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# Particulate Matter Pollutants and Cardiovascular Risk Management

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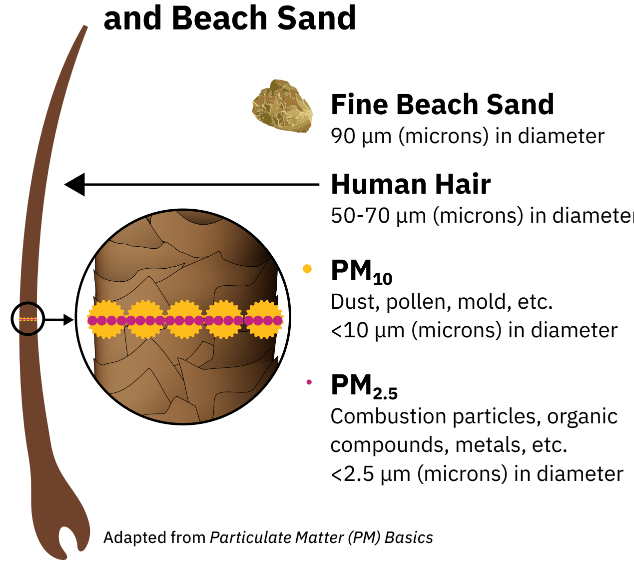
Exposure to pollution is a crucial piece of the cardiometabolic disease puzzle, as fine airborne particulate matter as fine airborne particulate matter < 2.5 microns in diameter ($PM_{2.5}$)(Figure 1)[1] from dust, dirt, soot, and smoke contributes broadly to cardiometabolic risk.[2]

**Figure 1. Size Detail of $PM_{2.5}$ Compared with Human Hair and Beach Sand**




Adapted from *Particulate Matter (PM) Basics*

Eighty-five million people in the United States live in counties with pollution levels above national standards, and recent transnational events, such as wildfires, show that even short-term elevations in $PM_{2.5}$ heighten rates of cardiovascular events.[3,4] Ambient $PM_{2.5}$ has been associated with 4.2 million premature deaths, more than half of these from cardiovascular disease.[5] Furthermore, there is unequivocal evidence associating this pollutant category with heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and premature birth.[6] Even short-term exposure (i.e., hours to days) increases risk of myocardial infarction, stroke, heart failure, arrhythmia, and sudden death by 1% to 2% for every 10 µg/m$^3$; longer-term exposure (i.e., months to years) increases those risks by 5% to 10%.[6] Knowing that $PM_{2.5}$ is the most dangerous environmental contributor to cardiovascular mortality worldwide amplifies the imperative to provide clinicians with tools to navigate this health crisis.[7]

Knowledge of mechanisms underlying PM-mediated cardiovascular risk is still evolving. PM pollution may trigger pathways of oxidative stress, inflammation, autonomic activation, and vascular and metabolic dysfunction, and the effects may differ depending on short-term versus long-term exposure.[6] Understanding of the mechanisms of cardiovascular disease affected by PM pollution may reinforce current recommendations for promoting cardiometabolic health (e.g., blood pressure regulation, anti-inflammation efforts, and mitigation of oxidative stress), if those actions also mitigate the risks from PM pollutants.

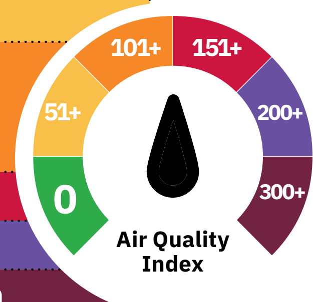
Clinicians can open conversations and educate vulnerable patients regarding limiting $PM_{2.5}$ exposure via local databases and smart devices or alert systems to determine Air Quality Index (AQI) and strategize about outdoor safety, air filtration, and when and how to utilize PM respirators or masks. In addition, lifestyle recommendations for heart-healthy diets and exercise are foundational for $PM_{2.5}$ safety.

## Monitoring Air Quality

Because fine airborne particulate matter comes primarily from the combustion of fossil fuels and traffic-related air pollution, national policies to reduce fossil fuel emissions at the population level have been created and remain effective. In the United States, air pollution levels have fallen 70% since the Clean Air Act was passed in 1970. The AQI is a nationally uniform color-coded index (Figure 3)[8] for forecasting daily air quality and communicate levels of the most common air pollutants regulated under the Clean Air Act: ground-level ozone, particle pollution ($PM_{10}$ and $PM_{2.5}$), carbon monoxide, nitrogen dioxide ($NO_2$), and sulfur dioxide. When air quality index values are above 100, air quality conditions are unhealthy, first for members of populations at greatest risk, then for the entire population as values rise. Those most susceptible are advised to reduce exposure and prolonged or heavy exertion.

**Figure 2. Air Quality Advisory**

| Air Quality Index (AQI) Values | Levels of Health Concern | Colors |
|---|---|---|
| When the AQI is in this range: | ...air quality conditions: | ...as symbolized by this color: |
| 0 to 50 | Good | Green |
| 51 to 100 | Moderate | Yellow |
| 101 to 150 | Unhealthy for Sensitive Groups | Orange |
| 151 to 200 | Unhealthy | Red |
| 201 to 300 | Very Unhealthy | Purple |
| 301 to 500 | Hazardous | Maroon |

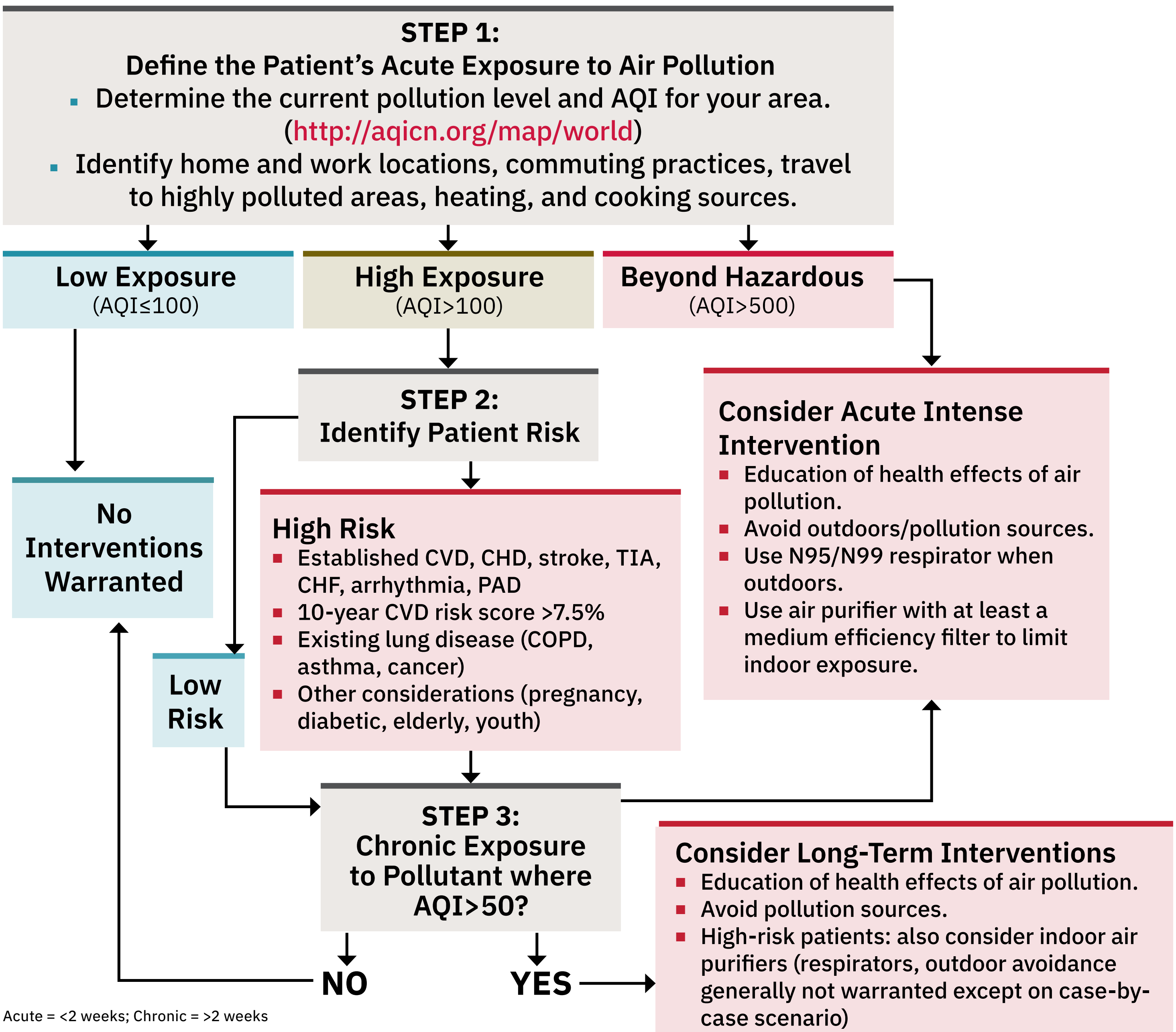



Adapted from *Air Quality for Northeast Ohio*

## Vulnerable Populations and Susceptibility Factors

Evidence suggests that health risks attributable to $PM_{2.5}$ persist even at levels below the United States Environmental Protection Agency (EPA) National Ambient Air Quality Standards, set at annual PM levels < 12 µg/m$^3$ and daily < 35 µg/m$^3$. The Clean Air Act requires the EPA to protect the public and identify the most susceptible populations.[6,9] Evidence indicates differences in vulnerability. Those most at-risk are children, older adults, pregnant individuals, and those with pre-existing heart and lung disease. Individuals in low socioeconomic communities are more susceptible to PM pollutants due to overlapping social and environmental stressors, such as proximity to industrial and roadway sources of PM, underlying health problems, and poor nutrition.

**Figure 3. Approach to Determine Whether Personal-Level PM Interventions Are Warranted**




Acute = <2 weeks; Chronic = >2 weeks

Adapted from *Interventions to reduce personal exposures to air pollution: A primer for health care providers*

## Personalizing Protection from $PM_{2.5}$ to Mitigate Risk

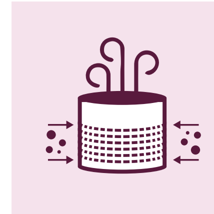
Whereas studies regarding personal-level measures for PM mitigation are still piecemeal, there is enough evidence of benefit in cardiovascular disease markers, such as blood pressure, endothelial dysfunction, heart rate variability, or markers of insulin resistance, to make recommendations for at-risk individuals. However, there is currently only population data affirming that the reduction of $PM_{2.5}$ exposure decreases overall cardiovascular events.[6] Although prevention of pollution-related cardiovascular disease is achieved best through government-supported interventions on a societal scale (Figure 4)[6], there are several general mechanisms for reducing individual exposure to particulate pollution.

**Figure 4. Personal and Local Interventions to Reduce Exposure or Susceptibility to Air Pollution**

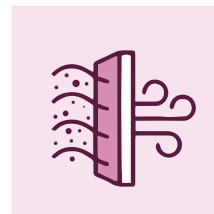
| | | |
|---|---|---|
| **Shifting to Clean Fuels** | ▪ Switch coal-fired power pants to low-polluting renewable energy sources such as wind, tidal, geothermal, and solar. | Societal and Governmental Interventions |
| **Transportation Reform** | ▪ Promote use of low-emission and zero-emission vehicles.<br>▪ Reduce sulfur content of motor fuels.<br>▪ Restrict trucks from city centers.<br>▪ Encourage active transport (walking and cycling). | Societal and Governmental Interventions |
| **Reduce Traffic Emission(s)** | ▪ Diesel particle traps.<br>▪ Catalytic converters.<br>▪ Alternative fuels (natural gas, electric cars). | Societal and Governmental Interventions |
| **Urban Landscape Reform** | ▪ Land use assessment.<br>▪ Minimum distances between sources and people.<br>▪ Relocation of traffic sources (including major trafficked roads).<br>▪ Avoidance of mixed-use areas (industrial-residential). | Societal and Governmental Interventions |
| **Emission Trading Programs** | ▪ Revenues raised through taxes can be directed to pollution control.<br>▪ Emissions trading programs compensate companies who adhere to controls through credits that can be traded akin to carbon credits. | Societal and Governmental Interventions |
| **Redirection of Science and Funding** | ▪ Modifying priorities of climate change mitigation investments to a focus on near-term health co-benefits.<br>▪ Focus on the imminent near-term danger of health effects of air pollution. | Societal and Governmental Interventions |
| **Empowering Civil Society** | ▪ Publicity and awareness campaigns through local data on air pollution within cities and counties. | Societal and Governmental Interventions |
| **Governmental and NGO-Led Publicity** | ▪ Hard-hitting media campaigns akin to smoking to mitigate lobbying by industries involved in power and automobiles. | Societal and Governmental Interventions |
| **Face Masks and Air Purifiers** | ▪ Wear face masks and install air purifiers in homes. | Personal Interventions |
| **Reduce In-Traffic Exposures** | ▪ Avoid commutes during rush hour. | Personal Interventions |
| **Reduce In-Home Penetration of Outdoor Air Polluion** | ▪ Indoor air purifiers and close windows.<br>▪ Air conditioners. | Personal Interventions |
| **Lifestyle Changes and Preventive Medicine** | ▪ Exercise and healthy diet.<br>▪ Preventive medications and screening programs. | Personal Interventions |

Adapted from *Air pollution and cardiovascular disease: JACC state-of-the-art review*

## Personal Exposure Mitigation

- 

  ***Portable Air Cleaners.*** Most people spend more than half their lives indoors; therefore, portable air cleaners (PACs) with high efficiency particulate air (HEPA) filters can significantly impact PM2.5 exposure, especially in vulnerable and high-risk populations living in heavily polluted locations or during heavy air pollution episodes. PM2.5 levels will be higher in residences that are not air-tight (e.g., leaks to outdoor air) or in hot environments without air conditioning where outside windows may remain open for prolonged periods of time. PACs are relatively inexpensive, can be used in nearly all homes and apartments with electricity, and are designed to clean the air in a small area (i.e., single room). If PACs cannot cover the entire home, create a clean sleeping room. Replace HEPA filters periodically when their capacity is reached (saturated with particles). Electrostatic precipitators and electronic air filters that contain ionizers can produce ozone and should be avoided.

- 

  ***Heating Ventilation and Air Conditioning: High-Efficiency Home Air Filtration Systems.*** Central heating ventilation and air conditioning (HVAC) units with built-in filters can effectively remove particles in residential indoor environments. Their efficiency depends on the particle size of the pollutants. Consider properly installed MERV 7–13 (or equivalent) filters and change filters frequently with high levels of indoor or ambient $PM_{2.5}$, and run furnace/air conditioning fan continuously during high pollution. HEPA filters are not usually incorporated in residential HVAC systems, because proper use requires professional modification not generally attainable for the home.[10] Regular maintenance of HVAC systems can be recommended to patients at the same time that clinicians advocate for yearly home carbon monoxide and fire safety-system updates.

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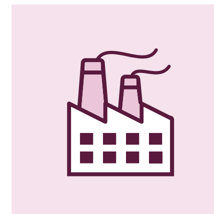
  ***Personal Air-Purifying Respirators and Masking.*** Personal protective devices that cover the nose and mouth can reduce inhalation of $PM_{2.5}$ and other particles depending on their rating efficiency (N95 removes > 95% and N99 removes 99% of inhaled particles at 0.3 μm). To be effective, however, these masks must fit the face appropriately.[11,12] Small studies on N95 respirator usage under ambient $PM_{2.5}$ exposure conditions for more than a few hours have shown that they may reduce systolic blood pressure and improve heart rate variability parameters in a short period of time.[7] Studies suggest that during high ambient $PM_{2.5}$ exposures, there could be meaningful reductions in blood pressure with an N95 respirator intervention. Gauze, cotton, or cloth face masks and procedural or surgical masks are more widely available but are not uniformly effective in filtering $PM_{2.5}$ as they do not form a tight facial seal.[13] In a comparative study with three different categories of masks (bandana, biker, and surgical), surgical masks significantly decreased $PM_{2.5}$ compared with the others, but their performance was highly variable.[14] Currently, clinicians have insufficient evidence to support or discourage the use of simple face masks for all but their most at-risk patients.

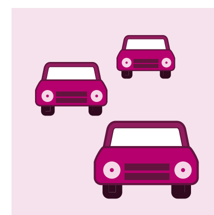
- ***Automobile Air Filters and Air Conditioning.*** Approaches to reduce $PM_{2.5}$ exposure during travel are advisable for those who are susceptible and spend considerable time in vehicles. Three in-vehicle approaches include: closing windows in the vehicle, using the air conditioning, and using the highest efficiency air filter available for the cabin and frequent changes in areas with high levels of chronic $PM_{2.5}$ exposure. Studies demonstrate lower oxidative stress markers for those using in-vehicle filtration, and improvement in heart rate variability for those using air conditioning with recirculated air during rush hour driving, compared with no air conditioning.[15]

## Lifestyle Strategies

- ***Air Pollution Avoidance.*** Avoid exposure to $PM_{2.5}$ during peak pollution times and various geographic areas by changing a commute's route/time to avoid rush hours. Global positioning system (GPS)-based resources that provide air pollution alerts can guide drivers through less polluted routes. There is compelling data to advise against exercising within 1,300 ft (¼ mile) of highways or major arterial roads to reduce exposure to traffic-derived air pollutants, especially for high-risk individuals.[16,17]



- ***Proximity to Roadways and Environmental Stress***. More than 30 million people in the United States live within 1,000 feet of a highway with four or more lanes. Those living near major roadways may be more consistently exposed to traffic-related air pollution than the average commuter during rush hour traffic.[18] Environmental justice research has repeatedly shown that under-resourced neighborhoods tend to have higher levels of air pollution across the United States.[19] Psychosocial and environmental stress exposures across the life course have been shown to affect the development of cardiovascular disease, with residential addresses serving as one proxy for assessing environmental stress, such as PM air pollution.[17] Given these concerns, prioritizing attention to those who live near such roadways is recommended.[20] Most electronic health records include patient billing addresses, and future research should employ methods of "geocoding" patients' residential locations to help clinicians better understand their unique environmental stressors.[21]



- ***Staying Indoors and Closing Windows***. Staying indoors in a building with good ventilation and low leakage reduces $PM_{2.5}$ exposure from outdoor ambient sources. Closing windows can lead to substantial reductions in outdoor $PM_{2.5}$ penetration and has been shown to offset increases in plasma C-reactive protein and fibrinogen and improve heart rate variability compared with leaving windows open. No further modification was noted from air conditioning.[22] However, staying indoors with closed windows may bring other potential harm due to elevated temperatures, secondhand smoke, or other indoor air pollutants. Improvements in HVAC systems play a key role in creating suitable indoor air quality but add to total energy consumption.

- ***Modification of Exercise and Activity.*** Clinicians must identify who/when/if to advise on limiting outdoor activity during episodes of $PM_{2.5}$ air pollution and the amount of exercise needed to offset the detriment of $PM_{2.5}$. Dose-response exists between exercise and the adverse effects of ambient $PM_{2.5}$ air pollution.[23,24] Beneficial effects of increased activity offset the combined potential risks of increased air pollution exposure and traffic accidents in all but the most polluted cities in the world. Although exercise in the cleanest cities improved health benefits throughout 90 minutes of exercise, no greater benefits were noted after 15 minutes of exercise in the most polluted cities (annual averages > 100 μg/m$^3$). Walking in a wooded urban park was associated with significant improvements in several markers, particularly heart rate variability and cortisol, compared to walking on a busy street.[6]

### Diet & Supplements

- Emphasis on a heart-healthy diet, already known to reduce cardiovascular disease mortality risk, dovetails well with efforts to mitigate the effects of exposure to air pollutants. Large studies that followed individuals in the United States for 17 years showed that a Mediterranean diet was associated with reduced harm from $PM_{2.5}$-triggered cardiovascular events.[25] Given the significant role of oxidative stress resulting from exposures to PM2.5 air pollution, several review articles have focused on omega-3 or antioxidant (Vitamin C) supplementation, demonstrating some support for preventing acute lung effects by $NO_2$ and ozone exposure,[26,27] and normalizing several markers of oxidative stress.[28,29] There is no evidence that prescriptive medications offset environmental impacts on cardiovascular events.

## Additional Resources

### Clinician Materials

- EPA, AirNow, Online Training for Medical Professionals
  airnow.gov/air-quality-and-health/online-training-for-health-professionals
- EPA, Patient Exposure and the Air Quality Index
  epa.gov/pmcourse/patient-exposure-and-air-quality-index
- Ohio EPA AQI Zip Code Locator
  airnow.gov

### Patient Education Materials

- California Air Resources Board, Air Cleaning Devices for the Home
  arb.ca.gov/research/indoor/acdsumm.pdf
- EPA, Be Smart, Protect Your Heart from Air Pollution (30-second video)
  youtube.com/watch?v=yHXUPZCUuGs
- EPA, Guide to Air Cleaners in the Home
  epa.gov/indoor-air-quality-iaq/guide-air-cleaners-home
- EPA Healthy Heart Toolkit and Research
  epa.gov/air-research/healthy-heart-toolkit-and-research
- Ohio EPA, Air Quality and Your Health (flyer)
  epa.ohio.gov/static/Portals/27/airohio/AirQualityandYourHealth.pdf

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