2-Year Durability Comparison of HEPA vs MERV 16 vs MERV 13 Air Filters in DIY Air Cleaners Used Daily in Elementary and Middle Schools

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May 12, 2023: CDC recommends 5 air changes per hour and DIY

How Much Ventilation Is Enough?

Aim for 5 Air Changes per Hour (ACH)

When possible, aim for 5 or more air changes per hour (ACH) of clean air to help reduce the number of germs in the air.

13. Are do-it-yourself (DIY) air cleaners effective at reducing the risk of COVID-19 transmission indoors? How do they compare to commercially-available products?

Yes, when built and used correctly, they can be a protective temporary intervention.

(archived) https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html
(new) https://www.cdc.gov/niosh/ventilation/prevention/Aim-for-5.html

DIY air purifiers evaluation and selection based on peer-reviewed publication

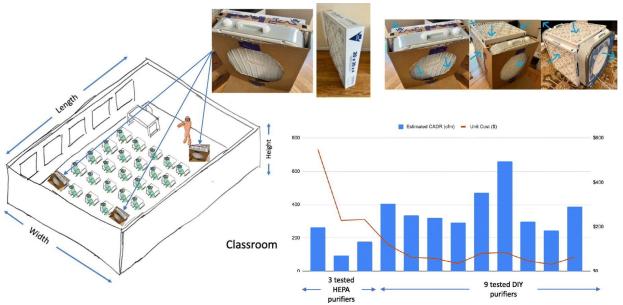
Science of The Total Environment
Volume 838, Part 1, 10 September 2022, 155884

Can 10× cheaper, lower-efficiency particulate air filters and box fans complement High-Efficiency Particulate Air (HEPA) purifiers to help control the COVID-19 pandemic?

Devabhaktuni Srikrishna

Key points:

- Evaluated: 1-filter, 4-filter (Corsi-Rosenthal), and 3-filter with 2 fans all using shroud for ‘laminar’ flow
- Single-filter MERV 13-16 works well with box fans even <u>on lowest fan speed</u>
- Choice of filter improves clean air delivery rate (measured at 0.3 µm to 10 µm)
- Velcro works (duct tape not needed)
- Lennox 5” MERV 16 had best results per unit
- Nordic Pure 2” MERV 13 was most cost-effective



https://www.sciencedirect.com/science/article/pii/S0048969722029813

SAFE DIY (open-source) air purifiers made by parent volunteers from Lasko fans and 5” Lennox MERV 16

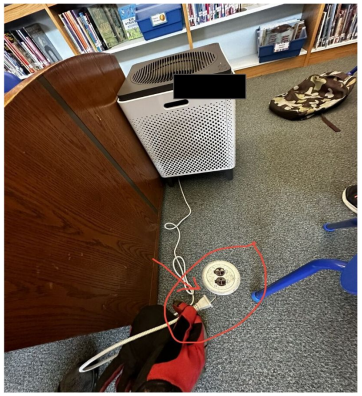
Supplementary Air Filtered Exchanges (SAFE) Air Filtration (Do-It-Yourself) for COVID, wildfires, pollution, allergies, etc.
https://www.patientknowhow.com/safe.html

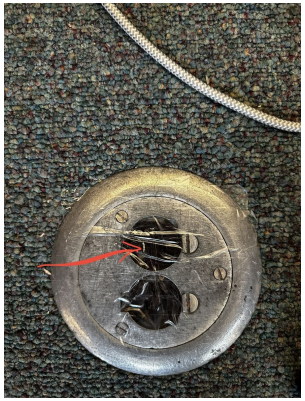
Assembly of SAFE DIY Air Purifier: 1-min video (8-min, speeded up 8x).
https://www.youtube.com/watch?v=EN3kYm7bXJs

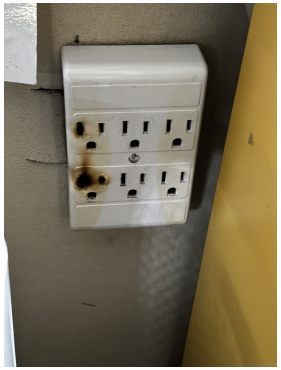
2022: 47 HEPA and 60 MERV 16 DIY air purifiers installed in San Francisco elementary school

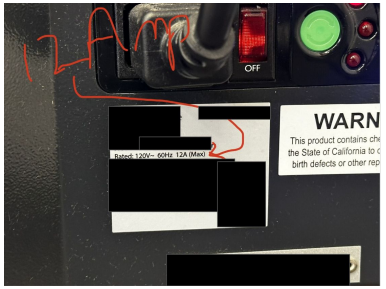
2023: 160 SAFE DIY installed for Fall 2023 in all classrooms, library, and lunchroom of a middle school in SF

Electro-mechanical safety!! Independent of HEPA or DIY









<u>Point-person:</u> Need an on-site safety point person (e.g. parent) to be “on call” for teachers to inspect and arrange for principal and electrical professionals to fix

Teacher and principal experiences with MERV 16 DIY (SAFE)

https://youtu.be/EYtmnUc8cBE?si=pgAamo4ReVOFZaaE

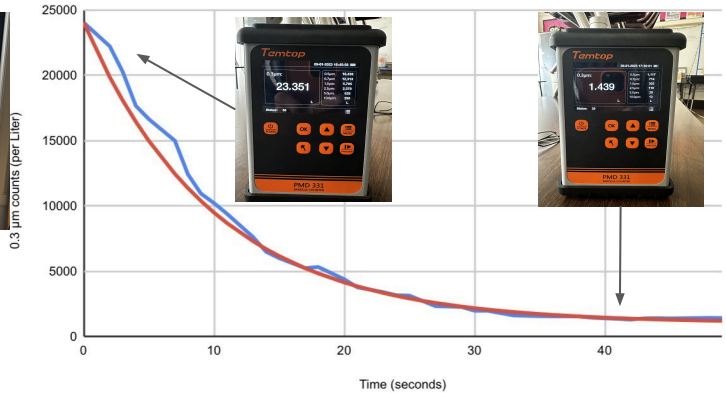
Teacher Survey at both schools (December 2023)

School	Survey date	Number of teachers surveyed	Using Daily	Using Weekly	Using Monthly
Elementary School	December 2023	18 / 18	**89%**	11%	0%
Aptos Middle School	December 2023	31 / 46	**65%**	32%	3%

Teacher Survey at both schools (December 2023)

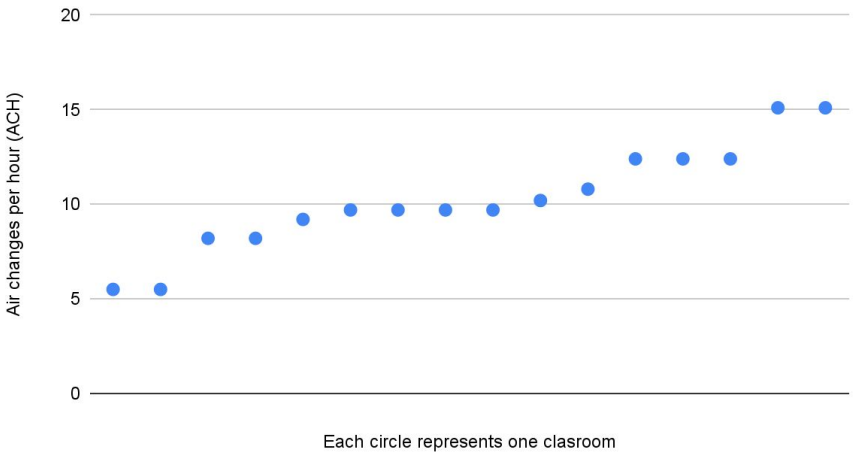
School	Why do you use air purifiers in your classroom?	What is the main reason you use air purifiers in your classroom
Elementary School	89% COVID 🦠 89% air circ. ♻️ 83% Respiratory viruses besides COVID (e.g. flu) 😷 67% wildfires 🔥 56% air circ. when hot 🥵 50% air pollution 🚭 39% allergies 🤧 17% control odors 💩 11% industrial pollution 🏭	44% COVID 🦠 22% — Respiratory viruses besides COVID (e.g. flu) 😷 22% air circulation ♻️ 6% — air pollution 🚭
Aptos Middle School	71% air circ. ♻️ 68% air pollution 🚭 65% COVID 🦠 52% Respiratory viruses besides COVID (e.g. flu) 😷 52% air circ. when hot 🥵 39% allergies 🤧 29% control odors 💩 26% wildfires 🔥 16% industrial pollution 🏭 16% road pollution 🚗	29% COVID 🦠 23% air circulation ♻️ 19% — air pollution 🚭 13% air circulation when hot 🥵 10% — Respiratory viruses besides COVID (e.g. flu) 😷

Middle School: Measured 6 ACH in 8000 cubic foot classroom



* with three MERV 13-16 DIY purifiers using ambient aerosols (at 0.3 µm) —> DIY air purifier ~ 250 cfm

Elementary school: Est. air changes per hour (ACH) in 16 classrooms



18 ACH measured in 9000 cubic foot classroom with 7 air purifiers

* using ambient aerosols (0.3 µm) –> DIY air purifier ~ 360 cfm

But how long do they last?

Elementary school: 47 HEPA + 60 DIY air purifiers

Air cleaner (purifier)	Approx. retail cost ($)	Est. CADR (cfm)	Number (approx. cost) of purifiers needed for 6 ACH in each classroom (9000 cubic foot)	Number (approx. cost) of purifiers needed for 12 ACH in each classroom (9000 cubic foot)
HEPA A	$500	300 cfm	3 ($1,500)	6 ($3,000)
HEPA B	$850	125 cfm	7 ($6,000)	14 ($12,000)
HEPA C	$150	235 cfm	4 ($600)	8 ($1200)
HEPA D	$279	315 cfm	3 ($900)	6 ($1700)
DIY (5” Lennox MERV 16)	$130	330 cfm	3 ($400)	5 ($650)
DIY (5” Lennox MERV 16)	$80	380 cfm	3 ($240)	5 ($400)
DIY (4” Nordic Pure MERV 14)	$80	290 cfm	4 ($300)	6 ($480)
DIY (2” Nordic Pure MERV 13)	$55	263 cfm	4 ($200)	7 ($400)

DIY air purifiers durability data in peer-reviewed publication

Health Security > Vol. 22, No. 2

Research Article | OPEN ACCESS | | Published Online: 16 April 2024

Pentagon Found Daily, Metagenomic Detection of Novel Bioaerosol Threats to Be Cost-Prohibitive: Can Virtualization and AI Make It Cost-Effective?

Author: Devabhaktuni Srikrishna | AUTHORS INFO & AFFILIATIONS

Publication: Health security • https://doi.org/10.1089/hs.2023.0048

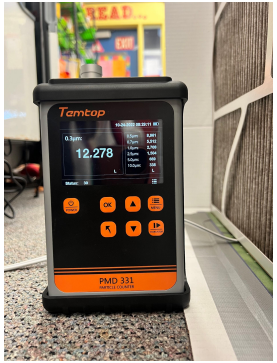
Permissions & Citations | PDF/EPUB

Operation and Maintenance: Filter Longevity and Replacement Cycle

https://www.liebertpub.com/doi/10.1089/hs.2023.0048#sec-5

Oct 2022 snapshot at elementary school: Filtration eff. at 0.3 μm of HEPA, DIY air purifiers

Air Purifier	Count	Average	Standard Deviation	Minimum	Maximum
HEPA A	18	93.51%	3.38%	84.96%	98.18%
HEPA B	18	89.79%	4.34%	81.48%	96.83%
HEPA C	9	88.69%	3.62%	83.49%	93.26%
HEPA D	2	97.11%	1.83%	95.81%	98.40%
DIY Lennox MERV 16 (Feb 2022)	24	76.87%	6.71%	59.68%	89.30%
DIY Lennox MERV 16 (New)	26	91.76%	5.08%	79.33%	98.55%
DIY Nordic Pure MERV 13	7	50.95%	6.76%	38.83%	58.55%
DIY Nordic Pure 4" MERV 14 (Jan 2022)	4	62.38%	4.42%	57.90%	66.35%

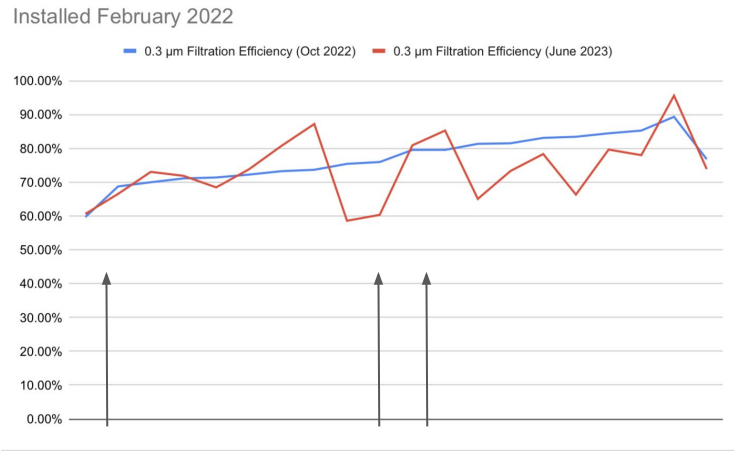


Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

Oct 2022 (blue) vs June 2023 (red) at elementary school: Filtration eff. of 5” MERV 16 filters at 0.3 µm

Filters Installed Feb 2022:

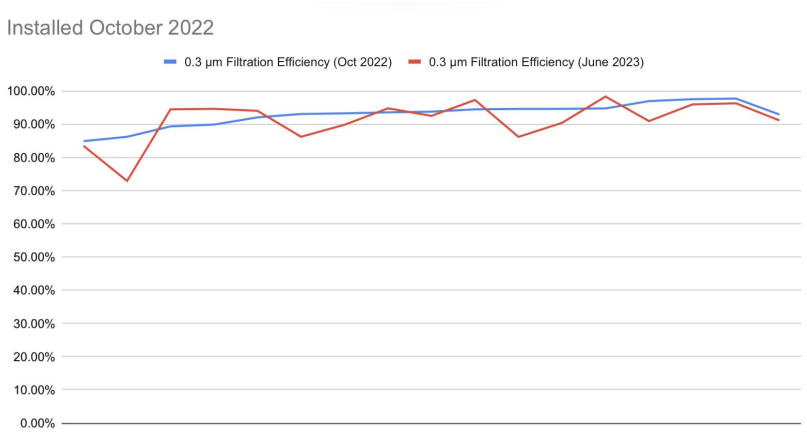
- 77% average in Oct 2022
- 74% average in June 2023



Supplemental Figures S8

Filters Installed Oct 2022:

- 93% average in Oct 2022
- 91% average in June 2023



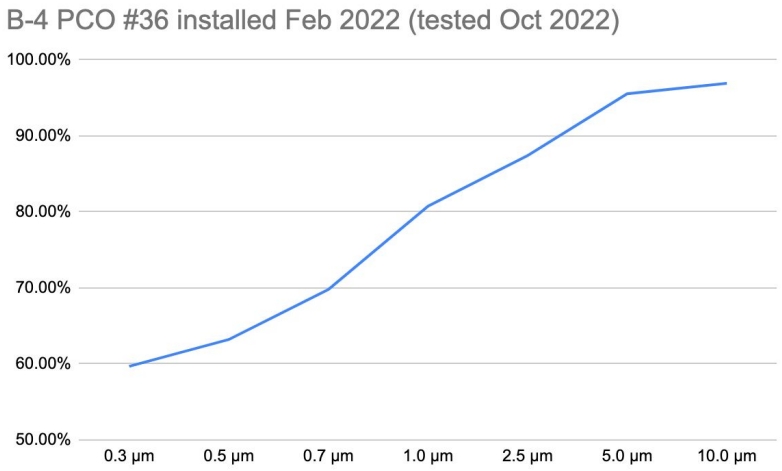
Supplemental Figures S9

Source: https://www.liebertpub.com/doi/10.1089/hs.2023.0048#sec-5

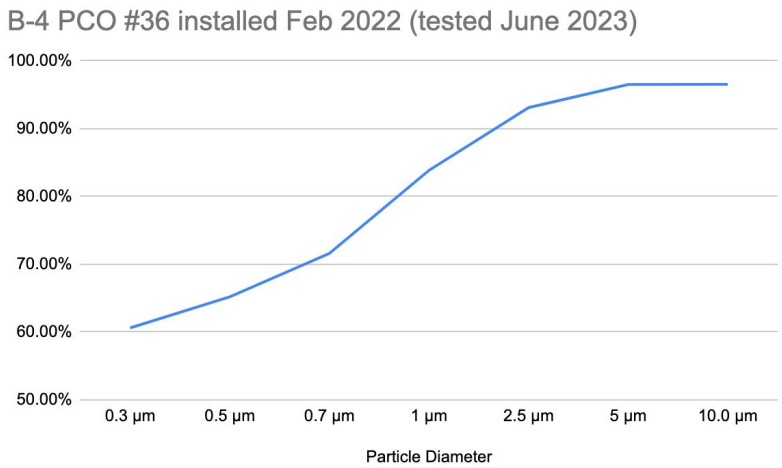
Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

Worst case: degraded filtration efficiency in a 5” MERV 16 filter by particle size (0.3 µm to 10 µm)

After one semester of use



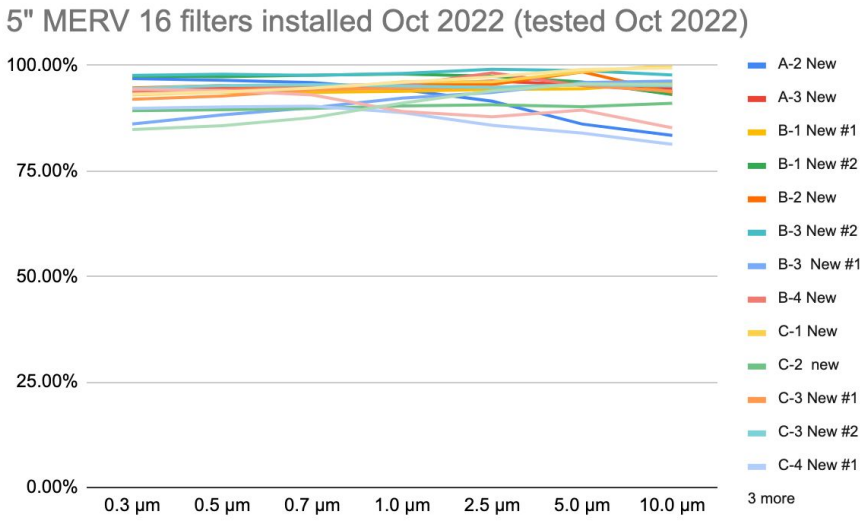
After three semesters of use



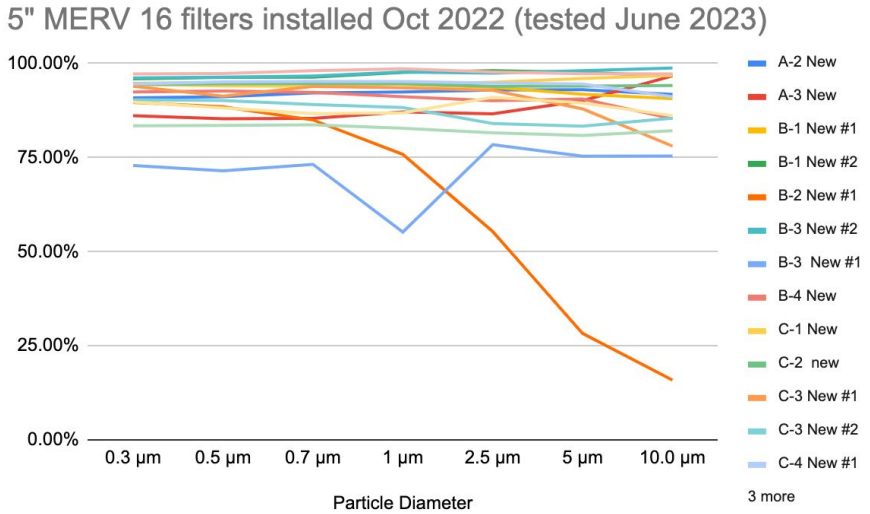
Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

Filtration efficiency of all 5” MERV 16 filters installed in Oct 2022 by particle size (0.3 µm to 10 µm)

After installation



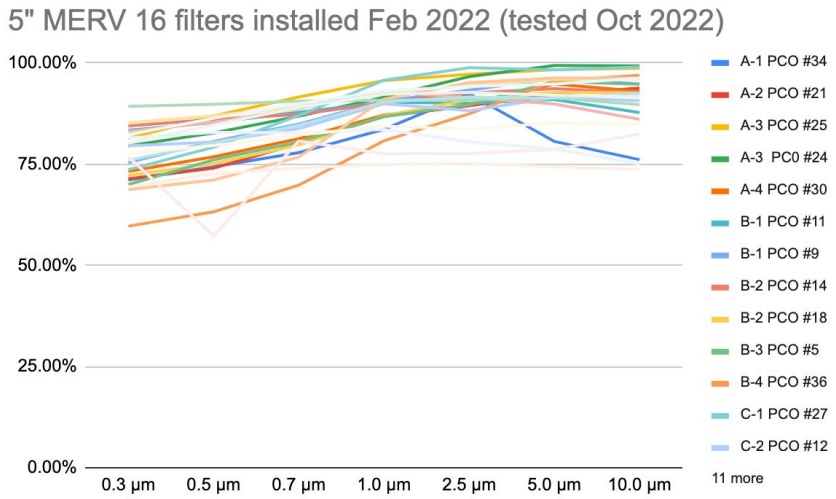
After 2 semesters of use



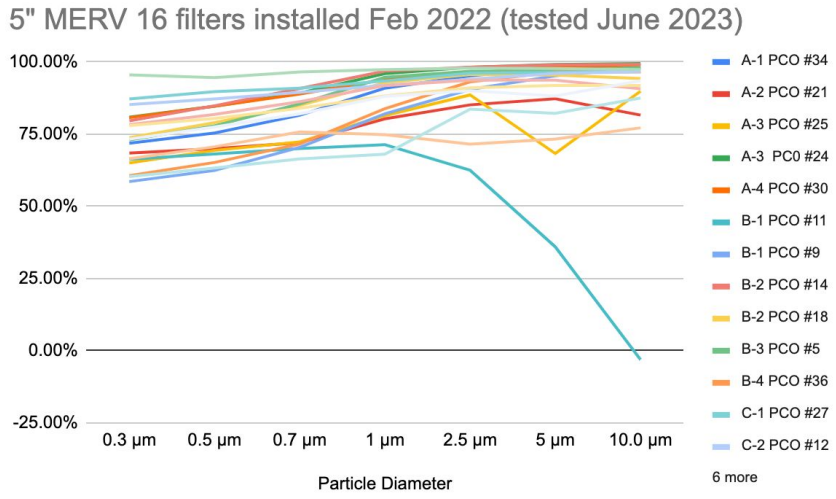
Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

Filtration efficiency of all 5” MERV 16 filters installed in Feb 2022 by particle size (0.3 µm to 10 µm)

After 1 semester of use

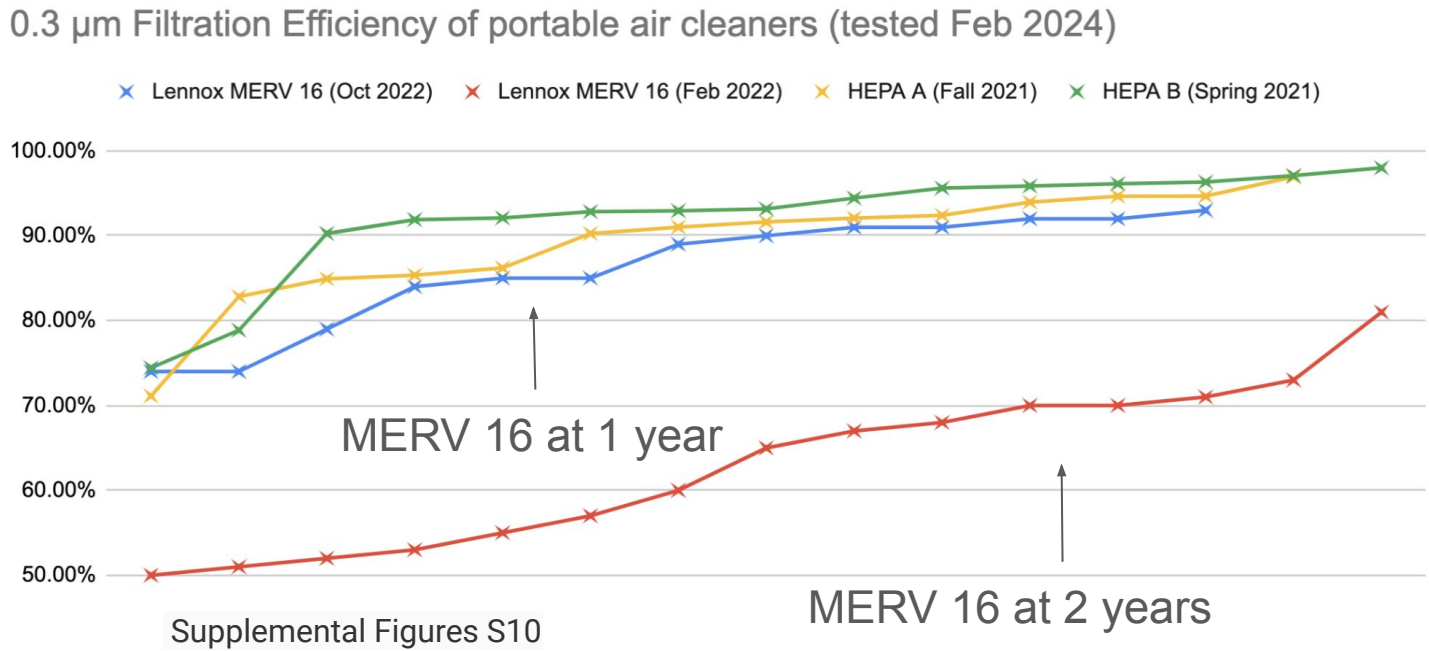


After 3 semesters of use



Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

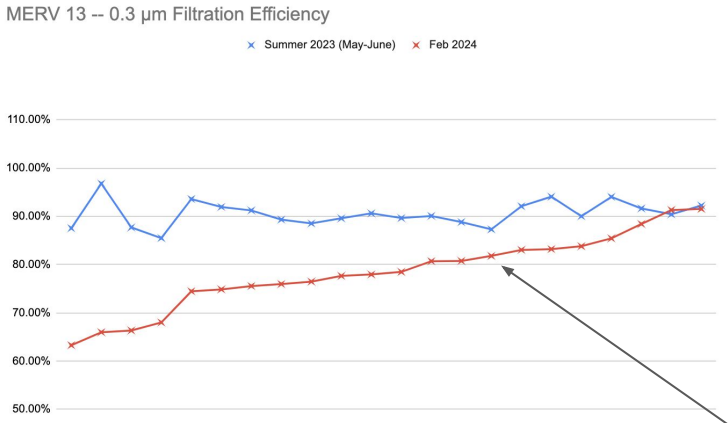
Feb 2024 snapshot at elementary school: two years of daily use resulted in degraded filters



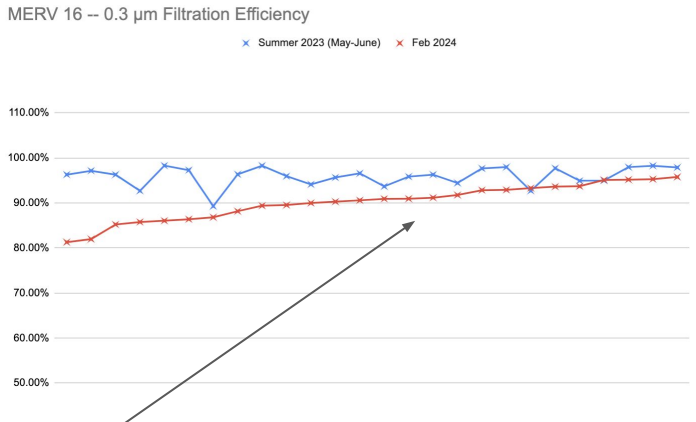
Source: https://www.liebertpub.com/doi/10.1089/hs.2023.0048#sec-5

Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

May-June 2023 versus Feb 2024 at middle school: In classrooms with teacher-reported daily usage, MERV 16 was more durable than MERV 13



Supplemental Figures S11



Supplemental Figures S12

MERV 13 filtration eff. degraded more than MERV 16 after semester of daily usage

Source: https://www.liebertpub.com/doi/10.1089/hs.2023.0048#sec-5

Method: https://www.sciencedirect.com/science/article/pii/S0048969722029813

Conclusions

- Cost-effectiveness: SAFE DIY air purifiers (5” MERV 13-16) are both economical and cost-effective to operate in schools to meet/exceed CDC standard of 5 air changes per hour

- Low-speed: Teachers find noise from Lasko box fan is acceptable in classrooms on low speed (speed 1)

- Limited number: Space and power outlets were at a premium in elementary school classrooms. Although some deployed 7 purifiers, others could only find space for 3 of them.

- Electro-mechanical safety: must be managed when deploying air purifiers of any type at scale

- MERV 16 Durability: Decent filtration efficiency was retained for MERV 16 after 1+ year operation in schools in most filters, but generally needed replacement after 2 years. A few units earlier.

- MERV 13 vs MERV 16: In classrooms with teacher-reported daily usage, MERV 16 was more durable than MERV 13

- Worst case: a few filters degraded and needed to be replaced earlier based on measurement

- Handheld filter testing tools: essential to identify failing filters in HVAC and air purifiers (HEPA/DIY)

- On-site IAQ pilot and co-pilot (e.g. parents): needs to be “on call” for teachers to inspect and arrange for fprincipal and electrical professionals to fix

Links

Long-term experience operating CDC recommended 5 air changes per hour in a K-5 elementary school using HEPA and MERV 16 Do-It-Yourself (DIY) portable air cleaners
https://www.medrxiv.org/content/10.1101/2022.11.05.22281734v2

Supplementary Air Filtered Exchanges (SAFE)
Air Filtration (Do-It-Yourself) for COVID, wildfires, pollution, allergies, etc.
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Assembly of SAFE DIY Air Purifier: 1-min video (8-min, speeded up 8x).
https://www.youtube.com/watch?v=EN3kYm7bXJs

5 teachers, principal at K-5 school explain why they use 4 to 7 air purifiers per classroom
https://youtu.be/EYtmnUc8cBE?si=pgAamo4ReVOFZaaE

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