UCDAVIS
Western Cooling Efficiency Center

CASE STUDY
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TESTING DIFFERENT CONFIGURATIONS OF DO-IT-YOURSELF PORTABLE AIR CLEANERS

This DIY air cleaner performs similarly to residential portable air cleaners in terms of estimated clean air delivered and costs approximately three times less.

Portable air cleaners are increasingly in demand to reduce concentrations of particulates and respiratory aerosols indoors. Researchers at the UC Davis Western Cooling Efficiency Center (WCEC) tested two types of Do-It-Yourself (DIY) portable air cleaners (standard box fans modified with added filtration on the suction side of the box fan) and documented the power draw, airflow, and noise for each configuration. Researchers calculated the clean air delivery rate based on filter test reports and reported energy efficiency and cost metrics for each configuration.

Note that while DIY portable air cleaners are a useful and easily accessible tool to reduce particulates in buildings, they should not be considered a substitute for ensuring adequate ventilation and filtration is provided by central building heating, ventilation, and air conditioning (HVAC) systems.

METHODS

WCEC procured two different box fans from Lasko (Figure 1), the lowest cost option (A, $30), as well as a higher cost model (B, $58) that was advertised to include a "powerful 3-speed fan specifically engineered to work with a filter to clean the air." The included filter was removed from model B as the intention was to test both fans with filters procured by WCEC.

Figure 1 – Box fans used in DIY Portable Air Cleaner Testing

1A. Lasko 20-inch Power Plus Fan Box ($30)

1B. Lasko 20-inch Box Fan and Air Purifier ($58)

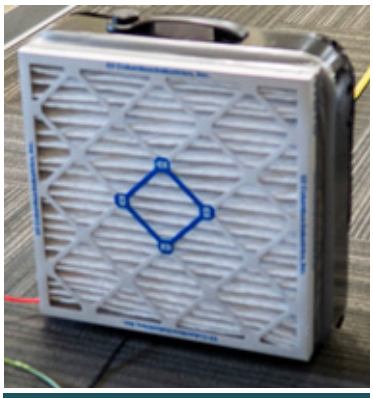
WCEC procured 2" deep filters with dimensions 20"x20" and a minimum efficiency reporting value (MERV) of 13 from a local air filter supplier. Filters were readily available and cost $11.12 each. The filters were manufactured by Columbus Industries and were clearly marked "MERV 13." Researchers contacted the manufacturer to obtain performance data on the filters. The composite minimum particle removal efficiency averaged over the 0.30 – 1.0 micron size range was 54% at a nominal face velocity of 492 feet per minute (fpm). Filter performance increases as face velocity decreases.

Researchers analyzed each fan in four configurations:

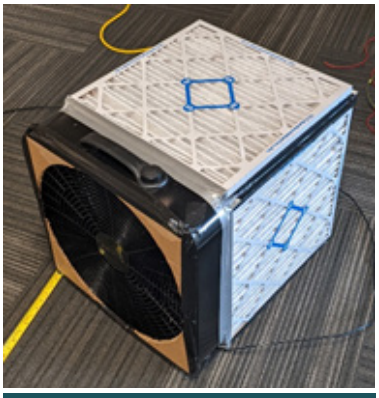
1. Unaltered fan (Figure 1A and Figure 1B).
2. Fan with a carboard shroud covering the four corners to improve efficiency and prevent backflow (Figure 2A).
3. Fan with carboard shroud and one filter on the suction side of the fan (Figure 2B).
4. Fan with cardboard shroud and four filters on the suction side of the fan, which is known as a Corsi-Rosenthal box and is designed to increase air flow by increasing the filter surface area and reducing resistance on the fan (Figure 2C).

Figure 2 - Fan configurations tested

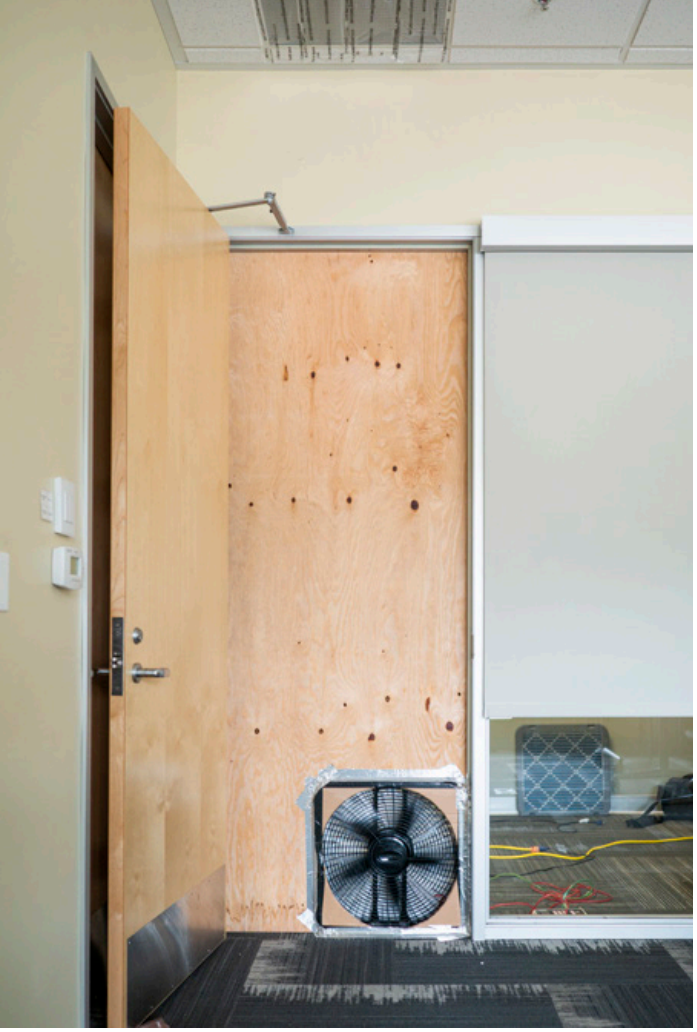
2A. Fan with cardboard shroud



2B. Fan with cardboard shroud + one filter



2C. Fan with cardboard shroud + four filters (Corsi-Rosenthal box)



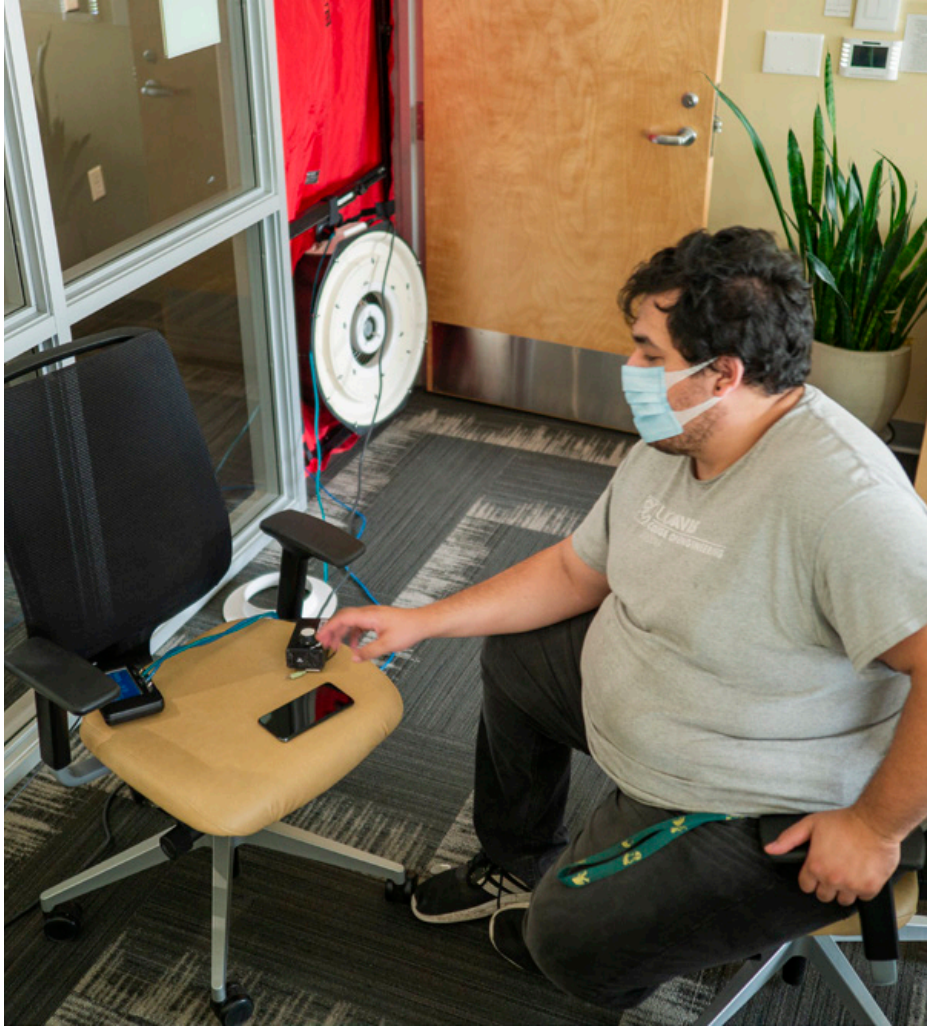


Figure 3 - Flow rate measurement using calibrated blower door

Researchers took the following measurements for each fan for power consumption, airflow and noise:

1. **Power consumption** using a DENT Power Scout 3 power meter.

2. **Airflow** using an innovative air balance method. The fan or fan-filter combo was mounted in one door of a conference room with the air supplied to the room. All supply and return registers of the conference room were sealed. A calibrated blower door fan was mounted in the second door of the same conference room. The test fan was turned on and the blower door speed was adjusted to maintain a pressure differential of zero in between the conference room and the adjacent hallway. With this set up, the exhaust measured by the calibrated blower fan is expected to approximately equal the amount of air supplied by the box fan (Figure 3).

3. **Noise** 10’ away from the front of the fan or fan-filter combo using an Extech decibel meter.

RESULTS

The simple addition of the cardboard shroud on the front of the fan improved the efficiency of both fans (between 9-26%, depending on speed), therefore all filter testing was done with the shroud in place.

Box Fan A with Four Filters

The DIY box fan filter that provided the best value was the least expensive box fan (A) with the four-filter configuration (Table 1, green highlight).

- Depending on speed, the measured airflow was 306-443 CFM, with an **estimated clean air delivery rate (CADR) of 165-239**, based on a 54% filtration efficiency for the MERV 13 filters. This is within the range of commercially available portable air cleaners designed for the residential market[1]. The calculated face velocity of the airflow through the filter was 34-49 fpm, which is significantly lower than the test velocity that filtration efficiency was measured at (492 fpm). Therefore, the CADR estimated is conservative and actual filtration efficiency and resulting CADR are likely to be higher.
- The **estimated energy efficiency was 2.17-2.19 CADR/watt**, which exceeds the Energy Star requirement of 2.0 CADR/watt[2].
- In terms of first cost, **cost per unit of air cleaning was $0.17-$0.24 per CADR**, depending on speed. This was significantly less expensive than commercially available small portable air cleaners that cost at least $0.71 per CADR[1].
- **Noise readings were in the 53-61 dB range**, with increasing noise as speed increased. This is within the range of noise reported for commercially available portable air cleaners[1]. If used in a classroom, a reasonable approach would be to operate the DIY portable air cleaner at low speed while teaching and then increase the speed to high during the lunch break to provide additional air cleaning prior to afternoon classes.
- Because the four-filter configuration contains such a large filter surface area, the filters are expected to provide up to a year of service. Performance degradation (i.e., reduced airflow) due the filter loading was not tested.

Box Fan B with Four Filters

Performance of the more expensive box fan (model B) with the four-filter configuration was similar to model A, with the minor difference that the CADR was estimated to be about 12% greater at high speed. However, this benefit was not justified by the additional cost of the fan. It would be more cost effective to build two DIY box fan filters with the lower cost fan if additional filtration is desired.

Box Fan A/B with One Filter

Performance of DIY box fan filters with the one-filter configuration was poor. In both cases regardless of speed, the CADR was 83 or less and the energy efficiency was 0.75 CADR/watt or less. This configuration is not recommended.

Table 1 - DIY box fan filter test results. Best value highlighted in green.

Fan	Fan Intake	Speed	Power (W)	Airflow (CFM)	CADR	Noise (dB)	Face Velocity (fpm)	Energy Efficiency (CADR/ Watt)	Cost ($)	Cost ($) per unit of CADR
Lasko (A) + Shroud	4 Filter	1	70	306	165	53	34	2.19	$74.48	$0.24
Lasko (A) + Shroud	4 Filter	2	88	407	220	58	45	2.31	$74.48	$0.18
Lasko (A) + Shroud	4 Filter	3	102	443	239	61	49	2.17	$74.48	$0.17
Lasko (A) + Shroud	1 Filter	1	70	85	46	53	38	0.61	$41.12	$0.48
Lasko (A) + Shroud	1 Filter	2	89	120	65	58	53	0.67	$41.12	$0.34
Lasko (A) + Shroud	1 Filter	3	102	142	77	61	63	0.70	$41.12	$0.29
Lasko (B) + Shroud	4 Filter	1	71	301	163	52	33	2.12	$104.48	$0.35
Lasko (B) + Shroud	4 Filter	2	90	422	228	57	47	2.34	$104.48	$0.25
Lasko (B) + Shroud	4 Filter	3	103	500	270	60	56	2.43	$104.48	$0.21
Lasko (B) + Shroud	1 Filter	1	71	91	49	52	40	0.64	$69.12	$0.76
Lasko (B) + Shroud	1 Filter	2	89	135	73	57	60	0.76	$69.12	$0.51
Lasko (B) + Shroud	1 Filter	3	103	154	83	60	68	0.75	$69.12	$0.45

[1] *Considerations for Use and Selection of Portable Air Cleaners for Classrooms: bit.ly/pacClassrooms*

[2] *ENERGY STAR® Program Requirements for Room Air Cleaners: bit.ly/energystarRequirements*

CONCLUSIONS AND LIMITATIONS

A standard box fan modified with four 2-inch filters on the fan intake was constructed for less than $75 in materials and was estimated to perform similarly to residential portable air cleaners that are approximately three times as costly in terms of clean air delivered.

Users should be aware that exposed filter surfaces may contain viable virus particles, therefore, it is important that occupants do not touch filter surfaces and that people handling the filters wear an appropriate mask and gloves and bag the filters when they are disposed of.

The testing has the following limitations:

- The CADR is only estimated, a true measurement of CADR would require measuring particle filtration in accordance to the AHAM-AC-1 test procedure.
- Only two fan models were tested; performance with additional fan models is unknown, however the low-pressure drop of the four-filter configuration, which was estimated at 0.02-0.03 inwc, is likely to be compatible with many box fans on the market.

WESTERN COOLING EFFICIENCY CENTER

The Western Cooling Efficiency Center (WCEC) is an authoritative and objective research center at the UC Davis Energy and Efficiency Institute that accelerates the development and commercialization of efficient heating, cooling, and energy distribution solutions.

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