Characterizing the Long-Term Performance of Four Corsi-Rosenthal Boxes

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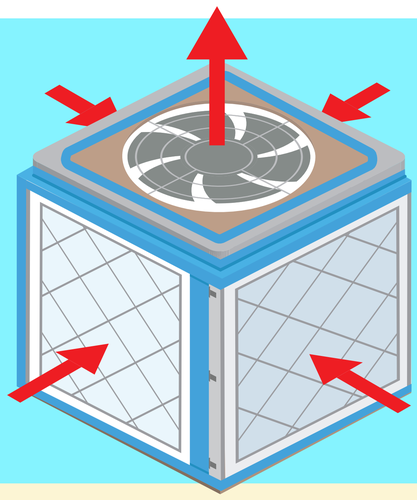


Background

- Do-it-yourself air cleaners consisting of four air filters, a three-speed box fan and cardboard base
- Easy to build and made out of affordable materials
- Often out-perform HEPA air cleaners[1]
- Reduce airborne disease transmission and exposure to air pollution

[1] *Rachael Dal Porto, Monet N. Kunz, Theresa Pistochini, Richard L. Corsi & Christopher D. Cappa (2022) Characterizing the performance of a do-it-yourself (DIY) box fan air filter, Aerosol Science and Technology, 56:6, 564-572, DOI: 10.1080/02786826.2022.2054674*

Research Questions

Do CR boxes maintain their performance (in terms of clean air delivery rate (CADR) and power consumption) over time?

Does CADR change across particle sizes and fan speeds?

Methods

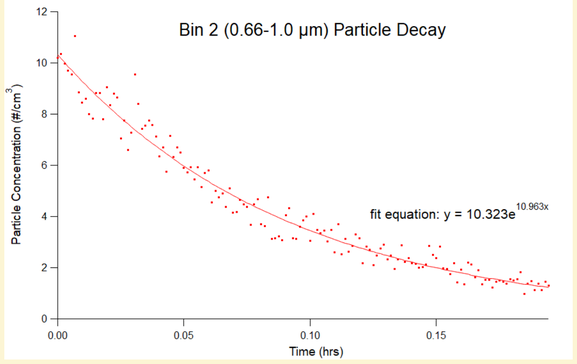
- Built 4 CR-Boxes with box fans and MERV-13 air filters. Filters for Box 1 were from Air Handler. Filters for Box 2-4 were from Tex-Air. The two brands of filters were observably different – Air Handler filters had more pleats and were fuzzier than Tex-Air filters.
- Measured the air cleaning performance of each box at each of the 3 speeds
- Placed boxes in different field settings at UC Davis
  - » Box 1 in a civil engineering lab
  - » Box 2 in a multi-use lab
  - » Box 3 in small office suite
  - » Box 4 in large office suite
- Outfitted CR boxes with timers to operate 8 AM – 5 PM every day, though occupants could override timers and change fan speed
- Outfitted boxes with HOBO plug load data loggers to measure power over time
- After 70 days retested performance

Air cleaning performance test:

- Introduced aerosolized particles generated from nebulized salt water to a conference room (volume of 4,251 ft^3) with outside air ventilation turned off and measured particle decay with air cleaner on
- Used QuantAQ Modulair-PM with Optical Particle Counter (OPC) sensor to measure particle concentration during test
  - » OPC reports particle number concentration (number/cm^3) in 24 size-based bins from 0.35 to 40 µmin diameter
  - » Analyzed data for bins 0-6 (0.3-3 µm) – data for larger bins had low particle counts and high uncertainty
- For each bin, fit particle decay data to exponential curve—time constant of fit equation is air changes per hour (ACH). The ACH attributable to background particle settling was calculated in a separate test and subtracted from the ACH measured during the air cleaning test.
- Multiplied ACH by volume of test space to obtain CADR

Power measurements:

- HOBO power meters with 5-min. logging
- Summed the total hours each box ran at each speed
- Calculated initial andfinal power draw for each box



Example decay of particles in Bin 2 during an air cleaning test. The coefficient of x in the fit equation is the particle removal rate time constant (or ACH), with units of 1/hr.

Example air cleaning test setup. CR box placed in center of room, and fans mix air during particle generation.

Results

Box 1's filters accumulated a substantial amount of particles, while Boxes 2-4 saw less accumulation:

Box 1 Filters **Box 2 Filters** **Box 3 Filters** **Box 4 Filters**

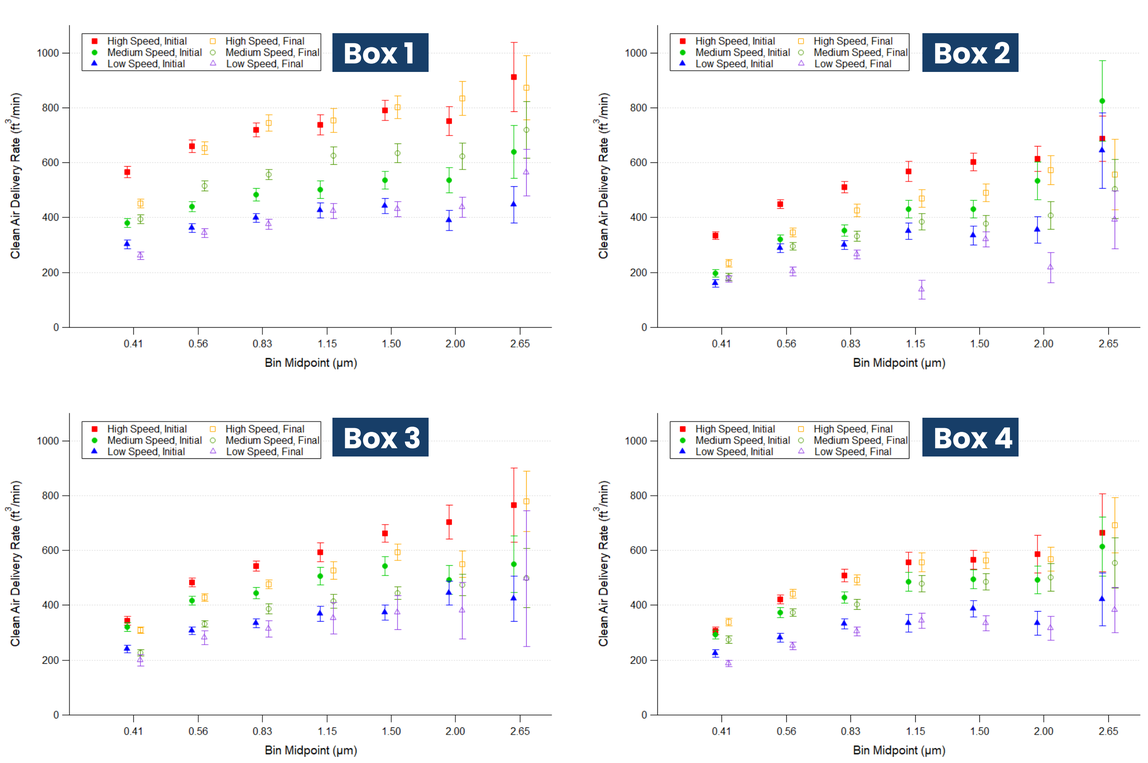
Photos depicting particle accumulation on each CR box's filters. From left to right: Box 1 - Box 4

The difference in power draw before and after the deployment period was less than 1% for all CR boxes (reported accuracy of the power meter is 0.5%).

Box#	Speed	Runtime (hours)	Avg Power Draw Day 1 (W)	Avg Power Draw Day 70 (W)
1	Medium	634	72.5	72.7
2	Low	634	63.6	63.1
3	High	365	86.2	86.5
3	Medium	260	—	—
4	Low	634	59.9	60.1

We set the boxes to unique speeds during field deployment, each box only has power data for an individual speed.

Air Cleaning Performance



Each graph shows the CR box CADR versus bin size. We tested each CR box at all three speeds before and after field deployment (6 CADR values per bin). The error bars show the 95% confidence interval for each CADR measurement.

Conclusions

- Starting at Bin 0 (0.3-0.46 microns), CADR generally increases with particle size
- Box 1's pre-deployment performance exceeded that of Boxes 2-4 by a CADR of 100-200 ft^3/min at high speed, showing that MERV 13 filters from different manufacturers may have different performance.
- For boxes 2-4, CADR decreased slightly after field deployment across all speeds
- CADR either stayed about the same or increased for Box 1 after field deployment, even though this filter appeared "dirtiest" by visual inspection.
- 70 days of field deployment had no discernible effect on power draw

Next Steps

- Return CR boxes to the field and reevaluate performance after another operational period
- Determine single-pass efficiencies for each box (percentage of airborne particles removed in one pass through filters)
- Analyze impact of CR box on particle concentration in field test spaces

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