Asthma and air pollution: health effects and prevention

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Asthma Initiative of Michigan Partnership Forum
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CDC’s National Asthma Control Program

Environmental triggers: indoor and outdoor

Criteria air pollutants
  - Particulate matter
  - Ozone

Health effects and epidemiology

Prevention
Asthma: A Burden on Americans

- About 1 in 12 Americans has asthma (24.6 million)
- About 1 in 26 Americans had an asthma attack in the previous year (12 million)
- About 1 in 10 American children has asthma (7 million)

http://www.cdc.gov/vitalsigns/Asthma/index.html
Asthma: A Burden on Americans

- Hospitalizations per year = 444,000 (>1,200 per day)
- School days missed each year = 12.8 million
- Missed or less productive workdays per year = ~12 million
- Deaths per year = 3447 (~9 every day)
- Costs the United States = $56 billion every year
Goal: To reduce the burden of asthma on the individual, the family, and the community.
CDC's State and Local Partners in Asthma Control
A Public Health Approach to Asthma Control

**Surveillance**
- What is the problem?
- Who is at risk?

**Risk Factor Identification**
- What are the causes?
- What are the triggers?

**Effective Intervention**
- What works?

**Implementation**
- How do we do it?
Common Indoor Asthma Triggers

- Environmental tobacco smoke
- Pet dander
- Dust mites
- Cockroaches
- Rodents
- Mold
Air Pollution Asthma Triggers

- **Indoor air pollution**
  - Particulate matter: Dust, cooking, smoking, air from outdoors, allergens
  - Nitrogen oxides: Gas stoves, furnaces, fireplaces
  - Volatile organic compounds (VOCs): Chemical sprays, fragrances

- **Outdoor**
  - Particulate matter
  - Nitrogen oxides
  - Ozone
  - VOCs
  - Pollen

[Link to EPA asthma flyer](http://www.epa.gov/airnow/asthma-flyer.pdf)
US Clean Air Act

- Criteria Air Pollutants:
  - Particulate matter (PM)
  - Ozone ($O_3$)
  - Carbon monoxide ($CO$)
  - Sulfur oxides ($SO_x$)
  - Nitrogen oxides ($NO_x$)
  - Lead

- Regulated using science-based guidelines
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Sources</th>
<th>Health impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide (CO)</td>
<td>- Incomplete combustion of carbon in fuel</td>
<td>Reduces oxygen delivery to the body's organs and tissues</td>
</tr>
<tr>
<td></td>
<td>- Component of motor vehicle exhaust</td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide (SO₂)</td>
<td>- Combustion of sulfur-containing fuels from power plants, boiler operations, rail, marine operations</td>
<td>Adverse respiratory effects including broncho-constriction and increased asthma symptoms</td>
</tr>
<tr>
<td></td>
<td>- Natural sources: volcanoes</td>
<td></td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>- Incomplete fuel combustion (engines, stoves, cigarettes)</td>
<td>Adverse respiratory effects: airway inflammation in healthy people, increased respiratory symptoms among those with asthma</td>
</tr>
<tr>
<td></td>
<td>- Contributes to formation of ground-level ozone and PM₂.₅</td>
<td></td>
</tr>
</tbody>
</table>
PARTICULATE MATTER
Particulate Matter (PM): What is it?

- A mixture of microscopic solids and liquid droplets suspended in air that can contain:
  - Acids
  - Organic chemicals
  - Metals
  - Soil or dust particles
  - Allergens

- Can vary greatly in shape and size
Sources of Particulate Matter

Man-made sources:
- Industrial processes
- Fuel combustion
  (e.g., gasoline, oil, diesel, wood)

Natural sources:
- Erosion, windblown dust
- Vegetation (e.g., pollen)
- Fires
- Volcanic emissions
Particulate Matter: Size distribution

Diette et al., 2008
Deposition and Fate of Particles in the Respiratory Tract
Particle Characteristics: Composition

# USEPA National Ambient PM Standards

<table>
<thead>
<tr>
<th></th>
<th>PM$_{2.5}$</th>
<th>PM$_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-hour</td>
<td>35 µg/m$^3$</td>
<td>150 µg/m$^3$</td>
</tr>
<tr>
<td>Annual</td>
<td>15 µg/m$^3$</td>
<td>--</td>
</tr>
</tbody>
</table>

- 24-hour PM$_{2.5}$ standard: 35 µg/m$^3$
- 24-hour PM$_{10}$ standard: 150 µg/m$^3$
- Annual PM$_{2.5}$ standard: 15 µg/m$^3$
- Annual PM$_{10}$ standard: --

![Annual Trend](chart.png)

**Annual Trend**

2001 to 2008: 18% decrease (observed)
2001 to 2008: 17% decrease (adjusted)

- 82 Sites

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**PM$_{2.5}$ concentration (µg/m$^3$)**

- 2001: 14 µg/m$^3$
- 2008: 12 µg/m$^3$
24-hr PM$_{2.5}$ Concentrations: 2008

**Concentration Range (µg/m$^3$)**
- 8 - 15 (51 Sites)
- 16 - 35 (743 Sites)
- 36 - 55 (43 Sites)
- 56 - 97 (12 Sites)
PM-related Health Effects

**Respiratory**
- ↑ Coughing, wheezing
- ↑ Lung inflammation
- ↑ Asthma and COPD exacerbation
- ↓ Lung function
- ↑ Lung cancer
- ↑ Respiratory mortality

**Central Nervous**
- ↑ Cerebrovascular impairment
- ↑ Stroke (?)

**Cardiovascular**
- ↓ Heart rate variability
- ↑ Heart rate dysrhythmias
- ↑ Systemic inflammation
- ↑ Atherosclerosis
- ↑ Myocardial infarctions
- ↑ Cardiovascular mortality

**Reproductive**
- ↑ Low birth weight
- ↑ Preterm births (?)
- ↑ Birth defects (?)
Susceptible Populations

- Elderly, very young
- Persons with:
  - Chronic cardiopulmonary disease
  - Influenza
  - Asthma
- Other factors affecting susceptibility:
  - Diabetes
  - Medication use
  - Gender, race, socioeconomic status
  - Genetic differences
Asthma and PM: Epidemiology

- Association observed between short-term PM$_{2.5}$ exposure and:
  - respiratory symptoms
  - pulmonary function
  - pulmonary inflammation among asthmatic children

- Evidence of associations between long-term exposure to PM$_{2.5}$ and:
  - decrements in lung function growth
  - increased respiratory symptoms
  - asthma development
Traffic-related Emissions and Asthma

- Living close to busy roads appears to be a risk factor for the onset of childhood asthma
- Evidence is “sufficient” to infer a causal association between traffic exposure and exacerbations of asthma
Woodsmoke and PM

Relative Emissions of Fine Particles

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Emissions (lbs/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fireplace</td>
<td>28</td>
</tr>
<tr>
<td>Uncertified Woodstove</td>
<td>4.6</td>
</tr>
<tr>
<td>EPA Certified Woodstove</td>
<td>1.4</td>
</tr>
<tr>
<td>Pellet Stove</td>
<td>0.49</td>
</tr>
<tr>
<td>Oil Furnace</td>
<td>0.013</td>
</tr>
<tr>
<td>Gas Furnace</td>
<td>0.0083</td>
</tr>
</tbody>
</table>

* Average emissions (lbs/MMBtu of heat output) for heat source type. Data from US EPA

http://www.epa.gov/woodstoves/refp.html
PM Concentrations and Wildfires

Sanhueza et al. (JAWMA 2009)
There is no persuasive evidence that woodsmoke particles are significantly less dangerous for respiratory disease than other major categories of combustion-derived particles in the same size range.

There is too little evidence available today, however, to make a judgment about the relative toxicity of woodsmoke particles with respect to cardiovascular or cancer outcomes.”
OZONE
Ozone: What is it?

- **Stratospheric ("good ozone")**
  - A gas that occurs naturally approximately 10–30 mi above the earth’s surface
  - Forms a layer that protects the earth from the sun’s ultraviolet rays

- **Ground level**
  - Main component of smog
  - Created when specific pollutants chemically react in the presence of sunlight

National Geographic, photo by Mike Abrahams/Alamy
Ozone ($O_3$) Formation

- Point and Area Sources
- Miscellaneous Sources
- Non-Road Engines
- On-Road Vehicles

$\text{NOx & VOC} + \text{Sun} = \text{Ozone}$
Diurnal Photochemistry in Atlanta

![Graph showing the diurnal photochemistry in Atlanta with plots for NO, NO2, O3, and temperature (Temp)].

- **NO**
- **NO2**
- **O3**
- **Temp**

**X-axis:** Hour of day

**Y-axis:** ppb

**Y-axis:** Deg C
USEPA National Ozone Standard

<table>
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<tr>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-hour (2008)</td>
</tr>
<tr>
<td>0.075 ppm (75 ppb)</td>
</tr>
</tbody>
</table>

8h Ozone Non-Attainment Areas: 2007–2009

- 36% of 2008 US population resided in non-attainment counties
- 79% of non-attainment counties had ≥250,000 in population

MMWR, 2011
Ozone: Pulmonary Health Effects

- Ozone impairs the normal mechanical function of the human lung and can lead to the following symptoms:
  - Lung and throat irritation
  - Lung inflammation
  - Chest pain
  - Wheezing
  - Coughing

- A known pulmonary irritant affecting the respiratory mucous membranes

- Exposure also found to aggravate bronchitis, emphysema, and asthma
Ozone: Susceptible Populations

- People vary widely in susceptibility to ozone toxic effects

- Populations commonly at-risk:
  - The elderly
  - Infants
  - Active children
  - Adults with outdoor occupations
  - Athletes of all ages
  - Persons with respiratory disease (including asthma)
  - Persons with cardiovascular disease
Ozone and Asthma: Epidemiology

- Asthma-related ED visits increase when ambient ozone levels exceeded standard

- Short-term exposure to ozone associated with respiratory problems including:
  - Increased asthma attacks
  - Increased wheeze and cough
  - Decrements in pulmonary function
  - Increases in lung inflammation

- Chronic health effects from ozone exposure:
  - Reduced pulmonary function
PREVENTION APPROACHES
Policy Interventions

- **California**
  - Reducing diesel emissions impact on seaport communities

- **New Hampshire**
  - Preventing idling of motor vehicles on school property
  - Requiring annual school indoor air quality checkups

- **Illinois**
  - Green Construction Executive Order requires state-funded road projects use cleaner fuels and pollution controls in vehicles
Clean School Bus USA

- National campaign by EPA
- Reduce children’s exposure via:
  - Anti-idling
  - Bus replacement
  - Engine retrofit
  - Clean fuel use
- Materials and funding available
Exposure to air pollution is associated with several adverse health outcomes, including asthma attacks and abnormal heart rhythms.

Reduce risks by exercising away from heavy traffic and industrial sites, especially during rush hour or times when pollution is known to be high.

However, current evidence indicates that the benefits of being active, even in polluted air, outweigh the risk of being inactive.

Can this guidance be enhanced? What is the current state of science?
State of the science

- A large body of evidence in each individual discipline
- Less known about interaction between physical activity and air pollution exposure

Public health guidance

- Physical activity is good; avoid creating another barrier
- Participants thought existing guidelines could be modified to better address air pollution exposure
## Air Pollution Alerts: AQI

### Air Quality Index (AQI): Ozone

<table>
<thead>
<tr>
<th>Index Values</th>
<th>Levels of Health Concern</th>
<th>Cautionary Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 50</td>
<td>Good</td>
<td>None</td>
</tr>
<tr>
<td>51 - 100*</td>
<td>Moderate</td>
<td>Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.</td>
</tr>
<tr>
<td>101 - 150</td>
<td>Unhealthy for Sensitive Groups</td>
<td>Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy exertion outdoors.</td>
</tr>
<tr>
<td>151 - 200</td>
<td>Unhealthy</td>
<td>Active children and adults, and people with lung disease, such as asthma, should avoid prolonged or heavy exertion outdoors. Everyone else, especially children, should reduce prolonged or heavy exertion outdoors.</td>
</tr>
<tr>
<td>201 - 300</td>
<td>Very Unhealthy</td>
<td>Active children and adults, and people with lung disease, such as asthma, should avoid all outdoor exertion. Everyone else, especially children, should avoid prolonged or heavy exertion outdoors.</td>
</tr>
<tr>
<td>301 - 500</td>
<td>Hazardous</td>
<td>Everyone should avoid all physical activity outdoors.</td>
</tr>
</tbody>
</table>

*An AQI of 100 for ozone corresponds to an ozone level of 0.08 parts per million (averaged over 8 hours).*
## DOH Guidance on Short-term Sulfur Dioxide (SO₂) Advisory Levels

<table>
<thead>
<tr>
<th>SO₂ Conc. (ppm)</th>
<th>Color Code &amp; Air Quality Condition</th>
<th>Air Quality Description</th>
<th>Sensitive Groups²</th>
<th>People Experiencing Health Effects³</th>
<th>Everyone Else</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0 – 0.2</td>
<td>Green (Good)</td>
<td>Considered satisfactory &amp; poses little or no risk</td>
<td>Highly sensitive individuals may be affected at these levels</td>
<td>Potential health effects not expected</td>
<td></td>
</tr>
<tr>
<td>&gt;0.2-0.4</td>
<td>Yellow (Moderate)</td>
<td>Acceptable, however, may be moderate health concern for small number of people</td>
<td>Be aware that levels are slightly elevated</td>
<td>If you experience breathing difficulties, such as chest tightness or wheezing, stop activities, use a rescue inhaler and find a place to sit down and rest.</td>
<td>Potential health effects not expected, however actions to reduce exposure to vog may be useful</td>
</tr>
<tr>
<td>&gt;0.4 - 1</td>
<td>Orange (Unhealthy for Sensitive Groups)</td>
<td>Members in sensitive groups, including healthy individuals with mild asthma, may experience health effects. They may be affected at lower levels than general public. Toward the upper end of this range, most asthmatics who are active outdoors are likely to experience some breathing difficulties. General public not expected to be affected in this range.</td>
<td>Avoid outdoor activities that cause heavy breathing or breathing through the mouth⁴</td>
<td>If you experience breathing difficulties, such as chest tightness or wheezing, stop activities, use a rescue inhaler and find a place to sit down and rest.</td>
<td>Potential health effects not expected, however actions to reduce exposure to vog may be useful</td>
</tr>
<tr>
<td>&gt;1 - 3</td>
<td>Red (Unhealthy)</td>
<td>Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.</td>
<td>Avoid outdoor activities &amp; remain indoors</td>
<td>Consider leaving the area</td>
<td>Avoid outdoor activities that cause heavy breathing or breathing through the mouth⁴</td>
</tr>
<tr>
<td>&gt;3 - 5</td>
<td>Purple (Very Unhealthy)</td>
<td>Triggers health alert, meaning everyone may experience more serious health effects</td>
<td>Avoid outdoor activities &amp; remain indoors</td>
<td>Leave the area &amp; seek medical help</td>
<td>Avoid outdoor activities &amp; remain indoors</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>Maroon (Hazardous)</td>
<td>Triggers health warnings of emergency conditions. Entire population is more likely to be affected.</td>
<td>Avoid outdoor activities &amp; remain indoors. Leave the area if directed by Civil Defense</td>
<td>Leave the area &amp; seek medical help</td>
<td>Avoid outdoor activities &amp; remain indoors. Leave the area if directed by Civil Defense</td>
</tr>
</tbody>
</table>

1. In ppm.  
2. Persons may include: the elderly, asthmatics, individuals with heart disease, and those who are pregnant.  
3. Consider an action if these symptoms occur: breathing difficulties, chest tightness, wheezing, coughing, eye, nose or throat irritation, or difficulty in speaking.  
4. Prevents choking on food or drink.
Next Steps in Assessing Health Effects of Air Pollution

- Identify specific pollutants, combination of pollutants, and characteristics of pollutants most responsible for observed health effects
- Improve understanding of biological mechanisms involved in observed health impacts at a cellular/molecular level
- Improve understanding of who is most at risk
One Death from Asthma is Too Many
Still More Work to Do

- 36 of 57 states and territories have CDC-funded asthma control programs.
- We have over 12 years of experience working with states.
- We are committed to advancing the prevention of asthma.
Thank you

www.cdc.gov/asthma

For more information please contact Centers for Disease Control and Prevention

1600 Clifton Road NE, Atlanta, GA 30333
Telephone, 1-800-CDC-INFO (232-4636)/ TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.