CHILDREN'S HEALTH AND WILDFIRE SMOKE EXPOSURE WORKSHOP

WORKSHOP RECOMMENDATIONS

JANUARY 24, 2022

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PREFACE

This document is a collection of evidence-based information presented and discussed at the virtual Children's Health and Wildfire Smoke Workshop for Public Health Officials held in May 2021. It is based on information available at the time of the Workshop. Information on this topic is expected to increase and be modified over time. Public health officials may find this information helpful in decision-making and developing educational materials concerning children's health and wildfire smoke. The chapters were drafted by multi-stakeholder workgroups spearheaded by the U.S. Environmental Protection Agency (EPA) and in close collaboration with tribal, federal, state, and local officials, health care professionals, and other non-governmental organizations, academics, industry, and Pediatric Environmental Health Specialty Units (PEHSU) representatives.

The genesis of this document stemmed from the original Children's Health and Wildfire Smoke Workshop, planned for 2020 by the EPA Office of Children's Health Protection. The workshop was going to focus on four main areas of concern: respirator use by children; indoor air quality in schools; sensor use; and school activity guidelines. The goal was to develop evidence-based recommendations that public health officials could use to protect children from the adverse health effects associated with wildfire smoke. The workshop was postponed because of the Coronavirus Disease 2019 (COVID-19) pandemic, but the organizers formed workgroups to develop recommendations that could be used until the workshop could take place. Workshop invitees were asked to volunteer for the workgroups that produced this document. Workshop attendees discussed these workgroup recommendations at the virtual Children's Health and Wildfire Smoke Workshop for Public Health Officials in May 2021.

Smoke can be present in the ambient air from a wildland fire, even if the fire is very far away. When smoke occurs, it is important to reduce children's exposure to it. Wildfire smoke is a mixture of air pollutants of which fine particulate matter ($PM_{2.5}$) is the principal public health threat. At lower smoke (or $PM_{2.5}$) levels, simple measures may be sufficient to prevent health effects such as respiratory symptoms or asthma attacks. As smoke levels increase, more significant measures such as cancelling outdoor activities or moving to an indoor environment with cleaner air, may be necessary to prevent health effects. This document provides recommendations for when to take action, what actions to take, and which children are at greater risk for health effects when smoke impacts air quality. The information in this document highlights important considerations for respirator or mask use by children, improving indoor air quality in schools, school activity guidelines, and the use of air sensors to inform school activities during smoke events.

An important source of information for decision making during smoke events is the U.S. Air Quality Index, or AQI. This nationally uniform index is used by federal, state, local, and tribal agencies in the United States for communicating about daily air quality. The AQI is used as the basis for air quality forecasts and current air quality reporting, as well as for historical trends. The index uses color-coded categories and provides statements for each category that tell you about air quality in your area, which groups of people may be affected, and steps you can take to reduce your exposure to air pollution like PM. For more information see https://www.airnow.gov/aqi/aqi-basics/.

Regardless of the following findings, messages and recommendations, parents and caregivers should always be reminded that if they have concerns, they should check with their child's health care provider.

WORKSHOP RECOMMENDATIONS

1. Recommendations for Mask or Respirator Use by Children and Pregnant Women During Wildfire Smoke Events

Note: This section provides sample messages that may be adapted by public health agencies for use with their stakeholders. References to the scientific information supporting the recommendations are included below many of the messages.

1.1. Overview

- ***Message:*** These recommendations on respirator and mask use should be considered during wildfire smoke events for children and pregnant women when the Air Quality Index (AQI) is greater than 100 and encouraged when the AQI is greater than 150, or if smoke is making a child or pregnant woman cough.
    - ***Supporting Information:*** An AQI level greater than 100 is 'Unhealthy for Sensitive Groups' and greater than 150 is 'Unhealthy',[1] but local factors could influence recommendations about masks and respirators as well, including factors such as duration of a wildfire smoke event and local meteorological conditions. Thus, these guidelines should be interpreted in light of local conditions and populations.

1.2. General Information

- ***Message:*** You can find the current AQI level for your area at AirNOW (https://www.airnow.gov/).
- ***Message:*** The best protection against wildfire smoke is to shelter in an indoor space with good indoor air quality. For recommendations on reducing smoke exposure indoors, see https://www.airnow.gov/sites/default/files/2020-06/reduce-your-smoke-exposure.pdf.
- ***Message:*** When wildfire smoke is present, and if children or pregnant women must spend time in an area where the AQI level is in the orange range or higher ('Unhealthy for Sensitive Groups', >100) or if your child is having breathing symptoms like coughing, you may want him or her to wear a mask or respirator to reduce exposure to wildfire smoke. When selecting a mask or respirator for your child, ask three questions:
    - How well does the material filter?
    - How easy is the material to breathe through?
    - How well does the mask or respirator fit my child's face?
- ***Message:*** Use good judgement and remember that these options reduce exposure; they do not eliminate exposure. Outdoor activity (e.g., playing sports) should follow the AQI category recommendations even if your child is wearing a mask or respirator. Don't increase your child's outdoor activity just because you feel they are protected wearing a mask or respirator.

1.3. Types of Respirators and Masks

1.3.1. Respirators

- ***Message:*** National Institute for Occupational Safety and Health (NIOSH)-approved respirators (N95, P95, and P100) will reduce exposure to wildfire smoke most effectively, especially if they seal well against the face. Respirators with or without valves can help protect the wearer from wildfire smoke.
    - ***Supporting Information:*** N95 is not a restricted term; anyone can use that term without meeting NIOSH testing requirements. People should look for "NIOSH N95" for an approved respirator. This webpage has good information about how to tell if a respirator has NIOSH approval: https://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/default.html.
    - ***Supporting Information:*** Previously, there had been some discussion that N95s with valves were not good source control for COVID-19, but the CDC has changed that recommendation. In sum, N95s with or

without valves can be recommended both for COVID-19 and wildfire smoke. https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirator-use-faq.html

- ***Message:*** When wearing a respirator with a good seal, your child will be protected from about 900 out of every 1,000 smoke particles. Without a good seal, for example, if there are gaps around the face or nose, more smoke particles will be able to pass around the respirator and be inhaled. The mask or respirator should fully cover the nose and mouth without gaps around the nose, cheeks, and chin. See NIOSH fact sheet about how to perform a seal check.
    - ***Supporting Information:*** NIOSH certification implies that when fit tested, an N95 respirator will decrease exposure 90% or more for 95% of the times someone puts on a respirator,[2] meaning that this is what is expected when there is a good seal. Without fit testing, 95% of tests with N95s in adults show that exposure is decreased 66% or more.[3,2]
    - ***Supporting Information:*** A small study of children using adult respirators found that similar protection from wildfire smoke particles was achieved for the children as adults.[4] The first published study of a respirator designed for children (as of May 2021, respirators approved for use by children are not available in the United States) demonstrated that a respirator designed for children could also achieve the levels of protection as those designed for adults.[5]
- ***Message:*** Check the seal of the respirator by cupping your hands around the edges of the respirator and your child's face. First, have the child blow out hard, as if they are blowing birthday candles, and feel for air leaking around the respirator. Then, have the child take a deep breath in. You should see the respirator suck toward the face. You should *not* feel air flow around the edges in either case. Pregnant women can also follow these recommendations.
    - ***Supporting Information:*** Valves are a comfort feature on some respirators, and you may feel airflow come out of the valve, but no air should go in through the valve.
    - ***Supporting Information:*** The CDC has information about seal checks here, though it is targeted at adult workers: https://www.cdc.gov/niosh/docs/2018-130/pdfs/2018-130.pdf.
- ***Message:*** NIOSH regulates N95 respirators so that the material must filter 95% of small and large particles and be easy to breathe through. Look for products labeled as NIOSH certified.
    - ***Supporting Information:*** Good general information about respirators is available from NIOSH here: https://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/respsource.html.
- ***Message:*** Even without a good seal, an N95 respirator will likely provide more protection than a medical face mask or cloth face masks.
    - ***Supporting Information:*** See references above and below on efficacy of N95 respirators versus medical face masks.
- ***Message:*** There are no respirators currently certified for use by children in the United States, but children aged 7 and older may be able to effectively wear small adult-sized respirators.
- ***Message:*** Dirty, torn, wet, or crumpled N95 respirators are not effective in reducing exposure to smoke particles and should be discarded.

1.3.2. Medical face masks

- ***Message:*** Medical (e.g., surgical) face masks generally do not seal effectively to the face. However, certain models may reduce exposure to smoke particles somewhat.
- ***Message:*** When wearing a medical mask, children may be protected from about 200 or 300 out of every 1,000 smoke particles.
    - ***Supporting Information:*** Average decreases in particle exposure for adults while wearing surgical masks ranged from 15–40% depending on the mask used.[6,7] In a small sample that assessed exposure through medical face masks specifically for children under highly controlled conditions, the medical face mask reduced particulate matter inside the mask by two-thirds or more.[4]
- ***Message:*** Gaps around the face or nose will allow more smoke particles to reach the child's nose or mouth.

    - ***Supporting Information:*** It is estimated that approximately 3–6 times more particles leak in around the edges of the medical face mask, compared to through the material of the medical face mask.[8] This suggests that how tightly the mask fits to the face is a key factor in the amount of protection provided.
- ***Message:*** The U.S. Food and Drug Administration (FDA) ensures that the material in medical face masks is safe for the wearer, but the material is not regulated for its ability to filter wildfire smoke, so there is more variation in how many smoke particles these masks filter. Some may be of limited help in reducing exposure.
- ***Message:*** Medical face masks come in adult and child sizes. Choose the type that best fits your child's face.

1.3.3. Cloth face masks or coverings

- ***Message:*** Cloth face masks or coverings, which help reduce the spread of infectious respiratory diseases (such as COVID-19) by protecting individuals from droplets, do not reliably reduce exposure to wildfire smoke and air pollution.
- ***Message:*** There are no regulations for cloth face masks or coverings related to how well the material filters smoke particles or how easy they are to breathe through.
    - ***Supporting Information:*** Multiple studies have found very wide ranges in filtration capability for different fabrics, including within categories of fabrics,[9,10] with a lot of variability within each category of fabric. Notably $PM_{2.5}$ concentration was substantially *increased* past some types of material in some instances, so we can't assume that all fabrics decrease exposure.[9]

1.4. Safety Considerations

- ***Message:*** Both NIOSH-approved respirators and medical face masks can be worn safely by most children, but younger children should be supervised.
    - ***Supporting Information:*** Most of the published safety studies of N95 respirators have been done in healthy adults, and have found that there are only small changes in physiologic parameters (respiratory rate, heart rate, and lung function).[11,12] There are often increases in perceived discomfort including facial heat. In studies of a general population of adults, there were also minimal physiologic changes but some changes in subjective comfort.[13,14] These findings would be expected to be similar for children and adults.
    - ***Supporting Information:*** Studies looking at prolonged respirator use have mostly been done in health care workers, and have shown no differences in physiologic parameters after an hour on the treadmill,[15] and no changes in blood pressure or blood oxygen after even a 12-hour shift.[16] The nurses who wore an N95 respirator for 12 hours had slight increases in blood carbon dioxide (CO_2) levels.[16]
    - ***Supporting Information:*** In the only study which directly assessed safety in children, there were no changes in heart or respiratory rate when the children exercised for 3 minutes with or without an N95 respirator. They had only small increases in end-tidal CO_2 (5 mmHg or less), suggesting only slight increases in their work of breathing.[5] The American Academy of Pediatrics (AAP) healthy children's webpage for parents recommends considering factors such as "age, developmental status and special health care needs" when considering use of a respirator. https://www.healthychildren.org/English/safety-prevention/at-home/Pages/Wildfires-Information-for-Parents.aspx
- ***Message:*** Your child can use a medical face mask or respirator safely in relation to wildfire smoke when they can tell you about any trouble the mask or respirator causes. If your child is uncomfortable or reports difficulty breathing, take off the mask or respirator.
    - ***Supporting Information:*** Because of the limited body of evidence in children specifically (see third bullet under first safety message), the best option is to only use respirators with children capable of expressing whether there is a problem. This can provide an extra measure of safety, by ensuring that it can be removed if the child has an issue.
- ***Message:*** Do not use a mask or respirator for your child if it could be a choking or strangulation hazard based on their developmental level or other medical conditions (e.g., if your child frequently puts things in their mouth, or if they cannot tolerate a mask or respirator on their face without pulling on it).
- ***Message:*** If you have concerns, check with your child's health care provider.

1.5. Pregnancy

- ***Message:*** If you are pregnant, these recommendations apply to you. If you aren't breathing well, your baby isn't either. Exposure to wildfire smoke may raise the risk that your baby would be born sooner than or smaller than normally expected.
    - ***Supporting Information:*** There are a few studies that have examined effects of wildfire smoke exposure on pregnancy outcomes. In one study, wildfire smoke exposure during the first trimester was associated with a 6 gram decrease in birth weight, and exposure anytime during pregnancy increased the chance of a preterm delivery (OR 1.076, 95% CI 1.016–1.139).[17] Following exposure from the 2003 San Diego wildfires, there were decreases in birth weight among babies who were in-utero and exposed during that event; the largest decrease was for those that were in the second trimester (-9.7g , 95% CI -14.5, -4.8).[18] In terms of safety for pregnant women, it is unknown whether N95 respirator use may affect the mother's physiologic parameters, but there is no effect on fetal heart rate.[19]

1.6. Preparing for Wildfire Season

- ***Message:*** Find out how you can protect your family from wildfire smoke and make a plan for what you will do during a smoke event.
- ***Message:*** Plan how you will improve your home's indoor air quality during a smoke event and stock up on emergency supplies like high efficiency particulate air (HEPA) cleaners, extra air filters, face masks, or respirators.
- ***Message:*** Talk to your child's health care provider about mask or respirator use before wildfire season.
- ***Message:*** Have your children practice using an N95 respirator if you are considering using them during a smoke event and check the fit to their face. Practicing wearing them may help children (and adults) to become accustomed to them.
- ***Message:*** If your child has asthma, know your child's asthma action plan, and keep refills of their medications handy.

1.7. References

1. AQI Basic | AirNow.gov. Accessed May 13, 2020. https://www.airnow.gov/aqi/aqi-basics/
2. Duling MG, Lawrence RB, Slaven JE, Coffey CC. Simulated Workplace Protection Factors for Half-Facepiece Respiratory Protective Devices. *Journal of Occupational and Environmental Hygiene*. 2007;4(6):420-431. doi:10.1080/15459620701346925
3. Coffey CC, Lawrence RB, Campbell DL, Zhuang Z, Calvert CA, Jensen PA. Fitting Characteristics of Eighteen N95 Filtering-Facepiece Respirators. *Journal of Occupational and Environmental Hygiene*. 2004;1(4):262-271. doi:10.1080/15459620490433799
4. Sande M van der, Teunis P, Sabel R. Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population. *PLOS ONE*. 2008;3(7):e2618. doi:10.1371/journal.pone.0002618
5. Goh DYT, Mun MW, Lee WLJ, Teoh OH, Rajgor DD. A Randomised Clinical Trial to Evaluate the Safety, Fit, Comfort of a Novel N95 Mask in Children. *Sci Rep*. 2019;9(1):1-10. doi:10.1038/s41598-019-55451-w
6. Bowen LE. Does That Face Mask Really Protect You?: *Applied Biosafety*. Published online June 1, 2010. doi:10.1177/153567601001500204
7. Oberg T, Brosseau LM. Surgical Mask Filter and Fit Performance. *American Journal of Infection Control*. 2008;36(4):276-282. doi:10.1016/j.ajic.2007.07.008
8. Grinshpun SA, Haruta H, Eninger RM, Reponen T, McKay RT, Lee S-A. Performance of an N95 Filtering Facepiece Particulate Respirator and a Surgical Mask During Human Breathing: Two Pathways for Particle Penetration. *Journal of Occupational and Environmental Hygiene*. 2009;6(10):593-603. doi:10.1080/15459620903120086

9. Patel D, Shibata T, Wilson J, Maidin A. Challenges in Evaluating PM Concentration Levels, Commuting Exposure, and Mask Efficacy in Reducing PM Exposure in Growing, Urban Communities in a Developing Country. *Science of The Total Environment*. 2016;543:416-424. doi:10.1016/j.scitotenv.2015.10.163
10. Mueller W, Horwell CJ, Apsley A, et al. The Effectiveness of Respiratory Protection Worn by Communities to Protect from Volcanic Ash Inhalation. Part I: Filtration Efficiency Tests. *International Journal of Hygiene and Environmental Health*. 2018;221(6):967-976. doi:10.1016/j.ijheh.2018.03.012
11. Jones JG. The Physiological Cost of Wearing a Disposable Respirator. *American Industrial Hygiene Association Journal*. 1991;52(6):219-225. doi:10.1080/15298669191364631
12. Roberge RJ, Kim J-H, Powell JB, Shaffer RE, Ylitalo CM, Sebastian JM. Impact of Low Filter Resistances on Subjective and Physiological Responses to Filtering Facepiece Respirators. *PLOS ONE*. 2013;8(12). doi:10.1371/journal.pone.0084901
13. Harber P, Bansal S, Santiago S, et al. Multidomain Subjective Response to Respirator Use During Simulated Work: *Journal of Occupational and Environmental Medicine*. 2009;51(1):38-45. doi:10.1097/JOM.0b013e31817f458b
14. Bansal S, Harber P, Yun D, et al. Respirator Physiological Effects under Simulated Work Conditions. *Journal of Occupational and Environmental Hygiene*. 2009;6(4):221-227.
15. Roberge RJ, Coca A, Williams WJ, Powell JB, Palmiero AJ. Physiological Impact of the N95 Filtering Facepiece Respirator on Healthcare Workers. *Respiratory Care*. 2010;55(5):569-577.
16. Rebmann T, Carrico R, Wang J. Physiologic and Other Effects and Compliance with Long-Term Respirator Use Among Medical Intensive Care Unit Nurses. *American Journal of Infection Control*. 2013;41(12):1218-1223. doi:10.1016/j.ajic.2013.02.017
17. Abdo M, Ward I, O'Dell K, et al. Impact of Wildfire Smoke on Adverse Pregnancy Outcomes in Colorado, 2007–2015. *International Journal of Environmental Research and Public Health*. 2019;16(19):3720. doi:10.3390/ijerph16193720
18. Holstius David M., Reid Colleen E., Jesdale Bill M., Morello-Frosch Rachel. Birth Weight following Pregnancy during the 2003 Southern California Wildfires. *Environmental Health Perspectives*. 2012;120(9):1340-1345. doi:10.1289/ehp.1104515
19. Roberge RJ, Kim J-H, Powell JB. N95 Respirator Use during Advanced Pregnancy. *Am J Infect Control*. 2014;42(10):1097-1100. doi:10.1016/j.ajic.2014.06.025

2. School Indoor Air Quality During Wildfire Smoke Events

2.1. Overview

- Public health officials and school administrators should consider the interventions highlighted in this section to improve indoor air quality (IAQ) in K-12 schools during wildfire smoke events. The interventions may also apply to childcare centers in similar building types. For childcare centers located in homes, refer to resources for improving home IAQ during wildfire events such as:
  - **AirNow:** Wildfire Smoke: A Guide for Public Health Officials and Factsheets: https://www.airnow.gov/wildfire-smoke-guide-publications/
  - **U.S. EPA:** Wildfires and Indoor Air Quality: https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq

2.2. Prepare and Respond to Wildfire Smoke

- Before wildfire smoke arrives, assemble a team, and create a plan for minimizing the impact of smoke on the school facility's IAQ. Consult resources such as EPA's IAQ Tools for Schools.

  Additional resources:
  - **U.S. EPA:** Indoor Air Quality Tools for Schools: https://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit
  - **U.S. Department of Education Readiness and Emergency Management for Schools Technical Assistance (REMS-TA) Center**: Wildfire Fact Sheet: https://rems.ed.gov/docs/WildfireFactSheet_508C.pdf
  - **California Department of Education, School Facilities Planning Division**: Indoor Air Quality, A Guide for Educators: https://www.cde.ca.gov/ls/fa/sf/iaq.asp

- When wildfire smoke is present, implement a combination of ventilation and filtration and other complementary strategies, as described below, to reduce the amount of smoke inside school facilities.

2.2.1. Minimize intrusion of outdoor air

- Before wildfire smoke arrives, ensure windows and doors can be opened and closed easily and tightly. Weather-proof windows and doors to ensure proper seal. Plan how to limit opening doors, as this can allow additional smoke to enter the building.
- During wildfire smoke events, close all doors and windows and limit door opening.

2.2.2. Ensure adequate ventilation and filtration

- **If the facility is served by a heating, ventilation, and air conditioning (HVAC) system, work with facility HVAC maintenance staff to take the following steps:**
  - Before wildfire smoke arrives, evaluate the HVAC system for air distribution, proper functioning of inside registers and outside air dampers, and control settings. Service as appropriate. Repair leaks and mitigate mold if found.
  - Check air filters and replace them as needed. Ensure the filter rack is sealed to prevent bypass of unfiltered air. Plan to replace filters more often than normal during smoke events.
  - Determine whether the system can accommodate a higher-efficiency air filter. Aim to use filters rated Minimum Efficiency Reporting Value (MERV) 13 or higher, if possible, during wildfire smoke events. This rating is often printed on the filter or its packaging.
  - Order replacement filters in advance as needed – filters will need to be inspected and replaced more frequently than normal during smoke events. Having higher-efficiency filters in place can also promote a healthier school environment year-round.

- Determine the optimal HVAC system settings for reducing wildfire smoke concentrations inside the facility.
  - Low-cost sensors may provide feedback about what settings work best to reduce indoor particulate matter (PM). See Section 3.6, *Using Air Sensors to Inform Decisions Regarding School IAQ During Wildfire Smoke Events* for information on using air sensors to inform decisions regarding school IAQ during wildfire smoke events).
  - When making changes to HVAC operation, aim to maintain a positive pressure in the building to prevent drawing smoke indoors.
- Respond promptly to maintenance issues affecting the HVAC system, such as fan noise, to help ensure continued operation of the system providing filtration during wildfire smoke events.

Additional resources:

- **ASHRAE:** Planning Framework for Protecting Commercial Building Occupants from Smoke During Wildfire Events: https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-commercial-building-occupants-from-smoke-during-wildfire-events.pdf
- **ASHRAE Epidemic Task Force**: Guidance for Reopening Schools & Universities: https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf
- **U.S. EPA**: Best Practices for Reducing Near-Road Pollution Exposure at Schools: https://www.epa.gov/sites/production/files/2015-10/documents/ochp_2015_near_road_pollution_booklet_v16_508.pdf
- **Collaborative for High Performance Schools:** School Ventilation for COVID-19: https://chps.net/sites/default/files/file_attach/CHPS_COVID-19_Whitepaper_June2020.pdf
- **National Air Filtration Association:** Guidelines: Recommended Practices for Filtration for Schools: https://www.nafahq.org/wp-content/uploads/Schools-Secured.pdf
- **U.S. EPA:** Mold Remediation in Schools and Commercial Buildings: https://www.epa.gov/mold/mold-remediation-schools-and-commercial-buildings-guide-chapter-1

- **If additional filtration is needed to reduce particle concentrations in the facility because spaces are not served by HVAC, or the existing HVAC does not provide adequate filtration, consider purchasing portable air cleaners suitable for the space.** In selecting a portable air cleaner, the following should be considered:
  - *Room size and Clean Air Delivery Rate (CADR):* Choose one or more air cleaners that can serve the square footage of the space.
    - Information about selecting an air cleaner that is appropriate for the space can be found at:
      - **U.S. EPA:** Guide to Air Cleaners in the Home: https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf
      - **AHAM Verifide** Program: https://ahamverifide.org/directory-of-air-cleaners/
      - **AirNow:** Indoor Air Filtration Fact Sheet: https://www.airnow.gov/sites/default/files/2020-06/indoor-air-filtration-factsheet.pdf
  - *Noise:* Consider an air cleaner with a low published noise rating (e.g., less than 45 decibels) and/or consider a model that is oversized for the space so that it can be operated at lower (less noisy) fan speeds.
  - *Avoid ozone:* In many cases, portable air cleaners that use a mechanical filter, such as a high-efficiency particulate air (HEPA) filter, may provide adequate particle removal. Do not use ozone generators that intentionally emit ozone. Avoid portable air cleaners that can produce ozone as a byproduct (e.g., ionizers, electrostatic precipitators). For a list of air cleaners that have been tested and shown to emit little or no ozone, see: https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm.
  - *Cost:* In addition to the initial cost of the device, consider the cost of replacement filters, energy use, and storage. As with most products, just because a device has more features and is more expensive does not

always mean it will perform better. In the long term, consider retrofitting facilities to provide improved mechanical systems against the cost of deploying portable air cleaners. EPA's Preventive Maintenance Value Proposition Worksheet (https://www.epa.gov/sites/production/files/2017-11/documents/iaq-preventive_maintenance_value_prop_worksheet_final_draft_11.7.17.pdf) can help make the case for these types of upgrades, which can promote a healthier school environment year-round.

2.2.3. Avoid activities that could add to indoor air pollution

- Avoid using air fresheners or sprays with odors, burning candles or incense, using paints or solvents, certain laboratory class activities, vacuuming (unless using a vacuum with a HEPA filter), or other activities that may generate indoor air pollutants.

2.2.4. When IAQ cannot be adequately maintained

- Consider using masks indoors, specifically N95 respirators or similar masks. Keep in mind that proper fit and use are needed for efficacy. See Section 1, *Recommendations for Mask or Respirator Use by Children and Pregnant Women During Wildfire Smoke Events*. for recommendations on mask or respirator use by children. For adults, see the fact sheet "Protect Your Lungs from Wildfire Smoke and Ash": https://www.airnow.gov/sites/default/files/2020-06/respiratory-protection-no-niosh.pdf.
- Consider changing school activities to reduce exposure. For more information and recommendations on school activities during wildfire smoke events, see Section 4, *Recommendations on Children's Physical Activity During Wildfire Smoke Events*.

2.2.5. Accommodate the needs of sensitive groups

- Some children may have preexisting conditions or special needs that make them more susceptible to health issues caused by smoke exposure. Consider creating spaces within the school that will provide the maximum protection for those who are at highest risk.
    - Every room should have the best air quality possible, but for those who have known respiratory or other issues exacerbated by exposure to smoke, identify a room that can be used as a dedicated "cleaner air space". This will be a room where there is maximum filtration and minimum (but not zero) air exchange with the outside. Ideally, this room will be well adapted for the use of children with special needs/preexisting conditions. A small classroom or quiet room (conference room) may work well. Multiple rooms could be set up as cleaner air spaces as needed to accommodate all those who are at highest risk.
    - For children with asthma, follow their asthma action plan.
    - If possible, monitor the IAQ of the chosen cleaner air space using sensors. It is difficult to provide a specific PM concentration to aim to achieve that could easily be evaluated with sensors. However, following the guidelines in Section 3, Using Air Sensors to Understand Air Quality During Wildfire Smoke Events, sensors could be used to make sure that this room's PM levels are at least as low or lower than other rooms in the building.
    - Consult with parents prior to a smoke emergency on when it may be appropriate to send a child home. For children with health conditions or special needs, it might be best to send them home, but in other cases where the air quality of the school is very good, or at least better than available in children's homes (or for homeless children), remaining at school might be a better option than being at home. Schools will also need to consider factors such as availability of space and staffing to meet the needs of sensitive groups.

Additional Resources:

- **AirNow:** Protecting Children from Wildfire Smoke and Ash Factsheet: https://www.airnow.gov/sites/default/files/2020-06/pehsu-protecting-children-from-wildfire-smoke-and-ash-factsheet.pdf

2.3. Considerations for Extreme Heat During Wildfire Smoke Events

- Heat can be an immediate threat to health and life, whereas smoke is often a longer-term risk. High temperatures can adversely impact student performance[1] and school-aged children may be at higher risk of adverse health effects including dehydration, intestinal infections, and mental health-related emergency room visits.[1-4]
- Use air conditioning to maintain appropriate temperatures during smoke events in order to keep doors and windows closed.
- In spaces that rely on open windows for cooling, open windows or discontinue use of the space if heat becomes excessive and smoke is too heavy.
- Use window treatments (e.g., blinds, screens) where possible to reduce or delay temperature increases if air conditioning is not available.
- On warm days, consider moving activities to other spaces that have air conditioning. If temperatures within the school cannot be maintained at a safe level, the best option may be to send students home for the day.
- Some jurisdictions provide temperature range requirements for classrooms. Consult local guidelines where available.
- Ensure students and staff are able to stay hydrated and consider providing thermometers in classrooms or other spaces for teachers and staff to track indoor temperatures.

Additional Resources:
- **U.S. EPA:** Extreme Heat: https://www.epa.gov/natural-disasters/extreme-heat
- **U.S. EPA:** Excessive Heat Events Guidebook: https://www.epa.gov/sites/production/files/2016-03/documents/eheguide_final.pdf
- **Harvard University:** Schools for Health Report available to download from: https://schools.forhealth.org

2.4. Considerations for Cleaning Up After Wildfire Smoke Events

- Clean up safely. Children should not participate in disaster cleanup.
- For severe wildfire smoke events or if the facility was directly impacted by a wildfire, consider hiring a restoration professional who follows widely recognized guidelines such as those of the Institute of Inspection, Cleaning and Restoration Certification (IICRC).
- Evaluate the HVAC system for leaks, mold, dust, etc. Service the HVAC system as appropriate to remove settled smoke particles and ash. If the facility's staff does not have the appropriate expertise, consider hiring a professional to inspect the system.
- Check filters and replace them as needed. Ensure staff wear appropriate personal protective equipment and handle and dispose of contaminated filters properly as filters are likely to be more heavily loaded than usual with more contaminants of concern. If the facility's staff does not have the appropriate expertise, consider hiring a professional for this task. For more information on filters, see Section 2.2, *Prepare and Respond to Wildfire Smoke* above.

Additional Resources:
- **AirNow:** Protect Yourself from Ash Fact Sheet: https://www.airnow.gov/sites/default/files/2020-06/protect-yourself-from-ash-factsheet.pdf
- **AirNow/PEHSU:** Protecting Children from Wildfire Smoke and Ash Fact Sheet: https://www.airnow.gov/sites/default/files/2020-06/pehsu-protecting-children-from-wildfire-smoke-and-ash-factsheet.pdf
- **AirNow:** Wildfire Smoke: A Guide for Public Health Officials (Chapter 5): https://www.airnow.gov/publications/wildfire-smoke-guide/wildfire-smoke-a-guide-for-public-health-officials
- **California EPA/OEHHA:** Guidance for Schools During Wildfire Smoke Events: https://oehha.ca.gov/media/downloads/air/fact-sheet/wildfiresmokeguideschoolsada.pdf

2.5. COVID Considerations During Wildfire Smoke Events

- Several organizations recommend precautions to reduce the potential for airborne transmission of the SARS-CoV-2 virus, the virus that causes Coronavirus Disease 2019 (COVID-19). These precautions include increasing ventilation with outdoor air and air filtration as part of a larger strategy that includes social distancing, wearing cloth face coverings or masks, surface cleaning and disinfecting, handwashing, and other precautions. It is also important to understand that improvements to ventilation and air cleaning cannot, on their own, eliminate the risk of airborne transmission of the virus.
- Increasing ventilation with all or mostly outside air may not always be possible or practical during smoke events. Follow local advisories during smoke events.
- However, improved filtration, whether through HVAC or by using portable air cleaners, is expected to help lower risk of airborne transmission of the virus, in addition to reducing wildfire smoke indoors.

  Additional resources are available and may be updated as understanding of COVID-19 transmission evolves:
  - Resources for Schools related to COVID-19 and Ventilation, Filtration and IAQ:
    - **CDC:** Operational Strategy for K-12 Schools through Phased Prevention: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/operation-strategy.html
    - **U.S. EPA:** Ventilation and Coronavirus (COVID-19) (including guidance for schools and on ventilation for cleaning and disinfecting): https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19
    - **U.S. EPA:** Air Cleaners, HVAC Filters and Coronavirus (COVID-19): https://www.epa.gov/coronavirus/air-cleaners-hvac-filters-and-coronavirus-covid-19
    - **U.S. EPA:** Resources for Healthy Indoor Environments in Schools During COVID-19 Pandemic: https://www.epa.gov/iaq-schools/epa-supports-healthy-indoor-environments-schools-during-covid-19-pandemic
    - **ASHRAE:** Coronavirus (COVID-19) Response Resources: https://www.ashrae.org/technical-resources/resources
  - Resources for Various Building Types related to Wildfire Smoke, COVID-19, and IAQ:
    - **CDC:** Public Health Strategies to Reduce Exposure to Wildfire Smoke during the COVID-19 Pandemic: https://www.cdc.gov/disasters/covid-19/reduce_exposure_to_wildfire_smoke_covid-19.html
    - **CDC:** COVID-19 Considerations for Cleaner Air Shelters and Cleaner Air Spaces to Protect the Public from Wildfire Smoke: https://www.cdc.gov/coronavirus/2019-ncov/php/cleaner-air-shelters.html
    - **CDC:** Wildfire Smoke and COVID-19: https://www.cdc.gov/disasters/covid-19/wildfire_smoke_covid-19.html
    - **U.S. EPA:** COVID-19, Wildfires, and Indoor Air Quality: https://www.epa.gov/coronavirus/covid-19-wildfires-and-indoor-air-quality

2.6. Frequently Asked Questions

- Can I operate the HVAC system/mechanical unit to reduce contaminants from smoke before/after the school day? Should I flush out the classroom by ventilating during periods of relatively good air quality?
  - Pre-occupancy operation of the HVAC system can help to remove contaminants that may build up while the HVAC is off overnight. For example, California requires that the HVAC system begin operation at least one hour prior to the building being occupied.[4,5] This will give time for classrooms to cool/warm as needed and to properly filter the air in the room. It is also important to continue operation of the HVAC system while the building is occupied outside of the normal school day, such as for after school or weekend activities and during routine cleaning and maintenance.
  - During periods of good air quality and comfortable temperatures, windows and doors to classrooms and other spaces within the school can be opened to ventilate the space. Sensors measuring $PM_{2.5}$

concentrations may be helpful for determining how long to continue to flush out spaces that were impacted by wildfire smoke (see Section 3.6, *Using Air Sensors to Inform Decisions Regarding School IAQ During Wildfire Smoke Events* below).

- What if I cannot find a portable air cleaner?
    - During high-smoke events, portable air cleaners are often difficult to obtain. A potential option for use in small classrooms or office/meeting spaces is a do-it-yourself (DIY) box fan air cleaner. Some organizations provide instructions to assemble a DIY box fan air cleaner, such as by attaching a 20" x 20" high-efficiency filter to a box fan (see additional resources below). There is currently some limited evidence to support the filtration efficacy of these DIY devices;[6] however, concerns have been raised that the box fan motor may overheat when operated with a filter attached. We acknowledge that during a wildfire smoke event some people may choose to assemble a DIY air cleaner to reduce their exposure to wildfire smoke. Those who make this choice should be advised to use the device with caution, under adult supervision, and not leave it unattended in a classroom or office space to avoid any potential fire or electrical hazard.

Additional Resources:

- **Climate Smart Missoula:** DIY Fan/Filter Combos: https://www.montanawildfiresmoke.org/diy-fan-filter.html
- **New York Times, Wirecutter:** How to Make a DIY Air Purifier: https://www.youtube.com/watch?v=YnIvLBe6xUE
- **Oregon Health Authority:** Fact Sheet: Do It Yourself (DIY) air filter: https://www.oregon.gov/oha/PH/PREPAREDNESS/PREPARE/Documents/Fact-Sheet-DIY-Air-Filter.pdf
- **Puget Sound Clean Air Agency:** DIY Air Filter: https://www.pscleanair.gov/525/DIY-Air-Filter
- **The Confederated Tribes of the Colville Reservation, Air Quality Program:** Box Fan Filter, A DIY Users Guide: https://www.youtube.com/watch?v=ukyF2xm8cws&feature=youtu.be

- How can I clean the air in a large room or space?
    - For large spaces in schools not served by a central HVAC system (e.g., gyms, cafeterias, hallways), a single portable air cleaner may not be sufficient to clean the air in these areas. One option is to use multiple portable air cleaners to clean the space.[7] Another option is to use a large air scrubber that would commonly be used for remediating buildings after a flood or fire. These devices have large fans that deliver a high volume of air, so they are generally very noisy. They are not likely appropriate for a classroom setting or small office space.

2.7. References

1. Eitland E, Klingensmith L, MacNaughton P, Cedeno Laurent J, Spengler J, Bernstein A, Allen JG. Schools for Health: Foundations for Student Success. 2019. Available from: https://schools.forhealth.org
2. Basu R, Gavin L, Peason D, Ebisu K, Malig B. Examining the Association Between Apparent Temperature and Mental Health-Related Emergency Room Visits in California. *American Journal of Epidemiology.* 2018;187(4):726-735. https://doi.org/10.1093/aje/kwx295
3. Basu R, Pearson D, Malig B, Broadwin R, Green R. The Effect of High Ambient Temperature on Emergency Room Visits. *Epidemiology.* 2012;23(6): 813-820. doi: 10.1097/EDE.0b013e31826b7f97
4. Greene RS, Basu R, Malig B, Braodwin R, Kim JJ, Ostro B. The effect of temperature on hospital admissions in nine California counties. *International Journal of Public Health*. 2010;55:113-121. doi: 10.1007/s00038-009-0076-0

5. California Energy Commission. 2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. CDC-400-2018-020-CMF. Published December 2018. Accessed October 27, 2020. Available from: https://ww2.energy.ca.gov/2018publications/CEC-400-2018-020/CEC-400-2018-020-CMF.pdf
6. US EPA. Controlling Pollutants and Sources: Indoor Air Quality Design Tools for Schools. Last updated October 26, 2020. Accessed October 27, 2020. Available from: https://www.epa.gov/iaq-schools/controlling-pollutants-and-sources-indoor-air-quality-design-tools-schools#AirOutandFlushOut
7. Tham KW, Parshetti GK, Balasubramanian R, Sekhar C, Cheong DKW. Mitigating particulate matter exposure in naturally ventilated buildings during haze episodes. *Building and Environment.* 2018;128:96-106. https://doi.org/10.1016/j.buildenv.2017.11.036
8. Pacitto A, Amato F, Moreno T, Pandolfi M, Fonseca A, Mazaheri M, Stabile L, Buonanno G, Querol X. Effect of ventilation strategies and air purifiers on the children's exposure to airborne particles and gaseous pollutants in school gyms. *Science of the Total Environment.* 2020;712:135673. https://doi.org/10.1016/j.scitotenv.2019.135673

3. Using Air Sensors to Understand Air Quality During Wildfire Smoke Events

3.1. Overview

- This section highlights important considerations for using low-cost air sensors to guide decisions about school activities, closures, and indoor activities in K-12 schools and childcare facilities during wildfire smoke events.
  - Low-cost air quality sensors can provide useful information about outdoor and indoor fine particulate matter ($PM_{2.5}$) concentrations and are increasingly being deployed at schools. Some $PM_{2.5}$ sensors can be placed in locations for locally relevant monitoring and the data can be accessed in real time. Sensor data can be used in areas without other informative monitoring (such as regulatory monitors) and/or in combination with other sources of air quality information such as the AQI and AirNow Fire and Smoke Map to help guide decisions about school activities and closures during wildfire smoke episodes.
  - However, proper use of sensors requires selection of the right sensors, care in operation of the sensors, correct interpretation of their data output, as well as the ability to recognize and fix errors, such as data quality problems, inappropriate siting, and other issues.
  - Several state and local communities have established programs using sensor data to guide decisions about school activities and much can be learned from these groups when deciding to adopt air sensor technology (see Section 5, *Appendix: Sensor Monitoring Programs* for more detailed information on programs using sensor data in decision making).

Additional resources:
  - **U.S. EPA:** Air Sensor Toolbox: https://www.epa.gov/air-sensor-toolbox. Provides the latest science on the performance, operation, and use of air sensor monitoring systems for technology developers, air quality managers, citizen scientists, and the public.

3.2. Choosing a Sensor

- Buying the appropriate sensor for the intended use is an important first consideration. Commercially available low-cost particle sensors vary in features and performance. Parameters relevant to wildfire smoke applications are:
  - The range of concentrations over which an instrument's measurements correlate well with established standards. Some sensors may not be sensitive to very low or very high concentrations, or may have a differing (i.e., nonlinear) response over large concentration ranges.
  - $PM_{2.5}$, the primary pollutant of concern in wildfire smoke, includes particles with diameters that are generally 2.5 micrometers (µm) and smaller, and sensors may perform differently for different sized particles in that range. Because wildfire particles tend to be very small in particle size, with a range of approximately 0.15 to 0.7 µm, consider sensors that perform well for these sizes.
  - Consider features that make it easier to use the sensor, such as the ability to obtain data in real-time either through a display on the sensor or through online operation.

Additional resources:
  - **South Coast Air Quality Management District:** The Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program http://www.aqmd.gov/aq-spec provides a thorough characterization of currently available "low-cost" sensors under ambient (field) and controlled (laboratory) conditions. While these evaluations might not directly translate to the conditions experienced in your area, they may be helpful to rank and decide on the most appropriate sensor to monitor the pollutant(s) of most concern to you (e.g., $PM_{2.5}$, ozone, nitrogen dioxide, etc.).

3.3. Understanding the Quality of the Data from Low-Cost Air Sensors

- It is important to recognize that sensor air quality data may not be accurate or precise. **Don't trust the raw data to represent exact quantities.** Low-cost optical $PM_{2.5}$ sensors generally report $PM_{2.5}$ concentrations that are

higher than those reported by regulatory $PM_{2.5}$ monitors. Qualitative information may be gleaned from the raw sensor data, but users should not place too much emphasis on the number itself.
  - For example, raw data can be used to indicate whether air quality is getting better or worse over time. It can also be used to compare PM levels in different locations around the school site.
- For more specific uses of sensor data, such as providing recommendations about children's activities, it will be necessary to correct or calibrate and interpret the data.

3.3.1. Correction or calibration

- Establish methods to verify the accuracy of the data to know how to interpret it. The simplest way to test the sensor data quality is to compare it to data from a collocated (i.e., placed within a few meters) monitor operated by a federal, state, tribal, or local air quality agency. Collocation should occur for long enough to capture a range of $PM_{2.5}$ concentrations, which may require anywhere from several days to two weeks. In doing so, it may be possible to develop a correction factor. Because sensor response may vary for different sources of $PM_{2.5}$, collocation with a regulatory monitor that is nearby and has similar air pollution sources is likely to provide a more accurate correction factor. **Correction, sometimes called calibration, is necessary to compare the sensor data to regulatory levels, such as the National Ambient Air Quality Standards (NAAQS) or the AQI.**
- If there is no access to collocated monitors for comparison and possible correction, measured quantities can still be considered approximate and informative.
  - For example, sensor data can be used to assess trends in ambient $PM_{2.5}$ concentrations and provide information about relative concentrations in different locations.
- Approach sensor readings with a critical eye and observe their behavior over time to know when the sensors might be starting to malfunction or become less sensitive (e.g., Are values going up when you expect them to? Are the readings becoming "flatter" over time?).
- Sensors set up by private citizens can also be used to compare the device to other nearby sensors. Nearby sensors can provide information about the performance of a particular sensor, or call attention to a problem with placement of the sensor (e.g., a sensor at a school consistently shows a much higher reading than the surrounding sensors in the neighborhood).

Additional resources:
  - **U.S. EPA: Air Sensor Toolbox:** https://www.epa.gov/air-sensor-toolbox/air-sensor-collocation-instruction-guide. More information on how to collocate a sensor and data analysis tools for correction.
  - More technical information is available in several peer-reviewed publications including (see full citations in the Section 3.7 References list):
    - Feenstra et al. (2019)[1] describe the performance evaluations of many sensors at the AQ-SPEC lab.
    - Maag et al. (2018)[2] describe various approaches and reviews some of the literature on air quality sensor calibrations.
    - Tryner et al. (2020)[3] describe the calibration of PurpleAir sensors with portable filter samplers.
    - Delp and Singer (2020)[4] describe a method for determining wildfire smoke adjustment factors for low-cost $PM_{2.5}$ monitors for indoor air.

3.3.2. Quality control

- Sensor quality control may be difficult to determine. Most sensors do not have a status indicator so routine data review is critical to identify problems.
- Sensors may fail more frequently than higher cost instruments and may fail in ways that are not immediately obvious.
- Sensors that experience repeated high concentrations of PM or have operated for long durations may experience drift (a gradual change in a sensor's response characteristics over time) or become less sensitive.
- There is limited information on how best to quality assure sensor data, but some steps to identify invalid data are:

- Look for suspect data. Some examples include sensors reporting a constant value (e.g., zero), sudden frequent jumps in the data, and sudden, very erratic data.
- Look for overall declines in measured values that might not reflect reality (e.g., sensor starts reading very low values, either suddenly or slowly over time). Do not confuse periods of very low indoor concentrations (common during low occupancy) with a sensor malfunction. Do not assume that constantly low values represent good air quality when there is a chance the sensor is malfunctioning. When in doubt, do a simple test to see if the sensor is responding (e.g., safely light a match or candle nearby for a few seconds, or kick up some dust, etc.).
- Compare redundant or repeated measurements if a sensor provides them. For example, some sensor products are equipped with two sensors and report data from each that can be compared to ensure both sensors respond similarly.
- In an outdoor setting, compare sensor data with measurements from nearest neighbors to ensure agreement of long-term trends, even though neighboring sensors might not necessarily have identical values.
- Periodically collocate sensors with a portable reference monitor or at the collocation site used for correction. Check with the appropriate air quality agency for suggestions about collocation sites.
- Select a collocation reference site with similar land use as where you plan to use your sensor. If calibrating a larger network, use multiple collocations if possible, both in space (area or location) and in time (different times of day, seasons, repeats, etc.).

Additional Resources:

- **Tracking California:** Guidebook for Developing a Community Air Monitoring Network: https://www.trackingcalifornia.org/cms/file/imperial-air-project/guidebook
- **Mazama Science:** PurpleAir Failure Modes: https://mazamascience.github.io/AirSensor/articles/articles/purpleair_failure_modes.html

3.4. Interpreting Data from Air Sensors for Health

- Very short-term sensor data (reported every few seconds or minutes) is hard to interpret for making health-based exposure reduction decisions. A 24-hour averaging period is used with the AQI for $PM_{2.5}$ and it is estimated using the NowCast approach on the AirNow website, including the Fire and Smoke Map. Research on the health effects of short-term exposures (hours to days) to $PM_{2.5}$ or smoke has associated health outcomes primarily with 24-hour average exposures at a population level.
- The health relevance of very short-term exposures to $PM_{2.5}$ is unknown, especially at an individual level, or as it relates to any one particular individual. For this reason, **it is inappropriate to compare very short-term sensor readings directly to the AQI for $PM_{2.5}$.**
    - For example, very short-term readings (e.g., 1-, 5-, 30-minute exposures) of 40 µg/m^3 should not be labeled "Unhealthy for Sensitive Groups" because time-averaging of sensor data is required when assessing the potential health impacts from exposure to wildfire smoke.
- There are several different approaches for interpreting hourly sensor data:
    - Once the sensor data is corrected and is consistent with data from the local air quality monitoring network, apply the NowCast algorithm (https://usepa.servicenowservices.com/airnow?id=kb_article&sys_id=fed0037b1b62545040a1a7dbe54bcbd4) to calculate the AQI directly.
        - EPA uses this approach with PurpleAir sensors in the AirNow Sensor Data Pilot. Data from all ambient PurpleAir sensors that meet quality control criteria are corrected and displayed as AQI values on the Fire and Smoke Map on the AirNow website.
    - Compare a peak-to-mean ratio to the 24-hour NAAQS for $PM_{2.5}$. EPA's pilot Sensor Scale[5] can be used with 1-hour sensor data to predict whether 24-hour $PM_{2.5}$ levels will be below, near, or above the 24-hour $PM_{2.5}$ NAAQS.

- Short-term sensor data can be helpful for showing you trends in your air quality, and when your air quality is starting to get better or worse. Examining these trends when air quality conditions are dynamic can help you make decisions about when to schedule outdoor activities. When conditions are changing quickly, the AQI, AirNow, or state webpages may not yet reflect changes in $PM_{2.5}$ concentrations taking place during shorter timeframes.
- Short term sensor data can also be used to compare ambient (outdoor) air quality to indoor air quality in schools, as well as to compare air quality in different indoor locations. This information could be useful for guiding children's activities and making decisions about school closures. However, keep in mind that corrections developed based on ambient data are most accurate for similar conditions. See Section 3.6, *Using Air Sensors to Inform Decisions Regarding School IAQ During Wildfire Smoke Events* below for more information.

3.5. Choosing Where to Place Sensors (Siting)

- Sensors should be sited (i.e., placed) to achieve meaningful air quality data that is balanced with conditions for optimal data quality. Optimal siting should be:
  - Representative of the area where people are being exposed.
  - Away from large structures if possible, or on the upwind side of the structure.
  - Placed at least 1 m above ground.
  - Able to get free air flow to the sensor, not hidden behind furniture or obstructed, or too close to a wall or surface.
  - Away from unpaved roads or dust impacted areas.
  - Away from areas with high humidity or strong air flows (e.g., vents, exhaust, air conditioning units) and high temperatures (e.g., heaters).
  - In a secure location or out of reach to prevent tampering.
  - Depending upon the sensor requirements, consider Wi-Fi or cellular signal strength, access to power (and perhaps sunlight for solar-powered sensors), and data storage needs.
  - Siting choices need to be considered in light of the sensing goals.
    - For example, if trying to get a background reading, ambient sensors should be sited away from dirt roads, idling traffic, barbecue grills, or other local air pollution sources that could affect them. However, if a line of children congregates near idling traffic during school drop-off or pickup, monitoring near those children's breathing zone gives a useful estimate of exposure.

Additional resources:

- **Tracking California:** Guidebook for Developing a Community Air Monitoring Network (Chapter 12): https://www.trackingcalifornia.org/cms/file/imperial-air-project/guidebook
- **U.S. EPA:** 58 CFR Appendix E: Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring: https://www.ecfr.gov/cgi-bin/text-idx?SID=7cad0f6670f475134104b1fdf1fb71da&mc=true&node=pt40.6.58&rgn=div5#ap40.6.58.0000_0nbspnbspnbsp.e

3.6. Using Air Sensors to Inform Decisions Regarding School IAQ During Wildfire Smoke Events

- Sensors may be used to evaluate trends in IAQ, or to provide a rough understanding of how IAQ compares to outdoor air quality. Understanding the relationship between indoor and outdoor air quality at a school and how IAQ varies within a school can provide information to help with decisions about indoor activities and whether to close certain rooms within a school or to close the entire school building during a smoke event.
- Sensors may be used to identify spaces in the school with relatively better IAQ. They may also be used to identify which interventions, such as using a portable air cleaner or higher-efficiency filters in the HVAC system, can make the most improvements in IAQ (see Section 5, Appendix: Sensor Monitoring Programs for an example approach

used by the Washington State Department of Health (DOH)). For more information about interventions to improve school IAQ during wildfire smoke events, see Section 2, *School Indoor Air Quality During Wildfire Smoke Events*.

- Some important potential issues with using sensors indoors include:
    - Sensors may encounter unique environmental conditions indoors, like frequent swings of temperature and relative humidity that can impact sensor performance.
        - For example, climate-controlled indoor environments can have frequent relative humidity and temperature changes with the cycling of HVAC systems that impact sensors that are sensitive to these conditions (e.g., volatile organic compound (VOC) sensors, some optical PM sensors) or result in spurious readings in sensors that correct for relative humidity and temperature.
    - There are also many other potential sources of PM that contribute to IAQ, like cooking and cleaning, which can result in PM concentrations much higher than outdoors.
    - Sensors may have very different responses to indoor pollutant sources, so corrections used on outdoor sensor readings may not result in accurate data indoors.
        - PM sensor correction depends on the size and composition of PM, and corrections developed from outdoor data may not apply indoors for a variety of reasons:
            - PM that infiltrates indoors may have different size than outdoor PM.
            - PM from typical indoor sources like cooking, dust-generating activities like cleaning, incense, or candles have a different size and composition from outdoor PM.
            - PM sensors may not respond to some indoor sources, like gas appliances that emit PM that is too small to be detected by the sensor.
    - Indoor concentrations can sometimes be very low during low occupancy periods and rise again when the building is occupied. Unoccupied concentrations will not reflect the true exposure of most of the building occupants.
- Sensors detecting $PM_{2.5}$ (as the primary pollutant of concern from smoke) and CO_2 (as an indicator of adequate ventilation) may be most informative for IAQ monitoring during smoke events.
    - Operating ventilation systems on the recirculate setting during smoke impacted times (in order to prevent smoke infiltration) may result in a buildup of compounds like CO_2, carbon monoxide (CO), or VOCs from indoor sources. Sensors for these other pollutants may be useful to ensure ventilation is sufficient to maintain good IAQ.
- To use sensors to evaluate HVAC system changes, consider placing a sensor indoors in one or more rooms and evaluate any changes in PM levels for at least several hours before and after making a change in the HVAC system setting. Another option is to use a handheld portable sensor and observe the PM levels in different rooms before and after making the HVAC system change.
- When using sensors indoors to compare changes between rooms or over time, remember **PATH**:
    - **P: Pollution**. Examine levels in indoor PM in tandem with levels in ambient PM. This means when evaluating changes in indoor PM, consider whether PM levels outside are changing rapidly. Otherwise, the indoor data alone might not accurately reflect what is happening indoors. For example, if the HVAC system settings are changed at the same time that outdoor pollution levels are increasing quickly, it might look like the HVAC system change made things worse, when really it could just be the outdoor pollution getting worse and further impacting IAQ. Also, changes in the indoor pollutant concentration will often lag behind changes in the outdoor concentration.
    - **A: Activity.** Outdoor air pollution is not the only source of PM in a school. Cooking, cleaning, and running around on carpet are examples of indoor activities that generate PM. When comparing IAQ data from different indoor sensors, make sure that activity levels are similar in the indoor spaces being compared. Activity includes things like students or staff being present, students moving around, cleaning, cooking, and printing. If an HVAC system change intended to reduce indoor $PM_{2.5}$ concentrations from smoke is made immediately following the end of the school day, and there appears to be an improvement in indoor PM levels, it might be hard to know if that is because of the HVAC system change or if it is because the students went home. If possible, it is best to evaluate IAQ during conditions that most represent the times

people are there and their usual activities in that space. That way the information is most relevant to IAQ impacts on students and staff. Collect several days of data when comparing PM levels before and after a change has been made.

- **T: Temperature** & **H: Humidity**. Both temperature and humidity can influence how air quality sensors work. Just like Pollution and Activity, try to time air monitoring so that it compares two time periods or two spaces that have similar indoor temperature and humidity levels.

3.7. References

1. Feenstra B, Papapostolou V, Hasheminassab S, Zhang H, der Boghossian B, Cocker D, Polidori A. Performance evaluation of twelve low-cost $PM_{2.5}$ sensors at an ambient air monitoring site. *Atmospheric Environment*. 2019;216:116946. https://doi.org/10.1016/j.atmosenv.2019.116946
2. Maag B, Zhou Z, Thiele L. A survey on sensor calibration in air pollution monitoring deployments. *IEEE Internet of Things Journal*. 2018;5(6):4857-4870. https://doi.org/10.1109/JIOT.2018.2853660
3. Tryner J, L'Orange C, Mehaffy J, Miller-Lionberg D, Hofstetter JC, Wilson A, Volckens J. Laboratory evaluation of low-cost PurpleAir PM monitors and in-field correction using co-located portable filter samplers. *Atmospheric Environment*. 2020;220:117067. https://doi.org/10.1016/j.atmosenv.2019.117067
4. Delp WW and BC Singer. Wildfire Smoke Adjustment Factors for Low-Cost and Professional $PM_{2.5}$ Monitors with Optical Sensors. *Sensors.* 2020;20(13):3683. https://doi.org/10.3390/s20133683
5. Mannshardt E, Benedict K, Jenkins S, Keating M, Mintz D, Stone S, Wayland R. Analysis of short-term ozone and $PM_{2.5}$ measurements: Characteristics and relationships for air sensor messaging. *Journal of the Air & Waste Management Association*. 2016;67(4):462-474. http://dx.doi.org/10.1080/10962247.2016.1251995

4. Recommendations on Children's Physical Activity During Wildfire Smoke Events

4.1. Overview

- This section highlights important considerations for use by schools and childcare facilities in making decisions about children's activities, both indoors and outdoors, during wildfire smoke events.
- In areas that regularly have smoke events, or in areas where the potential for significant wildfire is high, use this information to develop a plan to reduce smoke exposures in children. These recommendations are intended to be used in conjunction with related Sections 1, 2, and 3, on *Recommendations for Mask or Respirator Use by Children and Pregnant Women During Wildfire Smoke Events*, *School Indoor Air Quality During Wildfire Smoke Events*, and *Using Air Sensors to Understand Air Quality During Wildfire Smoke Events*.
- It is a good idea to learn as much as possible from programs with experience. Some states that have developed guidance for children's activities during smoke events are listed in the *Additional Resources* Section 4.7 below.

  Additional resources:
  - **U.S. EPA:** Air Quality and Outdoor Activity Guidance for Schools: https://www.airnow.gov/sites/default/files/2020-03/school-outdoor%20activity%20guidance.pdf. Provides information about when and how to modify outdoor physical activity based on the Air Quality Index (AQI).
  - **U.S. EPA:** Exposure Factor Handbook: Chapter 6 Inhalation Exposure. Table 6-2 provides estimates of ventilation rates by age and level of activity (mean, 95th percentile). The exposure estimates can be helpful for schools and managers to understand how children's rates of inhalation change with different levels of physical activity and what that means with respect to pollution exposures (see example inhaled dose calculations in the *Duration of activities* section below). This information can help with decisions about modifying children's activities based on AQI advisories.

4.2. Factors Affecting Children's Exposure to Smoke

- The purpose of developing recommendations is to reduce children's exposure to air pollution. Three factors influence the exposure, or amount of pollution a child inhales, during outdoor or indoor activities: (1) **concentration of the pollutant**; (2) **activity level**; and (3) **duration of the activity**. Reducing any of these factors will reduce the inhaled dose of pollution. Specific information about these factors should be provided, as shown in the example modifications below.

4.2.1. Concentration of pollutant during activities

- The AQI, or additional short-term particulate matter ($PM_{2.5}$) concentrations from air quality sensors, can inform guidance based on concentrations of exposures, with the most restrictions on activity during times with the highest pollutant concentrations.

4.2.2. Vigorousness of activities in relation to ventilation or breathing rate

- Ventilation rates and dose of inhaled pollutants will increase with increasing vigor of physical activities going from no activity (sedentary) to light, moderate, and heavy activity levels. Guidance and precautions should reflect vigor of activities, with the most restriction on the most vigorous activities.
  - *Light Activities* refer to activities that take little physical effort and do not make you breathe harder than normal: Examples include playing board games, throwing and catching while standing, and block stacking.
  - *Moderate Activities* refer to activities that take moderate physical effort and make you breathe somewhat harder than normal: Examples include yoga, shooting basketballs, dance instruction, and ping pong.
  - *Vigorous Activities* refer to activities that take hard physical effort and make you breathe much harder than normal: Examples include running, jogging, basketball, football, soccer, swimming, cheerleading, and jumping rope.

4.2.3. Duration of activities

- Guidance and precautions should be based on anticipated exposure time for typical activities for children in school environments, with the most restriction on the longest-duration activities during periods of poor air quality.
  - Typical recess is 15 minutes, typical physical education class is up to one hour, athletics practice is 2–4 hours, and an athletic event is 2–4 hours.
- Some example modifications to outdoor activities to reduce inhaled smoke:
  - Move outdoor activities to the times of day when smoke levels are forecasted to be lower or move them indoors if indoor air quality (IAQ) is better.
  - Substitute light or moderate activities for more vigorous ones.
  - Shorten the amount of time that children are active outdoors.
  - Make space with acceptable IAQ available for indoor activities for children who are having respiratory symptoms (see Section 2.2, *Prepare and Respond to Wildfire Smoke* on accommodating the needs of sensitive groups).
- Sports practices can result in greater exposures because typically all children are active for the duration of the practice. Exposures during sports practices can be reduced using similar modifications. Some example modifications to outdoor sports practices to reduce inhaled smoke:
  - Move practices to times of the day when smoke levels are forecasted to be lower or move them indoors.
  - Reduce exertion levels, for example, by using walking drills.
  - Shorten duration of activities, for example, by taking more frequent or longer breaks, or shortening practice.

Example calculations demonstrating how activity modifications can reduce a child's inhaled dose of $PM_{2.5}$.

Inhaled Dose = Concentration x Ventilation Rate x Time
Note: the calculation is expressed in terms of inhaled dose, but some inhaled particles are exhaled, so the inhaled dose is larger than the dose that deposits on the airways

Scenario: A child (6-11 years old) is playing outside at high activity level (0.042 m^3/min)[1] for 30 minutes, with an ambient $PM_{2.5}$ concentration of 160 µg/m^3 (AQI in "Very Unhealthy" range).
Inhaled dose: 201.6 µg = 160 µg/m^3 X 0.042 m^3/min X 30 min

Modification 1: Move activity indoors to a presumably lower $PM_{2.5}$ **concentration**.
Inhaled dose: 63 µg = **50 µg/m^3** X 0.042 m^3/min X 30 min
*Concentration of the inhaled dose is reduced by 66%.

Modification 2: Reduce outdoor **activity level** from high to light.
Inhaled dose: 52.8 µg = 160 µg/m^3 X **0.011 m^3/min** X 30 min
* Concentration of the inhaled dose may be reduced by 75%.

Modification 3: Reduce the **time** spent doing the outdoor activity
Inhaled dose: 100.8 µg = 160 µg/m^3 X 0.042 m^3/min X **15 min**
* Concentration of the inhaled dose is proportionally reduced by 50%.

4.3. Additional Considerations for Children at Greater Risk

4.3.1. Children with lung or cardiovascular disease

- Children with lung or cardiovascular disease are at greater risk for smoke-related health effects.

- Consider implementing more precautionary guidelines for at-risk children, including children with asthma, respiratory infection, heart or lung disease, and diabetes when smoke levels reach the unhealthy categories of the AQI.
  - Move children at greater risk indoors for prolonged or vigorous activities.
  - Watch for symptoms, such as coughing, shortness of breath, or tiredness. Reduce exposure if these occur.
  - Children with asthma should follow their asthma action plans and keep their quick-relief medicine handy.

4.3.2. Younger children

- Younger children (preschool-aged children in daycare environments) are also at greater risk because they take in more air (and pollutants in that air) on a per pound/per kilogram basis than older children. Younger children also have other exposure pathways, including more significant hand-to-mouth activity and ingestion of soil/dust that may contain contaminants such as ash from smoke. This means their total exposure to smoke/ash is likely to be greater than what they inhale, and both exposure pathways should be reduced.
- While most agencies currently use the same activity guidance for children aged 18 and younger, in general, a more precautionary approach for younger children is advisable.
  - Check both current air quality and forecasts to inform schedule changes.
  - Handwashing, limiting play in areas of bare soil, and cleaning deposited ash off outdoor play equipment will help reduce the ingestion exposure pathway.

4.4. Additional Considerations for Prolonged or Repeated Smoke Events

- Some long-term cohort studies, specifically the University of Southern California Children's Health Studies[1], have shown that long-term exposure to air pollution, including fine particulate matter or $PM_{2.5}$, can lead to permanent changes in lung function and the development of asthma. Additionally, these studies[1] have shown that reductions in air pollution over time have led to improvements in lung function growth and decreased symptoms of bronchitis and asthma in children.
- While studies of wildfire smoke exposure have not directly examined the health effects of prolonged exposures in children, wildfire events lasting for longer durations may increase overall exposures and contribute to some of the health effects observed in studies examining long-term ambient air pollution exposure.
- Because of the potential health implications of prolonged exposure to higher concentrations of air pollution from wildfire events, it is important to implement greater precautions for prolonged or repeated smoke events. If communities experience wildfire smoke exposure over multiple days, recurrent exposure within years, or exposure year after year, more precaution is merited to reduce potential adverse effects that have been associated with more chronic, repeated exposures to $PM_{2.5}$. The impacts may also be greater for communities that experience poor air quality or regular or recurrent additional pollutant sources, such as seasonal smoke exposures from temperature inversions that trap smoke from residential wood burning at ground level. For areas with prolonged and/or recurring wildfires:
  - Implement more precautionary approaches for smoke events that exceed a week, and in areas that consistently experience smoke events year to year. It may be necessary to re-evaluate precautionary approaches during fire season.
  - During prolonged or repeated smoke events, consider making indoor space available for children at greater risk or who have symptoms even when the AQI is in the Moderate category. See Section 2.2, *Prepare and Respond to Wildfire Smoke*, on accommodating the needs of sensitive groups.
  - Further reduce exertion levels or duration of outdoor activities and move physical activities indoors at lower AQI levels (ambient $PM_{2.5}$ or smoke concentrations).
  - Use seasonal forecasting as a tool to decide whether to implement more extensive changes, such as identifying indoor spaces for activities, that might take more time. State or regional forecasts may be available; on the federal level the National Interagency Fire Center (NIFC) issues National Significant

Wildland Fire Potential Outlooks for the current month, the month following and a seasonal look at the two months beyond that: https://www.predictiveservices.nifc.gov/outlooks/outlooks.htm.

- Consider developing a Smoke Ready Communities program. This type of initiative is being developed by federal, state, tribal, and local agencies.

4.5. Choosing Alternative Settings for Children's Activities During Smoke Events

- Employ school district best practices when developing plans for alternative settings for physical activities.
- Ensure access to safe indoor environments with acceptable, or relatively better IAQ, when alternatives to outdoor activities are needed, because of smoke (see Section 2, *School Indoor Air Quality During Wildfire Smoke Events*)

Additional resources:

- **U.S. Department of Education Readiness and Emergency Management for Schools Technical Assistance (REMS-TA) Center:** Wildfire Fact Sheet. https://rems.ed.gov/docs/WildfireFactSheet_508C.pdf

- Develop a plan to evaluate and maintain IAQ. When moving children from one location to another for access to an acceptable environment (indoors or outdoors) consider potential additional exposures related to their transportation.

4.5.1. Schools

- Physical activities should be held indoors in appropriate spaces with acceptable IAQ. Develop contingency plans at the district level that include plans for individual schools. Evaluate what state-level support is needed, especially for disadvantaged areas.
  - Survey options for creating safe indoor activity spaces. See Section 2.2, *Prepare and Respond to Wildfire Smoke* above.
  - Check in your district for existing guidance for schools about activities, staffing levels, and resources.
  - Monitoring with sensors may inform which schools or rooms/areas within a school building have the best IAQ (see Section 2, *School Indoor Air Quality During Wildfire Smoke Events* and Section 3, *Using Air Sensors to Understand Air Quality During Wildfire Smoke Events*). Make sure the indoor activity space is not adjacent to or heavily influenced by potential pollutant sources like kitchens, heaters, utilities, boilers, ventilation exhausts, etc.
  - Make sure the indoor activity space can be kept comfortably cool and that water is provided.

Additional resources:

- **U.S. EPA:** Indoor Air Quality Tools for Schools: https://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit
- **California Department of Education, School Facilities Planning Division:** Indoor Air Quality, A Guide for Educators: https://www.cde.ca.gov/ls/fa/sf/iaq.asp

4.5.2. Childcare/daycare facilities and camps

- Consider specific settings outside of school, including childcare/daycare facilities, before and after school programs, summer sports programs, and camps. For school-aged children, "daycare" means before and/or after-school care. Some schools do not offer on-site daycare. This means that children move to a different site, which may have worse IAQ than schools.
- With respect to smoke exposure decision making, IAQ could be the biggest difference between schools and daycare settings. Consider the relative IAQ in the various settings where children spend time, including daycares, after school activities, and at home, when deciding whether schools should remain open, hold regular after school activities, or provide after-care during smoke events.

- Keeping doors and windows closed during wildfire smoke events can effectively reduce the entry of smoke into indoor spaces. If outdoor temperatures are high, take steps to prevent heat-related illness. See Section 2.3, *Considerations for Extreme Heat During Wildfire Smoke Events*.
- During the COVID-19 pandemic, some daycares are focusing much more on keeping windows open and having more outside activities rather than keeping children inside.
    - In general, during wildfire events or times when outdoor pollution is high, reduce ventilation with outdoor air by closing windows and doors.
    - It is also important to understand that increasing ventilation by itself is not enough to protect people from exposure to the virus that causes COVID-19; it should be used along with other best practices (such as social distancing, use of masks, frequent hand washing, and surface disinfection), as recommended by CDC.

Additional resources for home IAQ that may be useful for many daycare settings in private homes.
- **AirNow**: Wildfire Smoke: A Guide for Public Health Officials and Factsheets: https://www.airnow.gov/wildfire-smoke-guide-publications/
- **U.S. EPA**: Wildfires and Indoor Air Quality: https://www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq

4.6. Have a Communication Plan

- A smoke communication plan is a useful tool to help parents understand what measures are being taken and why some schools might do different things. Have a communication plan in place before the wildfire season. Some considerations:
    - Reach out to parents ahead of wildfire season to let them know where to get information in case of a fire. Some schools may wish to post FAQs on their website.
    - Develop an email template and/or fact sheet ahead of time that can be quickly disseminated to parents during smoke events. Materials can be updated with details when there is a fire.

Additional resource:
- **U.S. Department of Education Readiness and Emergency Management for Schools Technical Assistance (REMS-TA) Center:** Wildfire Fact Sheet: https://rems.ed.gov/docs/WildfireFactSheet_508C.pdf

4.7. Additional Resources

- General activity guidance
    - **California Air Pollution Control Officers Association**: Air Quality Guidance Template for Schools: http://www.capcoa.org/wp-content/uploads/downloads/2019/06/Air-Quality-Guidance-Template-for-Schools-Updated-5.13.2019.pdf
    - **WA Department of Health:** Air Pollution and School Activities: https://www.doh.wa.gov/Portals/1/Documents/Pubs/334-332.pdf was not designed just for wildfire smoke, but also to give schools guidance during an inversion or periods of high air pollution.
- Guidance for smoke events
    - **Placer County Air Pollution Control District**: Recommendations for Outdoor Physical Activity during Smoky Conditions: https://placerair.org/DocumentCenter/View/1468/Outdoor-Activities-Smoke-Guide-PDF has recommendations for outdoor activities for kids at camp or people working. It is important to say, "if smoke is bothering you, don't go outside."
    - **California EPA**: Guidance for Schools During Wildfire Smoke Events: https://oehha.ca.gov/media/downloads/air/fact-sheet/wildfiresmokeguideschoolsada.pdf. This fact sheet provides guidance about duration of exposure. The main issue that came up is "How will these numbers be used and interpreted for non-wildfire events?"

- **Montana Department of Public Health and Human Services:** Outdoor Activity Guidelines Based on Air Quality for Schools and Childcare Facilities: https://dphhs.mt.gov/Portals/85/publichealth/documents/Asthma/Wildfire%20Smoke/AirQualityActivityGuidelines2020Schools.pdf.
- **U.S. EPA:** Wildfire Smoke: A Guide for Public Health Officials: https://www.airnow.gov/sites/default/files/2020-10/wildfire-smoke-guide-revised-2019-chapters-4-5_0.pdf. Chapter 5 has some recommendations for schools.

4.8. References

1. Gauderman, W James, Edward Avol, Frank Gilliland, Hita Vora, Duncan Thomas, Kiros Berhane, Rob McConnell, Nino Kuenzli, Fred Lurmann, Edward Rappaport, Helene Margolis, David Bates, John Peters. The effect of air pollution on lung development from 10 to 18 years of age. N Engl J Med. 2004 Sep 9;351(11):1057-67. PMID: 15356303 DOI: 10.1056/NEJMoa040610.
2. Gauderman, W James, Ph.D., Robert Urman, M.S., Edward Avol, M.S., Kiros Berhane, Ph.D., Rob McConnell, M.D., Edward Rappaport, M.S., Roger Chang, Ph.D., Fred Lurmann, M.S., and Frank Gilliland, M.D., Ph.D. Association of Improved Air Quality with Lung Development in Children. N Engl J Med 2015; 372:905-913. DOI: 10.1056/NEJMoa1414123.

5. Appendix: Sensor Monitoring Programs

5.1. Overview

- The following resources highlight several established federal, state, and local programs which use air sensor data to guide decisions about school activities. Much can be learned from these groups when deciding to adopt air sensor technology.

5.2. Established Sensor Data Programs

- **U.S. EPA/U.S. Forest Service (USFS)**
  AirNow Fire and Smoke Map
  (https://fire.airnow.gov/)
  To give users the most localized air quality information possible, the Fire and Smoke Map pulls data from monitors that regularly report to AirNow, temporary monitors such as those the Forest Service and air agencies have deployed near fires, and crowd-sourced data from more than 12,000 low-cost sensors that measure fine particle pollution, the major harmful pollutant in smoke. For each monitor and sensor, map users can click to see a "dashboard" of information to help them plan their activities. Before the sensor data show on the map, EPA and USFS run quality assurance checks, including applying a nationwide correction equation to account for a known bias in the sensor data.

  Please note:
  - The data on the AirNow Fire and Smoke Map are intended to help individuals make decisions to protect their health during fires.
  - If there is a wildfire in your area, please stay tuned to local authorities for the latest information on fire and smoke safety.
  - EPA will not use the data on this map to make regulatory decisions.
  - Mention of trade names or commercial products does not constitute EPA or USFS endorsement or recommendation for use.
  - Technical information about the underlying data and scientific approach used to develop the AirNow Fire and Smoke Map, including a video and webinar recording, is available at: https://www.epa.gov/air-sensor-toolbox/technical-approaches-sensor-data-airnow-fire-and-smoke-map.

- **California Air Resources Board (CARB)**
  Community Air Protection Program
  (https://ww2.arb.ca.gov/capp)
  AB 617 requires CARB to annually consider selection of communities for development and implementation of community air monitoring plans and/or community emissions reduction programs in communities affected by a high cumulative air pollution exposure burden. Fifteen communities are currently participating in the program. In September 2018, CARB Governing Board (CARB Board) adopted the Community Air Protection Blueprint that established the Program elements to accomplish AB 617 requirements and selected the first ten communities for development of a community emissions reduction program, monitoring plan, or both. The air quality for AB 617 communities can be viewed at the community air quality portal (which is currently under development). More information about the AB 617 and the Community Air Protection Program can be found at the following links:
  - **California AB 617, Appendix H:** https://ww2.arb.ca.gov/sites/default/files/2020-03/final_community_air_protection_blueprint_october_2018_appendix_h_acc.pdf
  - **Community Air Protection Program Communities:** https://ww2.arb.ca.gov/capp-communities
  - **Community Air Protection Blueprint:** https://ww2.arb.ca.gov/capp-blueprint
  - **Community Air Quality Portal:** https://ww2.arb.ca.gov/community-air-quality-portal

- **Denver Public Health and Environment**
  Love My Air Denver
  (http://www.LoveMyAirDenver.com/)
  The Love My Air program aims to empower Denver's communities to live better, longer by reducing air pollution and limiting exposure through behavior change, advocacy, and community engagement. Denver has the 14th-worst air quality among major U.S. cities. While multiple factors influence exposure to air pollution, schools are an ideal intervention point for sensor deployment, education, and empowerment. The Love My Air program, in partnership with Denver Public Schools (DPS), has created a citywide air quality monitoring network to provide real-time, hyper-local air quality data—utilizing low-cost cutting-edge air pollution sensor technology, redeveloped with solar, battery storage, and data connectivity to make it useful for widescale deployment. In addition to creating a citywide air quality monitoring network within DPS, Love My Air provides air quality curriculum for grade 6–12 students and hand-held air sensors to participating schools to allow students to have access to real-time data and hands-on learning experiences. Love My Air Denver also provides engagement materials and materials to implement behavior change initiatives, such as anti-idling campaigns and "walking school buses". Through a real-time, hyper-local air quality network, increased air quality education, and engagement, Love My Air Denver aims to decrease exposure to air pollution, increase student and parents' understanding of air quality, improved health, and better academic outcomes for students.

- **Puget Sound Clean Air Agency**
  Air Quality Sensor Map
  (https://www.pscleanair.gov/570/Air-Quality-Sensor-Map)
  Puget Sound Clean Air Agency in Washington State is currently testing an Air Quality Sensor Map which displays data from PurpleAir monitors along with conventional agency monitors. The PurpleAir data are compared to the data from the closest agency monitor in order to calibrate the PurpleAir data. There are two sensors within each PurpleAir monitor. These sensors are compared to each other to verify that they are functioning similarly. Data from sensors that are determined to be malfunctioning are not displayed on the map. Each PurpleAir monitor on the map has a confidence value that reflects the expected quality of the data. This confidence value is partly based on how the monitor data compare to data from other nearby monitors. For each monitor, a time series of the fine particulate matter concentration over last two days is shown. Each marker has a color based on the fine particulate matter concentration that matches the EPA AQI color scale. The map differentiates between "Health" view and "Instant" view. "Health" view shows averaged concentrations and is updated hourly, while "Instant" view shows data by minute. Impact messaging accompanies each monitor and shows activity recommendations for sensitive groups and healthy adults based on the AQI.

- **Oregon Department of Environmental Quality (DEQ)**
  Oregon DEQ's low-cost air quality SensOR™
  (https://www.oregon.gov/deq/aq/Pages/aqi.aspx)
  The Oregon DEQ developed a new lower-cost air quality monitor, the SensOR™, to allow the agency to provide timely air quality information at more locations throughout the state. Data from one SensOR™ (deployed at Station *Bend NE 8th & Emerson Sensors*) can be viewed on the Oregon DEQ Air Quality Monitoring Data page: https://oraqi.deq.state.or.us/home/map.

- **Washington State Department of Health (DOH)**
  Washington Wildfire Smoke Impacts Advisory Group Pilot Study
  The Washington Wildfire Smoke Impacts Advisory Group, led by staff from Washington State DOH, developed a preliminary approach to using low-cost sensors to inform school decisions during wildfire smoke episodes. With several technical and feasibility issues to address, the purpose of this project was to provide a starting point for future activities. DOH staff worked with local health jurisdiction staff to carry out the project. The basic study design had two components.

- The first component involved paired indoor-outdoor sensors. This means that one stationary (PurpleAir) sensor was sited indoors and one was sited outdoors on the school property. These two sensors collected measurements over one to two weeks. The data from the two stationary paired sensors was then compared to data from the nearest air quality regulatory monitor.* The raw $PM_{2.5}$ concentration data was averaged over 8-hour time periods and the indoor data was compared to the outdoor data to estimate how much outdoor air pollution enters the building (assuming that indoor sources are not present).
- For the second component, a third sensor, the portable sensor (Dylos), was used in a walk-around one day to collect a snapshot of variation in $PM_{2.5}$ between different rooms in the school, including the room with the stationary sensor. This involved walking to each room holding the portable sensor and collecting data in each room for at least a few minutes. The snapshot approach attempts to capture how infiltration of outdoor pollution is different across different areas of a building or buildings of a school.

*Note: At the time of this pilot study, there was not consensus on the correction factor for PurpleAir sensors. If the outdoor sensor were incorporated into the AirNow Fire and Smoke Map Sensor Data Pilot Layer, its reported concentrations from the sensor data layer could be used directly without the comparison to the nearest regulatory monitor.

AGENDA

DAY 1: WEDNESDAY, MAY 5, 2021

Time (EDT)	Topic and Presenter
12:00 PM	**Welcome and Opening Remarks** Jeanne Briskin | *U.S. EPA Office of Children's Health Protection* Erika Sasser | *U.S. EPA Office of Air and Radiation*
12:20 PM	**Overview of State of the Research White Paper (Health Effects in Children)** **Health Effects of Wildfire Smoke in Children and Public Health Tools: A Narrative Review (Overview of the White Paper)** Link: https://www.nature.com/articles/s41370-020-00267-4 Stephanie Holm | *California EPA and Western States Pediatric Environmental Health Specialty Unit*

Topic Overviews

Moderators:

- Stephanie Holm | *Western States Pediatric Environmental Health Specialty Unit*
- Catherine Karr | *University of Washington*

Time (EDT)	Topic and Presenter
12:45 PM	**Respirator Use by Children** **Respirator Use by Children** John Balmes | *University of California San Francisco* **Workgroup Synopsis** Mark Miller | *California EPA and Western States Pediatric Environmental Health Specialty Unit*
1:15 PM	**Indoor Air Quality in Schools** **Improving School Indoor Air Quality During Wildfire Smoke Events** Rengie Chan | *Lawrence Berkeley National Laboratory* **School Indoor Air Quality During Wildfire Smoke Events: Workgroup Recommendations** Alison Clune | *U.S. EPA*
1:45 PM	**BREAK**
2:00 PM	**Sensors** **Air Monitoring using Low Cost Sensors** Charles Pearson | *California Air Resources Board, Incident Air Monitoring Section* **Guidance on Using Air Sensors to Understand Air Quality During Wildfire Smoke Events** Amara Holder | *U.S. EPA*

Time (EDT)	Topic and Presenter
2:30 PM	**School Activity Guidelines** **Exposure and Health Consequences of Chronic Wildfire Smoke** Rima Habre | *Keck School of Medicine, University of Southern California* **Guidance on Children's Physical Activity During Wildfire Smoke Events: Workgroup Recommendations** Susan Stone | *U.S. EPA*
3:05 PM	**Crosscutting Questions** **Moderator:** Catherine Karr | *University of Washington*
3:35 PM	**Day 1 Closing** Erik Svendsen | *Centers for Disease Control and Prevention*
3:40 PM	**DAY 1 ADJOURNS**

DAY 2: THURSDAY, MAY 6, 2021

Time (EDT)	Topic and Presenter
12:00 PM	**Welcome to Day 2 – Introduction** Lauren Zeise | *California EPA Office of Environmental Health Hazard Assessment*
	Translation Successes and Challenges Moderator: Melanie Marty | *California EPA*
12:05 PM	**Framework for Decision-Making** **How to Develop School Emergency Operations Plans to Address Wildfires** Janelle Hughes and Alison Curtis | *Readiness and Emergency Management for Schools Technical Assistance Center*
12:35 PM	**Schools** **Planning Ahead: How to Prepare your School Community for a Wildfire or Smoke Event** Steve Herrington | *Sonoma County Office of Education* **Responding to Wildfire Smoke with Schools in Washington** Nancy Bernard | *Washington State Department of Health* **School Closure Guidance for Wildfire Smoke Events** Julie Fox | *Washington State Department of Health*
1:20 PM	**Questions and Answers: Schools** **Moderator:** Melanie Marty | *California EPA*
1:35 PM	**BREAK**

Time (EDT)	Topic and Presenter
1:50 PM	**Communities** **Let's Talk About Becoming Smoke Ready** Kris Ray | *Confederated Tribes of the Colville Reservation* **Protecting Children from Wildfire Smoke at Home** George Conway | *Deschutes County*
2:15 PM	**Shared Decision Making and Communication** **Bridging Public Health and Community Needs** Kalie Bonomo | *California Air Pollution Control Officers Association* **Communicating with the Public About Wildfire Smoke Health Risks** Sarah Coefield | *Missoula City-County Health Department*
2:40 PM	**Questions and Answers: Communities and Shared Decision Making and Communication** **Moderator:** Melanie Marty | *California EPA*
Research Needs and Policy Issues Moderator: Ambarish Vaidyanathan | *Centers for Disease Control and Prevention*	
2:55 PM	**Panel Discussion: Research Needs** Long-term high exposures, repeated exposures, extremely high exposures, and other issues **Moderator:** Ambarish Vaidyanathan | *Centers for Disease Control and Prevention* Kimberly Gray | *National Institute of Environmental Health Sciences* John Balmes | *University of California San Francisco* Jason Sacks | *U.S. EPA*
3:25 PM	**Presentations: Policy Issues** **U.S. Respirator Landscape and Policy Needs** Maryann D'Alessandro | *National Institute for Occupational Safety and Health* **The Future of Schools as Healthy Environments** Michael Brauer | *The University of British Columbia and University of Washington*
3:55 PM	**BREAK**

Time (EDT)	Topic and Presenter
	Selected Other Issues for Children's Health Moderator: Jeanne Briskin | *U.S. EPA*
4:10 PM	**Other Wildfire Issues for Children's Health – Flash Talks** **Research on Pregnancy and Prenatal Practice** Marya Zlatnik | *University of California, San Francisco, Western States Pediatric Environmental Health Specialty Unit* **Wildfire Issues for Children's Health: Mental Health Findings** Stephen Brock | *California State University, Sacramento* **The Mental Health Effects of Multiple Traumas on Adolescents: Contagion, Retraumatization, and Non-Recovery** Hannah Pazderka | *University of Alberta* **Responding to COVID-19 and Wildfire Smoke Simultaneously** Eva Smith | *K'ima:w Medical Center, an Entity of the Hoopa Valley Tribe*
5:10 PM	**Day 2 Closing and Thank You** Dave Rowson | *U.S. EPA* Jeanne Briskin | *U.S. EPA*
5:25 PM	**DAY 2 ADJOURNS**

WORKGROUP PARTICIPANTS

Workgroup 1: Recommendations for Mask or Respirator Use by Children and Pregnant Women During Wildfire Smoke Events

John Balmes *(Co-chair)*
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