Emerging Approaches to Cleaner Indoor Air During Wildfires

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Acknowledgements

Katie Stewart, EPA Region 9

Alison Clune, EPA Office of Radiation and Indoor Air

Topics to cover:

- EPA research on wildfire smoke indoors
- Overview of research needs on smoke infiltration
- Low-cost air cleaning
- Sensors for indoor air quality
- Future directions

EPA research on wildfire smoke indoors

What can communities do to reduce their exposure to wildfire smoke indoors?

Wildfire ASPIRE study

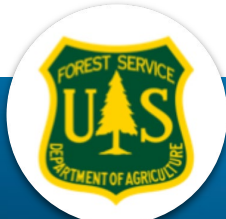Advancing Science Partnerships for Indoor Reductions of Smoke Exposures

EPA partnered with Missoula, MT and the Hoopa Valley Tribe in CA to develop research to meet their needs to protect public health from wildfire smoke

Partner discussions led to these research questions:

- What interventions are effective for reducing wildland fire smoke exposures and risks?

- What science is available to support recommendations for communities to develop cleaner air spaces in larger buildings (e.g., schools, community centers)?

- How effective are portable air cleaners (PACs) during smoke events?

Winnacker

https://www.epa.gov/air-research/wildfire-study-advance-science-partnerships-indoor-reductions-smoke-exposures

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Overview of research need on smoke infiltration

EPA hosted clean air spaces web summit in 2019

Clean Air Spaces: Indoor Air Filtration to Protect Public Health During Wildland Fire Smoke Episodes – *What are the Knowns and Unknowns?*

June 12 – 13, 2019

- Experts on indoor air quality and wildfire smoke from federal, state, local, and tribal governments; academia; and private industry

- Presented on topics:
  - Health effects of wildfire smoke
  - Wildfire air quality response
  - Smoke ready communities
  - How to make a clean indoor air space
  - Cost and benefits of filtration interventions
  - Real world performance of forced air systems for smoke removal
  - Impact of air filtration on health

- Most presentations available online: https://www.epa.gov/air-research/web-summit-presentations-clean-air-spaces-indoor-air-filtration-protect-public-health

How effective are strategies to achieve cleaner air indoor during smoke episodes

Better-sealed buildings

- How effective is sealing at reducing smoke indoors?
- What are the impacts on other pollutants' indoor air concentrations?
- Is there a health benefit from staying indoors?
- If no AC, what is the impact of high temperature and smoke exposure?

Central HVAC strategies

- How effective is the HVAC system for particle removal for different design and maintenance levels?
- What are the impacts on other pollutants?
- What is the lifespan of HVAC filters during smoke events?
- What is the best practice for communities with diverse infrastructure?

Portable air cleaners

- What is the lifespan of PAC filters during smoke events?
- What are the impacts on other pollutants?
- How effective are smart PACs or sensors for achieving cleaner indoor air?
- What is the optimal design for effective low-cost PACs?

Low-cost air cleaning

Low-cost air cleaners

DIY Air cleaner = Box fan + furnace filter

- Low-cost and accessible approach to air cleaning

- Instructions widely available online, multiple configurations

- Provided to community by some local air quality agencies

Confederated Tribes of the Colville Reservation
Air Quality Program

Issued : July 9, 2019

Protecting Yourself from Wildfire Smoke

Box Fan and Filter Instruction Guide To Decreasing Smoke in Your Home

A box fan combined with furnace filter(s) that collect smoke sized particles or smaller have become popular during wildfire smoke episodes. This combination is easily constructed, effective and economical. Adding a filter to the box fan can reduce air flow up to 75%. The air flow arrow should face the intake side of the fan.

Single Filter Configuration

One Step: Tape filter onto the intake side of fan, allow spaces for greater air flow needed by the fan. Alternative - turn on the fan and add the filter. The air flow will hold the filter to the fan

Tip for Using Box Fan and Filter
- *Do not* use the fan/filter while sleeping and remember to turn off when you leave home Close all windows and doors while fan/filter is in use
- Better to use in the room that you are in at that time.
- Position the fan/filter toward the middle of the room, away from walls and big objects.
- Replace filters when they look dirty/dark

Performance Comparison

GOOD   BETTER   BEST

Manufactured air filters are the best method and investment to protect your health from wildfire smoke in your home.

Materials needed:
- 20 Inch Box Fan - Make sure the controls are on top
- MERV 13 Rated 20" x 20" x 1" pleated filters
- Tape - Painter or Duct
- Two Cardboard triangles 21" on all sides

Price:
Box Fan about $22
Filter Prices Range $5 to $18, depending on brand and quality purchased

Double Filter Configuration
Twice the filtration and airflow than single, and is easier on the fan

Step 1: Lay two filters side by side with the flow arrow facing up and tape together to form a hinge.

Step 2: Stand filter up and tape a cardboard triangle to the top, flip over and tape the second triangle on.

Step 3: All that remains is to tape the filters to the box fan. Gaps are OK and help with air flow. Use a spacer under the filter assembly to match the fan better.

Filtered Air comes out of the front of the fan producing up to 95% reduction of harmful materials.

For more information go to:
https://www.colvilletribes.com/environmental-trust or email
Air.Quality@colvilletribes.com

Smoke Pollution Particulate matter & toxic gases are pulled in through the back of the fan.

DIY air cleaner safety

Wildfire Smoke Exposure — Jan 2021 UL *Chemical Insights Newsletter*

Research

Our newest research is evaluating the unintentional fire risks of operating DIY air cleaners. Increasing arid climates, extreme temperatures and neglected forest management are leading to more destructive wildfire events, resulting in harmful combustion aerosols entering homes, schools and other enclosed spaces. These aerosols contain harmful chemicals and particulate matter that can affect people's health. People are now taking steps to remove smoke from their homes, schools and workplaces by using simple and inexpensive DIY air cleaners built with a box fan and a common furnace filter. Working with the The Office of Research and Development at U.S. EPA, we are evaluating fire potentials under different dust loading conditions.

- Partnered with Underwriters Laboratories Research Division (Chemical Insights) for DIY safety evaluations

- Evaluating 5 commercial box fans with MERV 13 filters, 3 filter loading conditions:
  - Unloaded filter
  - Heavily loaded with dust (ASHRAE Test Dust no 2.)
  - Smoke loaded

- Measure temperatures on fan to identify potential fire risk

- Results coming soon…

Currently, recommend using only <u>NEW</u> box fans (since 2012) with added safety features of fused plugs and thermal cutoffs

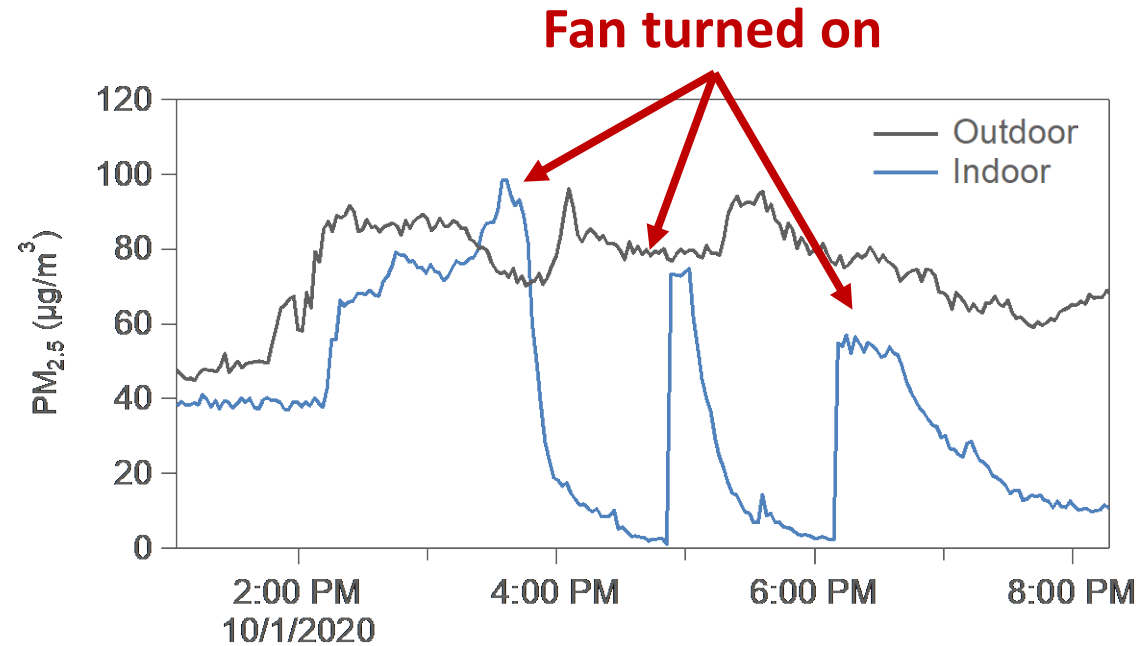# EPA ORD work in progress: DIY laboratory effectiveness

- Measuring CADR for simulated wildfire smoke (smoldering pine needles) in a 30 ft^3 chamber

- Completed 8 trial runs with Lasko box fan + Aerostar MERV 13 filters

- Repeatable results from PM$_{2.5}$ = 38 – 150 µg/m^3

Feature	DIY Air Cleaner	Commercial Air Cleaner
Price	~$30	~$100
CADR	113 ± 5	108
Noise (dB)	67 ± 1	55
Power (W)	77 ± 3	53

- Upcoming tests to focus on higher PM$_{2.5}$ concentrations, loaded filters, comparison to commercial units
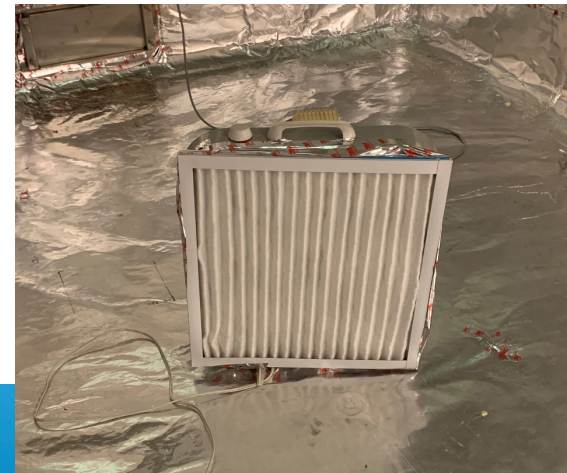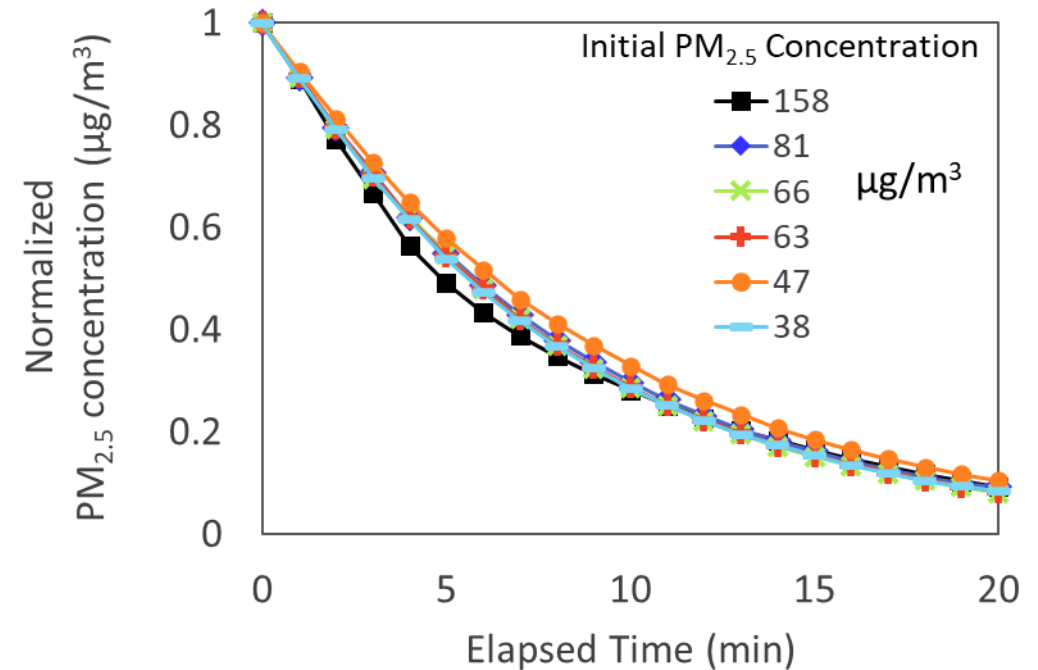
EPA ORD work in progress: DIY in-home effectiveness

PM2.5 Sensor

DIY Air Cleaner

DIY operated indoors in San Francisco during 2020 smoke episode

Fan turned on

- Effectively reduced moderate smoke concentrations to near zero

- Estimated CADR = 35

- Generated substantial heat in closed room

Cleaner air spaces

Cleaner air spaces

Resources for setting up cleaner air spaces

- [Wildfire Smoke: A guide for public health officials (2019)](#) – Appendix B Identification and Preparation of Clean Air Shelters for Protection of the Public from Wildfire Smoke, US Interagency

- [COVID-19 Considerations for Cleaner Air Shelters and Cleaner Air Spaces to Protect the Public from Wildfire Smoke](#), CDC

- [Evidence Review: Filtration in institutional settings during wildfire smoke events](#), British Columbia CDC

- [Create a Clean Room to Protect Indoor Air Quality During a Wildfire](#), US EPA

COVID-19 considerations
- Screen and separate infected individuals
- Ensure indoor air flow from infected individuals does not go into other spaces
- Setup more, smaller, cleaner air spaces to facilitate social distancing and comply with occupancy limits

1. Identify suitable building
   - Public spaces like libraries, schools, public buildings
   - Well sealed building envelope
   - Building has HVAC system that is:
     - Well maintained
     - Capable of potential increased cooling load
     - Sufficient outside air to provide adequate ventilation
     - High efficiency filters MERV 13 or high

2. Take steps to provide cleaner air
   - Close windows
   - Limit door opening and closings
   - Install additional air cleaners as necessary
   - High smoke concentrations may require higher CADR
   - Larger rooms may require higher CADR

3. Monitor indoor air quality
   - Install properly calibrated CO alarm
   - Install CO_2 sensor
   - Consider installing $PM_{2.5}$ sensor

Sensors for indoor air quality

EPA ORD work in progress: Smoke infiltration in public buildings during smoke episodes

- Measured in 10 outdoor locations across Hoopa, CA since November 2019
- Measured in 14 public buildings where people may stay for extended durations and those that may be used as a cleaner air shelters:

  - **Workplaces**

    Land Management, Wildland Fire, Forestry, Radio Station

  - **Places with Sensitive/Vulnerable Populations**

    Hoopa Elementary & High Schools, After School Program, Early Childhood Development Center, Senior Nutrition Center

  - **Potential Cleaner Air Centers**

    Neighborhood Facility, K'ima:w Medical Center, Baptist Church

  - ***COVID adaptation Private Residence***

Photos courtesy of Hoopa Valley Tribe
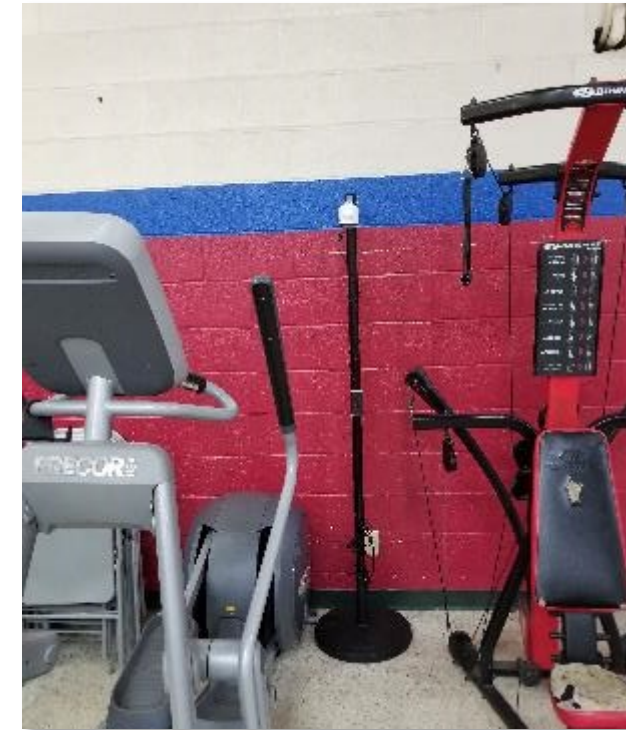
Monitored indoor/outdoor air quality with PM$_{2.5}$ sensors

- Low-cost PurpleAir sensors allow for multiple measurement locations

- PurpleAir report **accurate PM$_{2.5}$** concentrations with **correction**[†]

- Dual channel measurement allows for quality check on sensor data

- Sensors report to map in private mode – only study collaborators can view data

- Online sensors allow for:

  - Remote troubleshooting

  - Online data download

  - **More sensors in more locations!!**

A & B channels

PurpleAir underside view

Hoopa PurpleAir Deployment
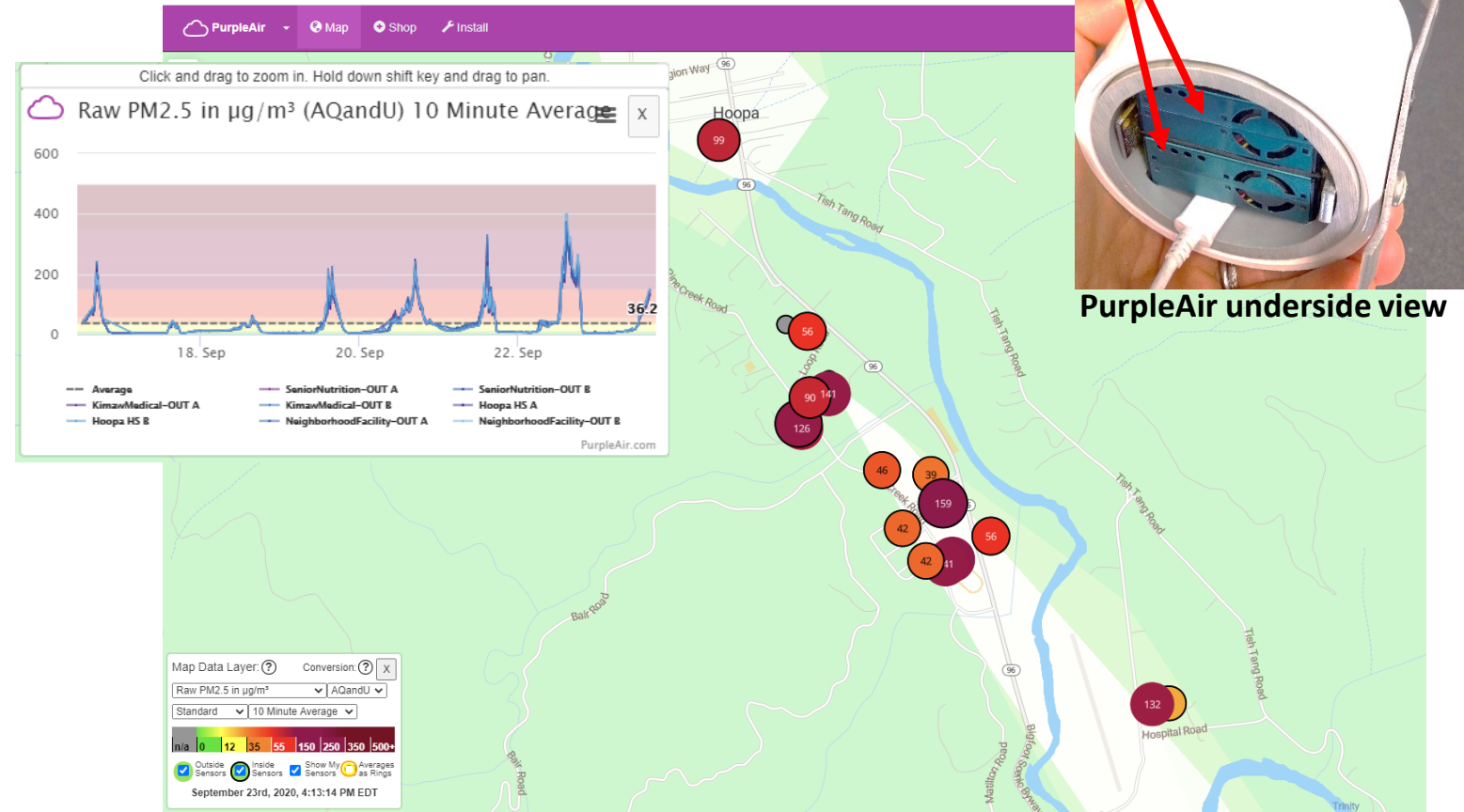
https://purpleair.com/map

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Preliminary results from 2020 fire season

Indoor PurpleAir sensor measurements demonstrated the effectiveness of HEPA filter use during extreme smoke event.

PurpleAir PM$_{2.5}$ at Daycare
(US-wide correction <223 µg/m^3, quadratic correction >223 µg/m^3)
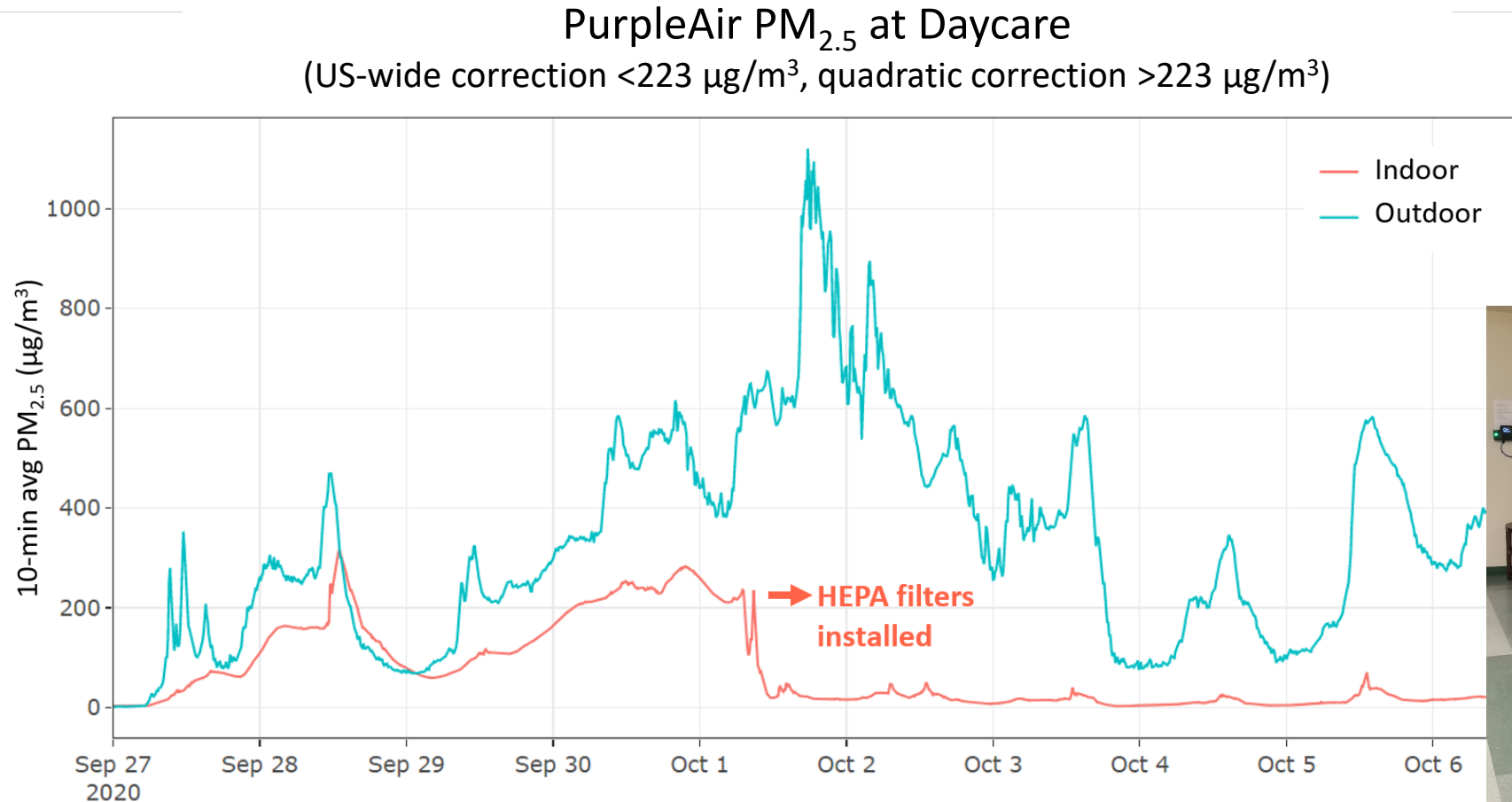
- Building has central air conditioning system
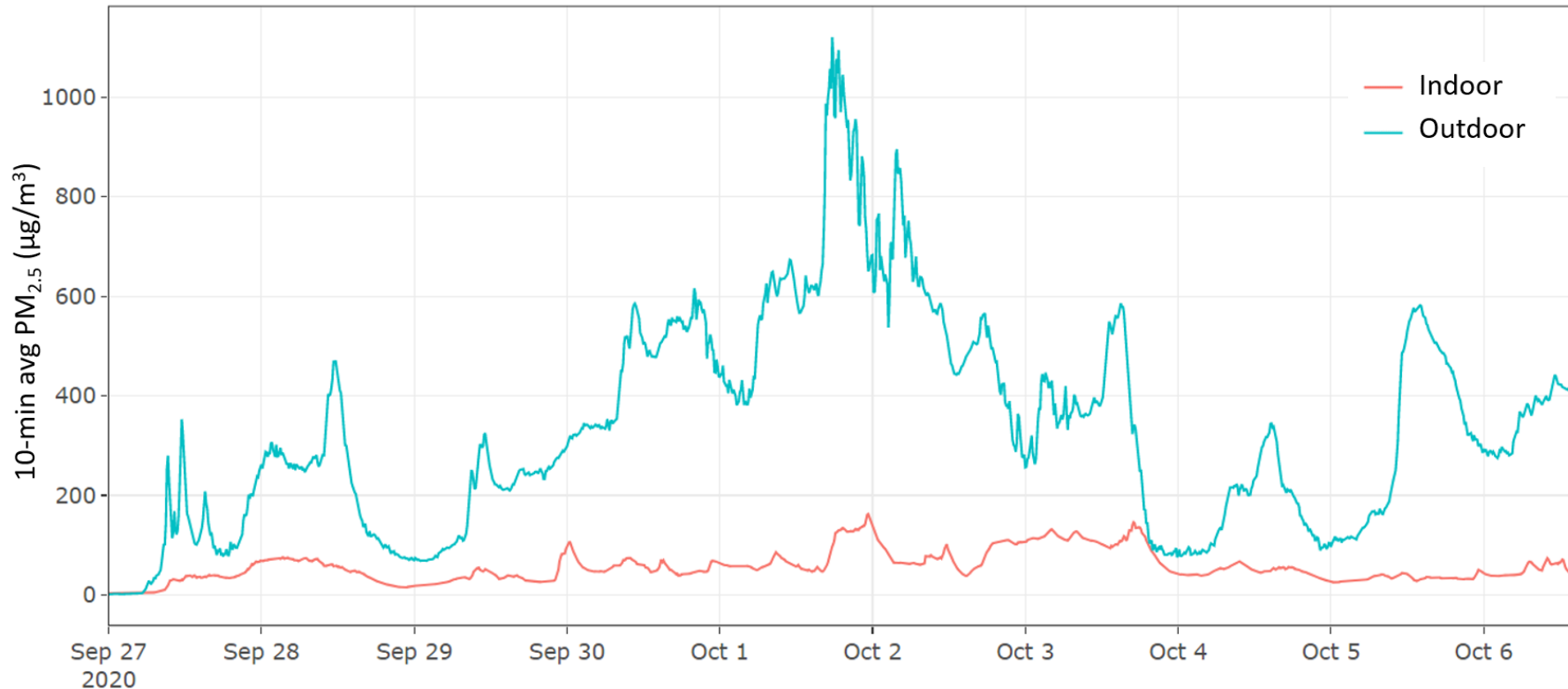- Mostly closed during COVID shutdown, 1- 3 people occupy the building daily
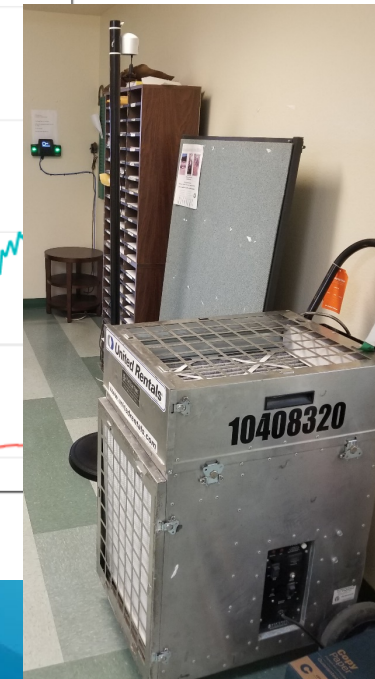
During smoke episode doors and windows were kept closed and an industrial rental air cleaner was used

Preliminary results from 2020 fire season

Some indoor sites were able to maintain consistent indoor concentrations, even when outdoor concentrations were extremely high.

PurpleAir PM$_{2.5}$ at Local Agency Building
(US-wide correction <223 µg/m^3, quadratic correction >223 µg/m^3)

- Building has no central air conditioning system
- Cooling is achieved with a window AC unit
- Mostly open during COVID shutdown, 30 – 40 people occupy the building daily
- During smoke episode doors and windows were kept closed and borrowed air filters were used (filter type not specified)

Preliminary results from 2020 fire season

Some indoor sites saw little-to-no reduction of $PM_{2.5}$ indoors

PurpleAir $PM_{2.5}$ at High School Classroom
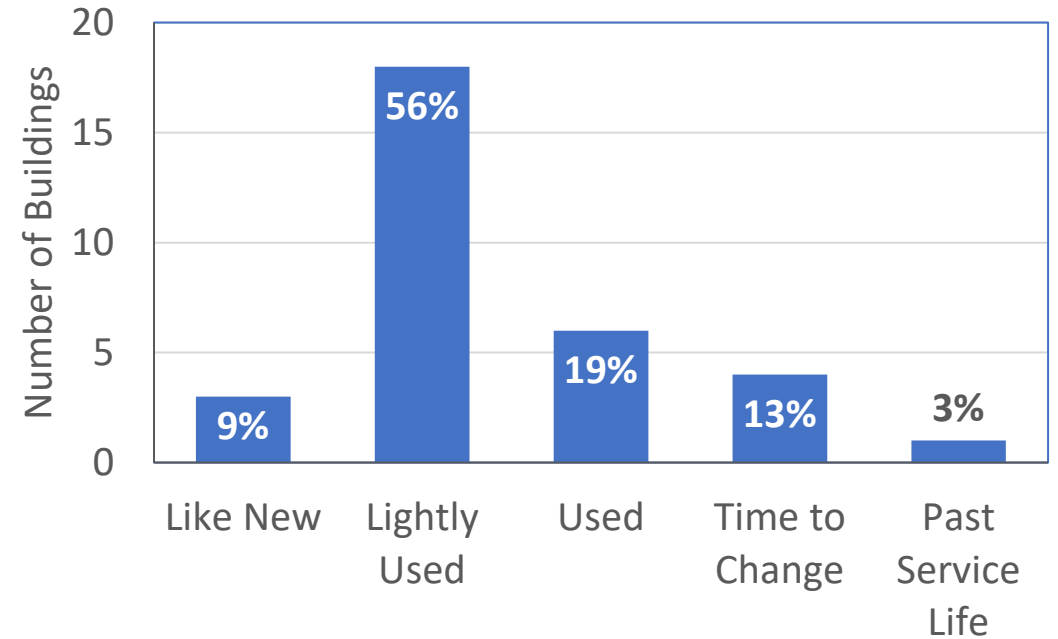(US-wide correction <223 µg/m^3, quadratic correction >223 µg/m^3)

- Building has a central air conditioning system, unknown MERV rating
- Closed during COVID shutdown, 1 - 4 people occupy the building infrequently
- During smoke episode doors and windows were kept closed no additional air filtration was used

ORD work in progress: Building/HVAC inspection

Carrying out inspections of study buildings:

- Air handling settings/schedules
- Building open/close hours
- Door counters to estimate occupancy
- HVAC system and filter conditions
- Gaps and seals around filters, doors, and windows
- Building age and construction type
- Building pressure
- Potential indoor sources (*e.g.,* cooking, tobacco smoke, vacuuming/sweeping)
- Use of portable air cleaners

Preliminary data from Missoula, MT study

Bar chart — Number of Buildings:
- Like New: 9%
- Lightly Used: 56%
- Used: 19%
- Time to Change: 13%
- Past Service Life: 3%

Polyester Media
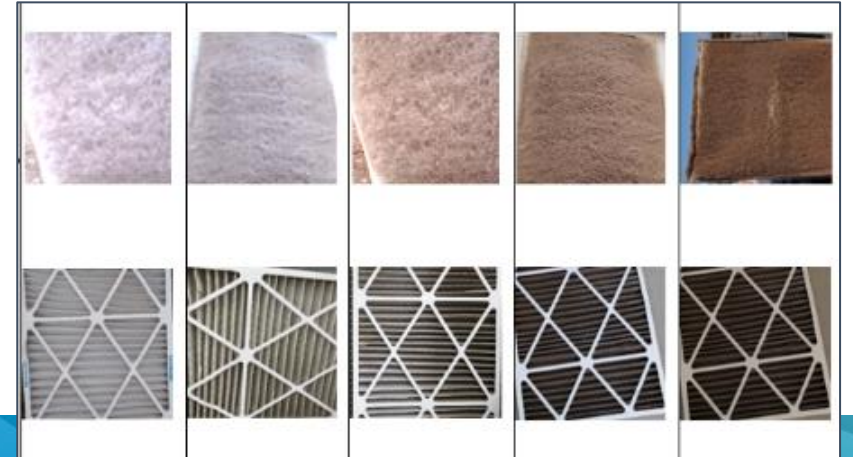
Pleated Filters

ORD work in progress: Building/HVAC inspection

✗ **Right Sized Filters**

✗ **Unobstructed Air inlets**

✗ **Clean Filters**

Crushed filter (too large for filter rack)

Obstructed air inlets

Dirty Filters

Photos by Tom Javins

Future directions

ORD work in progress: Informational materials

- Updates to *EPA Air Sensor Guidebook* on:
    - Community monitoring for wildfire smoke impacts and
    - Indoor air quality monitoring for wildfire smoke impacts

- Develop new summary of HVAC lessons learned training videos

- Host webinars on reducing smoke exposure indoors
    - Discuss what factors are important to air cleaner effectiveness, summarizing results from laboratory studies and Chemical Insights safety evaluation
    - Describe indoor/outdoor smoke sensor network and best practices for achieving indoor air during smoke events

MERV 13 filter installed on an outdoor air intake

Photos by Tom Javins

Future work research on exposure reduction interventions

- [EPA Science to Achieve Results Grant](#) – *Interventions and Communication Strategies to Reduce Health Risks of Wildfire Smoke Exposures* – Funded projects anticipated to be announced September 2021

- [NIH Notice of Special Interest](#) – *Stimulating intervention research to reduce cardiopulmonary impacts of particulate matter in air pollution among high-risk populations* – Research projects to anticipated to start summer 2021

- [Cleaner Air During Wildfire Smoke](#) – Multiagency sponsored competitive challenge to develop new, effective, low-cost approaches to reducing $PM_{2.5}$ indoors during high pollution episodes – Submissions closing May 17, 2021

Cleaner Indoor Air During Wildfires CHALLENGE

Thank you!

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Supplementary Slides

Performance targets for PM sensors published by EPA

EPA/600/R-20/280 | February 2021

Performance Testing Protocols, Metrics, and Target Values for Fine Particulate Matter Air Sensors

USE IN AMBIENT, OUTDOOR, FIXED SITE, NON-REGULATORY SUPPLEMENTAL AND INFORMATIONAL MONITORING APPLICATIONS

Office of Research and Development
Center for Environmental Measurement and Modeling
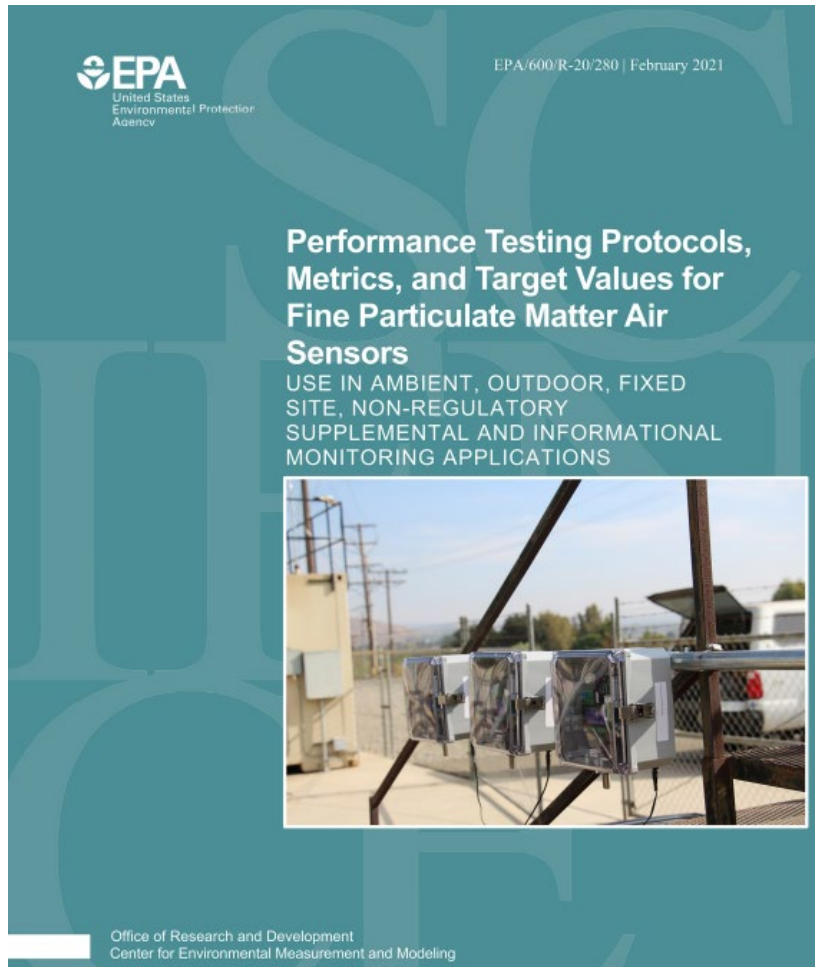
Important new reports for PM$_{2.5}$ and ozone sensors:

- Focus on non-regulatory, supplemental and informational monitoring applications (NSIM)
- Recommended performance metrics and target values
- Recommended test approach – Base (field) and enhanced (lab)
- Reporting templates for testers

Table 4-2. Base and Enhanced Testing – Recommended Performance Metrics and Target Values for PM$_{2.5}$ Air Sensors Used in Ambient, Outdoor, Fixed Site NSIM Applications

Performance Metric		Target Value		Associated Section Describing Calculation
		Base Testing	**Enhanced Testing** [*]	
Precision	Standard Deviation (SD)	$\leq 5\ \mu g/m^3$		3.1.3 and 3.2.3
	-OR-			
	Coefficient of Variation (CV)	$\leq 30\%$		3.1.3 and 3.2.3
Bias	Slope	1.0 ± 0.35	No target values recommended; report results	3.1.4 and 3.2.4
	Intercept (b)	$-5 \leq b \leq 5\ \mu g/m^3$		3.1.4 and 3.2.4
Linearity	Coefficient of Determination (R^2)	≥ 0.70		3.1.4 and 3.2.4
Error	Root Mean Square Error (RMSE) or Normalized Root Mean Square Error (NRMSE)	RMSE $\leq 7\ \mu g/m^3$ or NRMSE $\leq 30\%$ [†]		3.1.5 and 3.2.5

[*]No specific target values are recommended due to limited feasibility, lack of consensus regarding testing protocols, and inconsistency in sensor evaluation results that can result due to the limited amount of data that will be collected and variation in the tester's choice of PM surrogate. See Appendix D for further discussion.
[†]A sensor will meet this target if either the RMSE or NRMSE meet this criterion. See Appendix D for further discussion.

Wildfire smoke-specific: "For NSIM applications where high PM$_{2.5}$ concentrations are expected (e.g., wildfire smoke applications), it is recommended that testers conduct base testing in more than two locations and include sites impacted by wildfire smoke and higher PM$_{2.5}$ concentrations."

Adding new supplemental monitoring: Siting your selected sensor

Sensor Siting Best Practices

Ideally 360° free air flow at sensor and no less than 180°

Up wind side of buildings and away from vegetation

Away from PM sources and strong air flows:
- Exhausts and vents
- Air conditioning units
- Dusty roads or unpaved parking lots
- Heavily traveled roads
- Barbecue grills, fire pits, smokers

> 1 m

At least 1 m above ground to prevent contact with water

Not easily accessed location may prevent tampering or theft

Siting Quality Control Assessment
- Review the data to determine if the siting may be impacted by a local source or conditions
- Does high time resolution show spikes (e.g., indicative of a local source – smoking, cooking)? Do spikes have a routine nature (e.g., indicative of cyclic operation of a source like an HVAC fan)
- Compare to a nearby reference - do long term trends agree?

Indoor

Outdoor

Indoor Air Quality Resources

Wildfires and Indoor Air Quality (IAQ)

https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq

- *Create a clean room*
- *Guide to air cleaners in the home*
- *Residential air cleaners: A technical summary*
- *Evidence on the Use of Indoor Air Filtration as an Intervention for for Wildfire Smoke*
- *Wildfire smoke: A guide for public health officials*

Wildfire Smoke Resources

AirNow Fire Page https://www.airnow.gov/fires/

- AirNow fire and smoke map

- Factsheets

- Current Smoke Advisories

- Smoke Ready Toolbox

- Wildfire Smoke Guide for Public Health Officials

- For questions about AirNow Sensor Data Pilot Contact:

    Sensordatapilot@epa.gov

Air Sensor Resources

Air Sensor Toolbox http://www.epa.gov/air-sensor-toolbox

- Air sensor guidebook

- Air sensor loan programs

AQ-SPEC http://www.aqmd.gov/aq-spec

- Air sensor information and evaluations

Air Sensors International Conference https://asic.aqrc.ucdavis.edu/

- Recorded videos for 2020-2021, worldwide case studies