Air Pollution and Human Health

How high efficiency particle filtration and activated carbon can reduce harmful exposure

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Executive summary

Air pollution is a preventable contributor to disease. Fine particles can reach deep into the lungs, trigger inflammation, and affect the heart and blood vessels. Outdoor air pollution and its particulate component are established causes of lung cancer. Research also raises concerns about effects on the brain, pregnancy, and bone health, although the certainty of evidence differs across outcomes. [1-4]

High efficiency particle filtration and activated carbon serve complementary purposes. HEPA filters and suitable high efficiency HVAC filters capture airborne particles, including much of the particulate pollution in smoke and traffic emissions. Activated carbon adsorbs selected gases and vapors that pass through ordinary particle filters. Together, these technologies can lower exposure to a broader mixture of pollutants when the equipment is properly selected, sized, operated, and maintained. [5,6]

The strongest evidence is that effective filtration reduces indoor particle concentrations. Controlled studies also support improvements in some cardiovascular and respiratory measures. Evidence that household filtration prevents specific long-term diseases remains limited, and direct clinical evidence for carbon filtration is less developed than the evidence for particle removal. The defensible health claim is that filtration reduces avoidable exposure and can support better health; the magnitude of benefit depends on the person, pollutant, building, and system. [5-7]

Why the issue remains urgent

WHO estimated that outdoor air pollution caused 4.2 million premature deaths worldwide in 2019, predominantly through cardiovascular and respiratory disease. The American Lung Association reported that 156.1 million Americans lived in places receiving a failing grade for ozone or particle pollution in its 2025 report, which evaluated 2021-2023 data. Its 2026 report, evaluating 2022-2024, put the figure at 152.3 million, or 44% of the population. Los Angeles remained the worst metropolitan area for ozone. These are regional exposure indicators, not measurements inside every building. [1,2,8]

Purpose and audience

This paper explains the health rationale and practical requirements for cleaner indoor air in homes, workplaces, schools, and other occupied buildings, with particular relevance to Southern California. It is a narrative synthesis of public health assessments, primary research, and filtration guidance. Building filtration complements emission reduction, source control, and appropriate ventilation.

How polluted air harms the body

Pollution is a mixture. PM2.5 refers to particles with aerodynamic diameters of 2.5 micrometers or less. Ultrafine particles are generally smaller than 0.1 micrometer. Gases include ozone, nitrogen dioxide, carbon monoxide, and numerous volatile organic compounds, or VOCs. Their behavior and health effects differ, so controlling one component does not establish that the entire mixture has been controlled. [1,5,9]

Lungs and airways

Inhaled particles can deposit in the airways and the gas-exchange regions of the lungs. Ozone and other irritant gases can inflame respiratory tissues. Exposure can aggravate asthma and chronic obstructive pulmonary disease, provoke coughing and breathing difficulty, and contribute to serious respiratory illness. Children are particularly vulnerable because their lungs are developing and they breathe more air relative to body size. Older adults and people with existing lung disease also face higher risks. [1,2]

Heart and blood vessels

The consequences extend beyond the lungs. Particle exposure can promote inflammation and oxidative stress, alter blood vessel function, and disturb the nervous system signals that regulate the heart. EPA identifies a causal relationship between PM2.5 exposure and cardiovascular effects. Short episodes and long-term exposure can contribute to cardiovascular harm, including heart attacks, strokes, and premature death. A person does not have to notice smoke or develop a cough for exposure to matter. [3]

Cancer and biological mechanisms

The International Agency for Research on Cancer classifies outdoor air pollution and particulate matter in outdoor air as carcinogenic to humans. That classification establishes a cancer hazard; it does not mean every exposed person will develop cancer or that every exposure carries the same risk. [4]

Two research lines help explain the concern. A 2023 study combined human data and experimental models to investigate how PM2.5 can promote tumors in lung cells already carrying cancer-related mutations, including through inflammatory signaling. A 2025 genomic study of 871 never-smokers with lung cancer associated greater ambient pollution with particular mutation patterns. The findings support complementary mechanisms involving tumor promotion and genomic damage; they do not establish that a home air cleaner prevents lung cancer. [10,11]

Exposure and vulnerability

The health burden depends on concentration, time, breathing rate, and individual susceptibility. Pregnancy, childhood, older age, and existing heart or lung disease warrant particular attention. People near busy roads or industrial sources may face repeated exposure, while people with limited access to cooling and clean indoor spaces may have fewer ways to reduce it. Reducing indoor exposure is especially useful where people spend long periods resting, learning, or working. [1,2]

Southern California and the wider evidence

Traffic pollution includes more than exhaust

Diesel exhaust contains particles and gases, which makes it a useful example of why one filter medium cannot address every pollutant. Freight corridors, ports, rail operations, and heavily traveled roads are important exposure settings. A Southern California study published in 2021 identified both tailpipe and non-tailpipe contributions across particle sizes, including brake and tire wear and resuspended road dust. Its samples were collected in 2008-2009, so its source percentages should not be presented as current regional estimates. [12,13]

Electric vehicles eliminate exhaust from their own tailpipes, but tire wear and road dust remain relevant. This supports continued attention to particle exposure near roads. It does not justify a blanket claim that every electric vehicle produces more total harmful pollution than a comparable gasoline vehicle; that comparison depends on vehicle weight, tires, braking, driving, and which pollutants are counted. [13]

Wildfire smoke can create indoor exposure

Wildfire smoke travels beyond the fire perimeter and can enter buildings through openings, leakage, and ventilation systems. Burning structures can add contaminants from manufactured materials to the smoke mixture. A closed window therefore does not guarantee clean indoor air. Effective particle filtration can help lower indoor smoke particles, but cannot make an unsafe evacuation area or contaminated fire-damaged building safe to occupy. [5,14]

Brain and bone research adds concern

Research on ultrafine particles describes plausible pathways involving inflammation and effects on the brain. A 2025 Lewy body dementia study combined human epidemiology with experimental work on alpha-synuclein pathology. Its human findings were associations; the animal experiments strengthened biological plausibility but did not test dementia prevention through filtration. A separate wood-smoke experiment found persistent inflammatory and metabolic changes in female mice after exposure. Animal findings should not be restated as proven clinical outcomes in people. [9,15,16]

A prospective observational analysis of 9,041 postmenopausal women in the Women's Health Initiative linked long-term air pollution exposure to lower bone mineral density. It adds to concern about systemic effects, but does not establish that filtration prevents osteoporosis. [17]

What this means for action

The case for reducing exposure already rests on established cardiovascular, respiratory, and cancer hazards. Emerging findings broaden the reason for concern, but should not be used to inflate product promises. The practical response is to identify the pollutants entering a building and apply controls that can demonstrably lower them.

How high efficiency particle filtration helps

Mechanical particle filters remove contaminants as air passes through a fibrous medium. Interception, impaction, and diffusion help capture different particle sizes. They do not behave like a simple sieve with a fixed smallest opening. This is why particles smaller than 0.3 micrometer are not automatically beyond HEPA filtration. [5,18]

HEPA and HVAC filtration

Under the U.S. definition described by EPA, a HEPA filter removes at least 99.97% of particles at 0.3 micrometer under specified test conditions, with high capture efficiency for larger and smaller particles. This is a filter test rating, not a promise that 99.97% of a room's pollution disappears. Leakage, room mixing, fan speed, ongoing emissions, and operating time affect actual exposure reduction. [18]

For central HVAC systems, MERV 13 or higher is a useful starting point when the equipment can accommodate it. MERV describes particle capture, not gas removal. A qualified HVAC professional should check filter fit, pressure drop, airflow, and fan capability. Installing a highly restrictive filter without adequate airflow can undermine system operation and clean-air delivery. HEPA media usually require equipment designed for their resistance. [5,6]

Clean air delivery matters as much as the label

Portable air cleaners should be selected using particle clean air delivery rate, or CADR, at a fan setting people will actually use. A high efficiency filter with weak airflow can deliver less clean air than a system moving more air through a suitable filter. Place units where air can circulate freely and prioritize occupied rooms. Noise matters because a machine turned off at night provides no filtration. [5]

Sizing example. A 300-square-foot room with an 8-foot ceiling contains 2,400 cubic feet. A particle CADR of 200 cubic feet per minute provides 5 equivalent air changes per hour: 200 x 60 / 2,400 = 5. This is an illustrative calculation, not a universal target or a promise of a particular concentration reduction. Open doors, infiltration, and indoor sources change the result. Particle CADR does not rate gas removal.

What health trials actually show

In a randomized crossover trial of 40 older adults, three-day filtration periods reduced personal PM2.5 exposure. High efficiency filtration lowered average exposure from 15.5 to 7.4 micrograms per cubic meter, about 53%. Pooling the active filtration conditions, systolic blood pressure was 3.2 mm Hg lower than with sham filtration, with a 95% confidence interval of 0.2 to 6.1 mm Hg lower. The small sample and short duration limit conclusions about sustained benefit. The trial did not measure prevention of heart attacks or long-term disease. [7]

Particle filtration can also reduce airborne pollen, mold spores, and allergen-carrying dust. Symptom improvement varies, and filtration does not remove settled reservoirs or correct moisture problems that support mold growth. [5]

Why activated carbon adds protection

Many harmful substances are gases rather than particles. Activated carbon has an extensive internal surface on which selected gas molecules can collect through adsorption. Used with particle filtration, it can address part of the pollution mixture that HEPA or MERV filters alone leave behind. Its potential health value follows from lowering exposure to gases that cause irritation or other harm. [5,6]

The media must match the pollutant

Activated carbon can capture many organic vapors and may reduce ozone, but performance is pollutant-specific. Plain carbon is often less effective for formaldehyde and certain inorganic gases. Chemically treated carbon or other specialized sorbents may be needed for gases such as hydrogen sulfide or nitrogen dioxide. The appropriate choice depends on test results for the actual contaminant and operating conditions. A generic carbon label is insufficient evidence of protection. [5]

Pollutant or concern	Particle filter	Activated carbon or sorbent
Smoke particles and airborne dust	HEPA or suitable MERV filtration	Use alongside particle filtration
Selected VOCs and odors	Generally passes through	Can reduce selected compounds with suitable media
Ozone and difficult reactive gases	Generally passes through	Require documented gas-specific performance
Carbon monoxide or carbon dioxide	Does not provide protection	Ordinary residential carbon is not a reliable control

Table 1 General capabilities and limits of complementary filtration [5,6]

Capacity and service life determine protection

Carbon mass, bed depth, airflow, contact time, humidity, and competing pollutants affect removal and service life. Thin carbon-coated sheets may reduce some odors but should not be assumed to provide sustained gas control. Once the available capacity is used, pollutants can pass through: a condition called breakthrough. Some previously captured compounds can also be released under changed conditions. [5]

Ask for gas-specific removal and capacity data at realistic concentrations, humidity, and flow. Establish a replacement schedule based on expected loading and manufacturer data, with contaminant monitoring where warranted. Odor reduction alone does not demonstrate safety: some harmful gases are odorless, and smell sensitivity varies. [5]

A realistic health claim

Carbon can reduce exposure when it effectively captures a harmful gas. Direct evidence that carbon filtration alone improves long-term clinical outcomes is limited. Neither carbon nor HEPA replaces combustion safety, carbon monoxide alarms, adequate ventilation, or dedicated radon mitigation. Particle removal and odor improvement must not be treated as proof that all gas hazards are controlled. [5,6]

Putting filtration into practice

Start with sources and occupied spaces

Reduce avoidable indoor emissions first: control smoking, vent cooking outdoors where feasible, address moisture, and limit unnecessary combustion and high-emitting products. Evaluate outdoor sources such as traffic, wildfire smoke, or nearby operations. Identify who is exposed and prioritize bedrooms, classrooms, and other rooms with long occupancy. Carbon selection should follow identification of the gas problem. [5,6]

Specify a system that will perform in the building

For particles, use compatible high efficiency HVAC filtration, a portable cleaner with adequate CADR, or both. Confirm filter seals and delivered airflow. For gas concerns, specify the target compounds, sorbent type and quantity, rated operating conditions, expected capacity, and replacement criteria. A particle prefilter commonly protects the sorbent from dust; the final arrangement should follow the equipment design. Avoid equipment that intentionally generates ozone in occupied spaces. [5,6]

Operate and maintain it consistently

Run filtration during occupancy and increase clean-air delivery during smoke or pollution episodes. Manage doors and windows when outside air is polluted, while maintaining safe temperatures and necessary ventilation. Recirculation cleans indoor air but does not supply fresh air or control carbon dioxide. Severe smoke events may require a cleaner indoor room or relocation under public health guidance. [5,14]

Inspect particle filters for loading and bypass, replace them as recommended and as conditions require, and maintain a separate service plan for carbon. Carbon exhaustion cannot be inferred reliably from particle-filter appearance or pressure drop. Include fan electricity, noise, labor, and replacement media in the operating budget. An affordable system people can keep running and servicing is more useful than an impressive rating without consistent operation. [5]

Verify reduced exposure

Compare indoor particle trends before and after improvements, considering simultaneous outdoor conditions, occupancy, cooking, and device settings. Use suitable instruments and record where and when measurements were taken. Consumer PM2.5 monitors can help track trends but generally do not characterize ultrafine particle number, chemical toxicity, or gas removal. Investigate gas concerns with contaminant-specific assessment; a generic VOC reading cannot establish that every hazardous compound is controlled. [5,9]

Conclusion

Air pollution is an established health hazard with effects reaching well beyond the lungs. High efficiency particle filtration can substantially reduce airborne particle exposure, and controlled studies support benefits for some health measures. Properly designed activated carbon filtration extends control to selected gases and vapors. Their combined value depends on pollutant matching, clean-air delivery, installation, and maintenance. [1,3-7]

For building owners and occupants, the appropriate objective is measurable reduction of harmful exposure. Filtration deserves a place alongside source control, ventilation, and regional emission reduction because cleaner air reduces the pollution people inhale. Long-term disease-prevention claims should remain proportional to the evidence.

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