UL Research Institutes | Chemical Insights

DECEMBER 2024

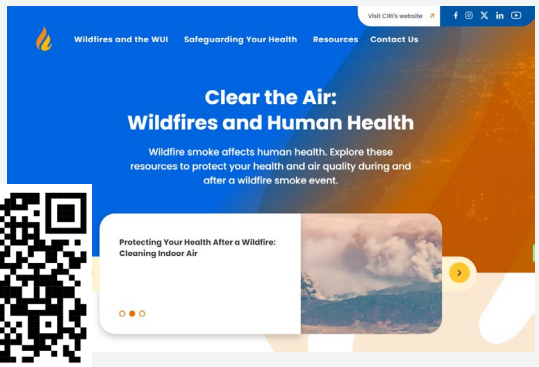
Clearing the Air on Wildfire Smoke:

A Toolkit for Reducing Downwind Exposure Risks

Table of Contents

WILDFIREHEALTHRISKS.ORG

Chemical Insights Research Institute (CIRI), along with their partners, have launched a public information site to share resources about wildfires and their impacts on human health. Visit this site for a growing library of resources.



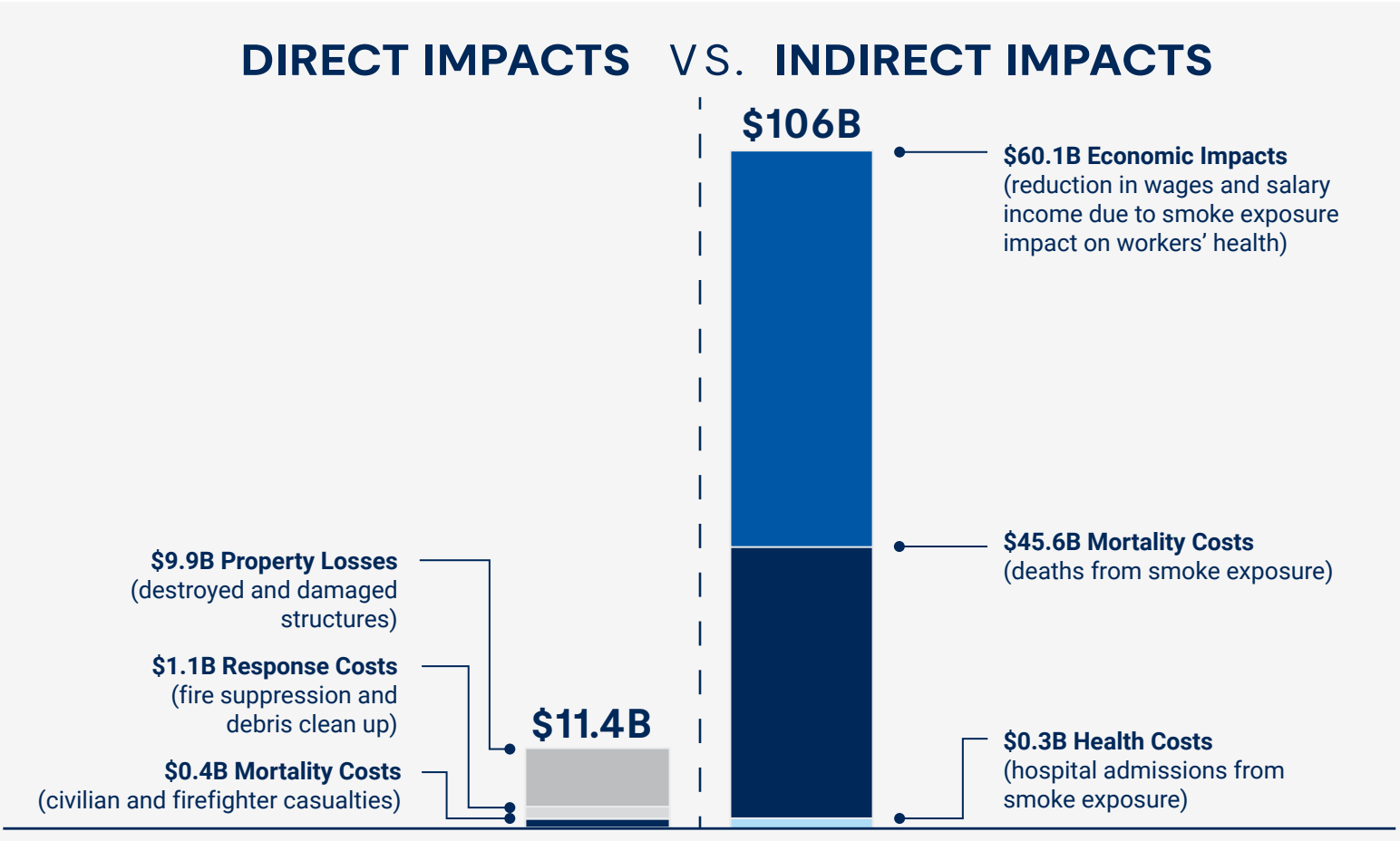
About This Toolkit

This toolkit, developed by Chemical Insights Research Institute (CIRI) of UL Research Institutes, is meant for individuals located downwind of a wildfire seeking to reduce their exposure to hazardous smoke and pollutants. It offers scientific guidance for safeguarding human health that focuses on protecting the indoor environment. This toolkit is not intended to offer guidance for those living in close proximity to a burning wildfire that may need to evacuate or take additional fire-related safety precautions.

Wildfire smoke can travel long distances, negatively impacting air quality across an entire continent. Even though the negative health effects associated with exposure to wildfire pollutants are well known and documented, this knowledge has not been effectively converted into actionable steps that people can take to clean and protect their homes and workplaces.

Yet, it is becoming increasingly clear that wildfire smoke can have a much greater influence on losses and negative human health outcomes than the fire itself. A recent study examined the economic toll of wildfires in California between 2017 and 2021, comparing "direct losses" (those primarily attributable to the wildfires' flames) and "indirect losses" (those primarily attributable to wildfires' smoke pollution). The overall indirect impacts were found to be nearly ten times higher compared to direct impacts ($11.4 billion vs. $106 billion). The indirect mortality and health costs were over one hundred times higher compared to direct impacts ($0.4 billion vs. $45.9 billion).

The content in this toolkit is developed from the information provided in Underwriters Laboratories Inc. *Guidance Document 200C: Guidance and Practical Strategies for Reducing Public Health Impacts of Wildland-Urban Interface (WUI) Fires on Community Populations*. Please read the guidance document for more comprehensive information on wildfires and their human health risks.



Wildfire Emissions

Wildfires have always had a natural role in our ecosystem. But today, wildfires are bigger, burning longer, causing more damage, and impacting public health more than ever before due to prolonged smoke exposure. As they burn, wildfires release emissions, like **particulate matter** and **chemicals,** into the atmosphere. These emissions form a giant mass of pollutants called a **plume**. A wildfire plume can travel over a thousand miles, affecting the air quality across a continent. Therefore, the consequences of wildfire emissions are not limited to the local community, they can impact large areas of the U.S. as well as the globe — affecting millions of people.

While a traditional wildfire can be a significant problem, it can quickly turn into a disaster when it meets the **wildland urban interface**, also known as the WUI. The WUI is where human development meets or intermixes with undeveloped wildlands. Whereas a traditional wildland fire burns mainly vegetation, a fire in the WUI also burns urban materials such as homes, cars, and other human-made structures. These items contain chemicals and materials of concern, such as halogens, plastics, and metals, that impact both ***how*** the fire burns and ***what*** it leaves behind. While more research is needed to fully understand emissions from WUI fires, it stands to reason that **if a fire starts in or spreads to the WUI, the produced emissions will contain a much more complex and potentially more toxic mix of pollutants compared to traditional wildfires.**

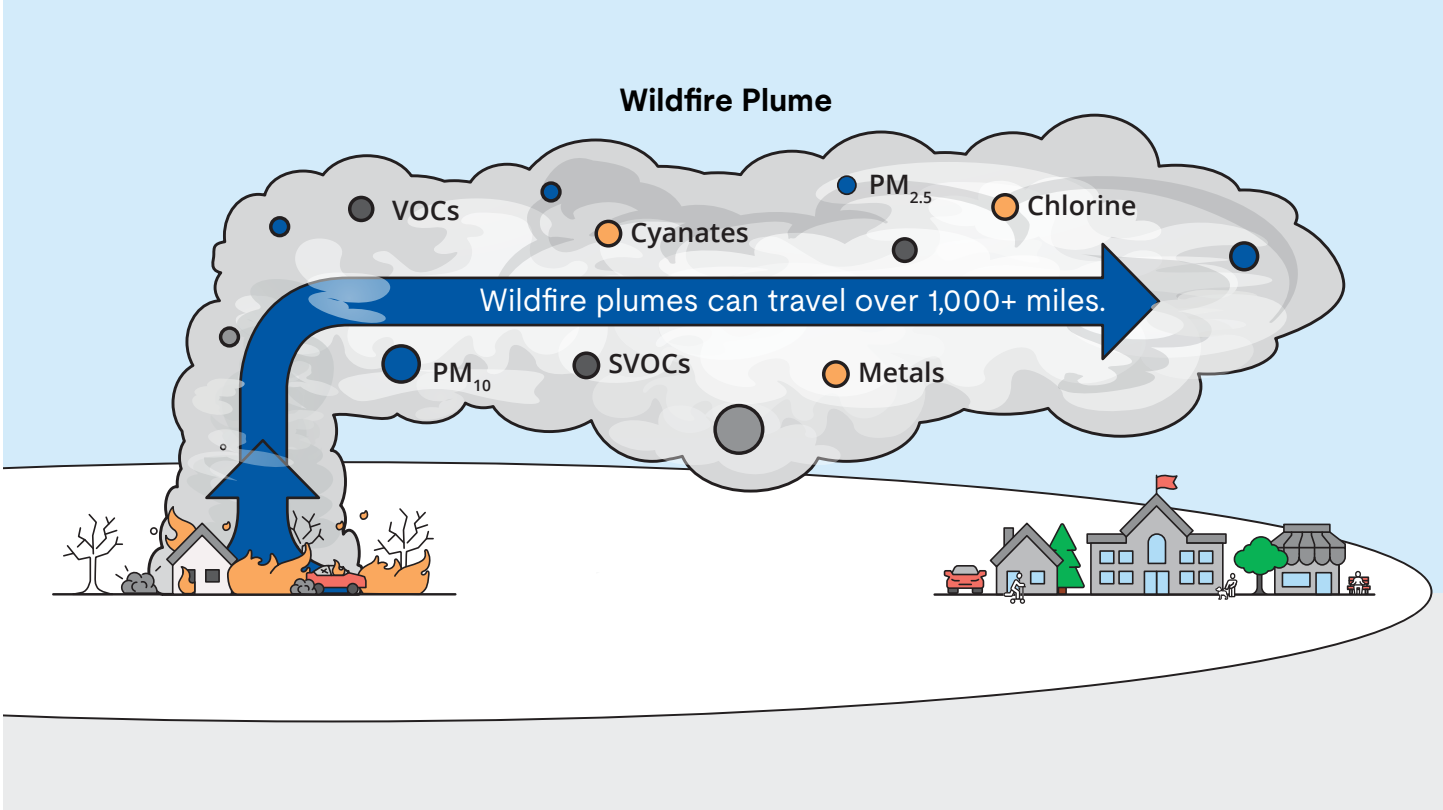
WHAT'S IN WILDFIRE SMOKE?

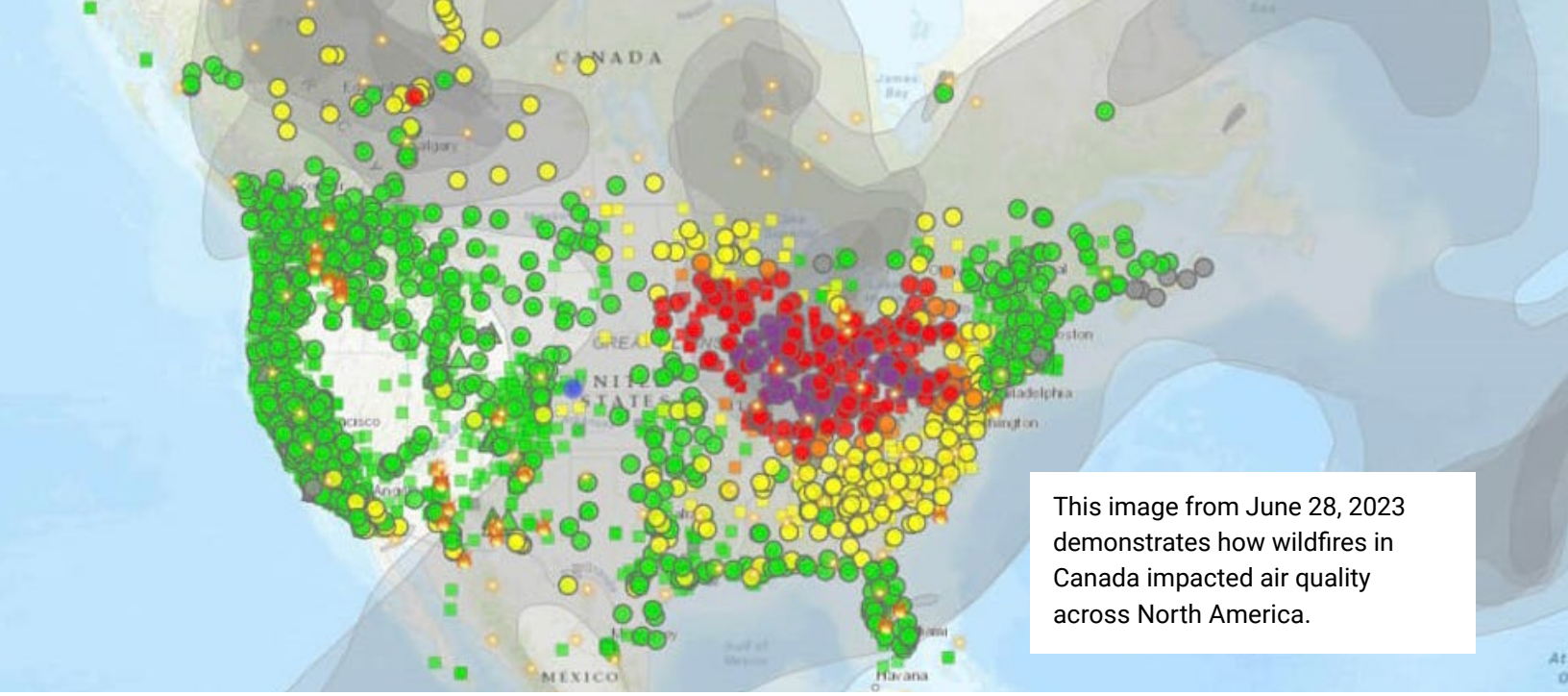
Wildfires are a major source of hazardous air pollutants, including:

- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)
- Airborne particles, also known as particulate matter, such as PM_{10} and $PM_{2.5}$

If the fire involves human-made structures and materials, the smoke may also contain:

- Metals and halogenated organics
- Chlorine
- Cyanates





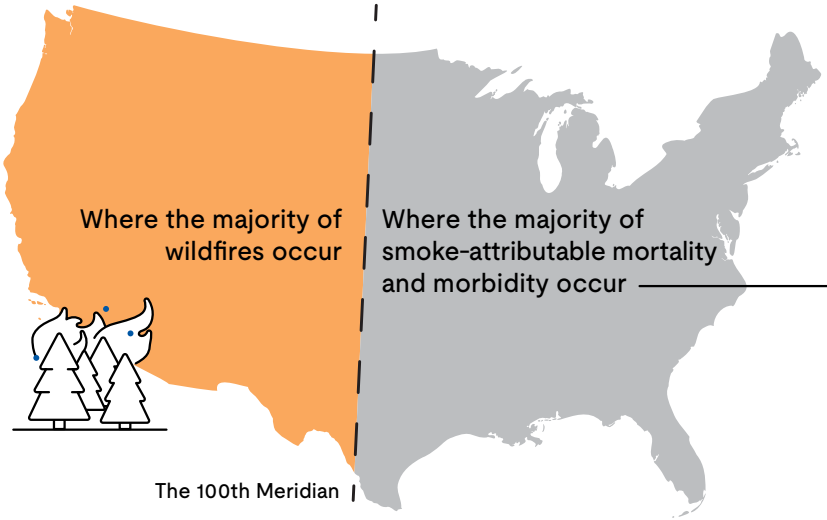
This image from June 28, 2023 demonstrates how wildfires in Canada impacted air quality across North America.

DOWNWIND IMPACTS ON AIR QUALITY

As a wildfire plume spreads downwind, its emissions change as they cool and react with each other and with sunlight. This process, called **atmospheric transformation**, continues as the plume mixes with other urban pollutants in the air, such as emissions from cars and industrial processes. As demonstrated in the image above, wildfires can create significant air quality risks across an entire continent.

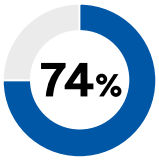
As the air quality gets worse, so does its impact on human health.

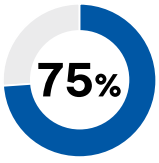
Awareness and mitigation of smoke exposure is important across the U.S. and not just in regions in proximity to large wildfires.



Smoke-attributable deaths

Smoke-attributable hospital visits and admissions





The large majority of deaths and emergency department visits and hospital admissions that are attributed to wildfire smoke occur **outside of the West (east of the 100th meridian).**

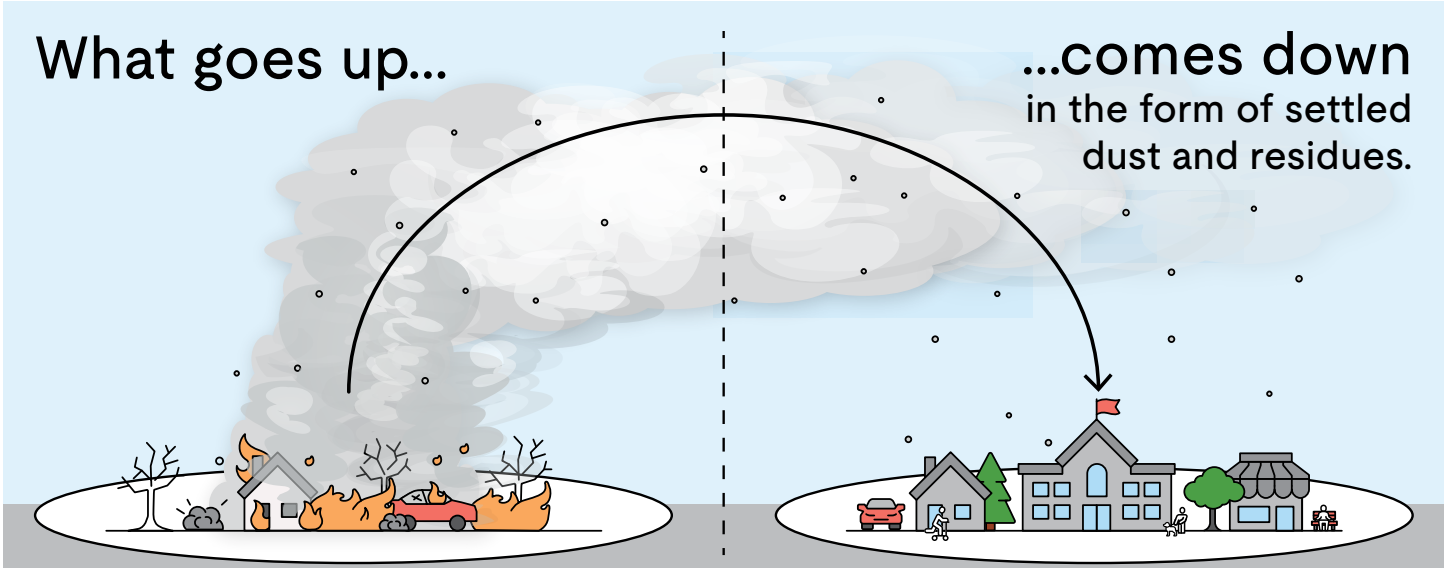
Source: Estimated Mortality and Morbidity Attributable to Smoke Plumes in the United States: Not Just a Western U.S. Problem

SETTLED DUST FROM WILDFIRES

As a wildfire plume moves further downwind, the process of atmospheric transformation slows and airborne particles fall from the sky in the form of settled dust. **This hazardous dust can infiltrate our homes and buildings through windows, doors, and vents.**

Settled dust contains a chemical memory of the fire, including particles and chemicals resulting from the combustion of natural vegetation and materials from the built environment that burned during the wildfire. If not properly removed, this dust can settle on surfaces, contaminate textiles like carpet and upholstered furniture, and even resuspend in the air, presenting a continued exposure risk for residents.

People are exposed to the pollutants left by a wildfire through three primary exposure routes: inhalation, ingestion, and skin exposure. Cleaning settled dust is particularly important to reduce the likelihood of swallowing and touching settled particulate matter, dust, and ash.



Children, especially infants and toddlers, are vulnerable to being exposed to settled dust. They receive a relatively higher dosage of pollutants through settled dust because they:

- Have lower body weights than adults
- Often play lower to the ground where dust settles
- Have frequent hand-to-mouth behavior
- Have developing bodies and unique vulnerabilities

How Wildfire Emissions Impact Health

$PM_{2.5}$ (particulate matter that is 2.5 microns or less in diameter) is a primary concern in all wildfires. When inhaled, $PM_{2.5}$ can penetrate deep into the lungs and may even infiltrate the bloodstream.

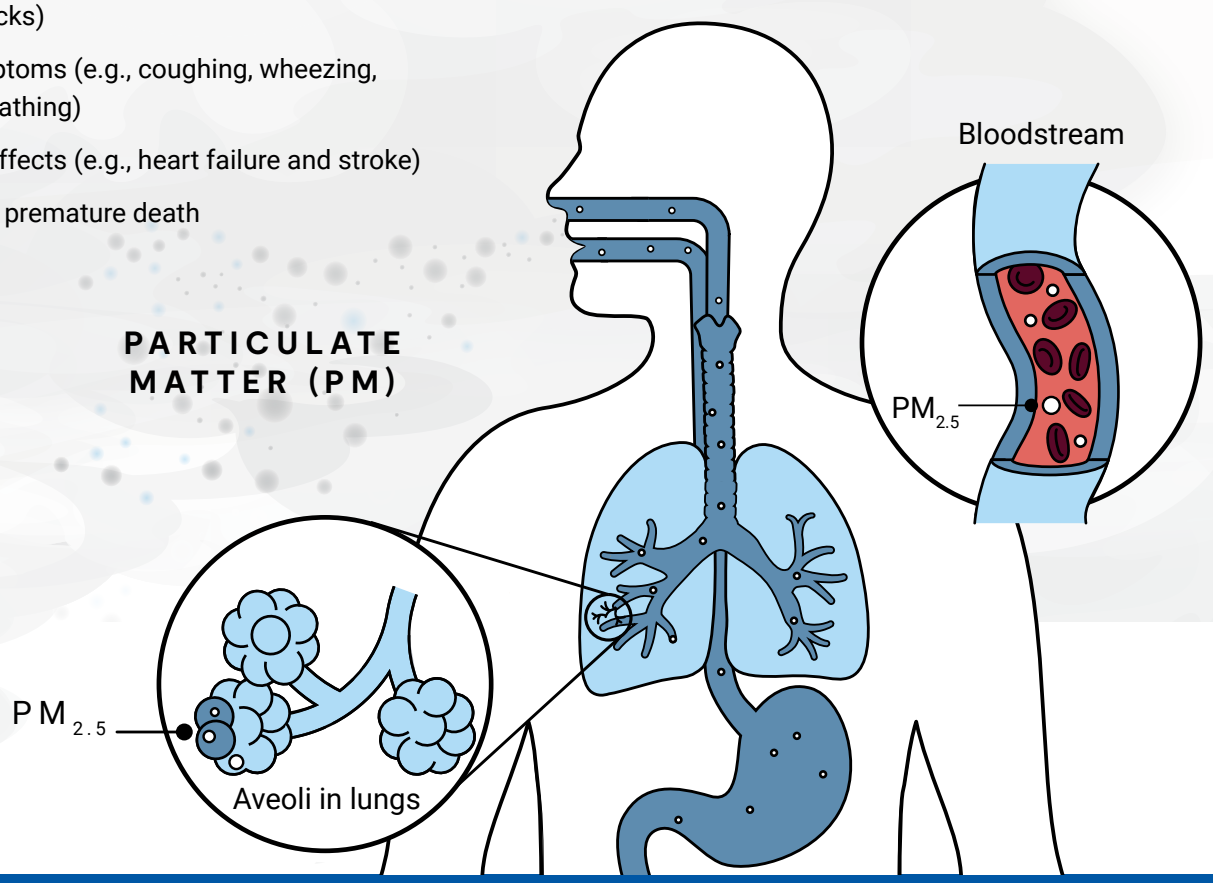
Studies have directly linked $PM_{2.5}$ from wildfires to health risks such as worsening of asthma, chronic obstructive pulmonary disease, cardiovascular disease, and premature death.

HEALTH EFFECTS OF WILDFIRE EMISSIONS MAY INCLUDE:

- Irritation of the eyes and respiratory tract
- Respiratory effects (e.g., bronchitis, reduced lung function, and asthma attacks)
- Respiratory symptoms (e.g., coughing, wheezing, and difficulty breathing)
- Cardiovascular effects (e.g., heart failure and stroke)
- Increased risk of premature death

WHO IS MOST IMPACTED BY THESE HEALTH RISKS?

Certain individuals may be more sensitive to exposure than others, such as children, older adults, the immunocompromised, people with respiratory and cardiovascular disease, and pregnant people.



Human exposure to wildfire emissions occurs through **breathing, swallowing, and touching**.

How to Monitor Air Quality Conditions

To know whether or not you need to take action, continuously monitor:

- **Indoor air quality (IAQ)** using any indoor air sensor(s) in your home or building.
- **Outdoor air quality** using resources like the U.S. Environmental Protection Agency's AirNow.gov. When conditions are changing rapidly, use resources such as Smoke Advisories (AirNow.gov) or Real-Time Air Quality Map (PurpleAir).
- The **weather forecast**.

IAQ

Measure IAQ using a low-cost stationary sensor for long-term data on indoor air quality, including $PM_{2.5}$ and carbon monoxide, and a portable handheld sensor to check for variations within the home. If these sensors are not economically feasible, assume indoor pollutant levels matches the outdoor air quality and take steps to reduce risks.

OUTDOOR AIR QUALITY

The U.S. Air Quality Index (AQI) is the EPA's index for reporting air quality. It ranges from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. The AQI is divided into six categories, each with different levels of health concern.

Limit the intensity and duration of outdoor activities when the AQI reaches a moderate level (51-100 AQI).

When possible, cancel outdoor activities when the AQI reaches an unhealthy or hazardous level (≥ 151 AQI).

If canceling outdoor activities is not possible, wear a NIOSH-approved P100, N95 mask, or KN95 mask to limit exposure and health risk.

Air Quality Index (AQI)			
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: Everyone is more likely to be affected.

If indoor or outdoor air quality is poor or forecast to be poor:

- Close all windows and doors
- Turn on interior exhaust fans (e.g. bathroom and kitchen fans)
- Run the heating, ventilation, and air conditioning (HVAC) system in recirculation mode only
- Run a portable air cleaner and/or DIY air cleaner), See pages 11-14
- Avoid activities that may introduce additional particulate matter, like burning candles, operating 3D printers, or cooking

Continue these measures until **both** indoor and outdoor air return to normal. The time to return to typical air quality after a fire can vary greatly and cannot be predicted. Once outdoor air quality is good (the AQI is ≤50), open windows and doors and replace all air filters.

When to Implement Strategies to Manage Smoke

To make an informed decision about when to implement strategies to manage smoke, monitor the following:

	Trigger	No action needed	Consider implementing strategies to manage smoke	Implement strategies to manage smoke
	Outdoor Air Quality Based in Air Quality Index (AQI)			
	AQI is good (0-50)	●		
	AQI is moderate (51-100)		●	
	AQI is poor (101+)			●
	Indoor Air Quality (IAQ) Based on $PM_{2.5}$ sensors			
	IAQ is good (<12 µg/m^3)	●		
	IAQ is poor (>12 µg/m^3)			●
	The Forecast Based on next 24 - 48 hours			
	Forecast does not call for smoke	●		
	Forcast calls for smoke			●

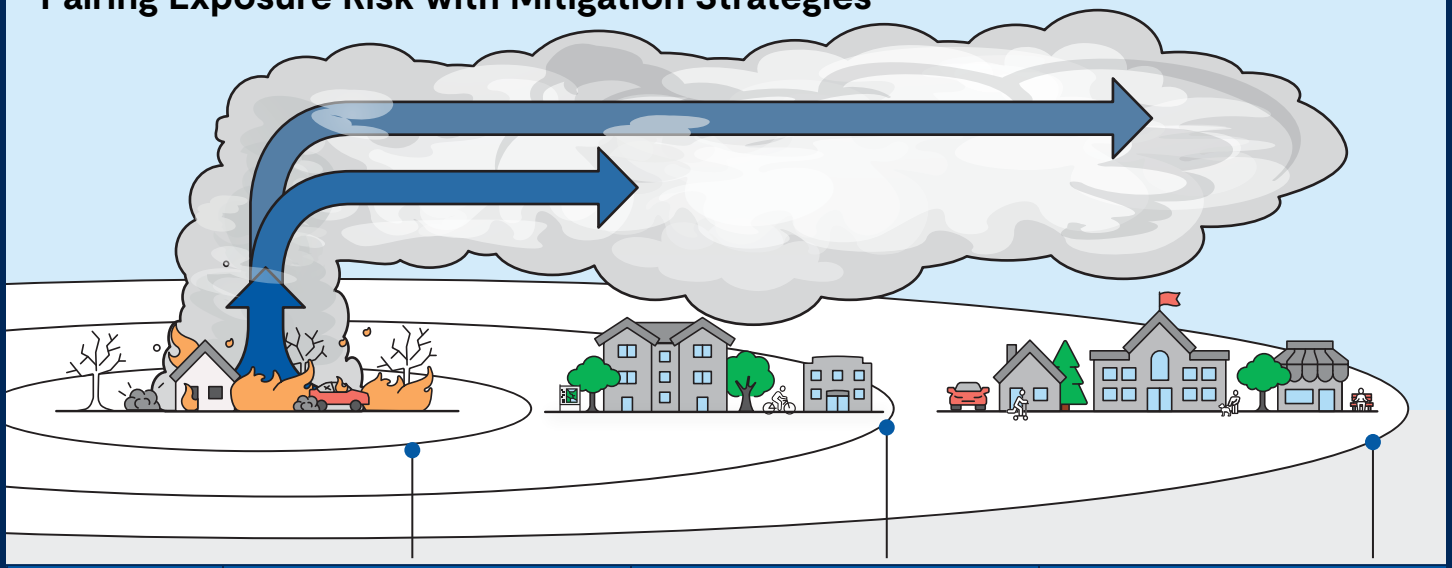
How to Protect Your Indoor Environment from Wildfire Emissions

Exposure to pollutants occurs in a many different ways (breathing, swallowing and touching) and varies depending on your proximity to the wildfire (immediate, regional, or continental).

Strategies for protecting your health from wildfire emissions focus on limiting exposure to outdoor air and **safeguarding the indoor environment by cleaning the air with high-performance filtration** and **removing settled dust.** Cleaning both the air and settled dust within an indoor environment (such as a home or business) can significantly reduce exposure risks to the pollutants that wildfires can bring to an area.

Air filtration is one of the most effective and feasible controls to improve indoor air quality for many affected by smoke events.

Pairing Exposure Risk with Mitigation Strategies



Exposure Route	Immediate Exposure (0-6 miles)	Regional Exposure (7-600 miles)	Continental Exposure (600+ miles)
Breathing	Inhalation of dust/ash	Inhalation of polluted air	Inhalation of polluted air
	Focus on air cleaning measures, See Pages 10-14		
Swallowing	Ingestion of dust/ash and contaminated water supply	Ingestion of impaired water	
	Focus on cleaning measures, See Page 15-16		
Touching	Skin contact with dust/ash and contaminated water supply	Skin contact with settled dust	
	Focus on cleaning measures, See Page 15-16		

Protecting Indoor Air Quality

Even in communities downwind from a fire, poor air quality can lead to significant adverse health effects. Therefore, taking necessary precautions to protect your health during and after a wildfire is critical. Air filtration (or “air cleaning”) is one of the most practical and effective ways to safeguard indoor air quality from wildfire smoke. Air filters are designed to capture pollutants and remove them from the indoor environment.

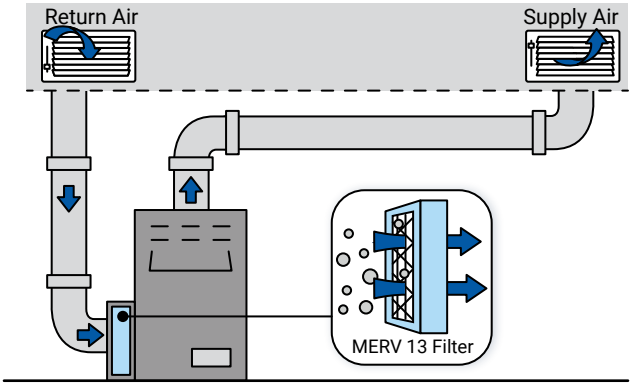
Since $PM_{2.5}$ is so small, a specialty or high-performance air filter is needed to capture it. $PM_{2.5}$ can be removed from the air by using either a MERV 13 filter in a home's heating, ventilation, and air conditioning (HVAC) system or a portable air cleaner with high-efficiency particulate air (HEPA) filtration. In some cases, it may be beneficial to use both strategies.

Strategies to Protect Your Indoor Air Quality During a Smoke Event

Does your home/building have an HVAC system?

Yes

Contact a professional to determine the highest level of MERV filtration the HVAC system can support.



The system supports MERV 13 filtration

During a smoke event, run the system continously and change the MERV 13 filter twice as often as under typical conditions or it becomes discolored.

If sensitive occupants are present and the AQI is >100 or the AQI <151, also use an air cleaner (see right side).

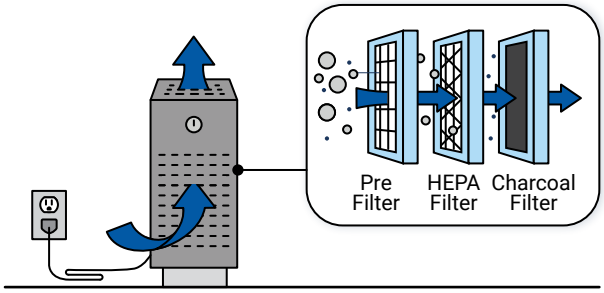
The system supports filtration lower than MERV 13

- Do not attempt to use a MERV 13 filter if the HVAC system is not designed to support one.
- Purchase the highest MERV filter that the HVAC system can support and change it more frequently during smoke events.

Use a supplemental air cleaner (see right side).

No

Use an air cleaner to filter the air in rooms that are frequently occupied and/or have sensitive occupants.



See more information on air cleaners on the next page.

UNDERSTANDING MERV RATINGS

MERV, which stands for "minimum efficiency reporting value", is a measure of an HVAC filter's ability to capture different sized particles. The higher the MERV rating, the better the filter is at capturing smaller particles. A filter must be rated as MERV 13 or higher to effectively capture wildfire smoke particles. Home improvement retailers also market alternative rating systems. Generally, a MERV 13 is equivalent to MPR 1500-1900 and FPR 10. Check the product specifications to verify MERV equivalency.

Portable Air Cleaners

Before selecting an air cleaner, decide which room it will be used in. The size of the room will determine the amount of air the unit will need to clean. Consider if multiple portable air cleaners are needed throughout the building.

PURCHASE A PORTABLE AIR CLEANER THAT HAS:

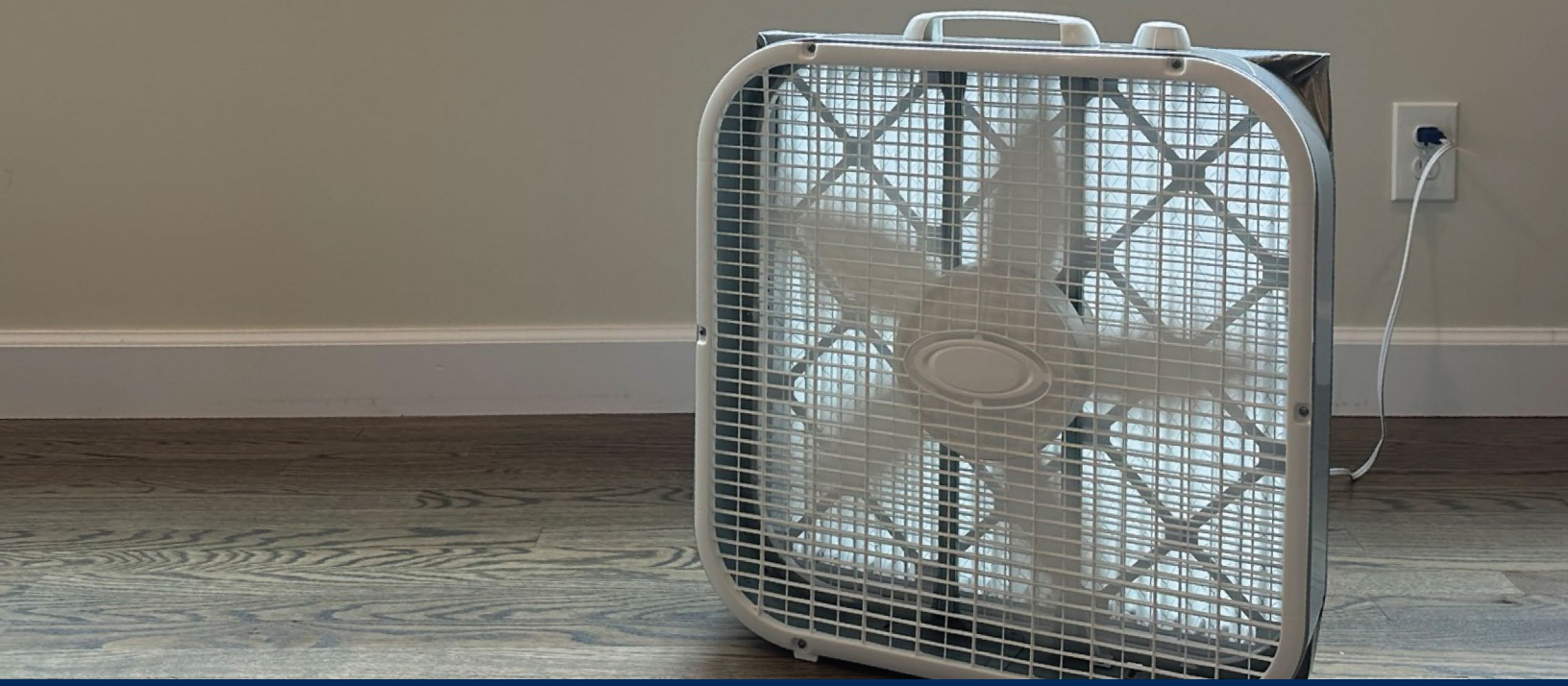
- A **high-efficiency particulate air (HEPA) filter.** HEPA is a type of pleated mechanical air filter capable of capturing at least 99.97% of particles.
- An **activated charcoal filter**: A type of filter containing charcoal granules that may remove some VOCs in the air.
- A **clean air delivery rate (CADR) that is 2/3 of the area** of the room where it will be used.
  - CADR is measure of how much filtered (cleaned) air an air cleaner can deliver. It is measured in cubic feet per minute (CFM).
  - The higher the CADR, the quicker clean air is being generated.
  - CADR rates must be verified by the Association of Home Appliance Manufacturers (AHAM).
- Been certified by the California Air Resources Board (CARB) to **not contribute to ozone emissions**.
- Been certified by AHAM for **removal of tobacco smoke, dust and pollen**.
- No additive technology, such as ionization and plasma.

PORTABLE AIR CLEANER SIZING TOOL

The Harvard Healthy Buildings Program recommends filtering the air within an indoor space at least **five times per hour** to maintain good air quality.

For example, a room of 450 square feet (with 8-foot ceilings) would need a portable air cleaner with a CADR of 300 CFM.

The Harvard Healthy Buildings Portable Air Cleaner Sizing Tool allows a user to input a “clean air” target (measured in units of equivalent air changes per hour, or ACHe) and information about the size of the room. The calculator provides the CADR the user should look for from the air cleaner manufacturer.

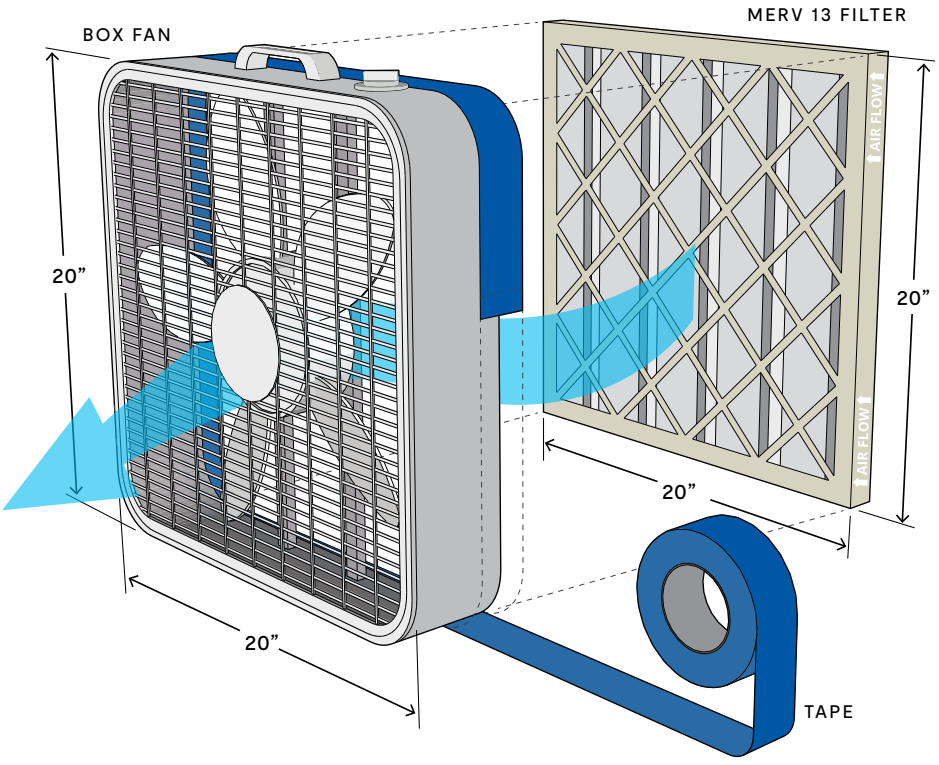


Do-It-Yourself (DIY) Air Cleaners

A DIY air cleaner is an affordable and effective alternative to commercially available air cleaners. Preliminary tests conducted by CIRI show that DIY air cleaners are effective at removing particles indoors and are comparable to commercially available air cleaners. The simplest DIY air cleaner construction utilizes affordable supplies readily available at a home improvement store.

SUPPLIES NEEDED TO MAKE A DIY AIR CLEANER:

- **An air circulating box fan:** The box fan should have a manufacture date after 2012 and be certified by an independent safety organization to meet the ANSI UL 507 safety standard for electric fans.
- **A MERV 13 air filter:** The air filter should be sized 20 inches by 20 inches to fit the box fan and be rated to capture small particles ($PM_{2.5}$) with a MERV rating of 13 or equivalent.
- **Duct tape:** Duct tape is recommended because it can provide a continuous seal around the fan and the filter, leaving limited residue.



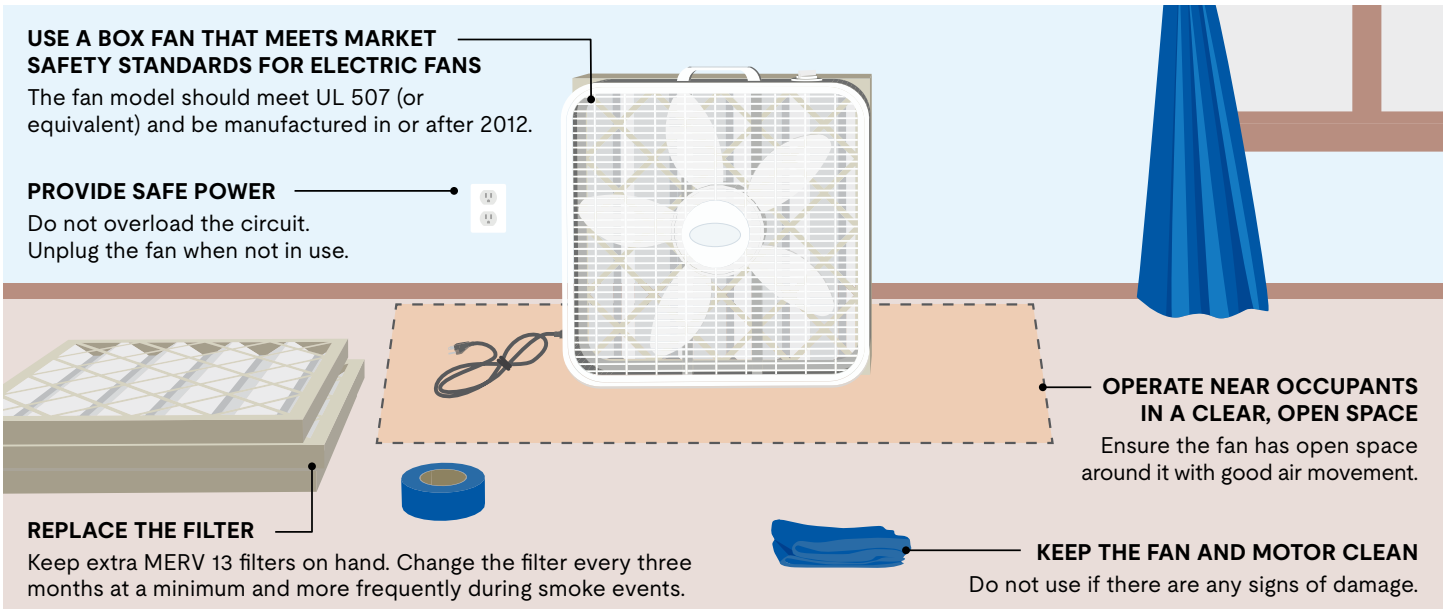
HOW TO ASSEMBLE A DIY AIR CLEANER:

1. Place the front of the fan on the floor.
2. Place the air filter squarely against the back of the fan. Make sure that the arrow indicating the direction of airflow is pointing towards the back of the fan (or the side that sucks air in).
3. Use duct tape to securely attach the filter on all four sides. The tape should be continuous with no gaps.

Once assembled, the DIY air cleaner is immediately ready for use.

Video: How to Make and Use a DIY Air Cleaner

This video summarizes how to make a DIY air cleaner. It also highlights important safety tips, including guidance for set-up and best practices related to use.

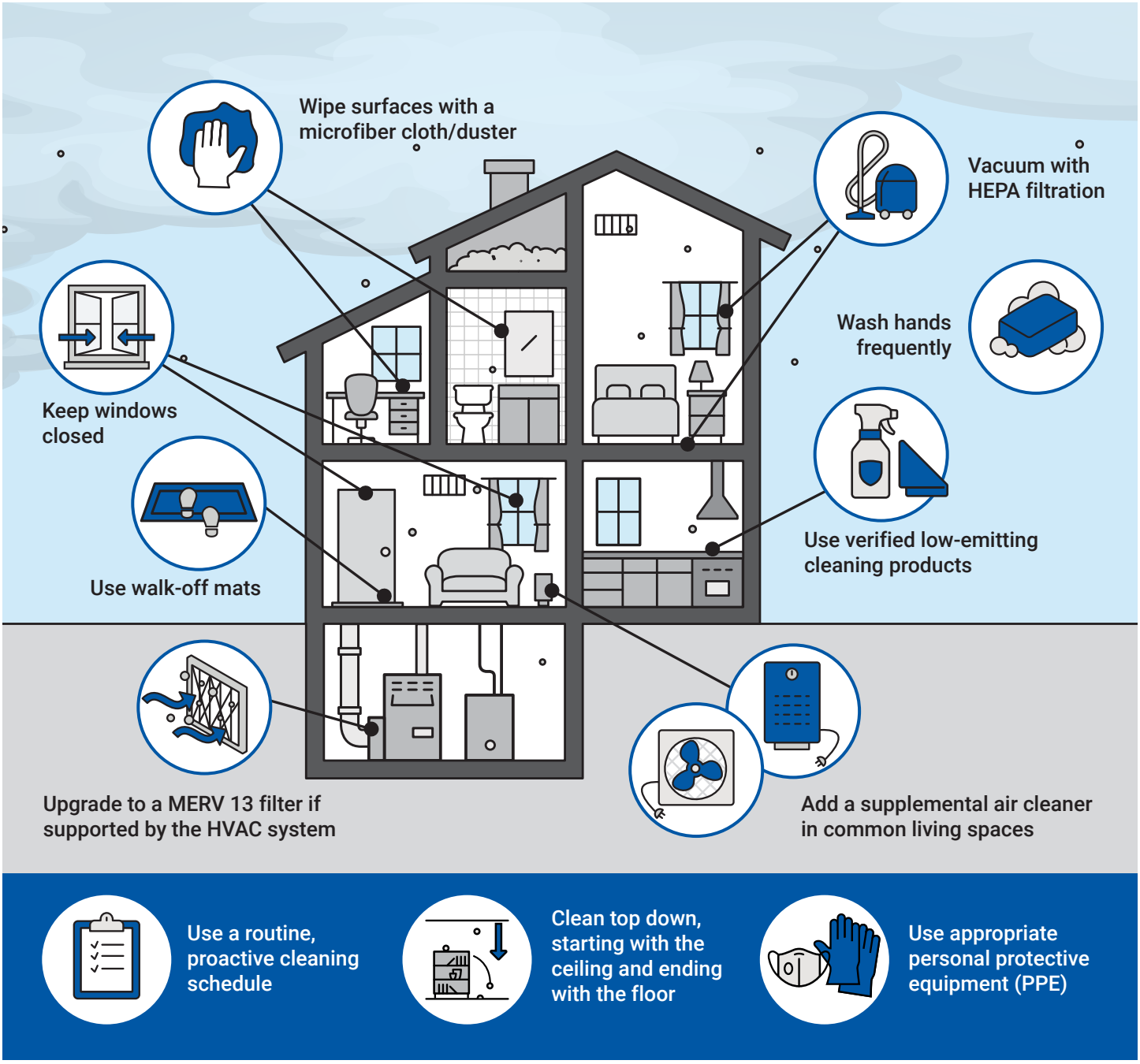


INSTRUCTIONS FOR SAFE, EFFECTIVE USE

- Use the DIY air cleaner in the room you spend the most time in.
- **Operate the fan in a clear, open space:** Ensure the fan is on the ground and has good air movement around it. Keep curtains or any loose material away from it.
- **Keep windows and exterior doors closed** if feasible.
- **Provide safe power:** Do not overload the circuit and unplug the fan when it is not in use.
- **Ensure good air flow:** Change filters every three months at a minimum and more frequently during and after a smoke event.
- **Make sure the fan and motor are clean:** Do not use the fan if there are any signs of damage.

Cleaning Settled Dust

During and after a wildfire, even after the sky clears, a hazardous mixture of particulate matter (PM), dust, and ash can infiltrate homes and other buildings. Accumulated dust contains a mixture of particles and chemicals resulting from the combustion of materials that burned during the wildfire. If not properly removed, this dust can settle on surfaces, contaminate textiles like carpet and upholstered furniture, and even resuspend in the air, presenting a continued exposure risk for residents. The majority of household dust comes from the outside through windows, doors, vents, and on the soles of shoes. Therefore, in the aftermath of a wildfire, it is particularly important to take additional steps to remove settled dust.



HOW TO EFFECTIVELY CLEAN SETTLED DUST IN YOUR HOME

1. **Remove dust from surfaces.**
   - **Hard surfaces.** Use a microfiber cloth/duster or damp cloth on furniture, countertops, baseboards, fan blades, windowsills, light fixtures, blinds, and electronics. Remember to hand- or machine-wash all cloths in warm water after use.
   - **Floors.** For hardwood, tile, or vinyl floors, first dust or use a HEPA vacuum, and then clean with a wet microfiber mop. Clean carpet and rugs with a HEPA vacuum and consider a deep cleaning with a hot water extraction system.
   - **Upholstered furniture, bedding, and curtains.** If possible, use a HEPA vacuum attachment on mattresses, comforters, curtains, and upholstered furniture. Wash bedding weekly in hot water. If an item cannot be laundered, consider getting it dry-cleaned.
2. **Limit the entry of additional contaminants.**
   - **Close windows and doors.** In the weeks after the event, avoid natural ventilation, such as opening a window to air out a room.
   - **Use walk off mats.** Place walk-off mats at doorways and remove shoes upon entrance. This will limit the entry of additional contaminants.
   - **Practice source control.** Some cleaning products may introduce additional pollutants into the indoor environment, including volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Only use cleaning products that have been independently verified to be low-emitting by a third-party program, such as UL GREENGUARD or EPA's Safer Choice.
3. **Clean the air via filtration.** Unlike surface cleaning, air cleaning is a continuous process to remove airborne contaminants. If your home has a mechanical heating, ventilation, and air conditioning (HVAC) unit, contact a professional to confirm if it can support a more efficient air filter, such as a MERV 13 filter. Air cleaning can also be accomplished by using a standalone air cleaner (either a portable air cleaner with HEPA filtration or a DIY air cleaner constructed from a box fan, MERV 13 filter, and duct tape). Use these devices in common living spaces, such as bedrooms and living rooms.

For more information on using air filtration, see pages 11-14.

4. **Establish a routine cleaning plan.** Since dust recirculates in the air, it can continuously deposit on surfaces. Set a routine, proactive schedule for cleaning. Do not wait until you see settled dust. Clean with greater frequency in the weeks and months following a wildfire.
5. **Practice good hand hygiene, especially after cleaning.** Frequent hand-washing can reduce ingestion of hazardous dust that can result from touching dust and then touching your face. While more common among children, even adults can lower exposure risks by regularly washing their hands.

Since dust tends to fall as you are cleaning, start from the top of a surface, such as a wall, staircase or bookcase, and work your way down.

RECOMMENDED CLEANING EQUIPMENT

Microfiber or Anti-Static Cloths, Mops, and Dusters

High-Performance Vacuum with HEPA Filtration

Personal Protective Equipment (PPE)

See the Supply Checklist on page 17 for more information on cleaning equipment.

A Supply Checklist: Preparing for Wildfire Smoke

SUPPLIES FOR MONITORING AIR QUALITY CONDITIONS

- ☐ **Air sensor:** Purchase and install a low-cost indoor air sensor(s) that measures $PM_{2.5}$. Air sensor readings can help when determining whether action needs to be taken to filter the indoor air and will also can help determine whether action needs to be taken to filter the indoor air. They will also help determine how well your filtration is working and the effectiveness of any other steps taken to reduce the intrusion of $PM_{2.5}$ into the indoor air.
- ☐ **Smoke alarm.** Ensure all smoke alarms work throughout the home. Follow the guidance of the U.S. Fire Administration and use smoke alarms that contain both ionization and photoelectric smoke sensors.
- ☐ **Weather apps and air quality websites:** Bookmark resources like the U.S. Environmental Protection Agency's AirNow.gov, Smoke Advisories (AirNow.gov), and Real-Time Air Quality Map (PurpleAir).

SUPPLIES FOR PROTECTING INDOOR AIR QUALITY

- ☐ **MERV 13 filters:** Purchase MERV 13 filters for use in either a mechanical internal heating, ventilation, and air conditioning (HVAC) unit or a DIY air cleaner. During and after smoke events, filters need to be replaced more frequently.
- ☐ **A portable air cleaner:** Purchase either a portable air cleaner or supplies to construct a DIY air cleaner (an electronic box fan, MERV 13 filter, and duct tape).
- ☐ **Caulk and weatherstripping:** Purchase caulk and weatherstripping to seal gaps along the baseboards, lighting and plumbing fixtures, switches and electrical outlets and use weatherstripping for windows and doors. Sealing any air leaks will prevent unwanted smoke from entering the home or building and improve energy efficiency.

SUPPLIES FOR REMOVING SETTLED DUST WITHIN YOUR HOME

- ☐ **Microfiber or Anti-Static Cloths, Mops, and Dusters:** Purchase these products, which contain both positively- and negatively-charged fibers, that attract and remove dust without the use of chemicals found in common dusting sprays. As an alternative, use a wet cloth or regular mop.
- ☐ **Vacuum with HEPA Filtration:** Purchase a high-performance vacuum that can remove smaller particles, such as $PM_{2.5}$, found in wildfire pollutants. They frequently come with a variety of attachments that can be used on hard surfaces, textiles, and in hard-to-reach places.

SUPPLIES FOR PROTECTING PERSONAL HEALTH

- ☐ **Respirator:** Purchase and have available respirators or NIOSH-approved P100, N95 masks, or KN95 masks, which are more effective than surgical masks for use if smoke is expected.
- ☐ **PPE:** Purchase gloves and eye protection for use while cleaning settled dust.

Research Institutes | Chemical Insights

Science for a safer, healthier tomorrow.

2211 Newmarket Parkway, Suite 106, Marietta, Georgia 30067
Web: chemicalinsights.org | **Email:** chemicalinsights@ul.org