
Image: Flickr Creative Commons Edmonton Public Schools

Washington State Department of HEALTH

INDOOR AIR MONITORING

November 2023 ● School Environmental Health & Safety Fall Workshop

Indoor Air Monitoring

Planning for Indoor Air Monitoring – Ali Boris, WA DOH

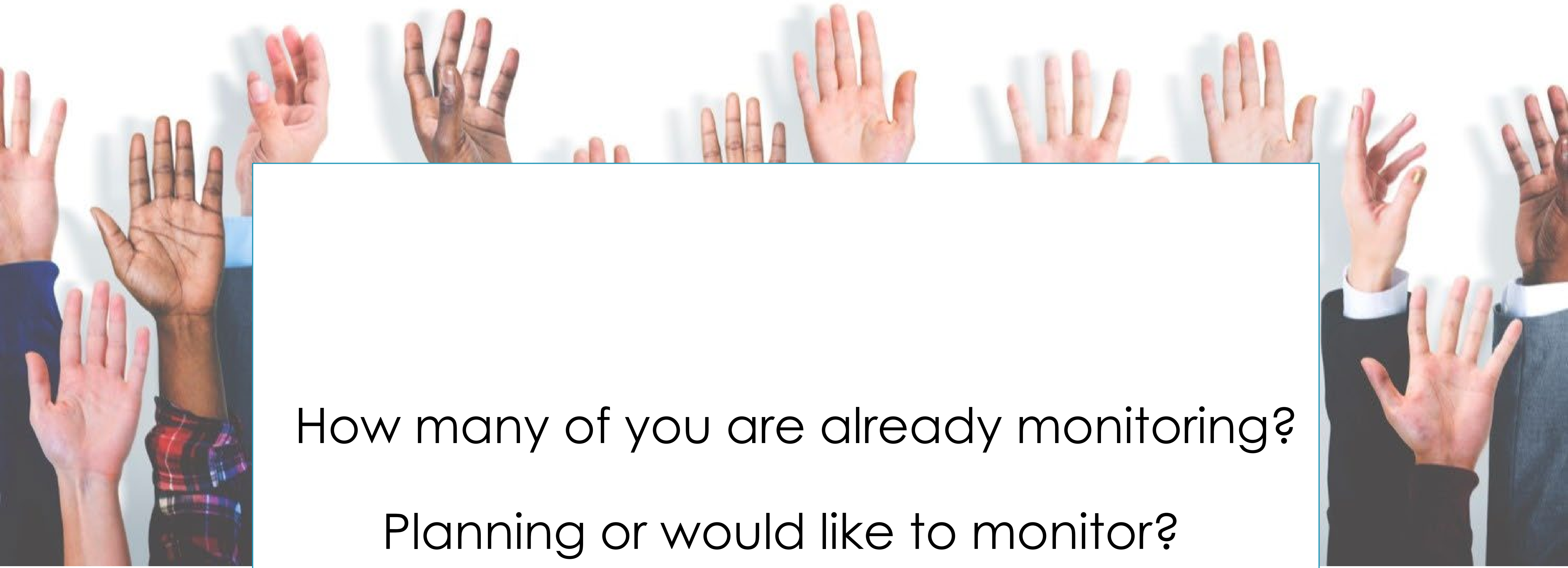
Indoor CO_2 monitoring – Becky Doe, WA DOH

Indoor $PM_{2.5}$ and CO_2 monitoring – Orly Stampfer, WA DOH

Monitoring for vaping – Elizabeth Jakab, PSWCT&UP, Ali Boris, WA DOH, Stephanie Tortorelli, PSESD, Shannon Marshall, TPS

Planning for Indoor Air Monitoring

Ali Boris, MS, PhD
Indoor Air Quality Specialist
Washington DOH



How many of you are already monitoring?

Planning or would like to monitor?

What is indoor air monitoring?

***Collection**, **monitoring**, **measurement**, and **evaluation** of indoor air quality data to take appropriate action and make improvements*[1]

- More than just placing a device
  - Data to be viewed, actions to be taken
- Use "low-cost sensors" (also called "monitors")
  - Lower data quality, lower power, higher time resolution than "reference monitors" used by researchers, regulatory

[1] Berkeley Lab webinar on School IAQ Management; South Coast AQMD presentation; image: Air Quality Sensors | Indoor Environment

Common IAQ Concerns in Schools (“Parameters”)

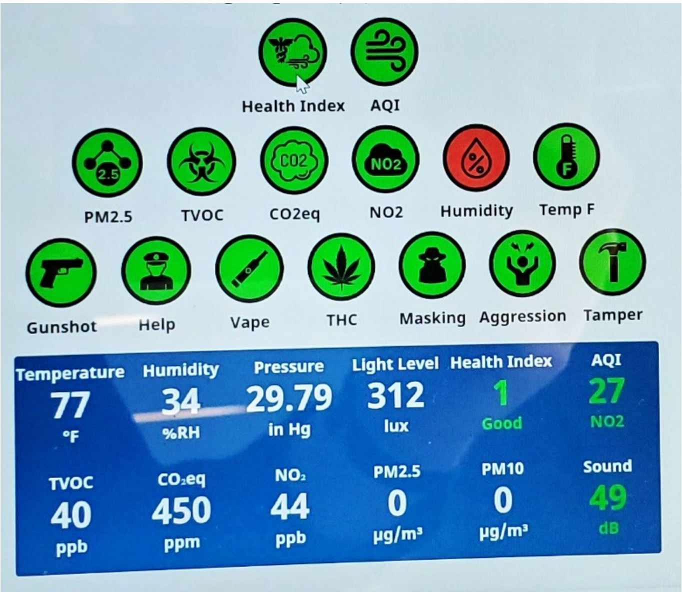
- **Particulate matter (PM)** from:
  - Smoke from fires
  - Traffic, industry
  - Dust – ex: art and shop activities
  - Pollen
- Harmful gases:
  - **Carbon monoxide (CO)**
  - Volatile Organic Compounds (VOCs):
    - From solvents, cleaners, arts, building materials, cooking, buses…
  - Ozone (O_3), nitrogen dioxide (NO_2)

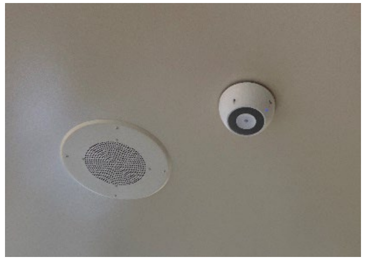
- Vaping
- Insufficient ventilation:
  - **CO_2 as proxy**
- Mold-Conducive Conditions:
  - **Temperature**
  - **Relative Humidity**
- Indoor Environmental Quality:
  - **Temperature**
  - **Relative Humidity**
  - **Noise**
  - **Light**

Bold: more accepted technologies in indoor sensors

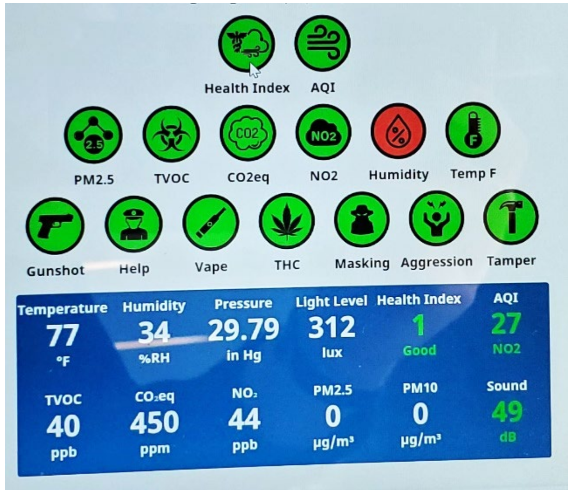
Multi-Parameter Sensors

- Some devices contain multiple sensors.
- Each parameter needs intention and resources.
  - Different locations, solutions, actions, etc.
- Perhaps plan for phases:
  - Prioritize concerns by risk, expand to other concerns
  - Work toward prevention, IAQ management





Why monitor indoors?



- To detect changes in a pollutant
  - From outside – ex: PM from wildfire smoke
  - From inside – ex: CO, NO_2 from gas stove
- To start actions such as safety protocols or increased ventilation
- To demonstrate need (or success!)

Sources: Berkeley Lab webinar on School IAQ Management, Air Sensor Technology and Indoor Air Quality | US EPA
Images: South Coast AQMD AQ-SPEC Sensor Detail, Ali Boris - DOH

When should we monitor?

- Do we know what our concern is?
  - May be from complaint, inspection/survey, event (s.a. building commissioning)
  - “We Can’t Manage What We Don’t Measure”
    - Information is powerful, but are we ready to manage what we measure?
    - Be aware of marketing, have a plan and resources
    - Idea: Start with loan (later slide) or pilot
- Will data inform our actions?
  - What will we do with the data? Source control, ventilation, and filtration are still needed.
  - Will a sensor achieve our goal? Limitations: accuracy, timing, sensitivity, drift…
    - Example: TVOCs: Is that freshly baked cookies or floor cleaner?
- Do we have the resources in place?
  - Monitoring requires time, people, funding (upfront, data, maintenance)
  - Plan for handling information

Image: Scott Burbells, WA DOH (Lake Chelan)

A Plan

- What's our goal?
- How do we set up?
  - Where? Resource: EPA's Guide to Siting and Installing Air Sensors
  - Who needs training?
- What do the numbers mean and how do we use them?
  - Trends/thresholds to look for and actions
  - There are no IAQ standards but guidance for CO_2, $PM_{2.5}$, T, RH
- How will we communicate?
  - "Counting makes you accountable"
  - Who sees the data, and who makes decisions?

Available Resources

More resources on indoor air monitoring for later

- Practical Webinar: Implementing an IAQ Monitoring Program | HGSC
- Good basic info: Low–Cost Air Pollution Monitors and Indoor Air Quality | US EPA
  - Advanced: EPA's Air Sensor Guidebook, esp. Ch. 3
- PM how-to: WA Children and Youth Activities Guide for Air Quality | WA DOH - appendices
- Sensor evaluations: Sensor Performance Data | South Coast AQMD AQ-SPEC
- Email alerts with funding, webinars: LBL Efficient and Healthy Schools
  - Webinar on School IAQ Management
- Ask your community!
  - Us, schools, local health, clean air agency

Image: Videos on Air Sensor Measurements, Data Quality, and Interpretation | US EPA

Available Resources: Air Monitors for Loan

- Tool Lending Library | Smart Buildings Center
  - For building owners, managers, professionals in WA/OR. 1-4 weeks. Ventilation/P Drop/CO_2, T, RH, light, PM, CO, multi-parameter. PSWCT&UP and SBC Demo December 7th!
- Wildfire Smoke Air Monitoring Response Technology (WSMART) Pilot | US EPA
  - Work with a state, local, or tribal air agency. Covers gaps in areas affected by wildfire. $PM_{2.5}$, CO, TVOCs, BC – stationary, mobile.
- EPA/LBL Efficient & Healthy Schools
  - For schools. PM, CO_2, T, RH. Email EHSC@lbl.gov.
- Some companies do trials…
- Talk with your local health and clean air agency. Some have started to loan sensors.

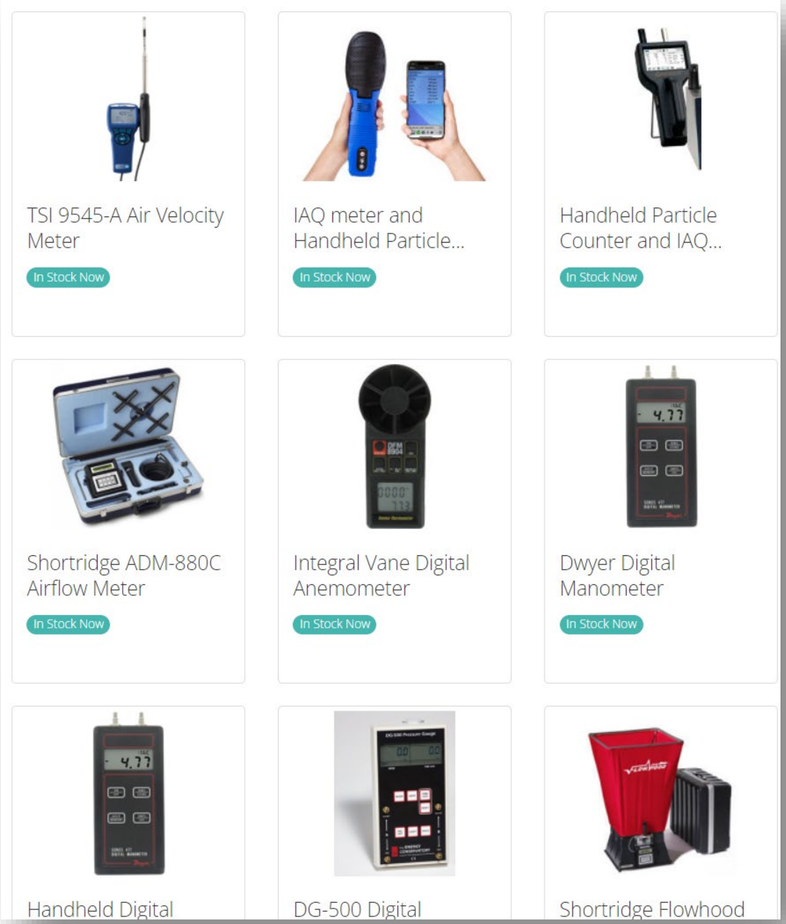


Image: Browse Tool Library Inventory - Smart Buildings Center

What Makes a Good Sensor? Some thoughts for later

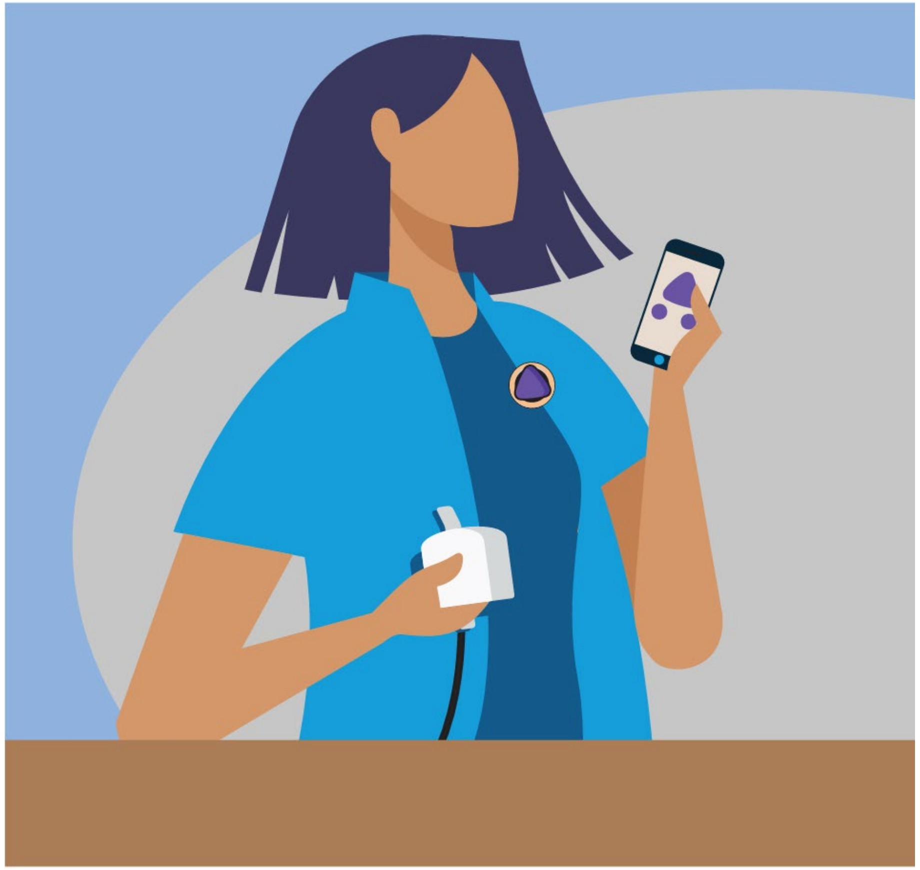


Image: [Community in Action: A Comprehensive Guidebook on Air Quality Sensors | SC AQMD]

Think about your goals.

- Low **Limit of Detection** is the lowest concentration the sensor can detect.
- Low **Error/Bias/Accuracy** (like **MAE**) is how close a sensor's measurements are to "true" (a reference monitor).
    - Sensors can drift over time.
- High **Linearity** (like $\mathbf{R^2}$) gives an idea of how *proportional* a sensor's measurements are to a reference monitor.
- Appropriate **Range** is the concentration range (high, low) the sensor can measure.
- Appropriate **Operating Conditions** (temperature, humidity)
- Few **Interferents** are other chemicals or conditions that will affect the sensor's measurement
- **Bonus: Annual calibrations**

Questions & Discussion

Thank You

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INDOOR CO_2 MONITORING

Becky Doe, MS, CIC, CIH
Industrial Hygienist/Infection Preventionist, WA DOH

Commonly Measured Parameters: CO_2

Why Measure CO_2?

- CO_2 is a useful surrogate for assessing adequate dilution ventilation
- Included in updated CDC ventilation guidance (May 2023):
  - Use portable CO_2 monitors to help you determine how stale or fresh air is.
  - Readings above 800 ppm suggest that you may need to bring more fresh, outdoor air into the space.

Commonly Measured Parameters: CO_2

What are the Sources of CO_2 in a Classroom?

- **Most Important- People**
  - Students age 5-8 produce 0.0043 liters/second
  - Students age 10-17 produce 0.0070 liters/second
  - Adult teachers produce 0.0122 liters/second

From Persily & Polidoro, Table 2, NIST Technical Note 2213 Indoor Carbon Dioxide Metric Analysis Tool

*These are average values. Specific rate depends on sex, age, body mass and activity level

- **Minor sources which may contribute**
  - Any source of combustion (stove, candle, infiltration from outside)

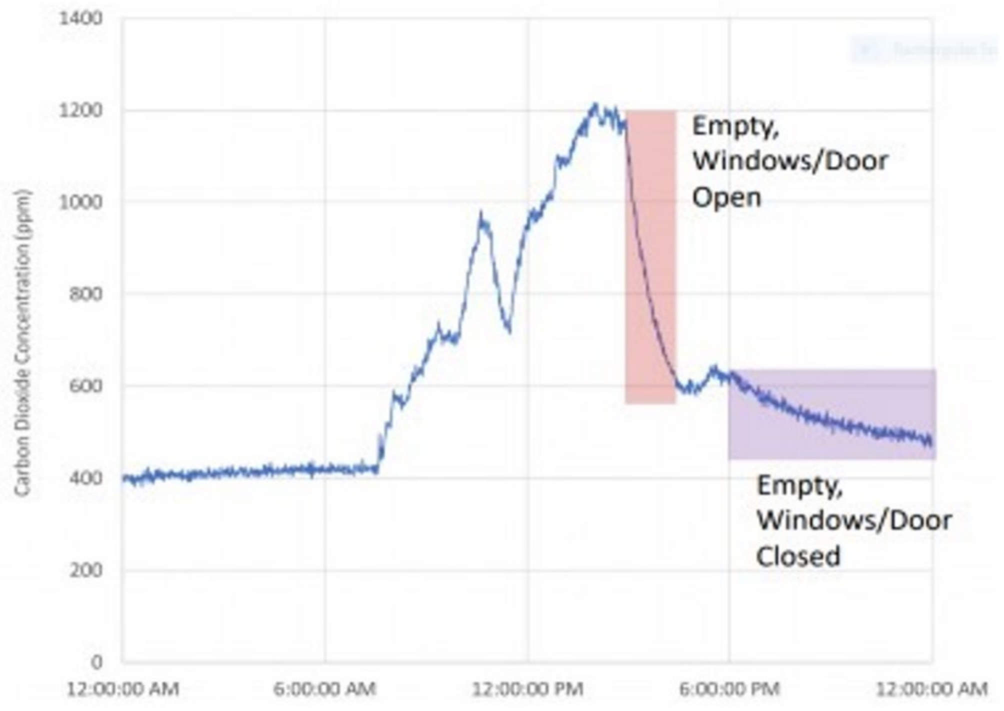
Commonly Measured Parameters: CO_2

Important Considerations

- Compare to Outside Measurements
- Measure in Center of Room
- Make sure it is out of breathing zone of occupants
- Don’t measure near air supply
- Helpful to log over a day if possible
- Concentration is a function of:
  - Room Size
  - Ventilation Rate
  - Occupancy
  - Age and Activity Level

Commonly Measured Parameters: CO_2

What a Typical Day Might Look Like



Example Classroom CO_2 Data

Source: Collaborative on Health and the Environment Webinar - https://www.healthandenvironment.org/ webinars/96581

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AIR MONITORING IN SCHOOLS AND CHILD CARE FACILITIES USING LOW-COST SENSORS

ORLY STAMPFER

What is a low-cost sensor?

- Instrument that measures gases and/or particulate matter
- Cost ~$100 to $2000
- Usually designed for general public use

PM2.5 or Fine particulate matter

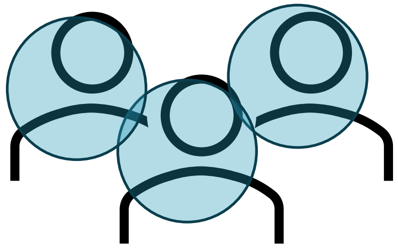
- Exposure to PM2.5 impacts lung, heart, and brain health
- Children are more vulnerable to health risks than adults
- Examples of indoor and outdoor sources of PM2.5 at a school:

How PM2.5 measurements can help

- Identify areas of the school that could use supplemental air filtration
- Get an idea of how well the building air filtration is working
  - Helpful to have both indoor and outdoor measurements
- Make decisions during periods of bad air quality, like wildfire smoke. For example:
  - Should we keep children indoors?
  - Should we keep windows and doors closed?
  - Is air quality bad even indoors? Should play be limited to lighter-intensity activities?

CO_2 (Carbon Dioxide)

- CO_2 indoors comes from people breathing
- If the amount of outdoor air coming inside is the same, but more people are present indoors, CO_2 levels will rise
- Without considering other ways besides ventilation to reduce the spread of airborne diseases, CO_2 levels can give you an idea of the potential for spreading airborne diseases
- Using other methods to reduce disease risk, like vaccination and masking, are still important even if ventilation is high



How CO2 measurements can help

- Identify areas of the school that could use more ventilation
- Increasing ventilation means bringing in more outside air
  - Open windows or doors and increase the movement of air inside the building by using fans and opening interior doors
  - Increase the amount of outside air coming in through the HVAC system
  - Balance with PM2.5 when outdoor air quality is bad

Sensor benefits and challenges

Benefits:

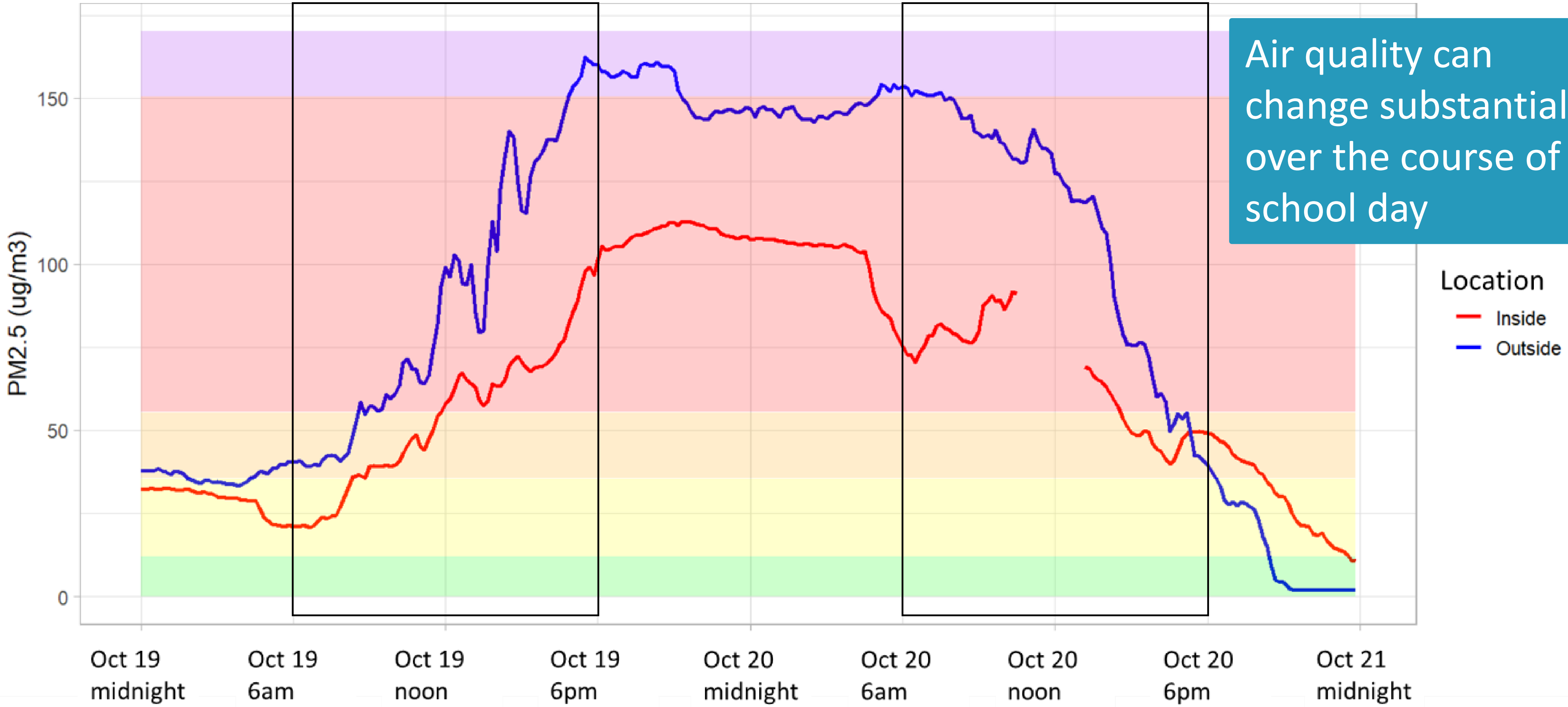
- More affordable
- Localized information
  - Outdoors at a school
  - Indoors throughout a school
- Immediate information

Challenges:

- Data quality issues
  - Accuracy
  - Maintenance
  - Siting
- Wifi or other connectivity issues
- Difficult to interpret short-term and immediate data
- Can be time consuming

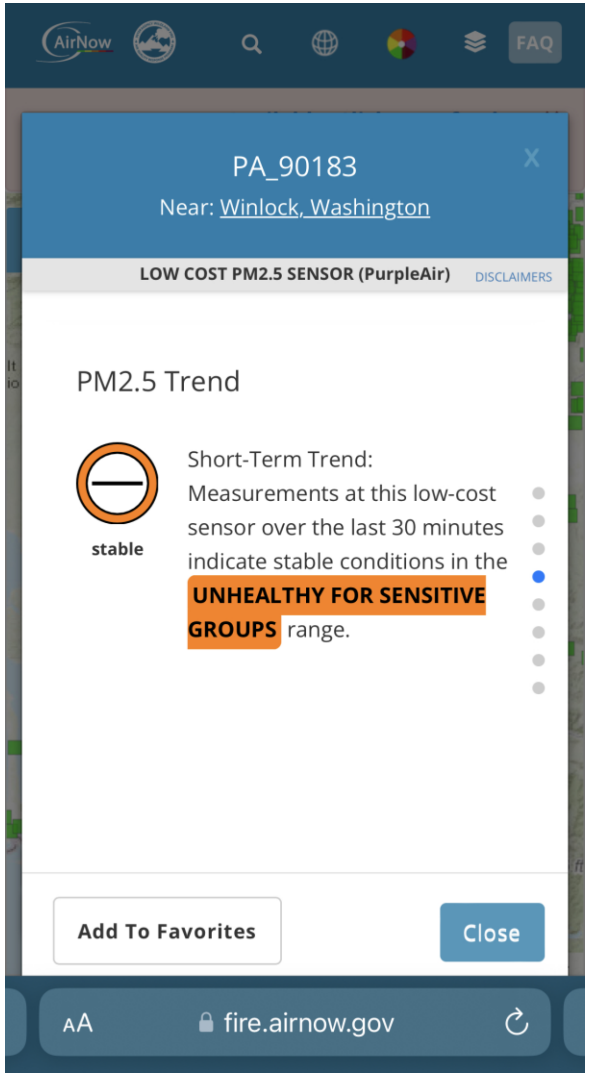
Immediate information can be useful to make decisions about activities

10-minute PM2.5 air quality during the two worst wildfire smoke days of 2022 in Tacoma



Air quality can change substantially over the course of a school day

Examples of immediate information

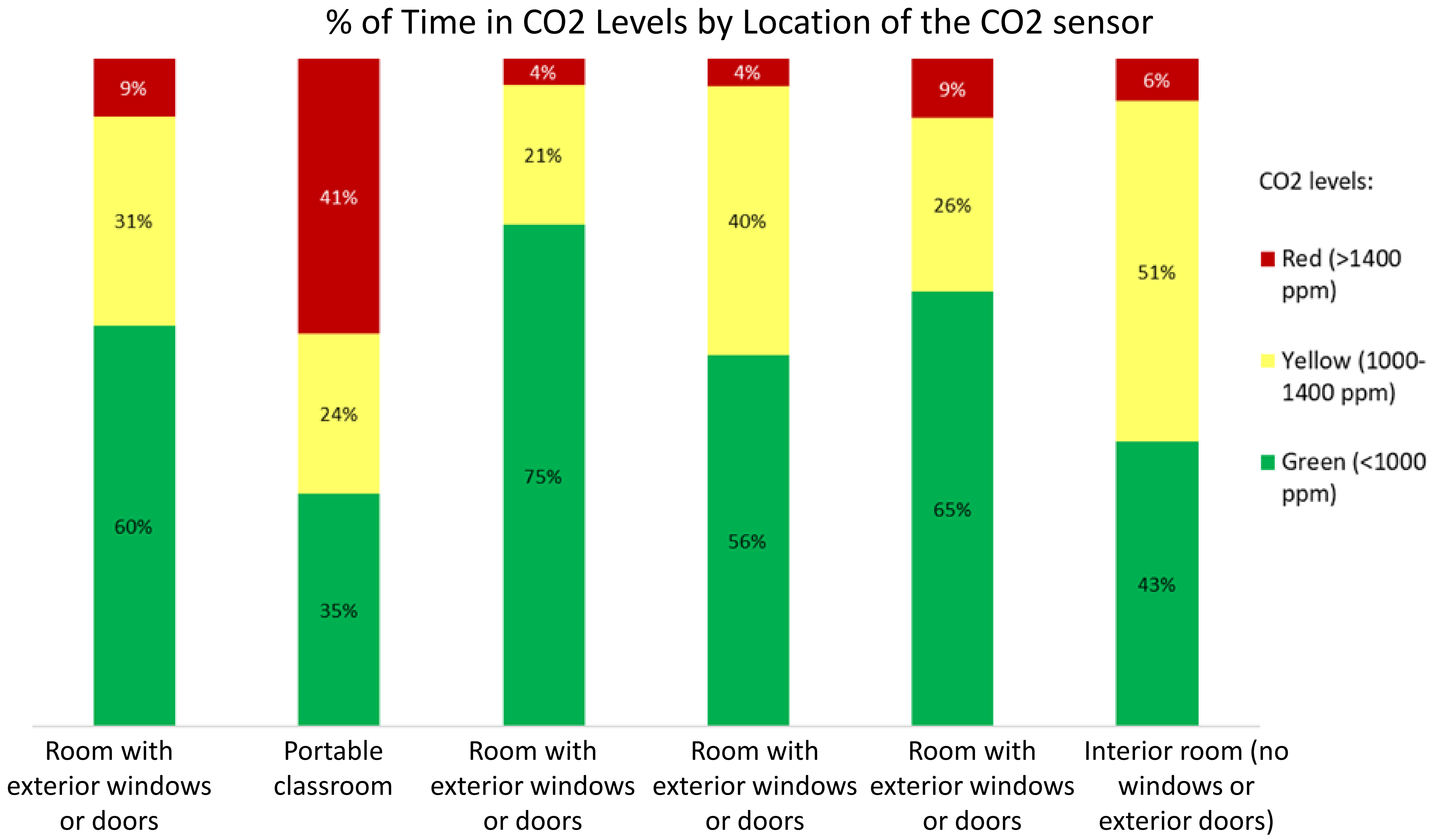


“Trend” (~30-minute) AQI category from Purple Air sensors displayed on the EPA Fire and Smoke map

Sensor with a near real-time display

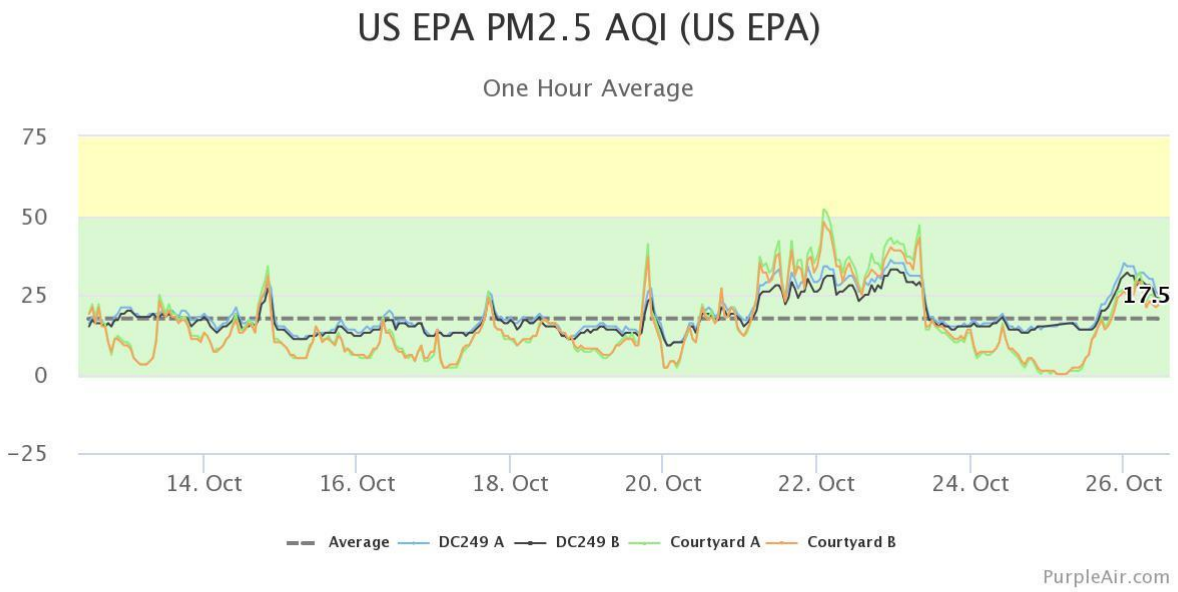
Handheld sensor with a near real-time display

Short-term information can be useful in identifying ventilation and filtration needs

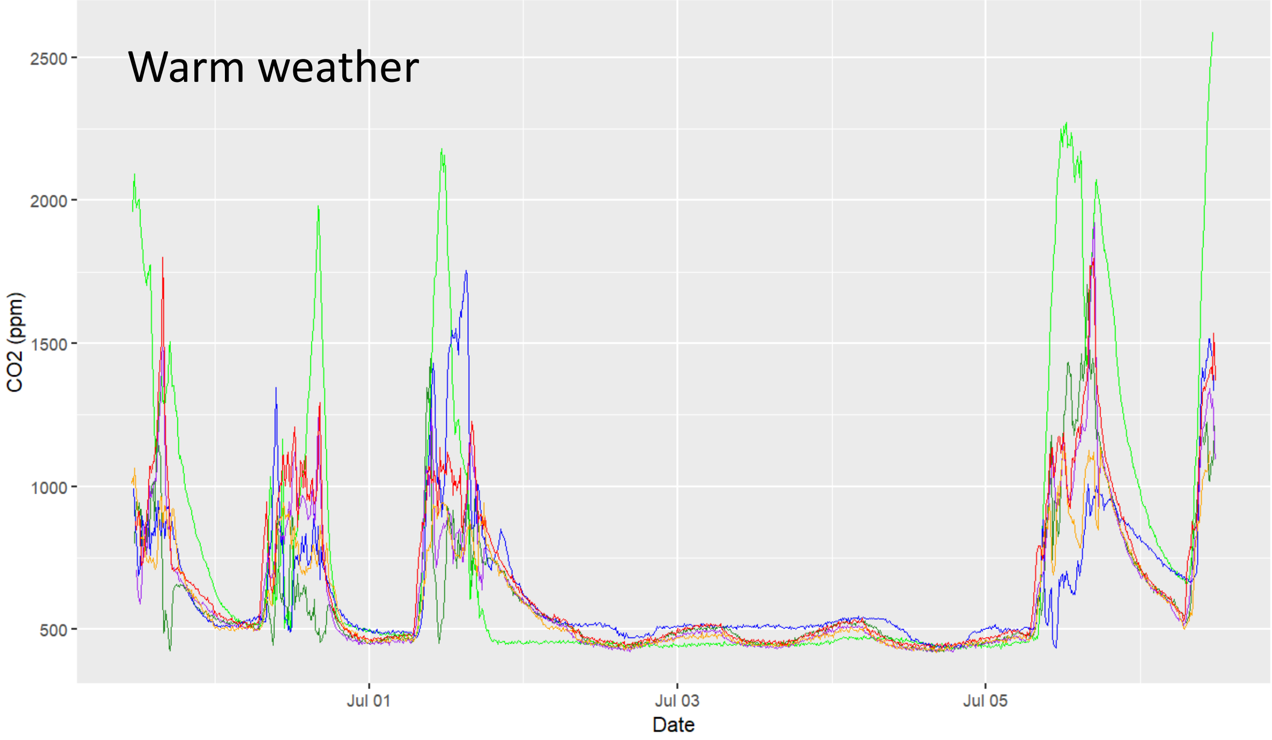


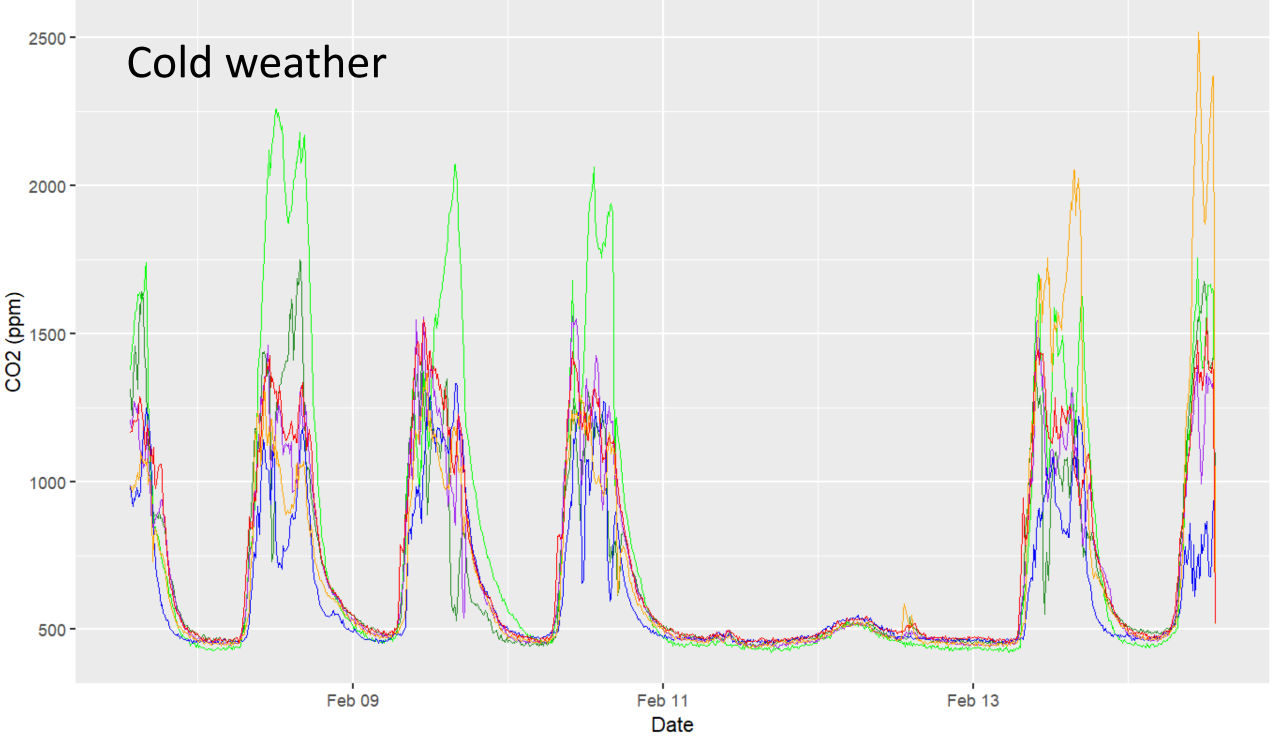
Examples of short-term information

UTCDateT	mac_addr	firmware_	hardware	current_te	current_h	current_d	pressure	adc	mem	rssi	uptime	pm1_0_cf_	pm2_5_cf_	pm10_0_c	pm1_0_at	pm2_5_at	pm10_0_a	pm2.5_aq
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	69	1010.32	0	18808	-73	89792	43.66	72.16	78.34	31.36	50.23	63.2	160
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	69	1010.28	0	18808	-70	89911	43.93	70.39	78.32	31.48	49.52	63.18	159
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	69	1010.33	0	18808	-71	90031	43.87	74.68	79.02	31.36	50.83	63.45	161
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	69	1010.27	0	18640	-71	90151	44.13	73.06	78.68	31.55	50.43	63.51	160
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	95	69	1010.31	0	18640	-72	90271	43.98	71.59	77.59	31.35	49.87	62.87	160
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	69	1010.29	0	18808	-72	90391	42.59	72.48	78.89	30.63	49.8	63.26	160
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	97	70	1010.31	0	18808	-69	90511	43.6	71.02	76.49	31.07	49.42	62.09	159
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	96	70	1010.28	0	18808	-70	90631	43.23	71.52	76.34	30.95	49.61	62.05	160
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	97	70	1010.27	0	18808	-72	90751	42.91	70.89	77.53	30.79	49.19	62.62	159
2022/10/1	48:3f:da:a	7	2.0+OPENI	71	97	70	1010.28	0	18808	-70	90871	43.55	71	77.64	31.13	49.4	62.64	159



Time(dd/mm/yyyy)	Carbon dioxide(ppm)	Temperature (Â°C)	Relative humidity(%)	Atmospheric pressure(hPa)
30/04/2023 11:33:37 AM	524	16.7	60	1006.5
30/04/2023 11:38:37 AM	520	16.7	60	1006.5
30/04/2023 11:43:37 AM	525	16.7	60	1006.5
30/04/2023 11:48:37 AM	524	16.7	60	1006.3
30/04/2023 11:53:37 AM	520	16.7	60	1006.3





Using immediate vs. short-term information

Immediate (minutes, < 1 hour):

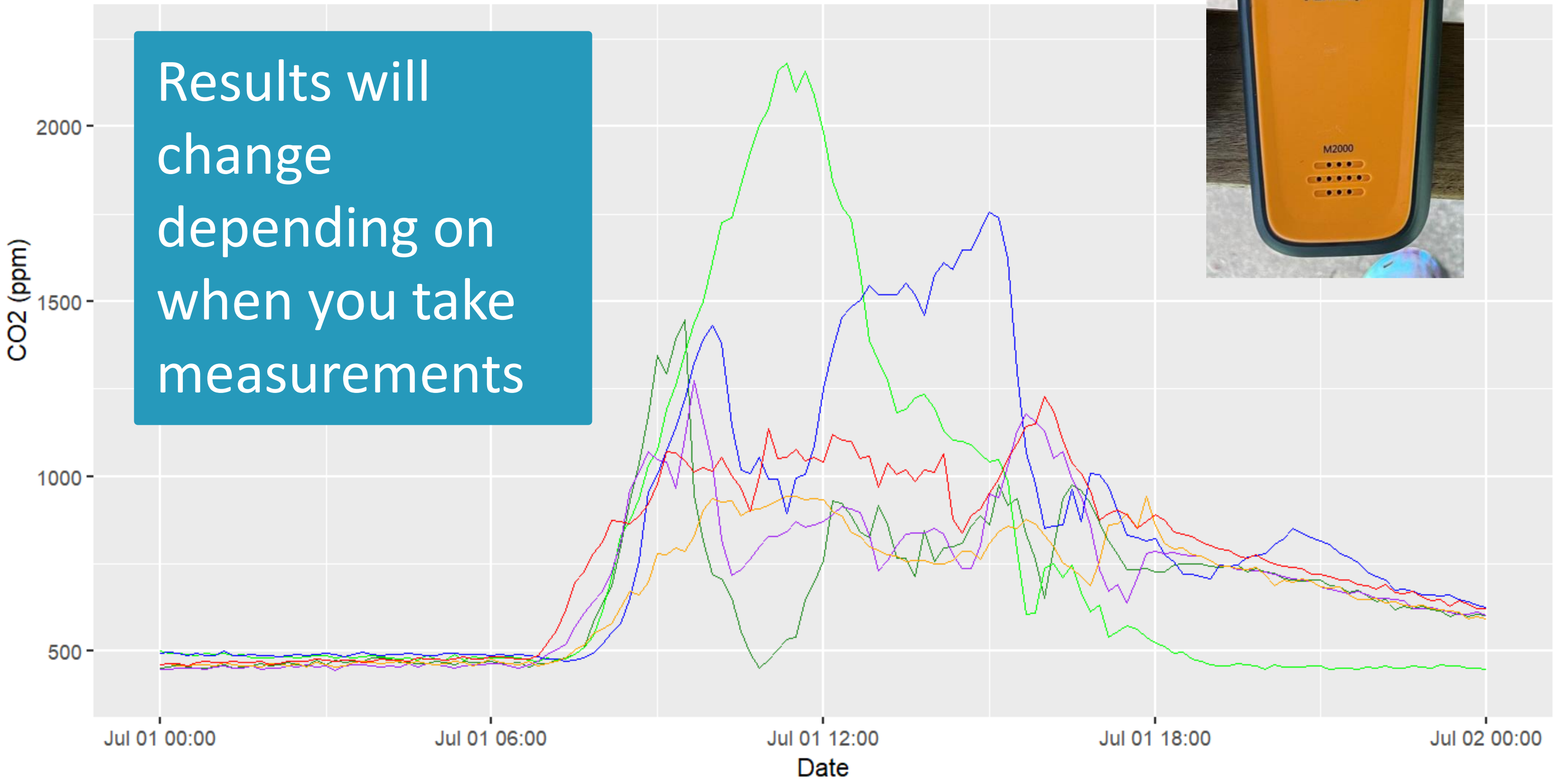
- Open or close windows/doors
- Identify current actions that might be contributing to air pollution indoors
- Make decisions about activities happening soon
  - Indoor vs. outdoor
  - Avoiding certain areas of the school
  - Level of intensity
  - Duration

Short-term (hours, days, weeks):

- Identify ventilation and filtration successes and needs
- Compare across different areas of the school
  - Identify rooms with generally better or worse filtration and ventilation
- Compare different schools to each other
- Time consuming:
  - Repeating measurements
  - Downloading and viewing data

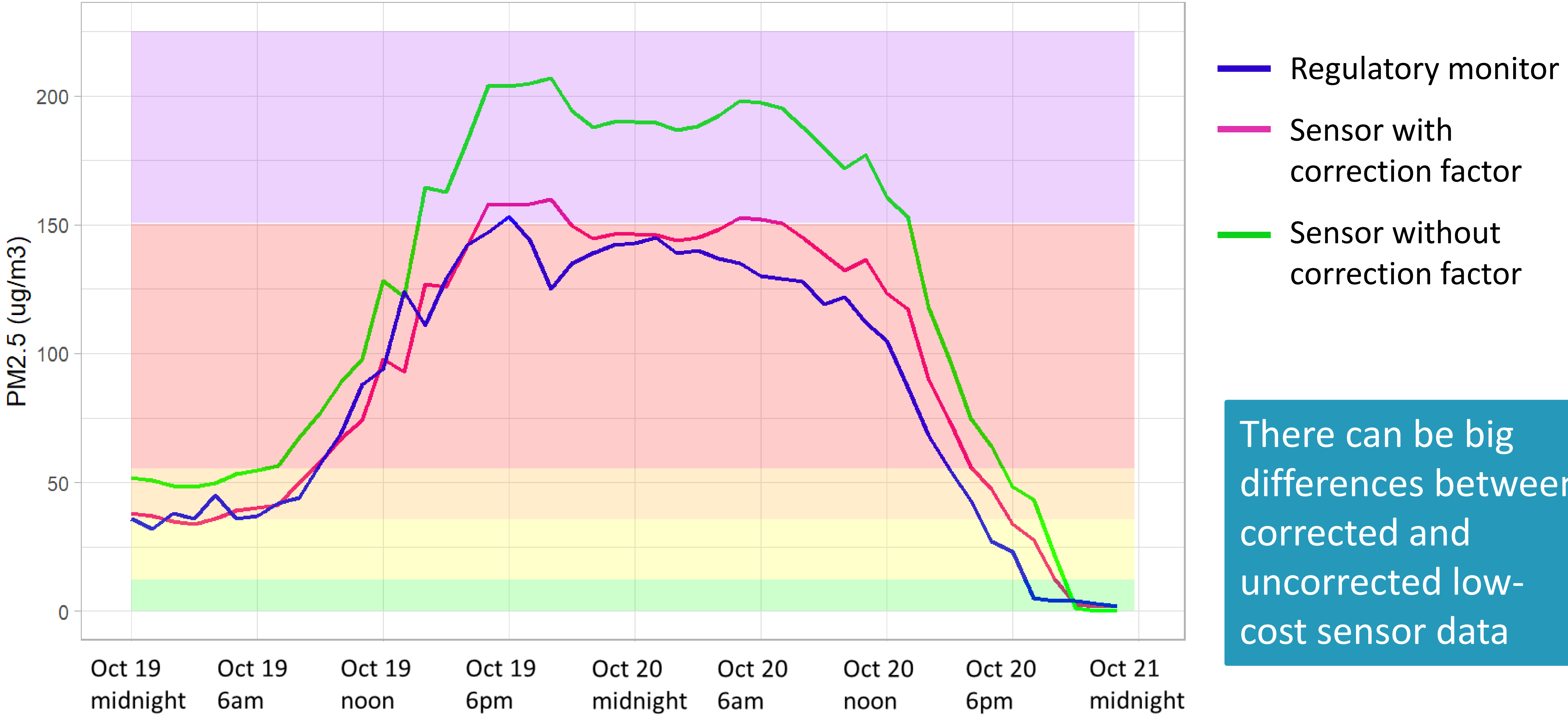
Handheld sensor use – a snapshot in time

- **Spot checks throughout a facility can be helpful**
  - Immediate decision-making about activities
  - Is there something happening in this room/area right now that should be changed
- **However, they only represent a snapshot in time**
  - Outdoor air pollution (PM2.5)
  - Ventilation system settings
  - Use of portable air cleaners (PM2.5)
  - Window/door opening
  - Occupancy
  - Activities



Data quality issues are a challenge with sensor use

PM2.5 air quality during the two worst wildfire smoke days in Tacoma of 2022: October 19th and 20th
Corrected and uncorrected Purple Air data compared with regulatory monitor data



There can be big differences between corrected and uncorrected low-cost sensor data

Siting sensors

More ideal

- Out in air generally representative of what people are breathing
- Plugged into power strip
- Out of reach of children

Less ideal

- Air may get trapped and be less representative of room in general
- Popular outlet
- May be in reach of some children

Washington Children and Youth Activities Guide for Air Quality

- Examples of applications of sensor use in the guide:
  - Viewing localized information
  - Assessing PM2.5 levels along transportation routes
  - Choosing alternative locations for activities
  - Adjusting activity intensity level or duration
  - Deciding when to open or close windows
  - Most useful for decisions about activities happening soon (within ~next hour)
- Sensor tools:
  - Handheld or stationary sensor for decisions indoors (can also use outdoors)
  - Sensors on the Fire and Smoke map for decisions outdoors
- Cautions:
  - Do not compare uncorrected sensor data to the Air Quality Index
  - Difficult to interpret comparisons between data averaged over different time intervals
  - Sensor displays vary (for example, PM2.5 concentration vs. AQI)

Sensor performance evaluations

South Coast Air Quality Management District: Air Quality Sensor Performance Evaluation Center

http://www.aqmd.gov/aq-spec/evaluations/criteria-pollutants/summary-pm

PM Sensors

Sensor Image	Make (Model)	Est. Cost (USD)	Pollutant(s)	*Field R^2	*Lab R^2	*Field MAE (µg/m³)	*Lab MAE (µg/m³)	Summary Report
				0.66 to 0.81		2.9 to 5.1		
	(AQY v0.5) Discontinued	$5,000	$PM_{2.5}$	0.84 to 0.87	0.99		28.8 to 36.0	PDF (1,178 KB)
	**Aeroqual** (AQY v1.0)	$4,000	$PM_{2.5}$	0.76 to 0.81	0.99	4.2 to 5.3	5.4 to 15.1	PDF (674 KB)
			PM_{10}	0.56 to 0.68		35.4 to 38.8		

Goal: minimum of 0.70 for PM2.5

Goal: maximum of 7.0 for PM2.5

- Lab results can give an indication of performance under more extreme conditions
- Evaluations are specific to sensor **model**
- Some sensors detect multiple pollutants, but only certain pollutants are evaluated
- Many sensors on the market not represented here
- Some sensors may have publicly available wildfire smoke correction factors - one example is Purple Air
- If you would like help interpreting this table, please contact me: orly.stampfer@doh.wa.gov

Thank you

Tacoma-Pierce County Health Department team members:

Jackie Busby

Reanna Bettencourt

Elodia Andres Cornelio

Kathy Ross

<u>**Thank you to the child care facility staff!!**</u>

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HEALTH

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