MOORE
MICHIGAN-OHIO OCCUPATIONAL RESEARCH EDUCATION PROGRAM

SRP Risk e-Learning Webinar Series

Emerging Technologies in Occupational Health and Safety

Michigan-Ohio Occupational Research Education Program (MOORE)

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Professor, Department of Civil & Environmental Engineering, College of Engineering
University of Michigan

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Professor and Section Chief, Environmental and Occupational Hygiene and Occupational Safety and Ergonomics
Environmental & Public Health Sciences, College of Medicine
University of Cincinnati

Program Details

Program Name: Michigan-Ohio Occupational Research Education Program (MOORE)

Project Leader: Stuart Batterman, PhD

Home Institution: University of Michigan at Ann Arbor, MI

Co-Investigator(s): Kermit Davis, PhD; Kenneth Rosenman, MD

Grant number: 1R25ES033042

Collaborating institutions: University of Cincinnati, Michigan State University

Goal(s): Develop and deliver training and research experiences for graduate students and OHS practitioners along several themes:

- *Emerging technologies in exposure assessment*
- *Home health care*
- *Sustainability and OHS practices*
- *Ergonomics and aerosol exposure*

Primary audience: Students, practitioners and others

Technologies/contaminants of interest: Aerosols, ergonomics, sensors, ventilation, controls, IAQ, Covid, ETS

Project sites: Ann Arbor, MI; Cincinnati, OH

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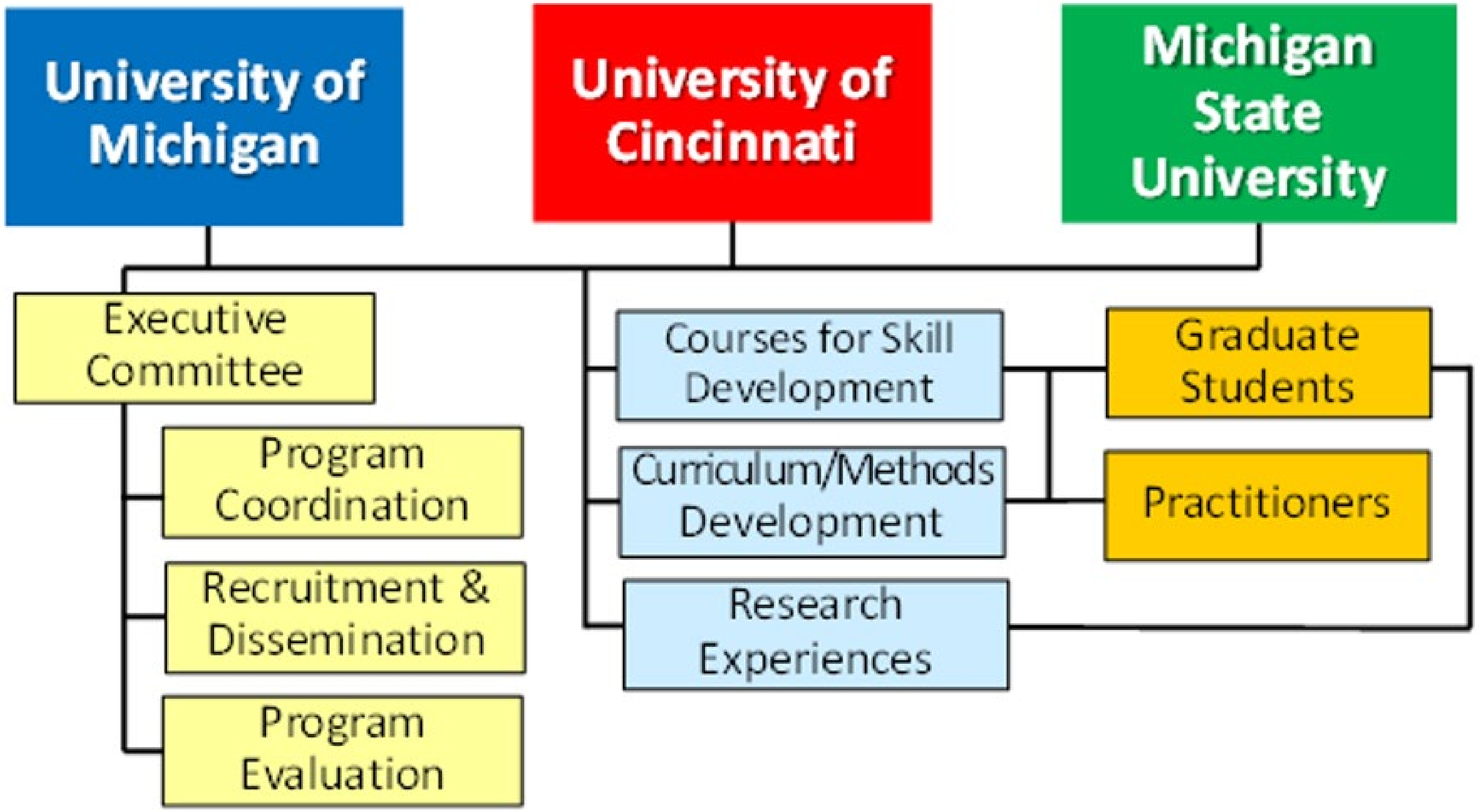
Overall goals

The overarching goal of this R25 program, entitled the Michigan-Ohio Occupational Research Education Program (MOORE Program), is to leverage activities at the University of Michigan, University of Cincinnati, and Michigan State University so as to develop and deliver training and research experiences for graduate students and professionals to advance skills in the field of occupational health and safety (OHS).

Specifically, we are examining advanced exposure assessment approaches applied to aerosols, indoor air quality, ventilation and filtration, and ergonomics.

Areas of particular interest include schools and health care settings, including care in residential settings often performed by low wage and disadvantaged populations and how posture and relative position to smoking sources affect exposures to healthcare workers.

Organization, products, participants



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Personnel and Interests

University of Michigan

- ***Olivier Jolliet,** PhD, sustainability and OHS
- **Chuanwu Xi,** PhD, exposure & controls for pathogens
- **Simone Charles,** PhD, sustainability and exposure
- **Frederique Laubepin**, PhD., curriculum design
- **Malinda Matney,** PhD, evaluation
- **John Meeker,** ScD, exposure assessment
- **Richard Neitzel,** PhD, exposure assessment
- **Leia Stirling,** PhD, exposure assessment and ergonomics
- **Sheryl Ulin**, PhD, CE, outreach, ergonomics
- **Stuart Batterman,** PhD, exposure & sustainability

University of Cincinnati

- **John Reichard,** PhD, PBPK modeling, uncertainty
- ***Tiina Reponen,** PhD, emerging tech, healthcare, exposures
- **Kermit Davis**, PhD, Health care safety
- **Jessica Bloomer**, MA, CE
- **Gordon Gillespie,** PhD, exposure tech, home healthcare
- **Lynne Haber,** risk assessment and sustainability
- **Jun Wang,** exposure tech, aerosols, hazardous substances
- **Yevgen Nazarenko**, aerosols, modeling, IAQ

Michigan State University

- **Kenneth Rosenman,** MD OM
- ***Melissa Millerick-May,** PhD, exposure and home health care

NIOSH

- **Thais Morata,** PhD., Wikipedian

Some Products & Outcomes

Best Practices Guide for on-line course development

- evidence-based backward curriculum design

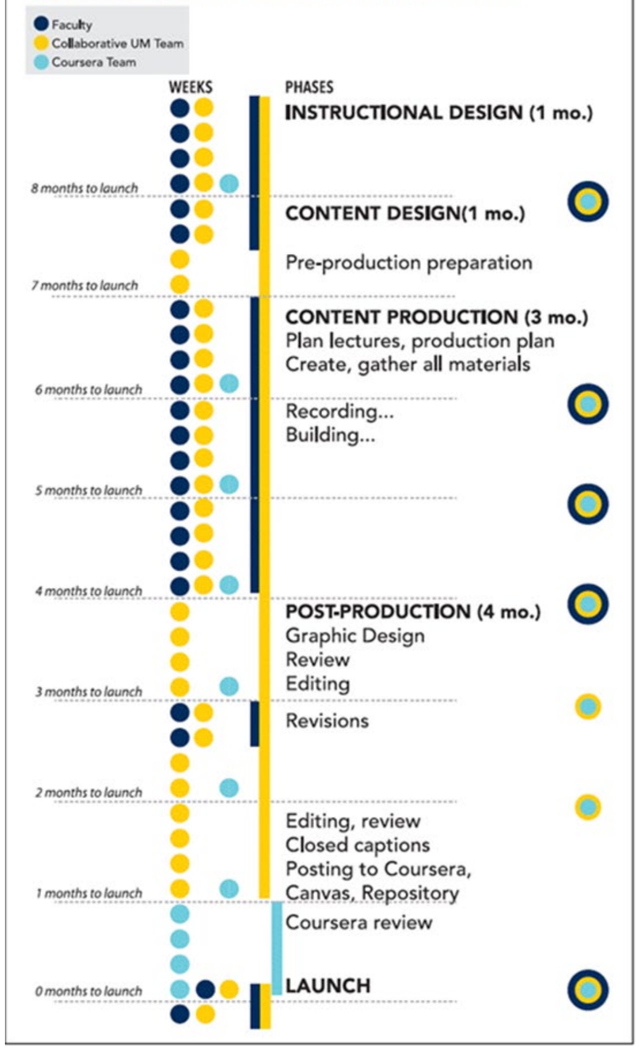
Lessons/courses/webinars

- Aerosols & virus exposure assessment in buildings
- Building controls in buildings
- Ventilation assessment using sensors
- CE Course on complex exposures (fall 2024)

Research camp

- Logistics: scheduling, recruitment, preparation, documentation, task organization, etc.
- Science: contrafactual results? New hypotheses, new collaborations
- Benefits: hands-on experience, critical thinking, active problem solving, team building, interdisciplinary education
- Questions: how to disseminate results? How to recruit trainees?

Fig. 2. Course/module development plan



Course Development

Development of Course

- *A **multidisciplinary team*** including Industrial Hygiene, Risk Assessment, and Occupational Nursing
- Developed initially as a class course and then converted into a continuing education course
  - Able to reach students through class course
  - Able to reach healthcare workers through CE course
- Focus is on Complex Exposures in Home Healthcare
  - Plethora of exposures in home healthcare
  - Every home is unique and different

CE Course: Complex Exposures in Home Healthcare

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UNIVERSITY OF MICHIGAN

UNIVERSITY OF Cincinnati

MICHIGAN STATE UNIVERSITY Founded 1855

GOALS

This course addresses key constructs regarding complex exposures in the home healthcare setting. Students draw upon their respective discipline to examine and measure complex exposures in home healthcare settings. Recommendations based on assessment findings will be considered.

*STU*DENT LEARNING OUTCOMES

1. Describe complex exposures in home healthcare.
2. Measure internal doses and responses to home hazards.
3. Identify administrative and engineering controls for the prevention of complex exposures in home healthcare.
4. Discuss case-based scenarios to identify, mitigate, and prevent risks for complex exposures in home healthcare.

ORGANIZATION

Module 1: Quantification of complex exposures in home healthcare

Module 2: Use of biomonitoring techniques to measure internal doses or responses to home hazards

Module 3: Implementation of proper data and statistical analyses for hazardous exposures

Module 4: Identification and assessment of controls to apply to hazards

Module 5: Approaches for consideration of the effects of complex interactive exposures

Module 6: Discussions, scenario analyses, and case studies of homes to identify exposures and potential controls

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Research Camp
August, 2023

Structure

At the University of Cincinnati, Aerosol Chamber

Objective: To understand the exposure to smoke in a home for healthcare workers

Investigated the impact of the ***source of smoke***

- Family member on the right side of the bed
- Patient in bed
- Family member on the left side of the bed

Investigate the impact of ***caregiver posture***

- Upright
- Bent over

Investigate the impact of ***purifier***

- Z-3500 (small)
- Z-7000 (large)
- None

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Research Camp

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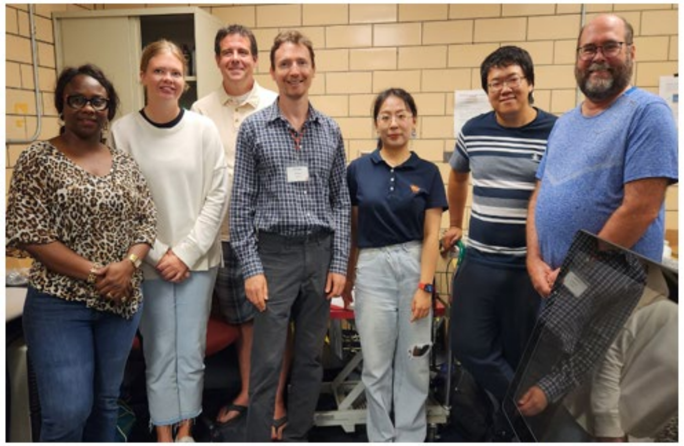

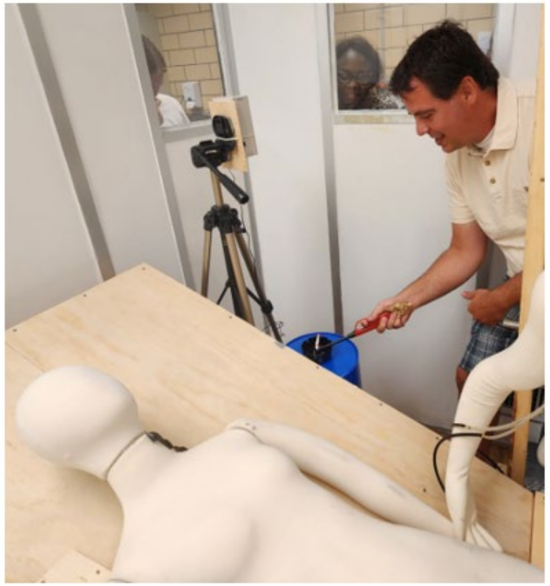

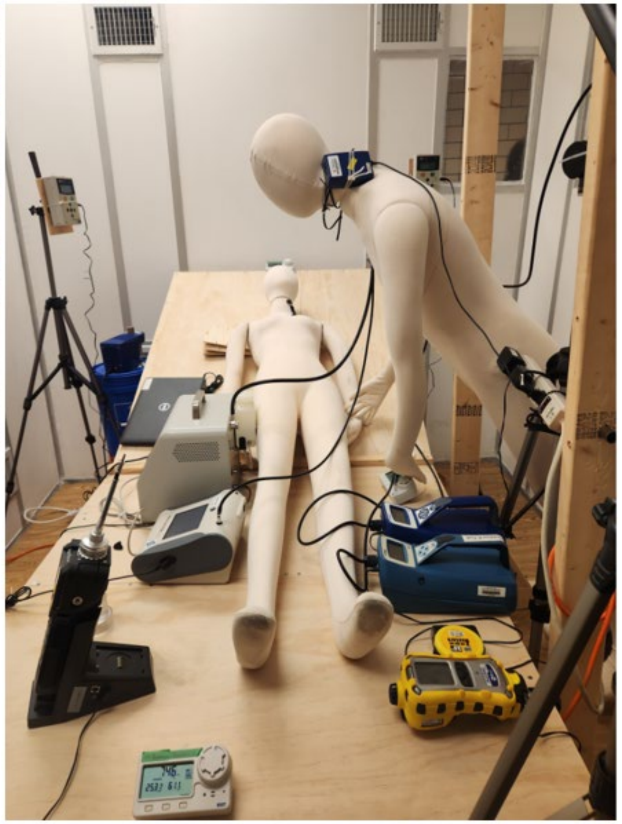

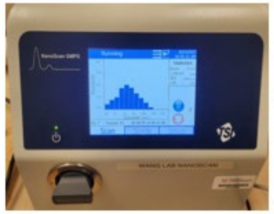

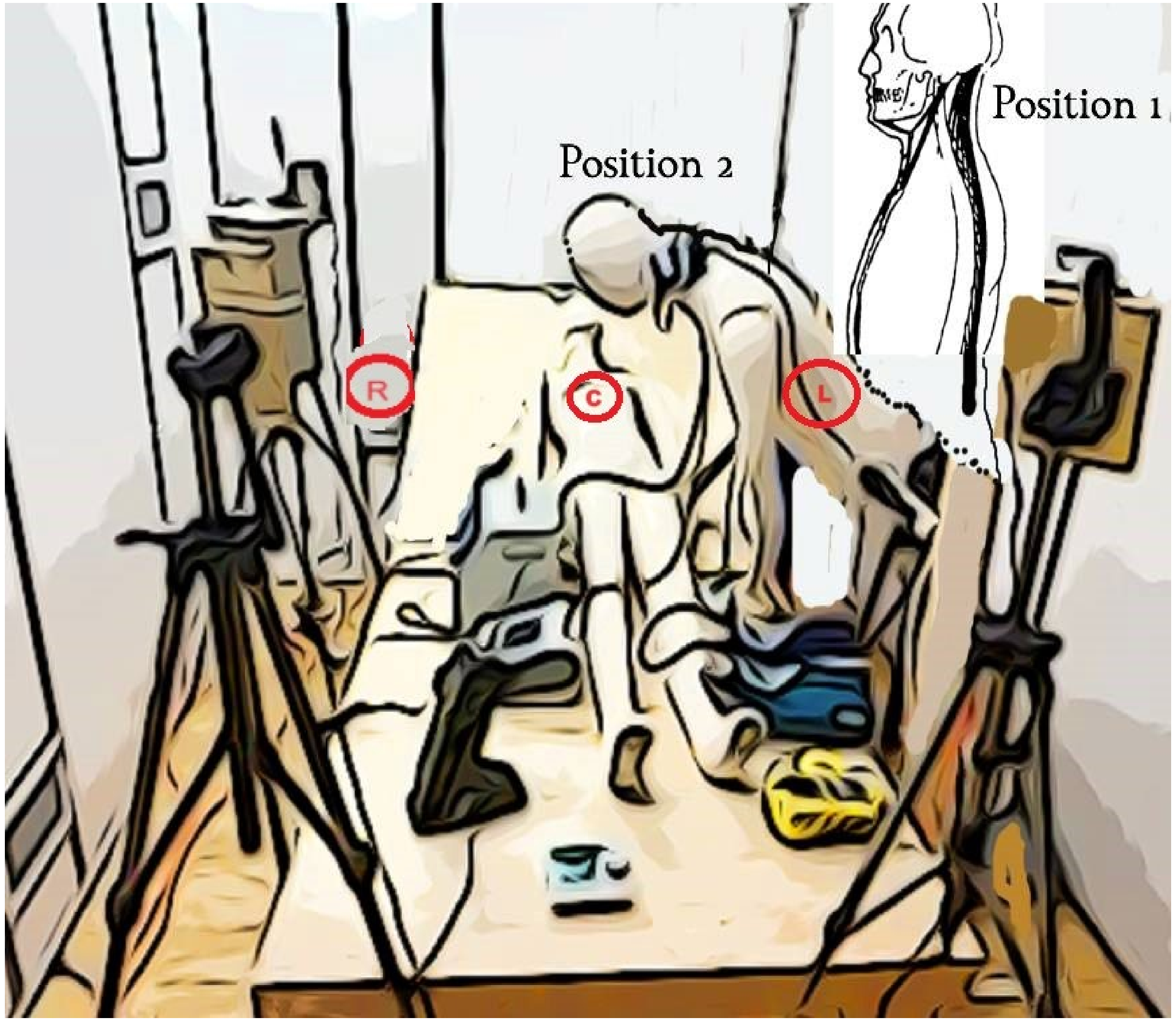

Research Camp

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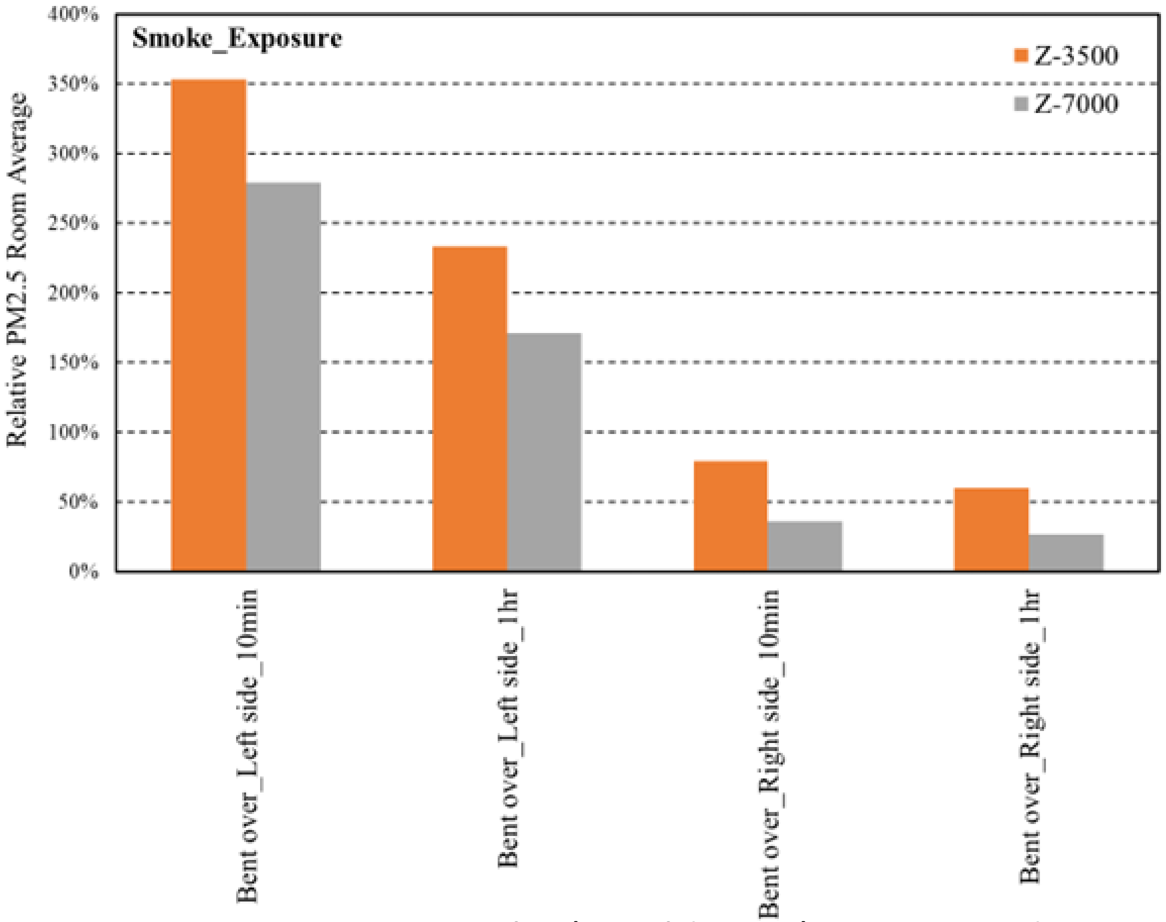
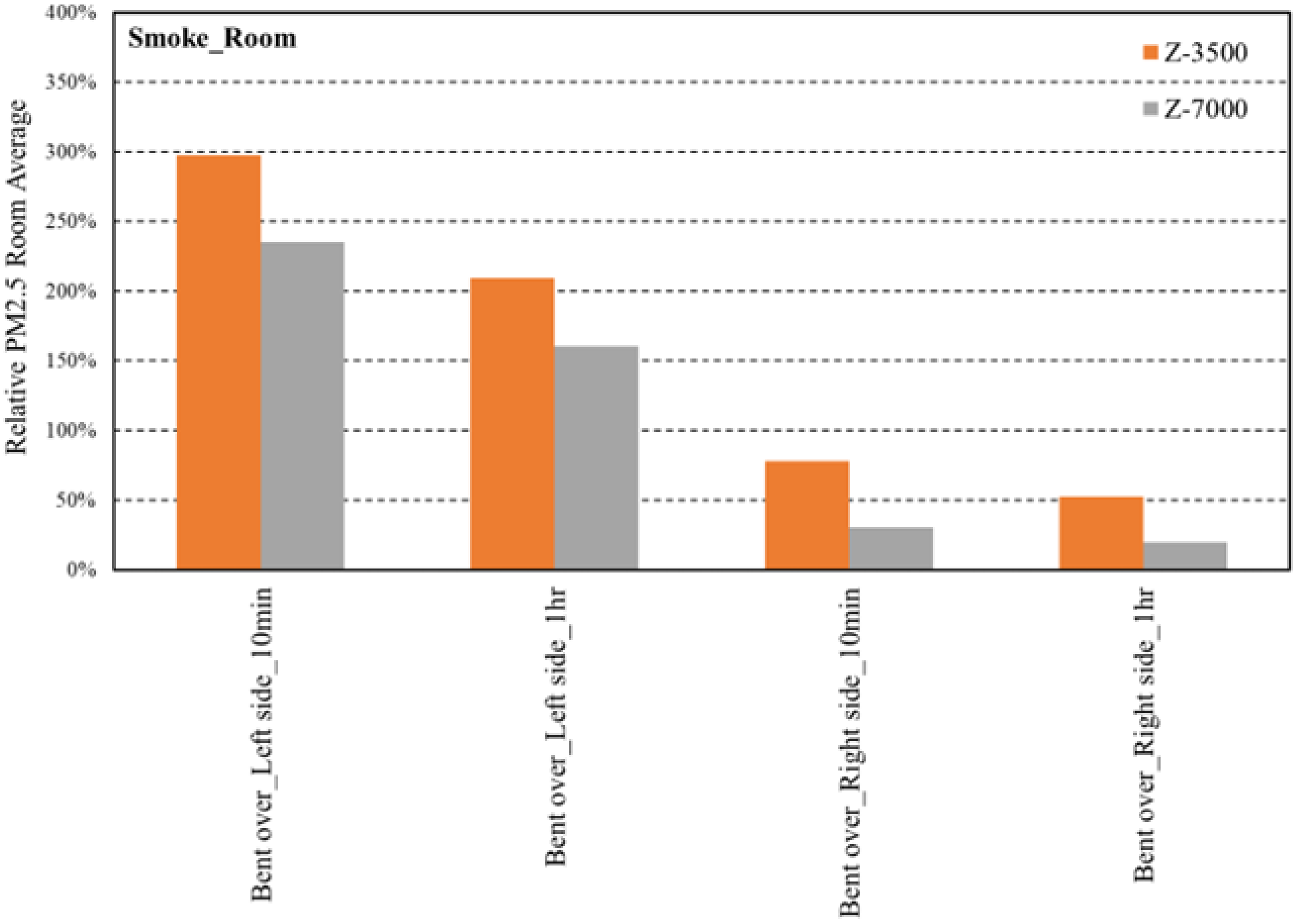
PM concentrations for caregiver relative relative to no-filter case



PM concentrations for room average relative to no-filter case



Source is cigarette smoke (smoldering): 10 min = during smoldering cigarette; 1 hr = smoldering plus decay for 1 hour

Research Camp

60 trials: 2 caregiver positions; 3 smoking positions; 3 filter settings (none, small, large filter); smoke and salt surrogate (including duplicates)

Trainees formed three teams with faculty mentors with goal to complete analysis and journal/conference presentations tentatively entitled:

Team 1: Effects of air purifiers in the personal exposure of caregivers to 2nd hand ETS in a home health care environment

- Metric – PM size distribution, exposure and dose
- Variable – posture
- Outcomes - Looking at size distribution, effect of filter/air flow, filter efficiency

Team 2: Effect of caregiver posture on personal exposure to 2nd hand cigarette smoke

- Metric – nanoscan, PTRACK
- Variables – caregiver posture, purifier use
- Outcomes – exposure and dose

Team 3: Effect of air purifiers on PM exposure and spatial distribution in a home health care environment

- Metric – spatial distribution, ACR, CADR
- Variable – directional air flows, time frame – short term vs long term
- Outcomes – Time resolved patterns, filter performance

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Demonstration & Application


PORTABLES


INNER CITY

BOOMERS


SHOWCASE


CONVENTIONAL


ENERGY STAR


LEED


OTHER

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Ventilation in schools

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Ventilation with outdoor air (OA) removes moisture, pollutants and virus emitted from indoor sources. Effectively dilutes source emissions.

- Sufficiently high VRs are needed to not compromise IAQ and cause health, comfort, absenteeism and productivity problems.
- ASHRAE sets minimum ventilation rates in model codes/standards
  - *General guidance: personal ventilation rate equivalent to ~15 CFM per person (~8 L/s-person)*
  - *Pandemic guidance: provide lowest possible particulate concentration, open outside air dampers fully, and achieve a minimum air change rate of 3 outdoor-air supplied air changes per hour (ACR) at standard occupancy and room sizes. Also, use enhanced filtration or air cleaners for a total of 4-6 air changes per hour of outdoor plus filtered air. Applies to rooms and zones.*

TARGET IS AT LEAST 5 TOTAL AIR CHANGES PER HOUR

- *Ideal (6 ACH)*
- *Excellent (5-6 ACH)*
- *Good (4-5 ACH)*
- *Bare minimum (3-4)*
- *Low (<3 ACH)*


ANSI/ASHRAE Standard 62.1-2004
(Includes ANSI/ASHRAE Addenda listed in Appendix H)

ASHRAE STANDARD

Ventilation for Acceptable Indoor Air Quality

Ventilation terminology

Natural ventilation: into/out of building via opened windows and doors.

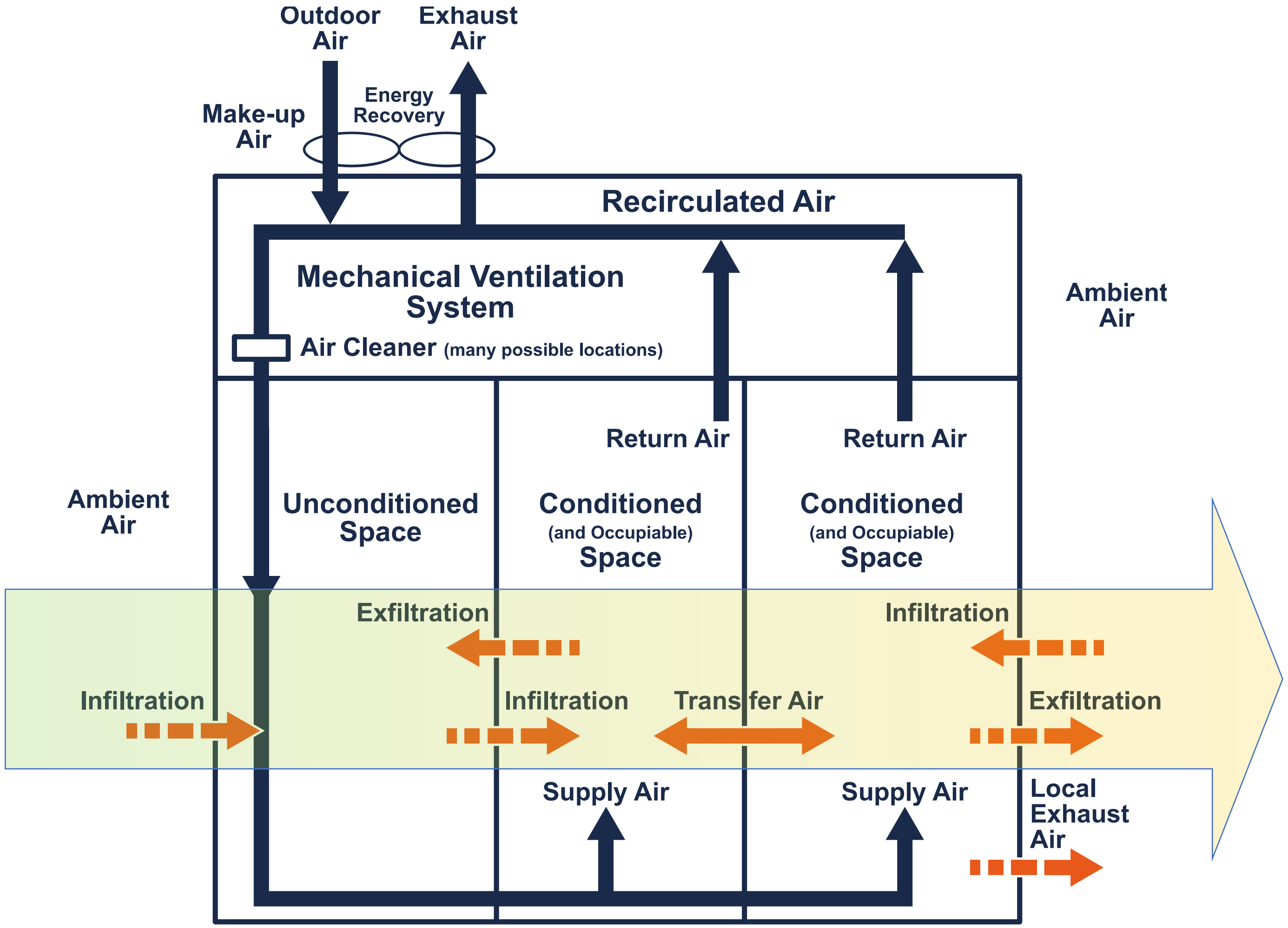
- Depends on indoor/outdoor temperature difference and wind speeds.

Mechanical ventilation: by the mechanical heating, ventilation, air conditioning (HVAC) system. *Only when operating!*

- **Outdoor air supply/exhaust air:** into/out of the building by
- **Recirculated air:** by the HVAC system

Both cases

- **Transfer**: air flow between building spaces
- **Infiltration/exfiltration**: into/out of the building through the building envelope (unplanned)



Replace air in all classrooms every 10 to 20 min

Ventilation in schools - status

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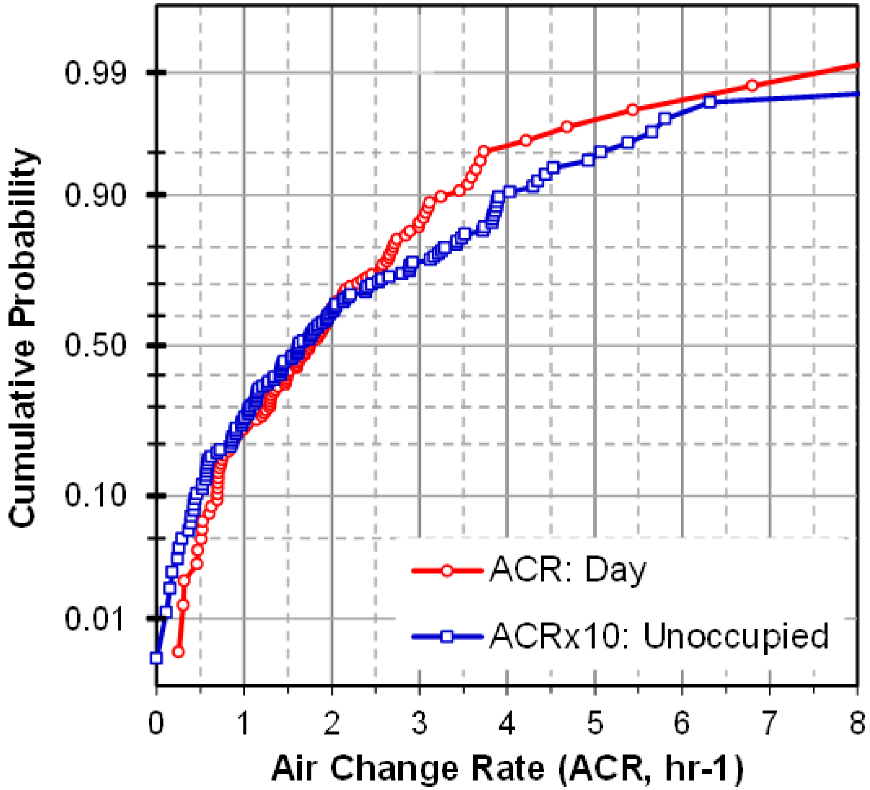
In relatively new or renovated buildings in the Midwest:

- *Air change rates (ACRs) averaged 1.95 ± 1.32 h^{-1} across schools*
- *Median CO_2 levels ~1000 ppm (range to 5000 ppm)*
- *Only 15% of classrooms met the recommended minimum VR*
- *HVAC systems were sometimes shut off immediately at the end of the school day, although facility managers recognized that both teaching staff and maintenance staff were still working in the building.*
- *OA dampers sometimes permanently shut*
- *Especially low VRs in smaller schools and classrooms using unit ventilators*

*Yet lower VRs in older buildings using radiators and **natural ventilation**, and in portable/modular classrooms.*

- *ACRs often below 1.0 h^{-1}*
- *Depend on window opening for additional ventilation*
- *Windows often opened at worst time of day*




Received: 26 September 2016 | Accepted: 24 March 2017
DOI: 10.1111/ina.12384

ORIGINAL ARTICLE

WILEY

Ventilation rates in recently constructed U.S. school classrooms

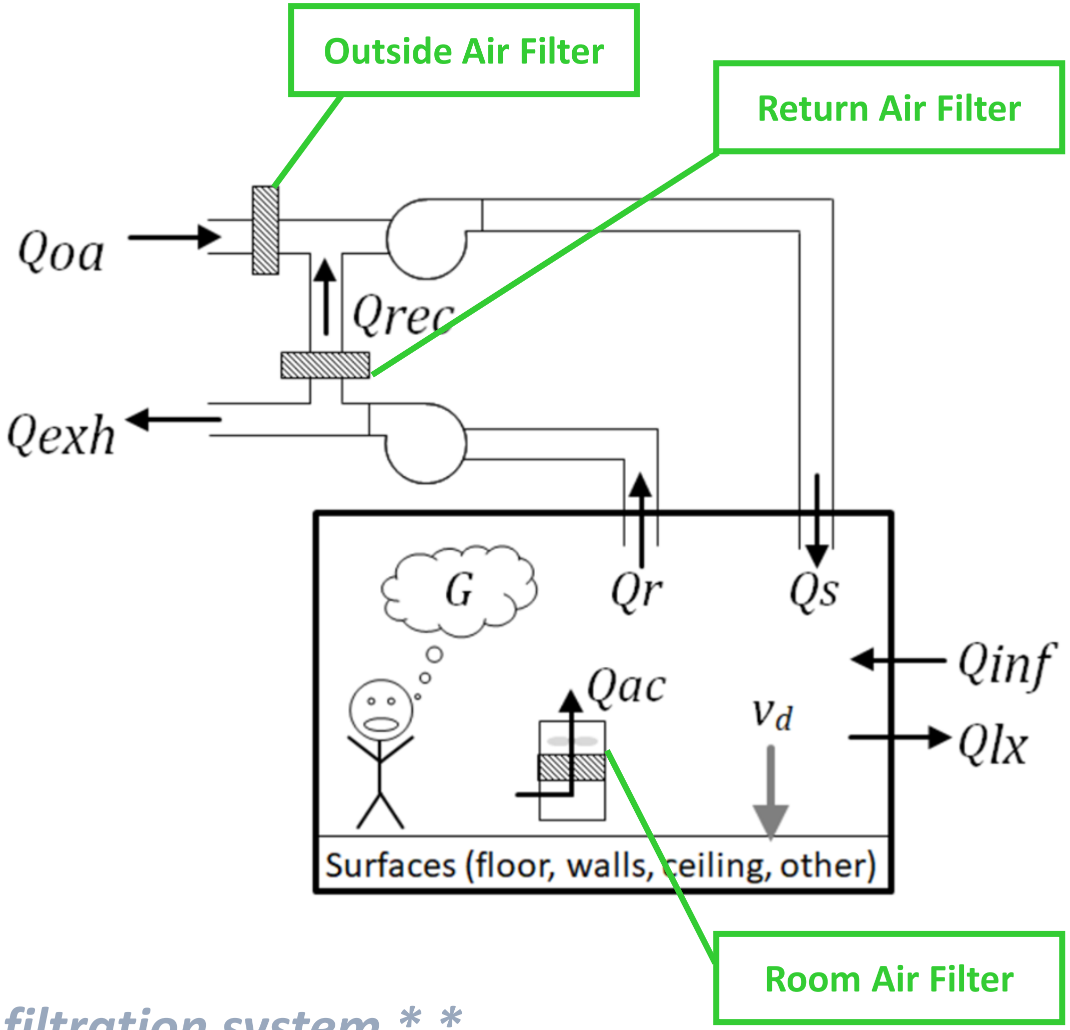
S. Batterman | F.-C. Su | A. Wald | F. Watkins | C. Godwin | G. Thun

** * Considerable opportunity to increase ventilation rates with only small energy penalty * **

Filters

- Filters remove particles, including dust, particles, pollen, allergens, animal dander and fibers. Some remove gases, e.g., sulfur dioxide (SO_2), odors, and volatile organic compounds.

- Effective filtration requires:
  - *High enough filter efficiency*
  - *High enough air flow rate*
  - *High enough run time*
  - *Frequent enough change out of filter*
  - *Proper installation*
  - *Consideration of particle size, air mixing, filter location (space configuration)*



**** * Not just the filter but the filtration system * ****

Types of particle filters

Stand-alone used anywhere and to supplement filters in mechanical systems

Free-standing filter with fan "air purifier"

Example of a portable air filter, Whirlpool Whispure Air Purifier. Equipped with HEPA filter (High efficiency particle arrestance)

Used in mechanical forced-air heating, ventilation, and air conditioning (HVAC) systems

- Extended area filters in three depths with ratings from MERV7 to 13 (high efficiency).

http://www.qualityfurnacefilters.com/are-pleated-furnace-filters-really-better-than-disposable-fiberglass-filters/

Secondary "bag" or "pocket" filter used in commercial HVAC systems.

http://www.filtrationgroup.com/WFS/FGCBusiness/en_US/-/USD/HVAC/hvac-pocket-filters

Low cost and inefficient filters often used as furnace filters in homes.

http://www.qualityfurnacefilters.com/are-pleated-furnace-filters-really-better-than-disposable-fiberglass-filters/

Air filter collection efficiency

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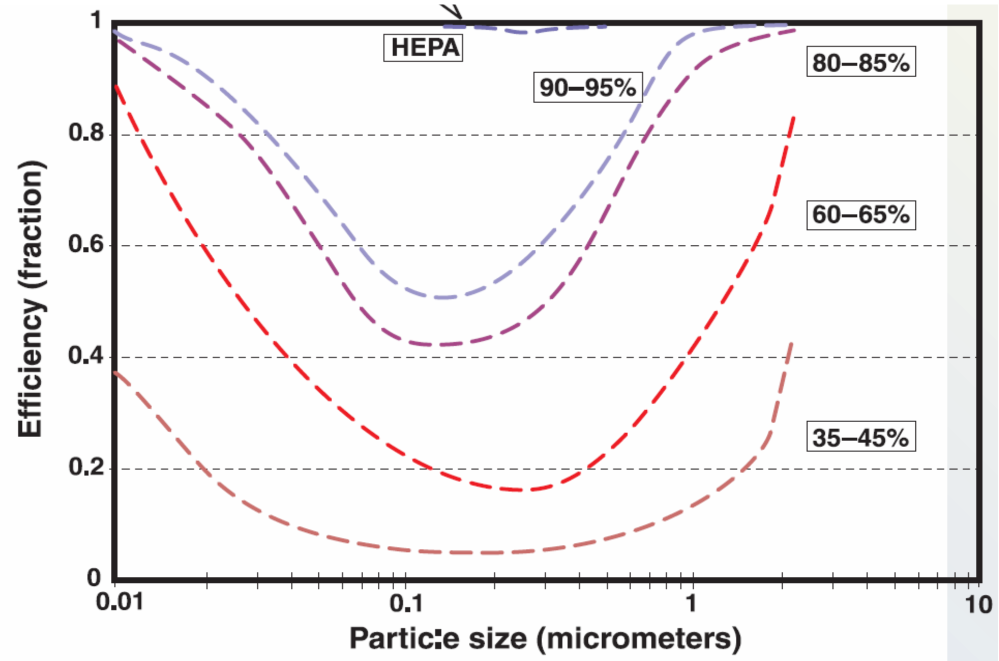
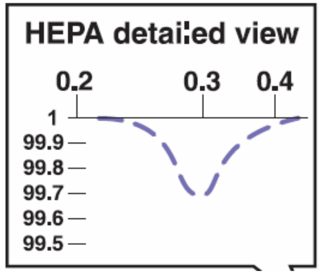
- **MERV - minimum efficiency reporting value**
- 1-4: typical residential filters, <2%
- 7-13: commercial spaces and schools
- 16+ cleanrooms, surgery, >99.97%.
- 13-14 Minimum for virus & $PM_{2.5}$





[Ensor et al. 1991, 2006

ASHRAE Standard 52.2-2017 -- Minimum Efficiency Reporting Value (MERV)

Table 12-1 Minimum Efficiency Reporting Value (MERV) Parameters

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			Average Arrestance, %
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0	
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg}$
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg}$
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

MERV-A ratings for electrostatic filters – accounts for filter performance when charge is removed or dissipated.

Clean air delivery rate (CADR) for purifiers.

CADR must be scaled to the space volume.

Filters - Status

Dirty filters were common.

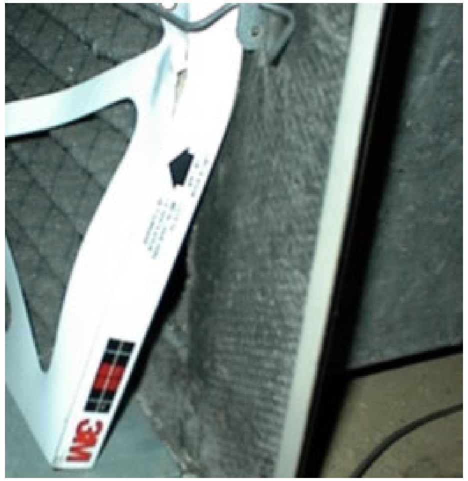
Reasons for not changing filters include

- cost of replacement
- inconvenient or difficult access
- inexperienced or overworked staff
- reliance on 3rd-party managers

Bypass was common

Typical MERV ratings from 7-8

Few if buildings used *in situ* tests that document performance



ISO 29462:2013

Field testing of general ventilation filtration devices and systems for in situ removal efficiency by particle size and resistance to airflow

Opportunities to use filter upgrades in schools

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Demonstrations

PM concentrations for caregiver and room average relative to no-filter case

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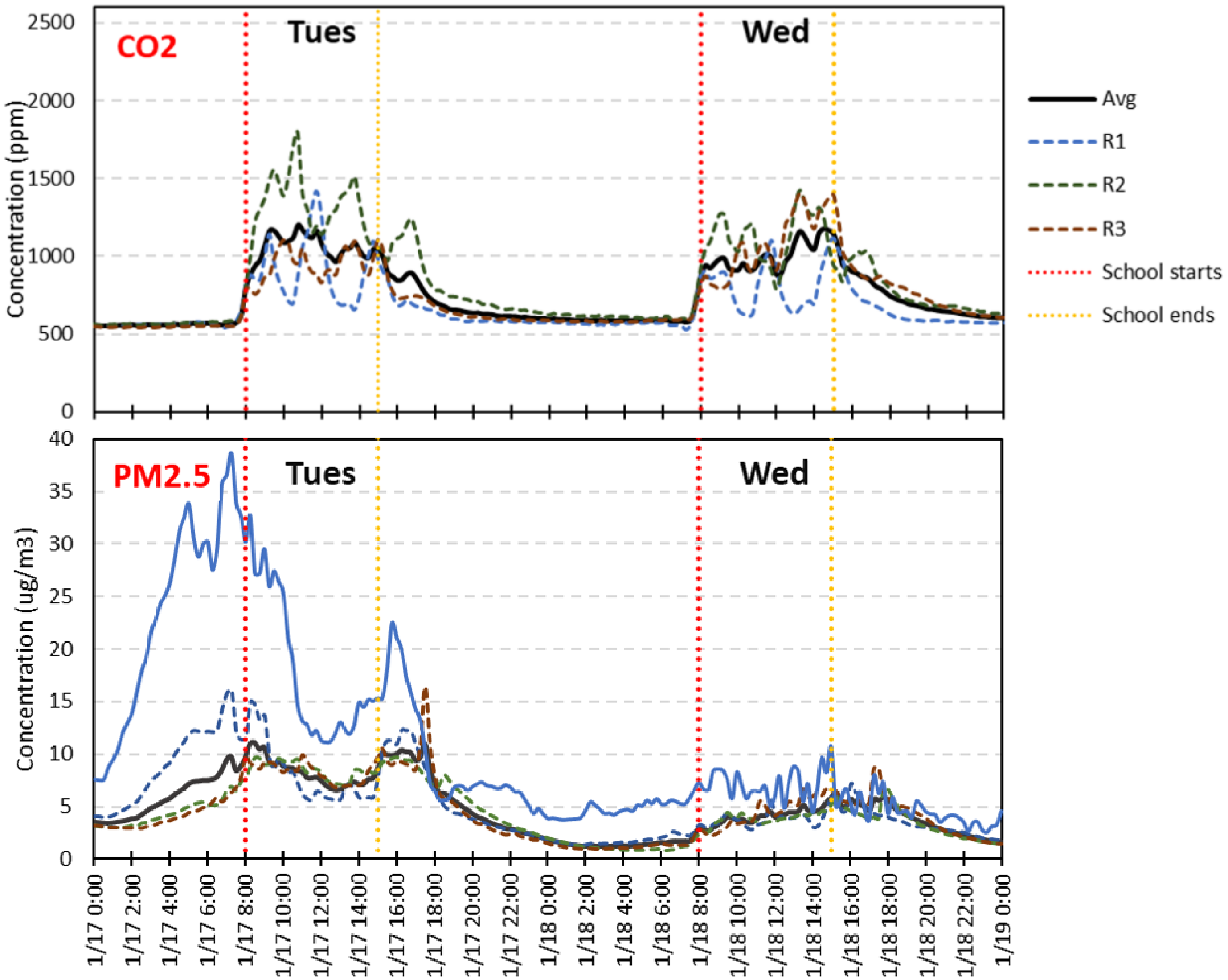

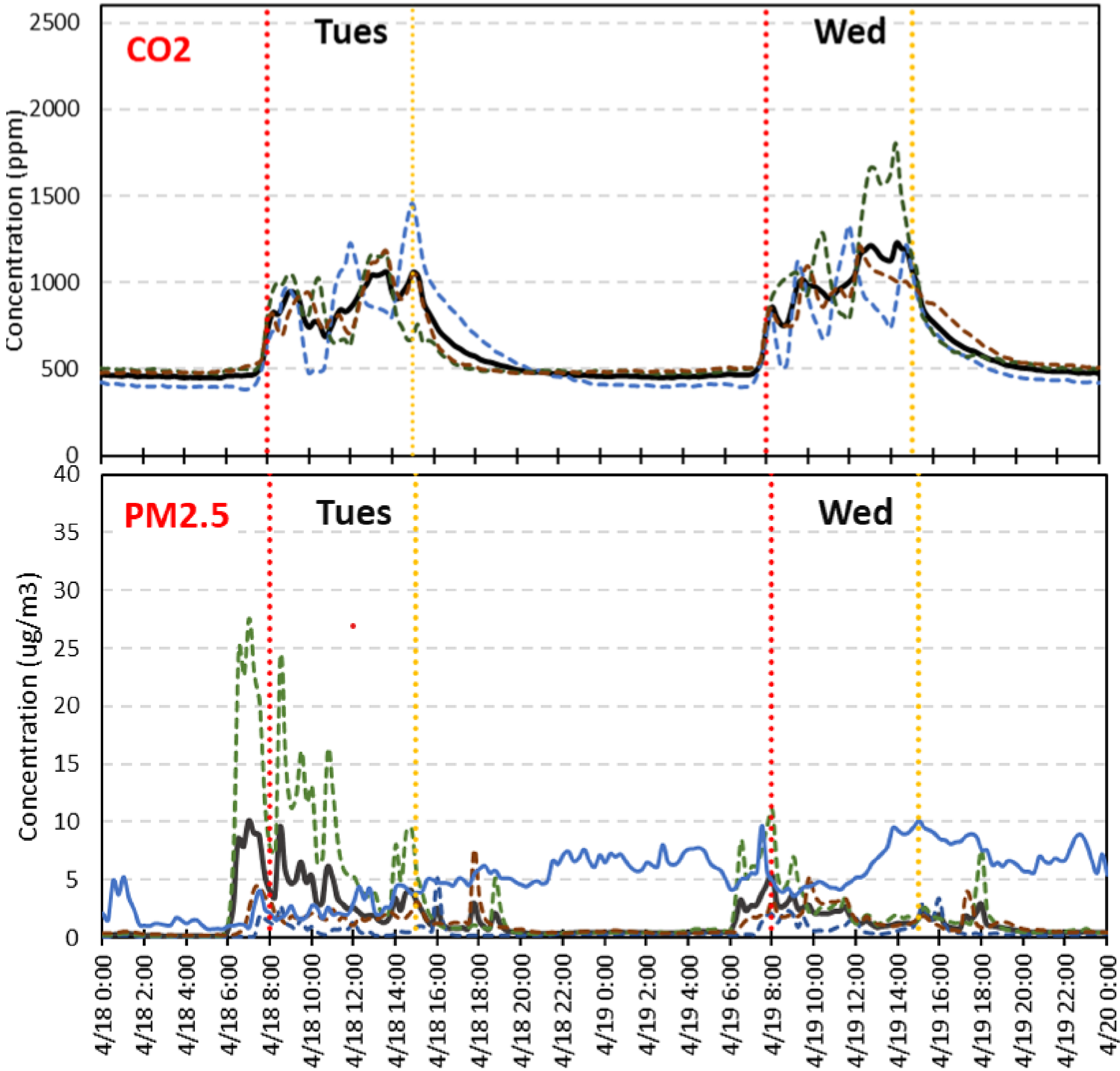

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Spreadsheet tools

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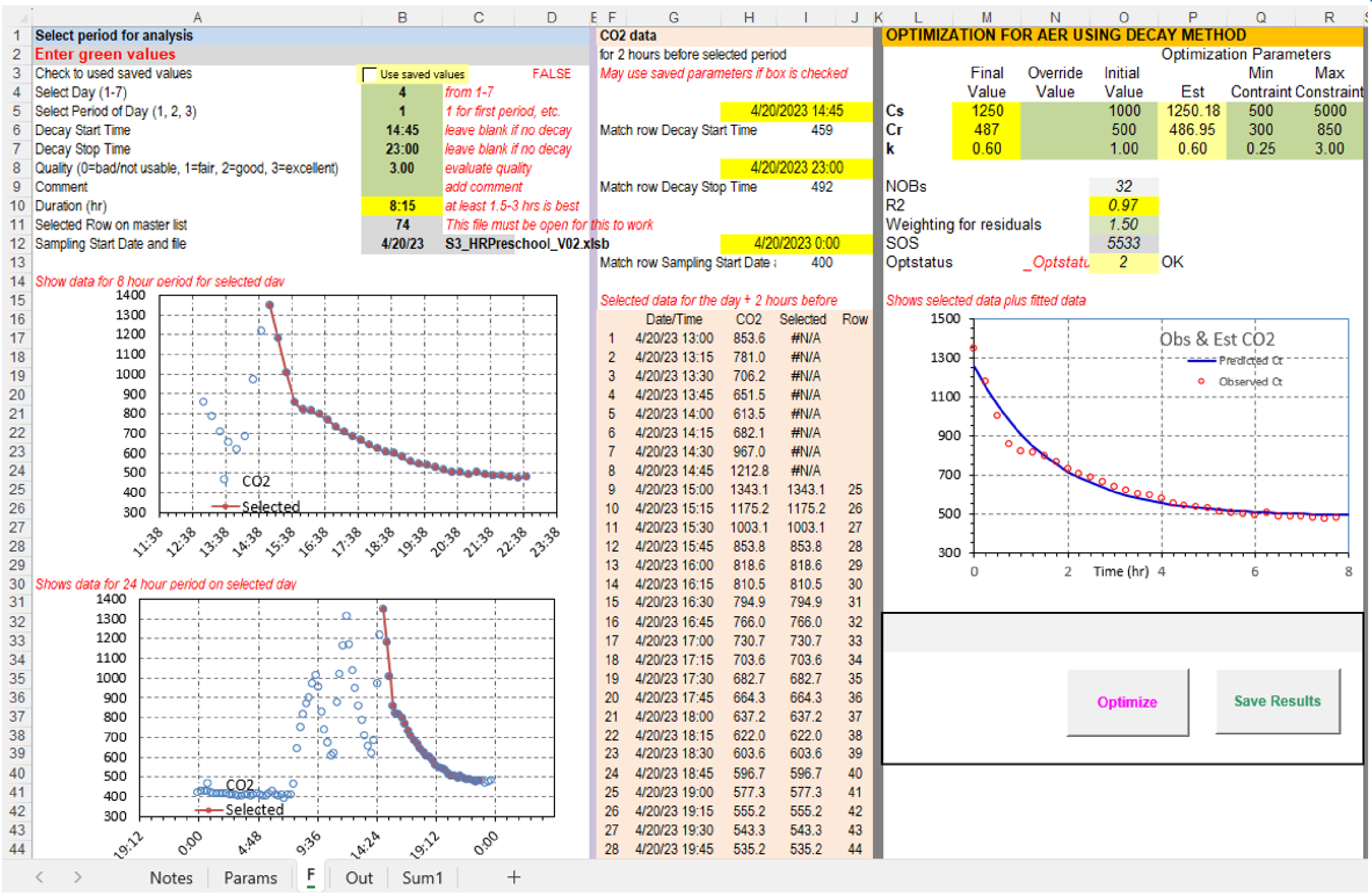


Estimates:

- Air change rates
- Pollutant clearance
- In-situ filter efficiency

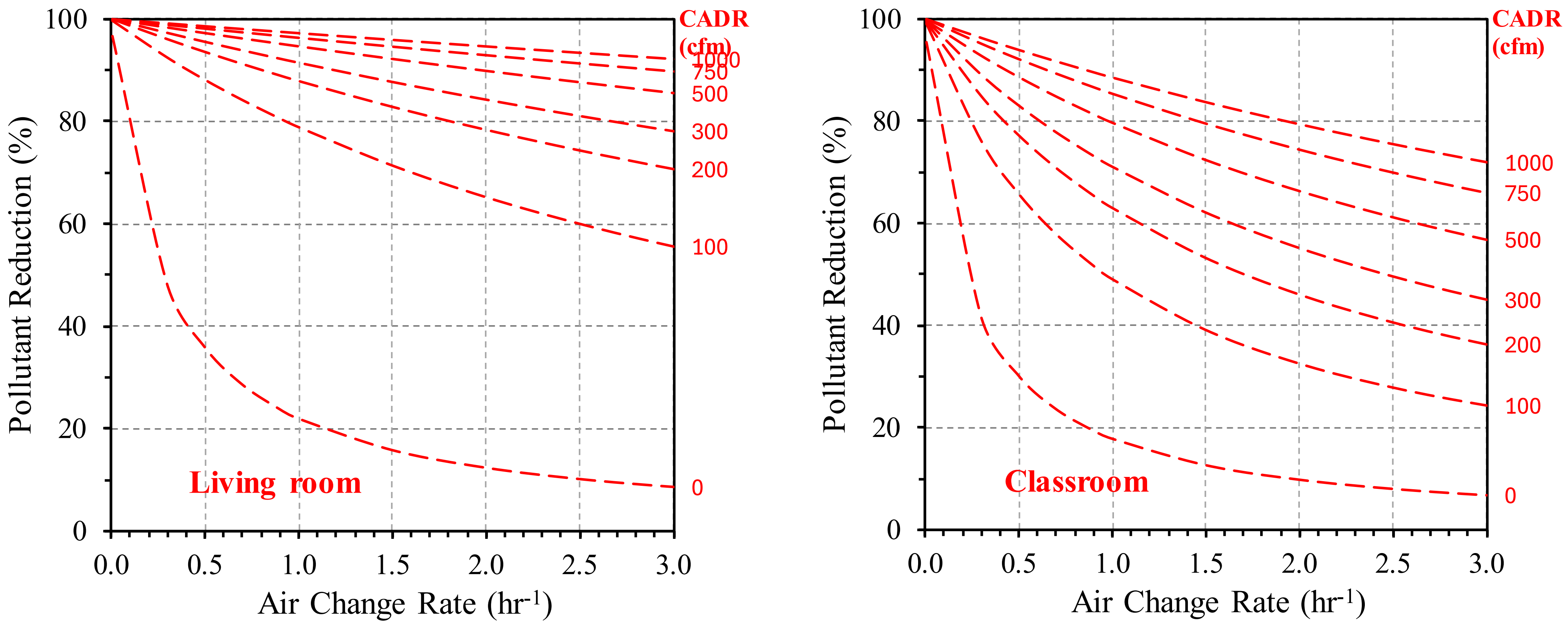
Uses low-cost sensor data

Easy and fast analysis using multiple methods:

- Build-up
- Decay (drop down)
- Steady-state
- Variable occupancy

Robust, constrained optimizer
Comparison to norms

Spreadsheet tools



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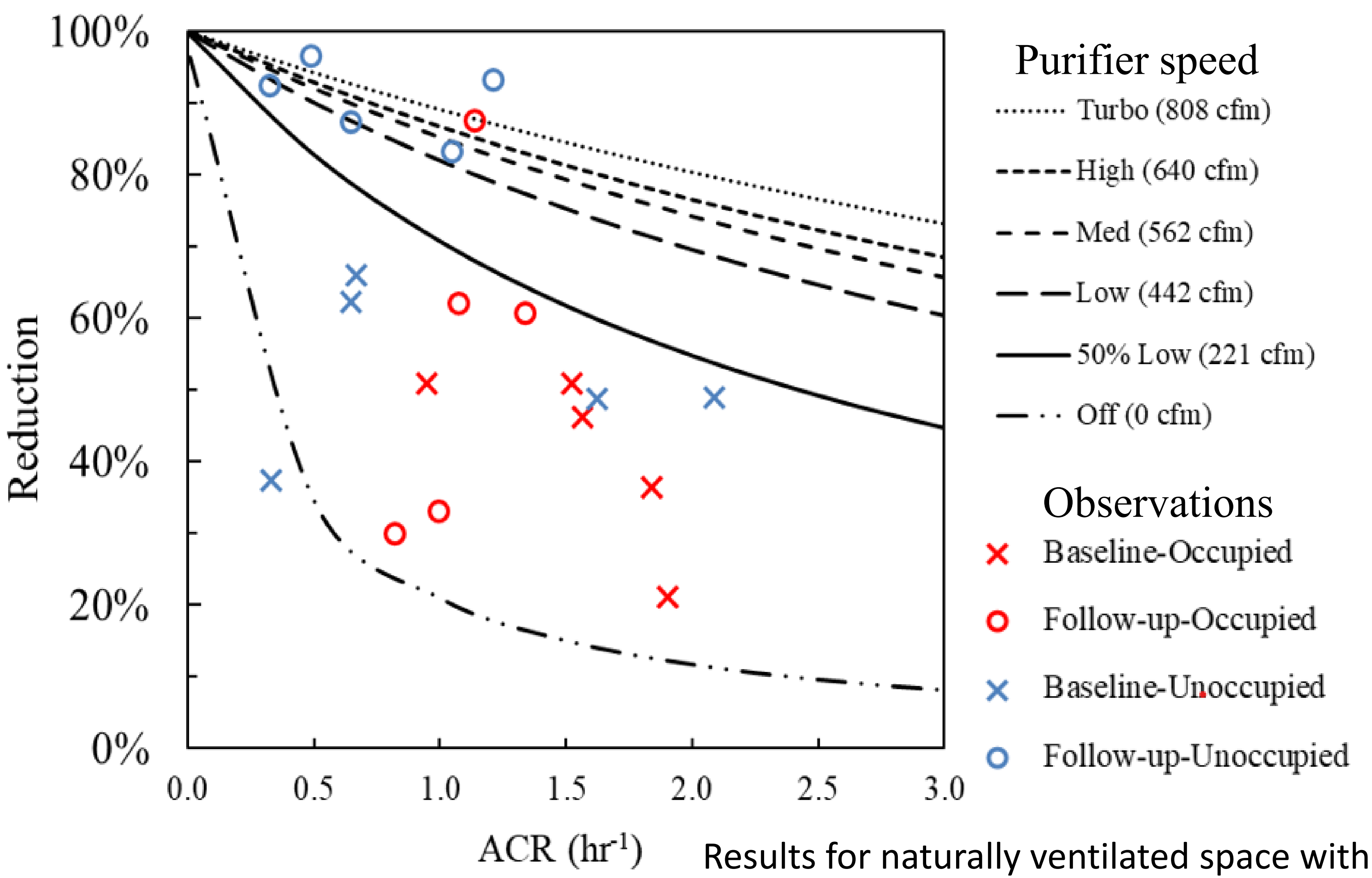
Follow-up-Unoccupied

Results for naturally ventilated space with volume = 6143 CF and 2 Whispure purifiers

Spreadsheet tools



Models air filter performance accounting for

- Room configuration
- Ventilation (Air change rate)
- Filter clean air delivery rate
- Deposition and mixing

Easy and fast application

- Minimal number of inputs
- Particularly useful for naturally ventilated buildings
- Can consider energy costs
- Considering developing a phone or web app

Results for naturally ventilated space with volume = 6143 CF and 2 Whispure purifiers

Outcome summary

Research experience:

~7 trainees in research camp + 4 faculty

Courses and seminars:

1 CE course developed

1 Academic course: “Responsible Conduct of Research and Scholarship” (UM + UC sharing)

4 Webinars and YouTube videos – on IAQ, schools, smoke exposure

Participation in ERC/MOORE supported research symposia – 2023 -“Meeting Challenges in Occupational and Environmental Justice” and 2024 – “Artificial Intelligence and the future of OSH”

New methodologies:

Spreadsheet tools

Possible phone or web app with linked Wikipedia page

Diversity

UM will host 6 undergrads from MSI/HBCUs this summer working on project (LEAD Summer 2024 R25) including 1 dedicated student from Hampton University

Thanks!

Contact information

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Kermit Davis - daviskg@ucmail.uc.edu

Kaley James – kaleyj@umich.edu

Web site - https://cohse.umich.edu/research-faculty/research/michigan-ohio-occupational-research-education-moore-program/