



# Affects of air pollution on pediatric asthma

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# + Objectives

- Note the impacts of air pollutants on pediatric asthma
- Discuss pathophysiology of air particulates on asthma (PM 10)
- Examine outcomes of poor air quality on asthma



# + Air pollution history



- Levels of outdoor air pollutants in the United States have shown general improvement since 1970, when the Clean Air Act was implemented
- In 2002, some 146 million persons in the United States lived in counties in which pollution levels remained higher than the National Ambient Air Quality Standards
- The majority of the developing world faces pollution in ways that are inherently different but just as risk prone as first world countries.



# Definitions



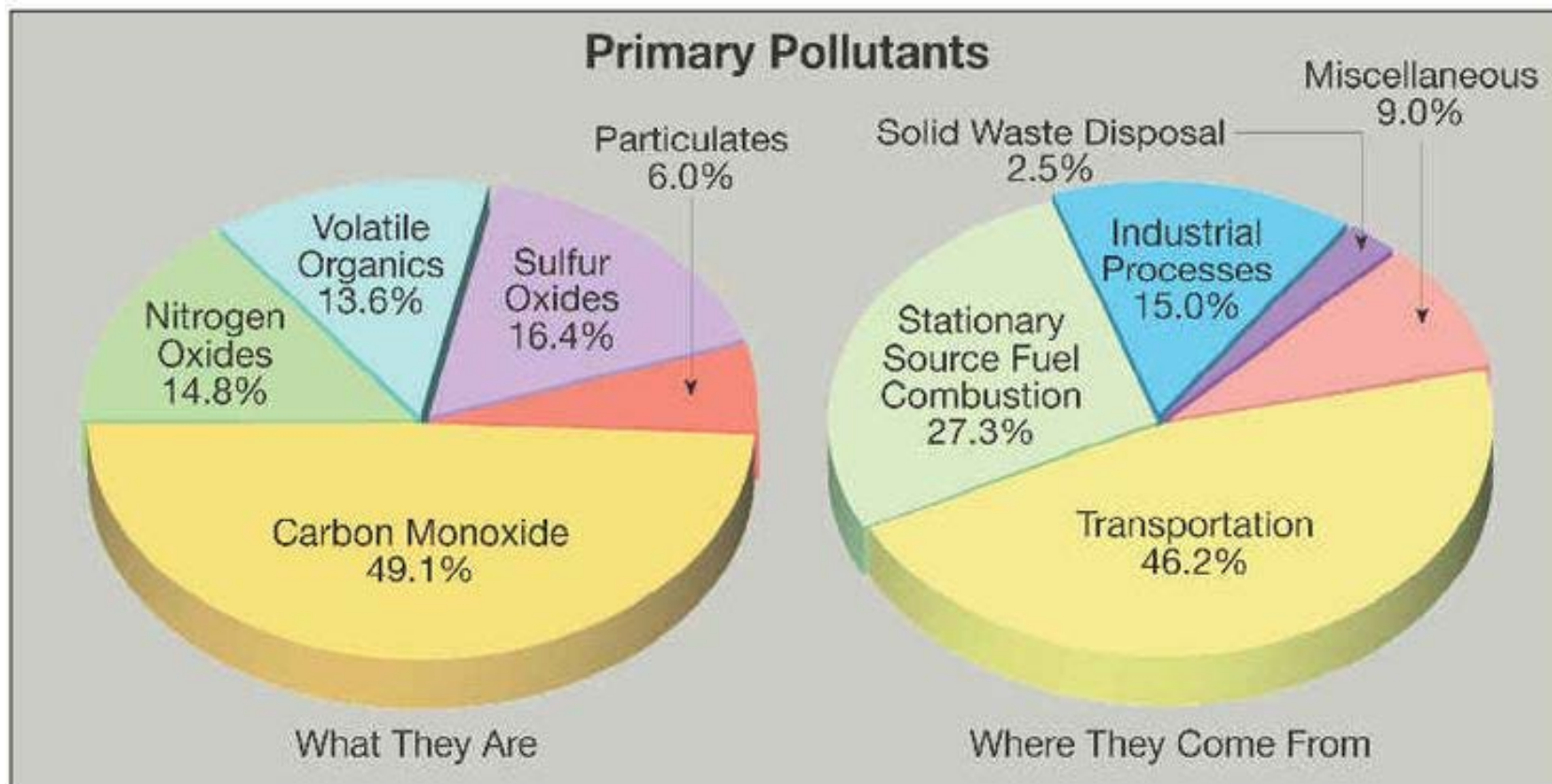
- Pollutants directly emitted into the atmosphere are known as primary pollutants
  - SO<sub>2</sub>, some NO<sub>x</sub> species, CO, PM
  
- Pollutants that form as a result of chemical reactions with other pollutants or atmospheric gases are known as secondary pollutants.
  - ozone, NO<sub>x</sub>, and some particulates

# + Where pollution comes from

- Outdoor air pollutants can come from many sources and include both gaseous and particulate pollution.
- Air pollution arises in 2 ways
- Primary pollutants emitted directly out of exhaust pipes and stacks (including the gaseous pollutants NO<sub>x</sub> and SO<sub>2</sub>, as well as PM, such as soot)
- Secondary pollutants formed from the primary pollutants in the atmosphere in the copresence of sunlight, moisture, or both (including O<sub>3</sub> and secondary particles, such as sulfates).



# + What's in pollution



# + It's in the news

CBS/AP / February 10, 2016, 8:26 PM

## Feds: Harmful formaldehyde levels in Lumber Liquidators flooring



A sign marks the location of a Lumber Liquidators store on April 29, 2015 in Cicero, Illinois. / SCOTT OLSON, GETTY IMAGES



# Indoor vs Outdoor Pollutants



- Indoor pollutants
  - Sources: cooking and combustion, particle resuspension, building materials, air conditioning, consumer products, smoking, heating, biologic agents
  - Combustion products (eg, tobacco and wood smoke), CO, CO<sub>2</sub>, SVOC (eg, aldehydes, alcohols, alkanes, and ketones), microbial agents and organic dusts, radon, manmade vitreous fibers



# + Outdoor Pollutants



- Sources: industrial, commercial, mobile, urban, regional, agricultural, natural
  - Products: SO<sub>2</sub>, ozone, NO<sub>x</sub>, CO, PM, SVOC
- Gaseous: SO<sub>2</sub>, NO<sub>x</sub>, ozone, CO, SVOC (eg, PAH, dioxins, benzene, aldehydes, 1,3-butadiene)
- Particulate
  - coarse PM (2.5-10 μm; regulatory standard = PM<sub>10</sub>),
  - fine PM (0.1-2.5 μm; regulatory standard = PM<sub>2.5</sub>); ultrafine PM (<0.1 μm; not regulated)

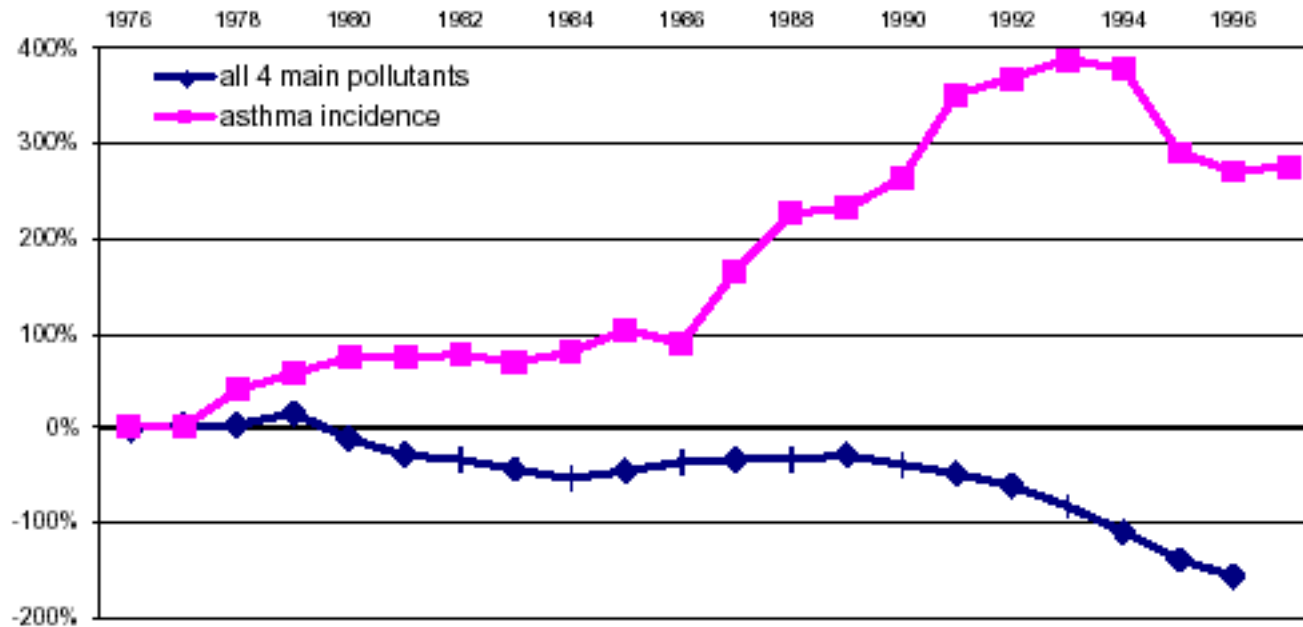
# + How is pollution created



- The dominant anthropogenic origin of all these pollutants is the combustion of fossil fuels.
- In most urban areas, and increasingly in suburban areas, traffic-related emissions are a major source of air pollution.
- Truck, car, and bus traffic produces a complex mixture of toxic chemicals (eg, benzene from unleaded gasoline and the organic chemicals in diesel exhaust), PM, and a variety of irritant gases (including nitrogen dioxide [NO<sub>2</sub>], SO<sub>2</sub>, and O<sub>3</sub>).

# + Asthma trends and pollution

**National trends in the incidence of Asthma**  
and 4 major pollutants: PM<sub>10</sub> - SO<sub>2</sub> - NOx - CO (summed)



# + Particulate Matter



<b>Pollutant</b>	<b>Time period</b>	
PM <sub>10</sub> (μg/m <sup>3</sup> )	150 (24 h)	50 (annual)
PM <sub>2.5</sub> (μg/m <sup>3</sup> )	65 (24 h)	15 (annual)
Ozone (ppm)	0.12 (1 h)	0.08 (8 h)
NO <sub>2</sub> (ppm)		0.053 (annual)
SO <sub>2</sub> (ppm)	0.14 (24 h)	0.03 (annual)

# + Who's most vulnerable



- Children, the elderly, and persons with preexisting respiratory conditions, such as asthma, are among those most affected by air pollution.
- Children spend more time outdoors and exercise more, and therefore they breathe a greater amount of pollution per pound of body weight than adults.
- Children's bodies are growing and can be more affected by pollutants that impair organogenesis and other developmental processes.

# + Kids are most vulnerable

- Children also have greater activity levels than adults and therefore are likely to have increased personal exposures relative to adults because of an enhanced personal cloud of particles.
  - This is the result of the air intake of a resting infant being twice that of an adult.
- Largely for anatomic reasons, the peripheral airways of infants are more susceptible to inflammatory narrowing than are those of adults.
  - Irritation caused by breathed air pollution can also result in proportionally greater airway obstruction than in adults.



# Pathophysiology of vulnerable kids



- Organogenesis of the lung begins in fetal life and is especially rapid in early childhood.
- The number of alveoli in the human lung increases from 24 million at birth to 257 million at the age of 4 years and changes in the lung continue through adolescence.
- Exposure to air pollution alters the normal process of lung development, which is guided by a complex and precisely timed sequence of chemical messages.
- Molecular mechanism studies have suggested that environmental exposures influence the development of TH2 (humoral immunity dominant) versus TH1 (cellular immunity dominant) phenotypes.

# + The early studies

- A landmark event in the recognition of the disastrous effect of air pollution on child health occurred from December 1 through 5, 1952, in London.
- Trapped coal smoke in the Thames valley accumulated as a result of a stationary high-pressure cell accompanied by wind speeds near zero. Approximately 4000 excess deaths occurred in London that week and excess deaths continued for weeks afterward, indicating that there were delayed, as well as prompt, effects.
- More recently, there were regional air pollution episodes of PM from massive forest fires in Southeast Asia and Mexico in the 1990s, shutting down businesses, schools, and airports.





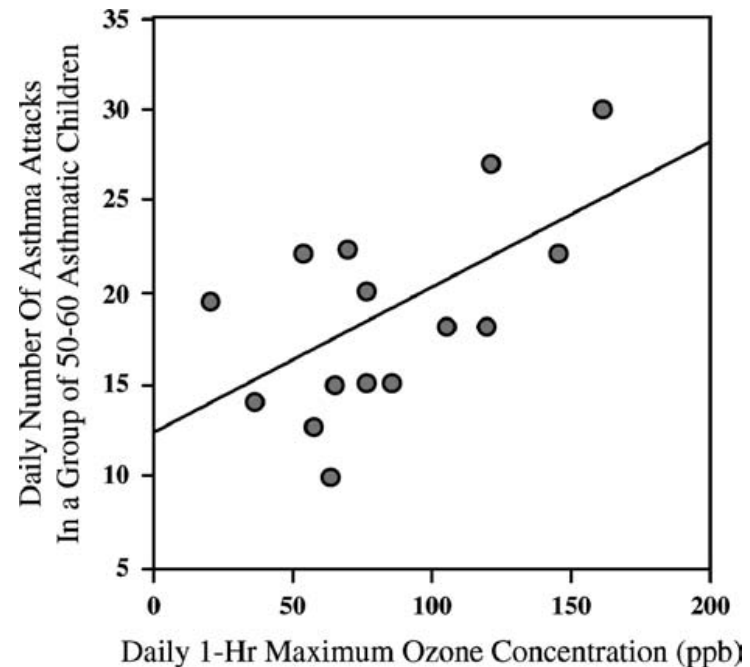
# + Major pollution players



- ozone (O<sub>3</sub>)
- fine particulate matter (PM; PM<sub>2.5</sub> [,2.5 mm in aerodynamic diameter])
- thoracic PM (PM<sub>10</sub> [,10 mm in aerodynamic diameter])
- lead
- sulfur dioxide (SO<sub>2</sub>)
- carbon monoxide (CO)
- nitrogen oxides (Nox)

# + Ozone (O<sub>3</sub>)

- O<sub>3</sub> is a highly reactive gas that results primarily from the action of sunlight on hydrocarbons and NO<sub>x</sub> emitted in fuel combustion.
- It oxidizes lung tissues on contact, acting as a powerful respiratory irritant at the levels frequently found in most of the nation's urban areas during summer months



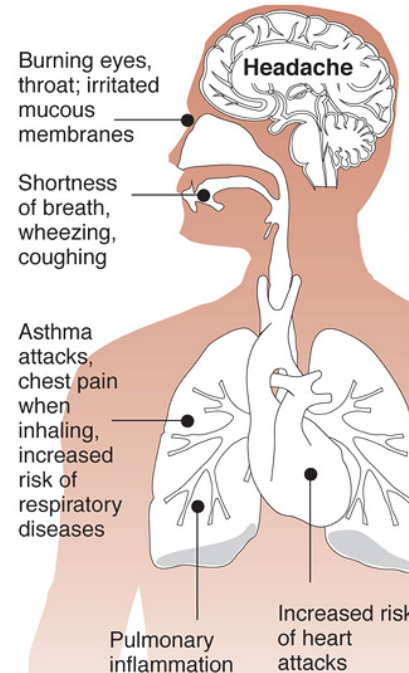
# + Ozone

- Ozone has been associated with an increased risk of asthma development among children in California playing outdoor sports;
- Ozone can increase airway inflammation and airway responsiveness and also can potentiate the airway response to inhaled allergens.

## Why smog is harmful

Ozone, the main ingredient in smog, is one of the most widespread air pollutants and among the most dangerous.

### Effects on health



### How ozone forms

- 1 Oxygen in the atmosphere O2
- 2 Nitric oxide, byproduct of combustion NO
- 3 Sunlight breaks up nitric oxide
- 4 Ozone formed by three oxygen atoms O3

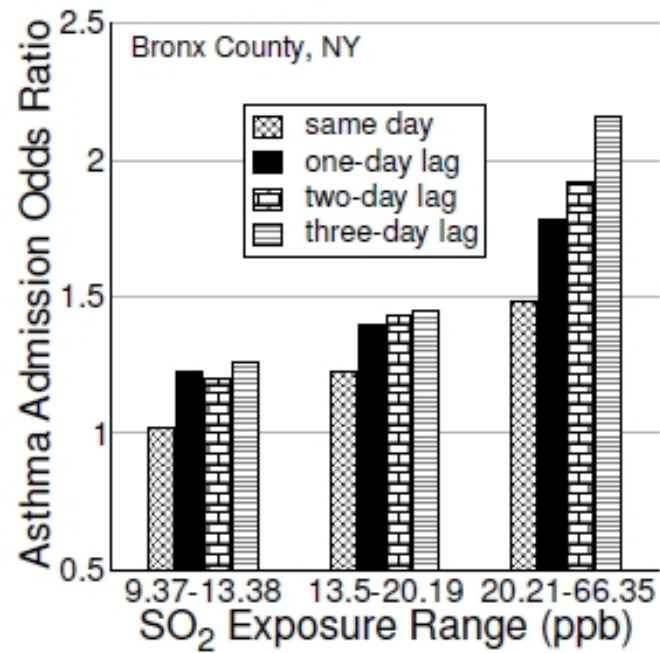
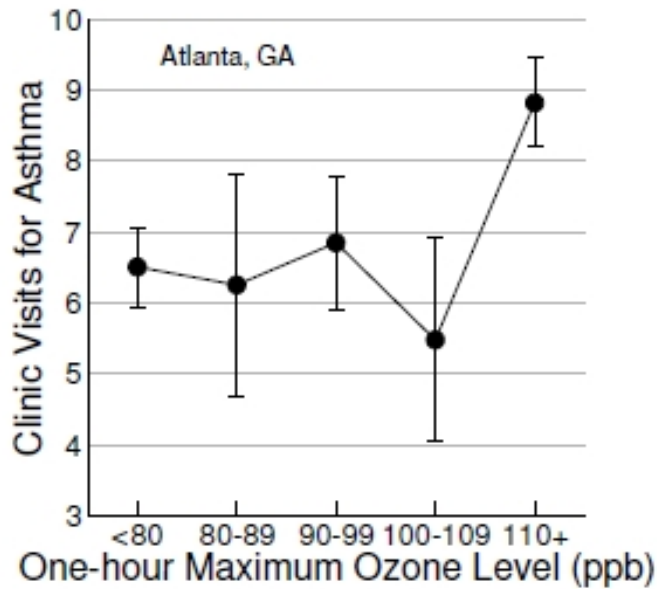
### U.S. ozone limits

In parts per billion	
• 1997-2008	<b>84</b>
• 2008-present	<b>75</b>
• New EPA proposal	<b>60-70</b>

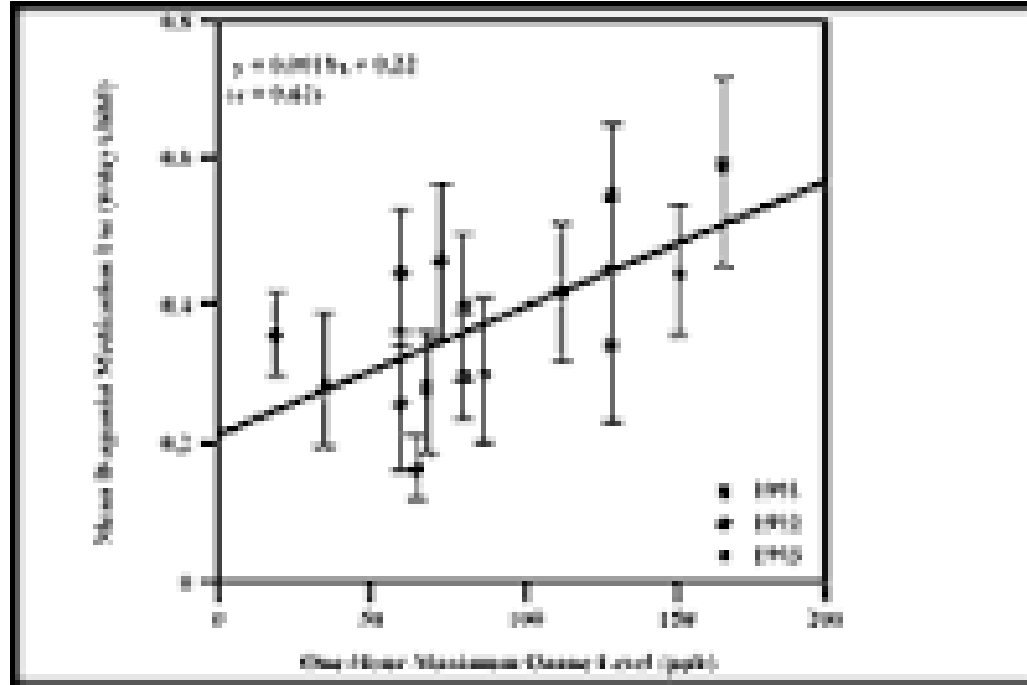


# + Ozone and hospitalizations

**High ozone and SO<sub>2</sub> levels predict high asthma hospitalizations.**



# + Rescue med use and ozone levels



# + SO<sub>2</sub>



- Controlled human exposure studies have yielded substantial data on the direct effects of SO<sub>2</sub> and NO<sub>2</sub> on healthy and diseased individuals over relatively short exposure times.
- Exposure (5 minutes) to inhaled SO<sub>2</sub> induces rapid-onset bronchoconstriction (decreases in FEV<sub>1</sub> or increases in airway resistance within 2 minutes of exposure) in both healthy and asthmatic subjects.

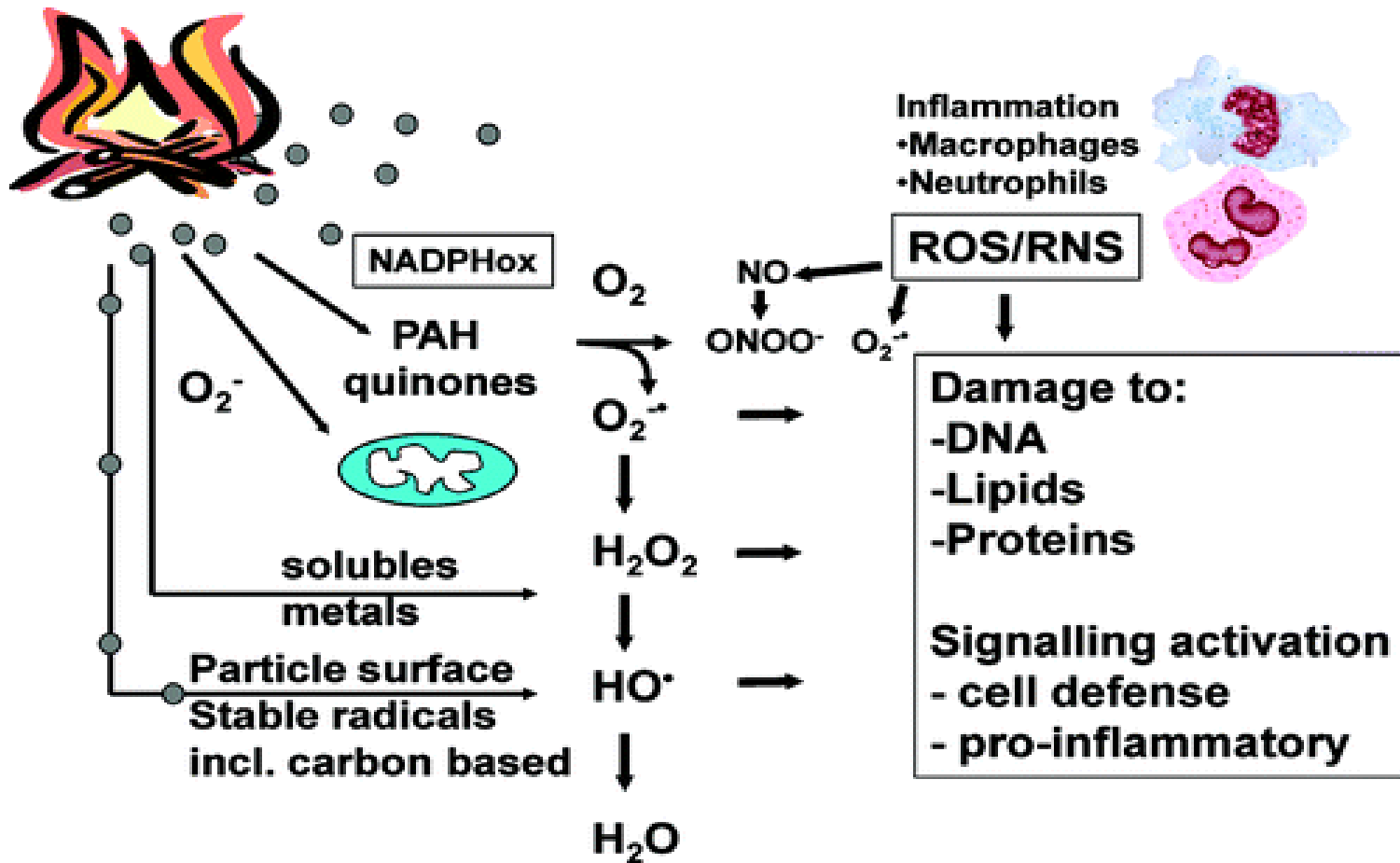
# + Particulate Matter (PM)

- PM is a general term that refers to a mixture of solid particles or liquid droplets of varying chemical composition and physical properties suspended in the air.
- Particles larger than 10 mm in diameter do not typically pass beyond the larynx, but because of their frequent mouth breathing behavior, these particles can more often deposit in the respiratory tract of children.
- Fine particles, including those that are formed in the atmosphere from gaseous pollutants, are less than 2.5 mm in diameter (PM<sub>2.5</sub>) and result from the combustion of fuels used in motor vehicle, power plant, and industrial operations, as well as the combustion of wood (eg, in wood-burning stoves) and other organic material.





# + Wood fire immune damage



# + PM10

- PM10 exposure has been increasingly associated with infant respiratory illness and infant death in recent studies across the globe.
- Woodruff et al found an association with infant deaths in the United States, even when they excluded neonatal deaths.

## Hearthside hazards

Fine particles known as particulates are carried into our lungs when we breathe wood smoke. They can cause a variety of health problems, and are a serious concern for federal and regional air-quality agencies.

### Unseen harm

Smoke particles are so fine they can slip past macrophages, immune cells inside the alveoli that destroy foreign particles. We cannot see the tiny particles that are being embedded in our lungs.

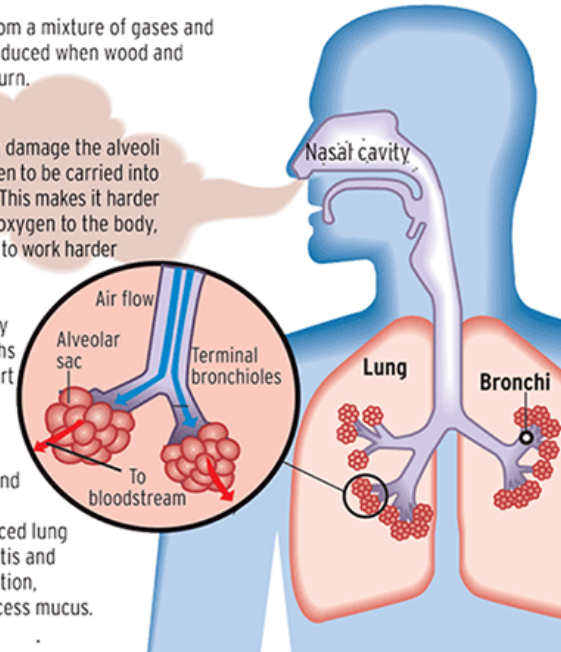
Substance	Size	
	Micrometers	Inch
90% of wood smoke particles	1 micron	0.00004
Red blood cell	8 microns	0.0003
Human hair	70 microns	0.003

**Smoke** comes from a mixture of gases and fine particles produced when wood and organic matter burn.

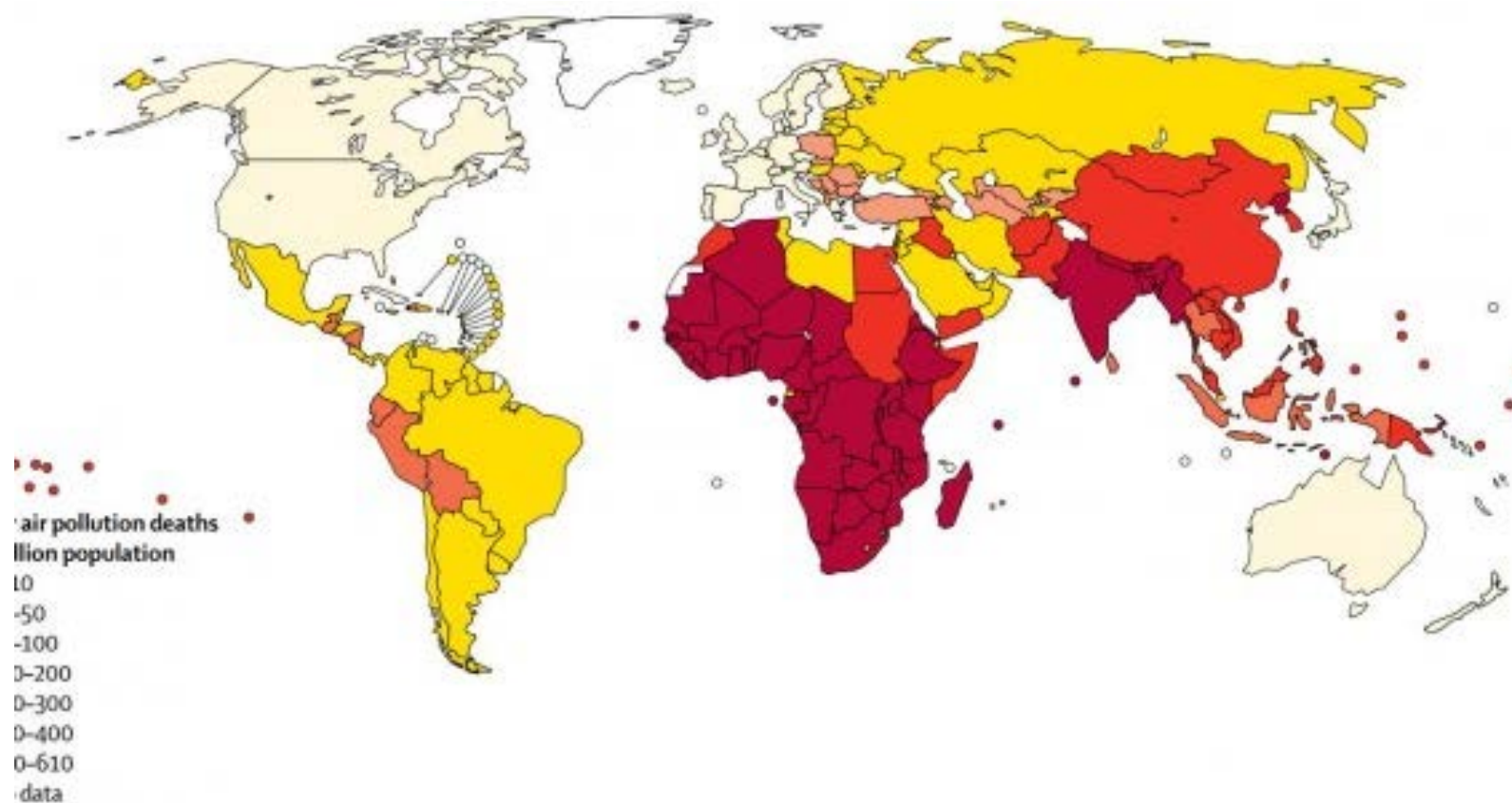
**Particulates** can damage the alveoli which allow oxygen to be carried into the bloodstream. This makes it harder to get sufficient oxygen to the body, causing the heart to work harder to compensate.

**Particulates** may cause more deaths in people with heart disease.

**Smoke effects** range from eye and respiratory tract irritation to reduced lung function, bronchitis and asthma exacerbation, coughing and excess mucus.



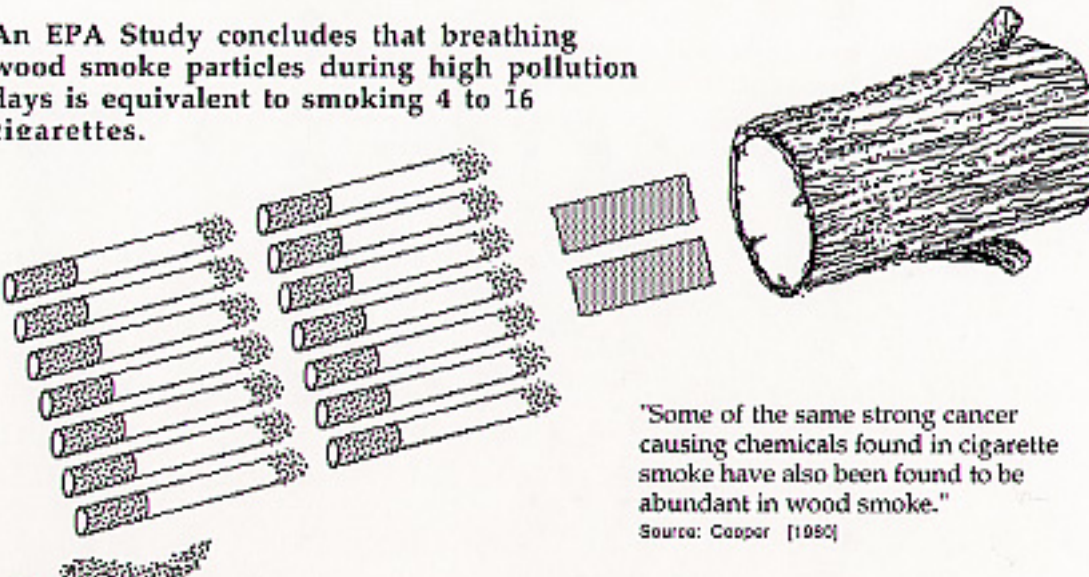
# + Cooking fires and asthma risks



# + Like cigarettes but necessary

**Wood Smoke Versus Cigarette Smoke**

An EPA Study concludes that breathing wood smoke particles during high pollution days is equivalent to smoking 4 to 16 cigarettes.



"Some of the same strong cancer causing chemicals found in cigarette smoke have also been found to be abundant in wood smoke."  
Source: Cooper [1980]

Particulate Pollution Project

*The Dangers of Particulates*

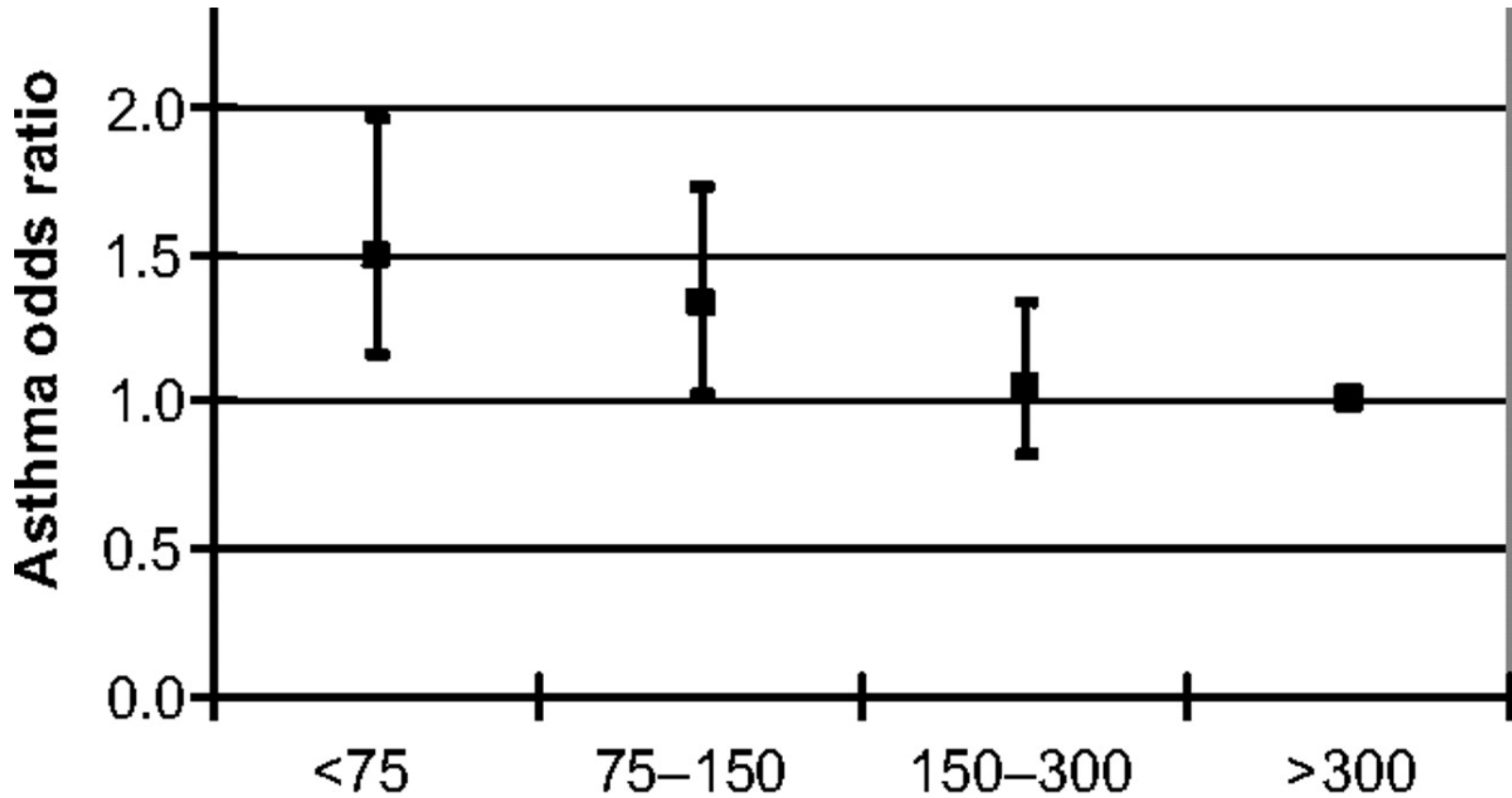
# + Nitric Oxide (NO<sub>x</sub>)

- Diesel and gasoline-powered vehicular engines and coal and oil-fired power plants are the main sources of ambient NO<sub>x</sub> emissions, which typically result from the fixation of nitrogen in the air during high-temperature combustion.
- Most of the nation's school bus fleets run on diesel fuel, and many of these fleets contain a significant number of buses that are 15 years of age or older and are much more polluting than diesel buses manufactured today.
- A recent study of diesel pollution exposures in school buses found that children riding inside of a diesel-powered school bus might be exposed to as much as 4 times the level of diesel exhaust as someone riding in a car ahead of it.
- In fact, the study notes that these exposures pose more than 20 times the cancer risk level considered significant under federal law.
- Exposure to nitrogen oxides has been associated with an increase in respiratory infection

# + School buses?



# + Asthma vs distance from roads



# + Pollution and allergens



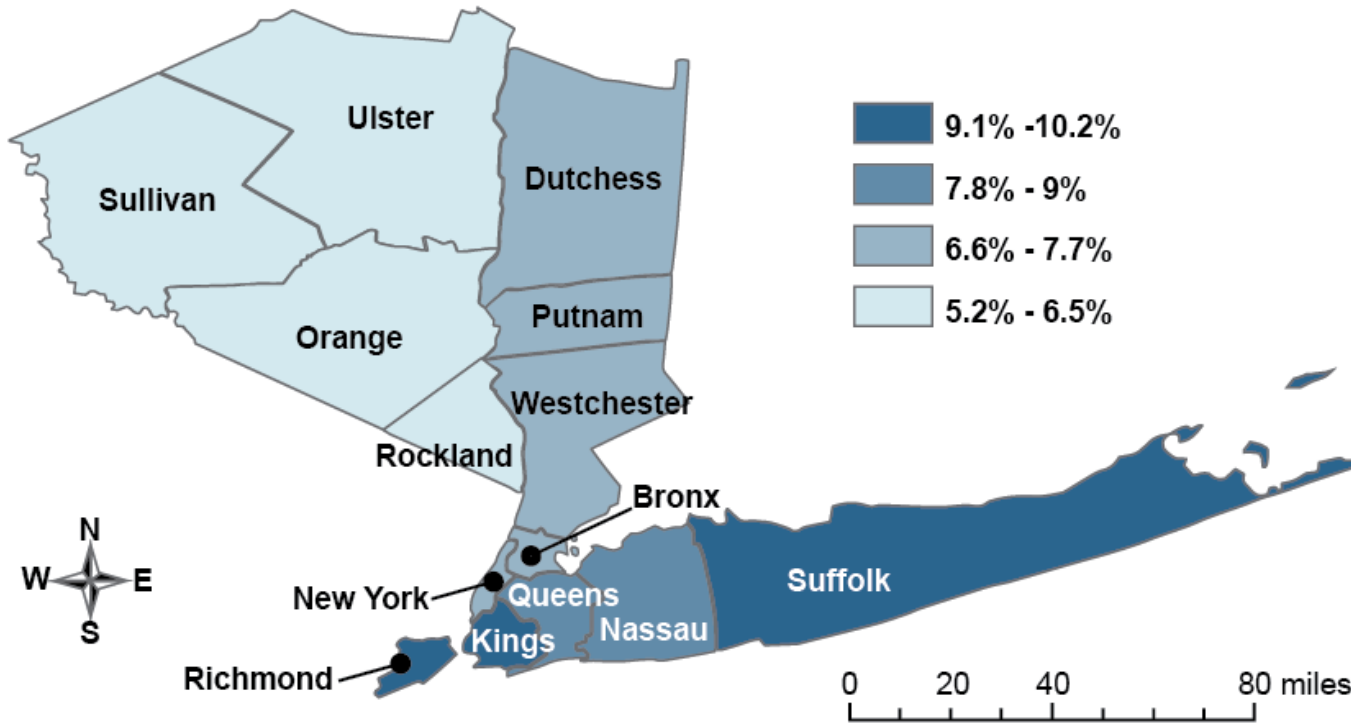
- Four major issues concerning the interaction of outdoor pollutants and allergens include the following:
- Epidemiologic studies of pollution and aeroallergens on the genesis of asthma
- Epidemiologic studies of pollution and aeroallergens on the exacerbation of asthma
- Experimental studies on the adjuvant effect of pollutant particulates (DEPs) on specific TH2 responses
- The role of pollution and global warming on natural allergen production.



# + Climate change and asthma

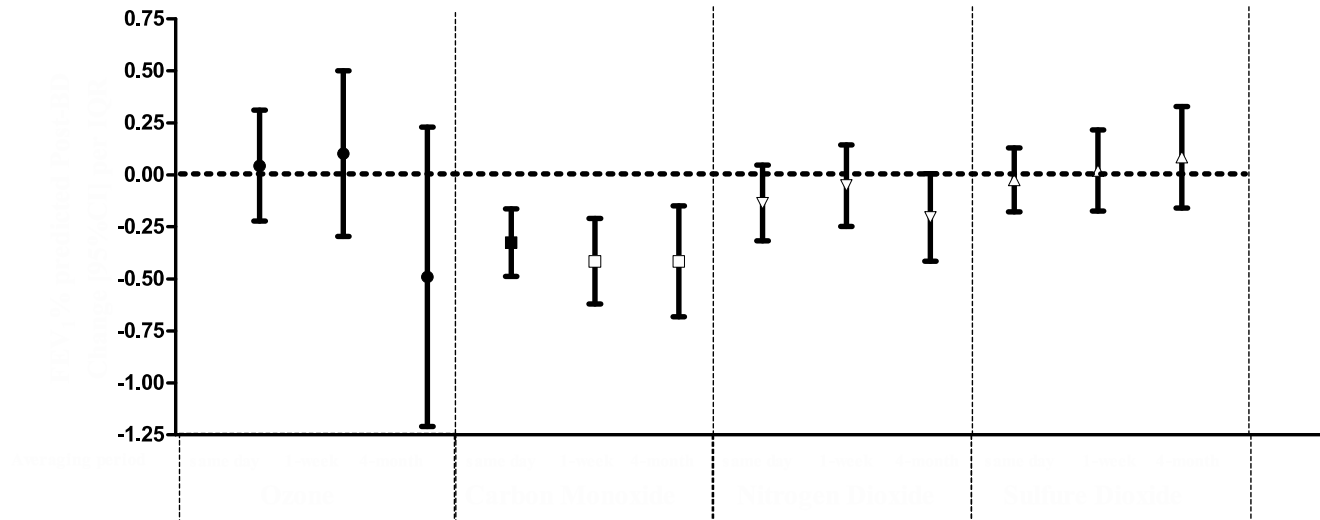


Climate Change Projected to Worsen Asthma

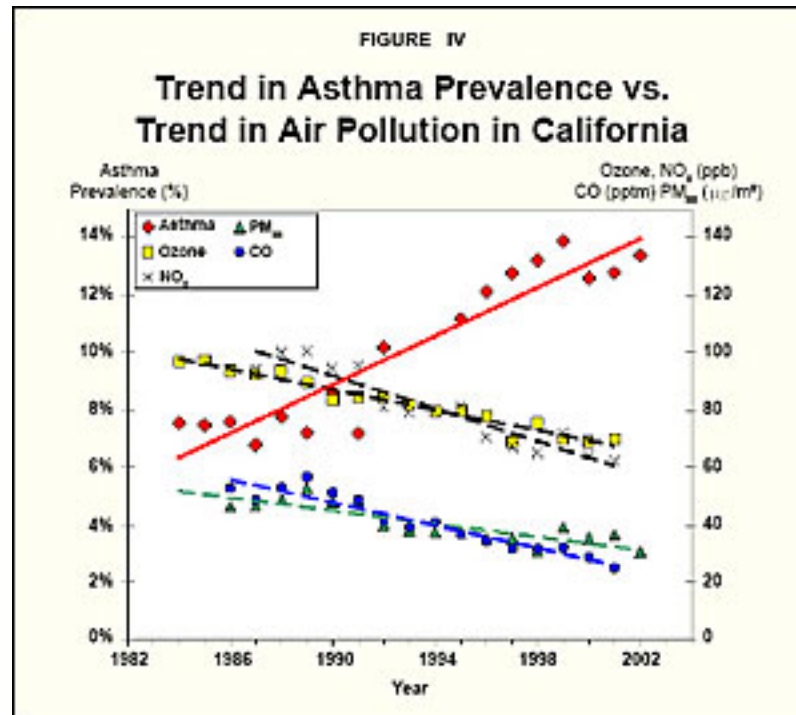




# Effect of pollution on FEV1 in children

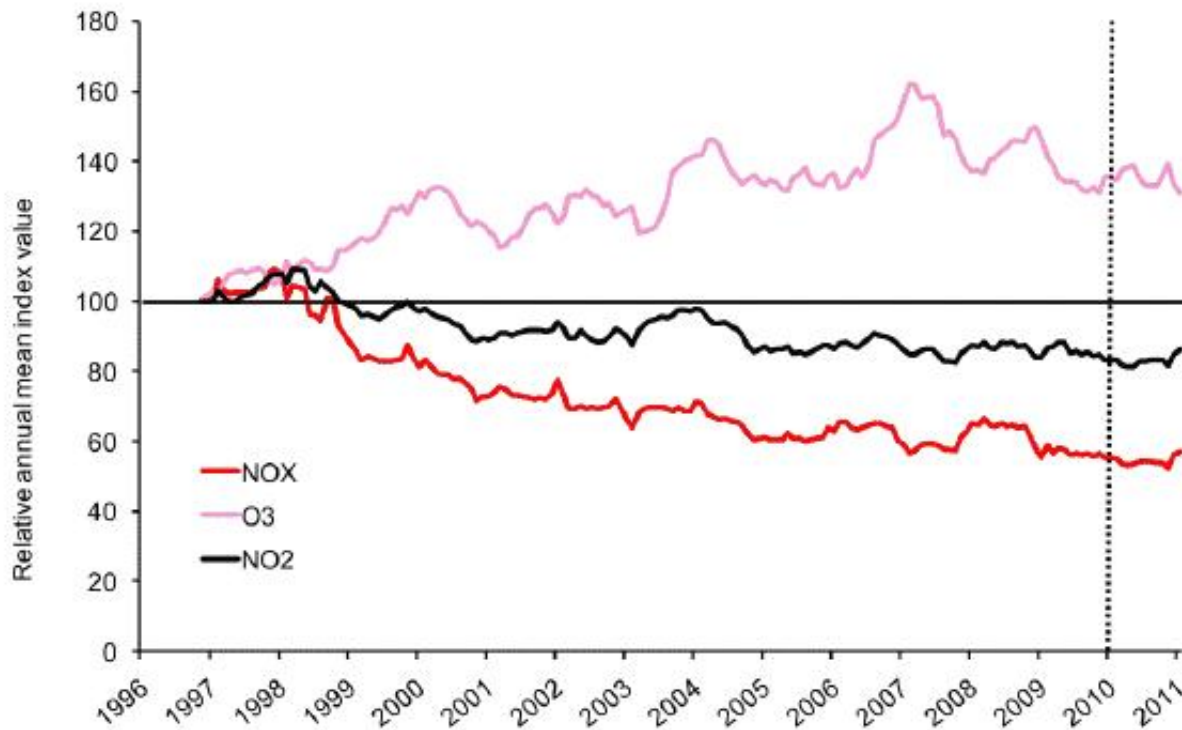


# + Asthma and pollution

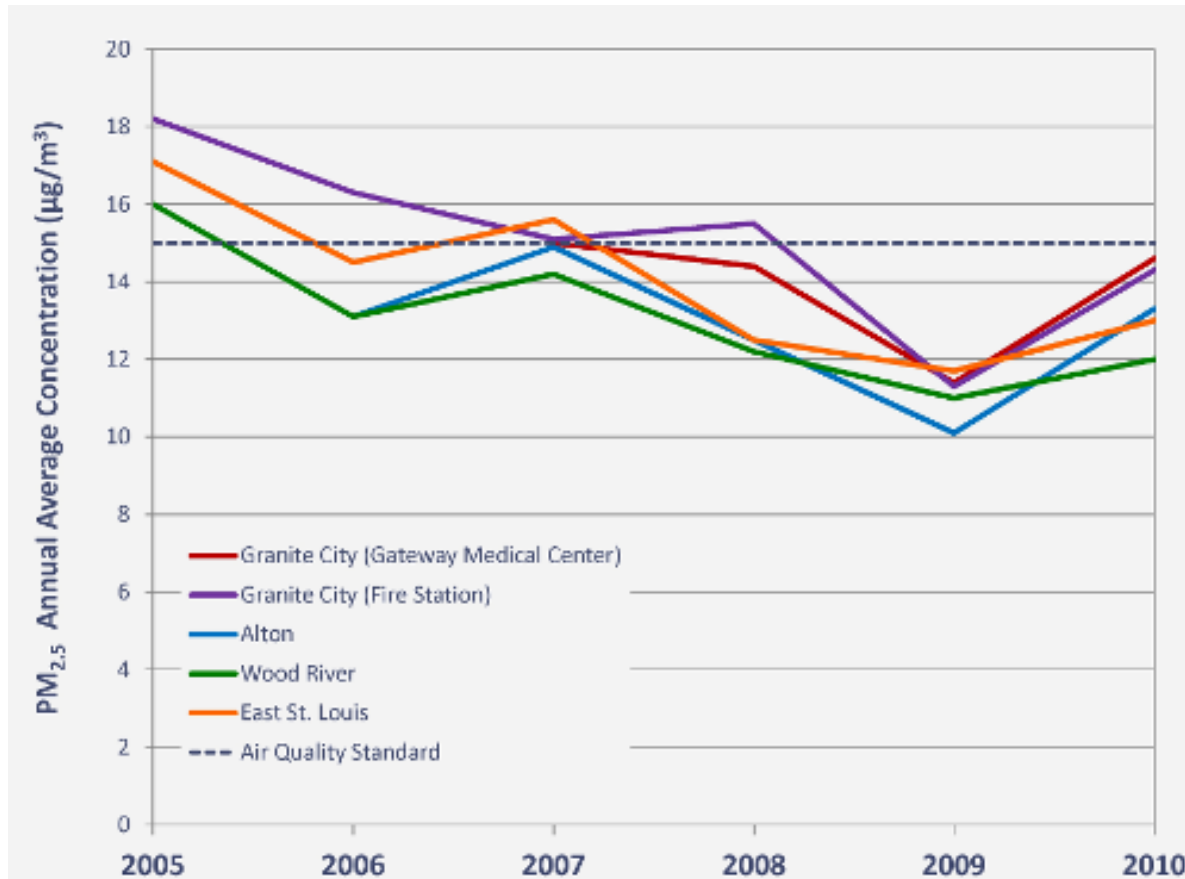


# + Can we fix it?

Figure 3 – London Air Quality Network Index (Average) for NO<sub>2</sub>, NO<sub>x</sub> and O<sub>3</sub><sup>3</sup>



# + Maybe we can change it



# + What can we do?

- Practitioners can significantly reduce morbidity in children and other vulnerable populations by advising families to minimize air contaminant exposures to children with asthma
- At a broader level by educating policy makers about the societal need to act to reduce pollutant emissions.

