimental or real-world settings. Modelling studies were excluded. Both peer-reviewed and pre-print sources were considered, as were technical reports or white papers from public health and academic institutions. After selection, this review included 20 studies: nine peer-reviewed articles,[8-16] three preprints,[17-19] and eight technical reports.[20-27] Each study was assessed by a single reviewer and the results were synthesized narratively. The synthesis was subjected to internal and external review.

Results

What DIY designs have been evaluated?

This document covers five of the most common DIY air cleaner designs, which are referred to as the 1×1 (one filter, one fan), 2×1 (two filters, one fan), 4×1 (four filters, one fan), 5×1 (five filters, one fan), and 3×2 (three filters, two fans) designs throughout (**Figure 1)**. The 4×1 design is also commonly known as a Corsi-Rosenthal box.

Each design uses the same components in different configurations: one or two square box fans (20" × 20"), one to five square 20" × 20" furnace air filters (typically MERV 13, of varying thicknesses), tape (or other fastener such as Velcro, clamps, or bungee cords), and cardboard to make a base panel and/or a "shroud" on the front the fan. The shroud (see **Figure 1**) is intended to block the re-entrainment of air back into the fan through the gaps in the corners around the circular blades. In all designs, the air flows in through the filters and out through the fan(s). Using the fan to pull the air through the filter (rather than push it through) decreases stress on joints that have been taped together. The initial construction cost of the design depends on the quality and number of fans and filters.

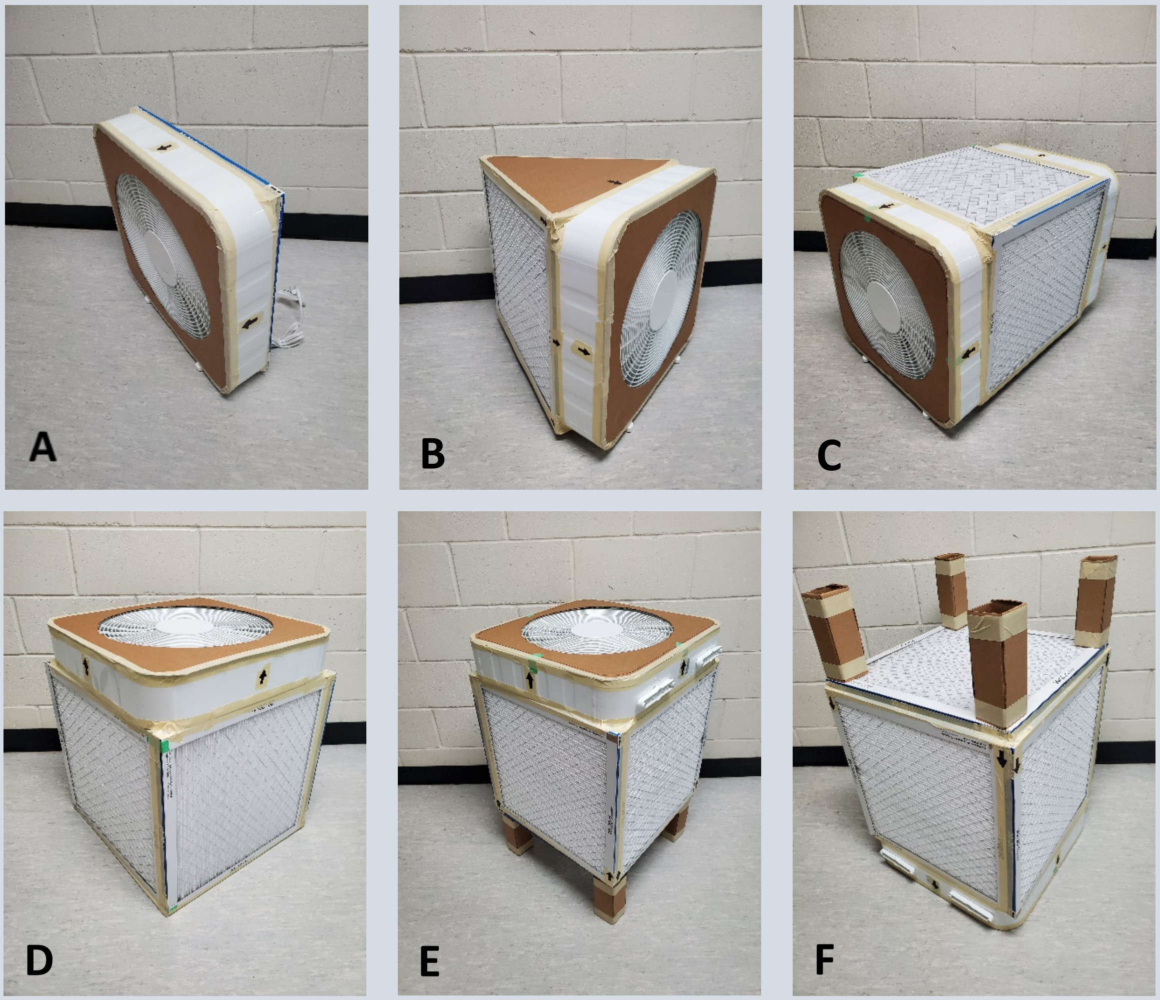
How is effectiveness evaluated in portable air cleaners?

The key criterion for air cleaner effectiveness is CADR based on PM removal. Commercial air cleaners are evaluated using established methods from AHAM.[28] In these standard protocols, CADR is determined by measuring how quickly the device removes particles released into a closed chamber or room compared with the natural dissipation or "decay" of particles in the same room. This rate of reduction is measured across three size fractions: for small particles such as wildfire smoke and viruses (0.09–1 µm), medium particles such as dust (0.5–3 µm), and large particles such as pollens (0.5–11 µm). In this document, the DIY CADR values reported are those for the smallest or most penetrating particle size class measured in each study, typically 0.3–1 µm, which is also the size class most relevant to indoor air quality (IAQ) hazards like wildfire smoke and COVID-19.

Some of the studies included in this review evaluated CADR using methods very similar to the standard protocol,[9,10,25-27] whereas others sought to validate a lower-cost or simplified method.[13,17] Some authors simply estimated the CADR by measuring the unit's airflow (with an anemometer or other method) and then multiplying this value by the filter's removal efficiency, based on the manufacturer's claims.[24] This method assumes no leaks or flaws in the filter.

CADR can also be used to understand how use of an air cleaner contributes to a room's ventilation requirements. Room ventilation rate is often described as air changes per hour (ACH). These air changes are primarily met through the introduction of fresh outdoor air via mechanical ventilation, as well as the filtration and recirculation of some fraction of the indoor air. However, outdoor air also enters buildings through doors, windows, and other openings in the building envelope. The contribution of a portable air cleaner to total ACH can be calculated by first multiplying CADR (in cfm) by 60 minutes and then dividing by the room size (in cubic feet; see here for a sample calculation). For a respiratory pathogen like SARS-CoV-2, it is generally recommended that classrooms receive 3–6 ACH, with as much as possible being outdoor air and the remainder (if necessary) being recirculated air that has been filtered or cleaned.[29] During a wildfire event, outdoor air intake would be minimized in favor of recirculated or filtered air.

Figure 1. DIY air cleaner designs included in this review.



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. *Photo credit: Molly Mastel, BCCDC.*

What is known about the effectiveness of DIY air cleaners compared with commercially available units?

Table 1 summarizes data from studies that evaluated the effectiveness (as CADR), noisiness, and energy usage of DIY air cleaners. Only five studies compared DIY designs with commercial air cleaners that use HEPA filters.

Although differences in the methods and materials make it difficult to compare CADR across studies, within-study comparisons showed that DIY designs consistently performed comparably with commercial units (**Table 1**). Furthermore, the relatively high CADR values combined with the low cost of construction meant that DIY designs had a much lower cost per CADR values ($0.06–0.83) than commercial units ($0.64–6.80). DIY designs also met or exceeded the Energy Star threshold of 2 cfm/W in all but two studies that reported on energy efficiency, making them comparable with commercial units. Overall, DIY air cleaners were marginally noisier than commercial units, but both types of units produced more than 50 dB (**Table 1**). This noise level is similar to a loud conversation and may be problematic in a classroom environment or for those who are hard of hearing. Although in one study the 4×1 design appeared to produce less noise than the 1×1 or 2×1 designs, the authors attributed this to placement of the microphone.[10]

Table 1. Comparison of DIY air cleaner designs and commercial units. Clean air delivery rate (CADR) and noise generation values were those measured at highest fan speed. NR indicates not reported.

Study	Design (n)	Filter type	CADR (cfm)	Cost per CADR	CADR per watt (cfm/W)	Noise (dB)
Dal Porto et al.[9]	4×1 (n=1)	MERV-13	903	$0.06	8.7	67
	Commercial units (n=2)	HEPA	118–300	$0.74–0.86	3.0–3.2	54–59
Holder[22]	1×1 (n=1)	MERV-13	113	$0.27	1.5	67
	Commercial unit (n=1)	HEPA	108	$0.93	2.0	55
Holder et al.[10]	1×1 (n=1)	MERV-13	156	$0.29	2.0	62
	2×1 (n=1)	MERV-13	263	$0.21	3.5	61
	4×1 (n=1)	MERV-13	401	$0.18	5.3	55
	Commercial unit (n=1)	HEPA	119	$1.03	2.9	51
Leutwyler 2021[23]	2×1 (n=2)	ISO16890: ePM1 50% (equivalent to MERV-13)	224–388	NR	NR	NR
Li et al.[11]	1×1 (n=1)	MERV-13	318	NR	NR	NR
May et al. [12]	1×1 (n=1)	MERV-13	330	$0.14	5.6	NR
Pistochini and McMurry[24]	1×1 (n=2)	MERV-13	77–83	$0.54–0.83	0.7–0.8	60–61
	4×1 (n=2)	MERV-13	239–270	$0.31–0.39	2.2–2.4	60–61
Srikrishna[13]	1×1 (n=6)	MERV-13–16	342–645	$0.09–0.12	NR	62–64
	4×1 (n=4)	MERV-13–14	570–652	$0.12–0.14	NR	NR
	3×2 (n=1)	MERV-13	1017	$0.08	NR	NR
	Commercial units (n=3)	HEPA	216–354	$0.67–2.07	NR	59–66
Srikrishna[17]	1×1 (n=3)	MERV-13–16	263–360	$0.21–0.36	5.3–7.2	NR
	Commercial units (n=4)	HEPA	125–315	$0.64–6.80	NR	NR
Zeng et al.[25-27]	1×1 (n=2)	MERV-10 and -12	132–150	NR	NR	NR
	5×1 (n=1)	MERV-13	168	NR	NR	NR

A number of other studies assessed effectiveness in terms of removing PM, but did not report CADR:

- The BC Centre for Disease Control (BCCDC) demonstrated that a 1×1 DIY air cleaner with a MERV-13 filter achieved a 75% reduction in PM less than 2.5 µm in diameter ($PM_{2.5}$) from diesel exhaust in a small test chamber within roughly five minutes. The best results were obtained at medium fan speed.[30]
- Carvlin[20] found that a 2×1 design reduced PM by ~90% within 15 minutes, with best results at high fan speed and in a small room.
- Van Valkenbirgh et al.[16] found that a 1×1 design with a MERV-13 filter performed similarly to a commercial HEPA unit, roughly halving the half-life of the smallest particle size fraction (0.3 µm), although it generated noticeably more noise than the HEPA unit.
- Derk et al.[18] set up a chamber with aerosol-emitting mannequins whose exposures to each other's emissions could be assessed with or without masking and/or a DIY air cleaner (either a 1×1 or 4×1 design). The study found that universal masking alone (no air cleaner) reduced exposure to the aerosol by 70%; turning on an air cleaner further reduced exposure by 10% for each ACH provided.
- Li et al.[11] also investigated a 1×1 design using a "breathing" infected mannequin and fluorescein-tagged aerosol particles (1–3 µm). They found that a 1×1 design (with a CADR of 318 cfm) more than quadrupled the room's effective ACH. However, particle deposition also increased within 2 m around the infected mannequin when the DIY air cleaner was operated in a small space. The authors suggested that indirect transmission risk from surfaces might be greater in a small space, but this would depend on the pathogen in question.
- Cadnum et al.[8] used the 4×1 cube design with MERV-13 filters to remove MS2 bacteriophage (rather than abiotic particles) from the air, and compared the results with two commercial HEPA units. One of the HEPA units also included photocatalytic oxidation via ultraviolet and titanium oxide treatment (UV/TiO_2 treatment). The DIY unit and the HEPA+UVC/TiO_2 unit rapidly reduced recoverable MS2 bacteriophage within the first 15–20 minutes, whereas the simple HEPA unit took 60 minutes. The best results were obtained at the highest fan speed.

How well do DIY air cleaners perform in real-world settings?

Although the bulk of the research on DIY air cleaners has been conducted in controlled settings, a few studies have examined DIY air cleaner effectiveness in the real world. This type of evaluation is important to examine factors such as the effects of daily use, filter durability, and whether noise or other features impact room occupants.

In a recent preprint, Srikrishna[13] investigated whether DIY air cleaners could be used to achieve relatively high ventilation rates (6–12 ACH) in occupied classrooms, with the objective of hypothetically reducing COVID-19 transmission, although COVID-19 cases or outcomes were not measured. Devices were run at low speed to reduce noise disruption. In total, the study deployed 47 HEPA air cleaners and 60 DIY air cleaners in 16 classrooms. The DIY air cleaners featured a 1×1 design using a MERV-16 filter. The large classrooms (~9000 ft^2) required 3–6 air cleaners each to achieve the required CADR, leading to approximately 18 ACH. Measuring airborne PM of ~0.3 µm showed that the DIY air cleaners performed comparably with commercial portable air cleaners that cost roughly twice as much. However, there was one DIY air cleaner that performed poorly and was replaced using new materials from the same manufacturer. Teachers reported that noise from the DIY units was “tolerable” at low speed. The study did not collect detailed information on user engagement or acceptability, nor did it monitor devices to make sure that they were routinely used as instructed.

In another recent preprint, Gasparrini et al.[19] ran three trials using two 4×1 DIY air cleaners in opposite corners of a university classroom. Once again, the intention was to reduce the risk of COVID-19 transmission, but COVID-19 cases or outcomes were not measured. The units were run on low speed as medium speed was too disruptive. After leaving the filters off for the first 30 minutes of class, turning the units on at low speed resulted in 80–96% reductions in $PM_{2.5}$ over the remaining 30–40 minutes of class. These data and some additional modelling work indicated that placing the DIY air cleaners in opposite corners provided “sufficient” mixing throughout the space.

Several other field studies examined the use of DIY air cleaners to reduce exposure to infiltrating PM. Tham et al.[14] evaluated a window-mounted DIY air cleaner, very similar to the 1×1 design in **Figure 1,** composed of a 13” window fan drawing air inward through a MERV-13 filter. The unit was placed in a classroom in Singapore to counter hazy conditions due to industrial, vehicular, and other urban pollutants. Such events are challenging because of the high PM concentrations and buildup of heat and moisture indoors when windows must remain closed. The DIY air cleaning unit was effective in reducing indoor PM by 80–95% due to filtration of incoming air and creation of a positive pressure environment that reduced infiltration. Tham et al.[15] also deployed a window-mounted DIY air cleaner in an occupied third-floor hostel room. The unit reduced PM exposure by approximately 80% compared with a reference room, and reduced exposure to potentially toxic $PM_{2.5}$-bound trace elements. The device also helped to maintain indoor temperatures closer to those which 80% of occupants would generally deem acceptable. In another residential setting, May et al.[12] deployed two DIY air cleaners (1×1 design with a MERV-13 filter) in a Seattle home during a wildfire event, and found that the devices provided a 56% reduction in $PM_{2.5}$ over 90 minutes in a larger room (200 m^3) and a 99% reduction in 60 minutes in a smaller room with fewer openings (50 m^3), despite ongoing smoky conditions outside.

Overall, these field experiments showed that DIY air cleaning units were effective for increasing ACH and reducing PM exposure. However, with the exception of Srikrishna,[17] none examined performance over the long term or user experience (acceptability and diligence in everyday use). Previous work examining the use of carbon dioxide sensing in schools suggests that user engagement and training are critical to success when attempting to manage indoor air quality at the room level.[31]

What is the most effective DIY design?

The best design for a given space will depend on multiple factors, including the size of the space to be treated, the cost of materials, and the materials available. In general, the CADR values from reported studies increased with more filters, thicker filters, and filters with higher ratings.[10,13,18] Increasing the number of filters increases the surface area through which air flows, allowing the box fan to continue pulling air with a lower pressure drop. This produces a higher air output. Higher wattage box fans increase air output, but also tend to increase noise and cost of operation, and may not be more efficient in terms of cost per CADR.[10] In addition, increasing the number of fans increases the amount of air being moved through the filters, making the 3×2 design the overall highest CADR with a very low cost per CADR ($0.08 per CADR, **Table 1**). However, as noted by Srikrishna,[13] having a single 3×2 or 4×1 unit with a high CADR located in the centre of the room may not be as effective as having multiple 1×1 units spread around to increase mixing, at a similar cost. In addition, as noted by Holder et al.,[10] the much larger footprint of a cube design may be problematic in crowded spaces. Other important design considerations include the following:

Sealing the gaps. DIY air cleaner resources typically recommend sealing the gaps between fans and filters with a strong, wide tape such as masking tape or duct tape. Srikrishna[13] used either duct tape or Velcro to construct the 4×1 and 3×2 designs, and a simple vacuum (suction created by the fan itself) to seal the 1×1 designs. The author did not note a marked difference among these types of sealing, but sealing type was not rigorously assessed. Similarly, Holder et al.[10] did not observe a difference in CADR when using duct tape or bungee cords to secure the filter to the back of the 1x1 design. However, it is best to use a method that seals gaps between the fan(s) and the filter(s) to prevent filter bypass, which would contribute to more airflow but less filtration. Taping the filter to the front (outlet) of the fan rather than the back (inlet) did not affect the CADR, but did create more noise.[10]

Using a fan "shroud." A cardboard shroud (**Figure 1**) on the fan's outward face prevents the air expelled from the inner part of the fan from being re-entrained and pulled back in through the corners of the fan box where the blades do not reach. Pistochini and McMurry[24] tested DIY air cleaners with and without a cardboard shroud and found that including a shroud increased efficiency by 9–26%. Holder et al.[10] found that although adding a shroud increased noise by roughly 7 dB (~13%), the shroud also increased CADR by 40% with no additional material costs. Shrouds can be easily constructed out of the box that the fan came in, or by using duct tape to tape off the corners of the box fan (**Figure 1**).

Using a newer fan to minimize risk of burns and fire. Davis and Black[21] investigated heat generation and risk of ignition under various scenarios using five new low-cost fans in a 1×1 design with a MERV-13 filter. The 1×1 designs were tested under five different conditions: a clean filter (20 minutes), a smoke-laden filter (20 minutes), a dust-laden filter (20 minutes), blocked on one side (30 minutes), or blocked on two sides (seven hours). The study confirmed that attaching a filter to any of the fans caused some heat generation on the interior and exterior surfaces, but this heat did not exceed acceptable levels or create a risk of burns, melting, or ignition, even under the most extreme conditions. However, the authors also noted that the tests were conducted at 20°C, and that the results may not hold true in a hotter environment (e.g., in a 40°C room during an extreme heat event). Similarly, May et al.[12] did not observe an increase in motor temperature in a 1×1 unit over an eight-hour run time. To minimize fire risk, the US EPA[32] and the BCCDC[30] recommend using a newer fan (2012 or later), with a safety fuse, that has been certified by Canadian Standards Association (CSA), Underwriters Laboratories (UL), or Intertek ETL (ETL).

How can I be sure that the DIY air cleaner is functioning as intended?

As shown in **Table 1**, CADR can differ substantially in DIY air cleaners due to differences in the quality and source of the components used, even when the design has been well tested. Srikrishna[17] reported that airflow from DIY devices varied substantially when using fans from different manufacturers, and even from the same manufacturer, which will greatly impact their CADR. CADRs from commercial air cleaners can also vary from the manufacturer's claims. Because of this, a **quality control strategy** should be considered when deploying DIY or commercial air cleaners.

Proposing a quality control strategy for DIY air cleaners is challenging because the methods used to evaluate CADR in commercial air cleaners require expert knowledge and costly equipment.[28,33] Although several studies in this review proposed simplified methods to estimate CADR, based on PM or airflow data collected using low-cost sensors,[13,17,24] these methods have not been validated, require some technical proficiency, and must be repeated to observe changes over time.

Therefore, rather than attempting to estimate CADR, the simplest and most user-friendly approach may be to monitor PM with mobile, low-cost sensors. Mobile PM sensors allow room occupants to "see" real-time changes in PM levels in relation to indoor activities (e.g., cooking, opening windows, or turning on a DIY air cleaner), and can also be carried outside to observe the effects of outdoor conditions (e.g., smoky skies, rush hour traffic). Best practice for reducing PM from outdoor sources would be to install one low-cost sensor outdoors and then use another indoors to ensure that air cleaners are reducing PM concentrations.

Many PM sensors also measure particles across different size fractions, which may help to highlight the source of PM contamination to a limited degree. For example, because wildfire smoke and respiratory viruses are amongst the smallest types of PM, a sensor that monitors across different size fractions will help the user distinguish these types of particles from larger particles such as pollen or mould. The US EPA has evaluated a number of commonly used low-cost PM sensors and has shared their data online.[34]

Troubleshooting may be required if PM levels remain elevated or are increasing over time, despite air cleaner use. It is important to note that there is no health-based threshold or recommended limit for PM in indoor spaces. In 2010, Health Canada reported that average $PM_{2.5}$ concentrations were less than 15 $\mu g/m^3$ in nonsmoking homes. However, because there is no apparent threshold for health effects of $PM_{2.5}$, Health Canada subsequently recommended that indoor levels of $PM_{2.5}$ should be kept **as low as reasonably achievable (ALARA)**.[35] If a DIY air cleaner is in use, but PM levels remain elevated, it may be possible to increase CADR by increasing the fan speed, increasing the MERV rating of the filters, increasing the thickness or number of filters used, or adding another DIY air cleaner to the space.

Although a detailed discussion of PM sensors is beyond the scope of this document, the US Environmental Protection Agency (EPA) has recently released the *Enhanced Air Sensor Guidebook,*[36] a comprehensive resource on the use of low-cost air quality sensors, including PM sensors. This resource provides detailed information on the following:

- Understanding indoor and outdoor sources of pollution and how they are related;
- Understanding how low-cost sensors function and how to interpret the data;
- Selecting an appropriate air quality sensor, based on the needs of a given project or application;
- Designing an air quality monitoring campaign that includes important items such as establishing baseline conditions and conducting appropriate quality control and assurance activities;
- Communicating and acting on the results of a monitoring campaign.

The *Guidebook* is part of the EPA's Air Sensor Toolbox,[37] a collection of resources for understanding low-cost air sensors and how they can be used to understand indoor and outdoor air quality through community science.

What are the recommendations for operating DIY air cleaners safely?

Know the hazard you are addressing. As mentioned in the Introduction, there are several situations in which portable air cleaners may be useful, but how the device is used will differ based on whether the pollutant source is indoors or outdoors, and whether it is continuously generated, seasonally generated (cold and flu season, allergy season), or episodic (wildfires).

For example, when working to reduce outdoor pollutants such as wildfire smoke, portable air cleaners should be run with the windows closed or otherwise limiting the influx of smoke into the space. When working to reduce indoor sources (including viruses), air cleaners should be run while also increasing the amount of fresh air entering the space. Air cleaners may need to be run continuously in some settings (e.g., when trying to reduce allergens in the home), whereas in others air cleaners can be turned on and off as needed (e.g., when hosting a gathering).

Do not leave the unit unattended and keep it clear of walls, furniture and curtains. Dal Porto et al.[9] found that impeding the fan resulted in a lower overall CADR with the same airflow, suggesting that the impeded fan was either re-entraining air or resuspending particles off the impeding surface (the floor). In contrast, Holder et al.[10] did not observe a robust effect on CADR when a 1×1 DIY air cleaner was faced into a corner. This was attributed to the relatively high airflow created in a small room with no furnishings, which facilitates mixing. Accordingly, the unit should be placed to maximize airflow and mixing, but without creating the risk of obstructions or tripping hazards due to the electrical cord.

Mixing is good, but drafts and noise are bad. Generally, studies found that running fans at the highest speeds produced the highest CADR.[8,10,13,20] However, in some contexts, running the fan at the highest speed may not be as effective in cleaning the air due to creation of turbulent flows,[30] and will also result in increased energy usage, increased operational cost, and increased noise.[10] In a school setting, it may be preferable to run the fan at a speed that will minimize noise, but still provide adequate CADR.[17,19] Noise can also be managed by modifying usage (e.g., operating at low speed during lectures, or at high speed during breaks).

Another consideration with portable air cleaners is that they can create directional airflows within the room that might result in higher exposure to some occupants depending on their position relative to the air cleaner versus the source of the pollutant or pathogen.[1] This is of greater concern when dealing with an acute hazard, such as a respiratory pathogen, rather than a chronic hazard such as PM. Derk et al.[18] observed directional airflows when using a single 4×1 design sitting at the front or back of a room; air flowed toward the air cleaner, causing nearby seats to have higher exposure to the experimentally produced aerosol, a proxy for SARS-CoV-2. The problem was resolved by deploying two units (at the front and back), which avoided a concentration of aerosols at one end of the room. This is also consistent with Gasparrini et al.[19] who placed DIY air cleaners in opposing corners of a large classroom to facilitate mixing.

These results suggest that it may be better to have multiple air cleaners rather than a single unit when the key concern is a respiratory pathogen. Lowering fan speed may also help to avoid drafts. However, despite concerns about drafts, it should be strongly emphasized that room occupants do not remain stationary. Infected and uninfected occupants move about the room, facilitating both mixing and (in the case of a respiratory disease) distribution of the pathogen. Overall, it is preferable to deploy a device and reduce overall exposure, rather than allow pathogens to accumulate.

Change the filters as needed. As with commercial units, the filters in DIY air cleaners must be changed periodically. Davis and Black[21] observed that preloading the filters with smoke or dust particles caused large decreases in airflow output (29% and 70%, respectively), which would translate to a corresponding decrease in CADR. Similarly, Holder et al.[10] found that preloading the filters with dust or simulated smoke effectively eliminated the CADR for a 1×1 design. For smoke-loaded filters, airflow through the fan was not greatly impacted; low CADR was rather attributed to the buildup of charged smoke particles on the electrostatic filter that prevented smoke aerosol in the room air from binding. Dust-loaded filters showed a higher CADR than smoke-loaded filters even with a much greater mass of dust present. These results emphasize the importance of changing filters when dirty, and especially so after a wildfire event and if electrostatic filters are used.

In a school setting, Srikrishna[17] observed that filtration efficiency decreased from 92% to 77% on average for DIY air cleaners operated for six months. In contrast, the commercial portable air cleaners operated in the same school showed a lesser decrease, as they provided a marginally lower CADR. Based on the observed decline in filtration efficiency over the six-month deployment period, the author estimated that filters would need to be replaced after one to two years of normal use (i.e., no wildfires or other extreme events).

Pistochini and McMurry[24] emphasized that soiled filters, which may carry various biological and chemical contaminants, should not be handled without a mask and gloves, and should be bagged for disposal. It should also be noted that the filters in DIY air cleaners are open to the surrounding environment. This can make it easier to observe filter soiling, but may also allow room occupants to touch soiled filters or to damage filters in use.

Know when to buy a commercial unit. DIY air cleaners are not suitable for every context, and commercial cleaners have a number of additional features and functions that may be important for some people. For example, some commercial units can be set to automatically increase the fan speed when high PM levels are detected (i.e., “set and forget”). Commercial units may also offer other features, such as active carbon filtration to remove odour or secondary treatment of pathogens in the air with UV/TiO_2. Many commercial units also alert the user when the filters need to be changed, reducing the likelihood that critical maintenance will be forgotten. Finally, commercial units are fully housed; neither the fan nor filters are exposed. If a commercial air cleaner is preferred, Health Canada provides helpful guidance on *Choosing an air cleaner*.[38]

What are the limitations of portable air cleaners, including DIY designs?

Portable air cleaners have two major limitations related to their overall contribution to creating good indoor air quality and their ability to reduce the occurrence of disease.

Although portable air cleaners, including DIY air cleaners, are effective in removing PM from room air, air filters alone do **not** remove other problematic indoor air pollutants, such as the following:

- Radon, a cancer-causing gas that is associated with approximately 3,000 deaths in Canada annually[39];
- Volatile organic compounds, which can cause breathing problems, headaches and other symptoms at high concentrations[40];
- Carbon monoxide (CO), which kills approximately 300 Canadians per year and causes an estimated 200 hospitalizations[41];
- Carbon dioxide (CO_2), which may cause occupants to experience stuffiness, discomfort, or reversible neurological symptoms such as headache or fatigue if the room is not receiving sufficient fresh outdoor air.[42]

Portable air cleaners, including DIY air cleaners, may be less effective than expected if incorrectly placed, not maintained, or if they are bumped or damaged. For all these reasons, DIY air cleaners do not replace the need for adequate ventilation and are not a long-term solution for spaces with poor indoor air quality. Rather, they should be considered a useful supplementary measure to improve air quality in combination with existing ventilation or to address imminent health hazards, such as a wildfire event or a respiratory outbreak.

Similarly, portable air cleaners cannot be used in isolation to eliminate the risk of acute (e.g., COVID-19 or asthma attacks) or chronic (e.g., atherosclerosis) diseases. Although there is ample literature to show that portable air cleaners are very effective in reducing **exposure** to PM, there is inconsistent evidence that these devices lead to improved respiratory or cardiovascular health outcomes.[43] The development of disease depends on a complex interaction of host, agent, and environmental factors. Air cleaners will certainly reduce exposure to harmful PM, but this may not be sufficient to eliminate the risk of disease for all individuals.[1]

With respect to the COVID-19 pandemic, portable air cleaners can be used to reduce the amount of virus in the air and on surfaces.[44,45] However, there is very limited data to indicate that these devices reduce COVID-19 transmission.[45] Once again, the risk of transmission is highly dependent on the interactions between host, agent, and environmental factors. In particular, the degree to which an air cleaner reduces an individual's exposure to a pathogen is strongly dependent on their position relative to the source of clean air and the source of the pathogen. In other words, an air cleaner in the room will have limited benefit to the individual seated directly beside a sick person. Thus, although air cleaners likely have a positive overall effect in reducing the presence of respiratory pathogens like SARS-CoV-2, and may help some occupants avoid infection, they remain a complement to other critical health protective measures such as vaccination, staying home when sick, masking, ventilation, barriers, surface cleaning, and hand hygiene.[46]

Summary

This document reviewed the scientific and technical literature comparing several common DIY air cleaner designs with commercial portable air cleaners. It found that DIY air cleaners are a safe and effective alternative to more expensive commercial portable air cleaners, providing comparable CADR for lower material costs and without excessive energy usage or large differences in noise generation.

Although air cleaners studied in controlled settings generally performed well, it is important to note that CADR values can vary substantially in both DIY and commercial units, and not always in a predictable manner. For this reason, it is important to choose a design that is appropriate for the space, its occupants, and their activities, and to follow the best practices identified here when constructing and operating DIY devices. It may also be prudent to consider how or whether air cleaner effectiveness can be verified *in situ* using low-cost PM sensors. Finally, engagement with building occupants is necessary to ensure that DIY air cleaner initiatives have the best chance for success. Overall, however, DIY air cleaners appear to be a valuable, low-cost tool to reduce hazardous PM exposures.

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Appendix A

To capture relevant, published literature, the following simple search strategy was used with these terms, variants and Boolean operator combinations.

(do-it-yourself OR DIY OR improvised OR constructed OR box OR Corsi-Rosenthal OR Wedge OR “filter unit”)

AND

(“air cleaner” OR “air purifier” OR “air cleaning” OR “air purification” OR ventilation OR fan OR filter OR MERV OR filtration OR box)

Additional considerations

wildfire OR pathogen OR covid-19 OR sars-cov-2

“clean air delivery rate” OR CADR OR “energy efficiency” OR noise

school OR building OR room

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