

*Today's Talk:*

# Characterizing Health Risks from Exposure to Wood Smoke

*(and other carbon-based combustion byproducts)...*

**What clinicians, public health practitioners  
and environmental health advocates  
should know.**

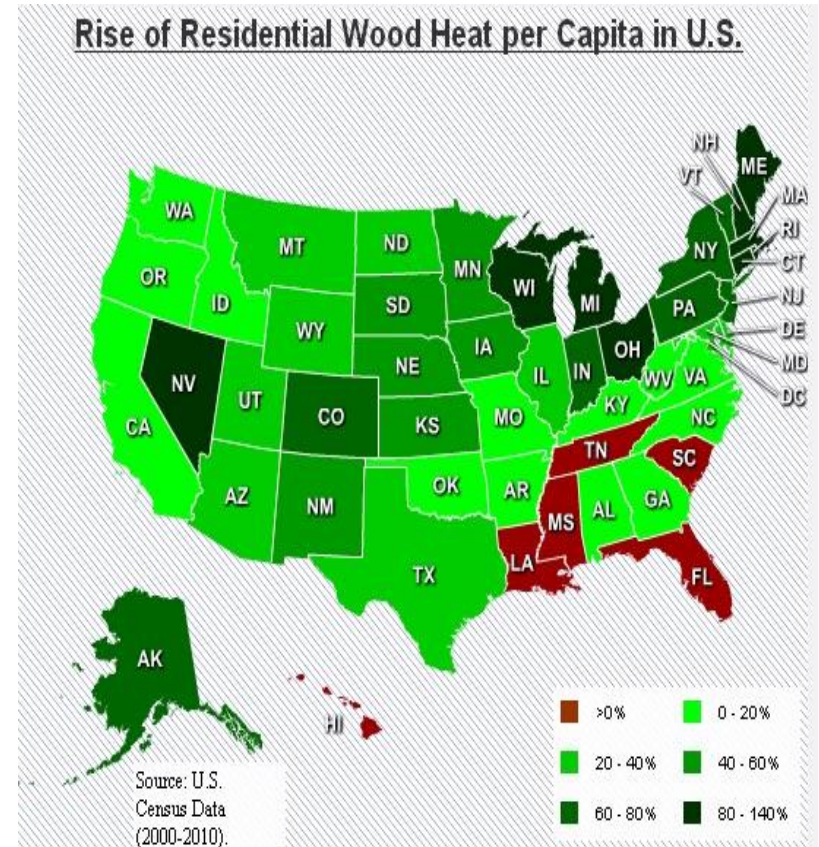
*Gillian Gawne-Mittelstaedt, MPA  
Director, Tribal Healthy Homes Northwest*

## Top 5 Concepts to Know and Communicate:

1. **Physiochemical properties** of woodsmoke and lung/environment interface
2. **Respiratory** outcomes - Particulates
3. **Infectious** outcomes – PAHs and immune suppression
4. **Chronic** exposure outcomes - mutagenic and carcinogenic properties of woodsmoke
5. **Cumulative** risk

- “Heating with wood ...is proving to be the **workhorse of residential renewable energy production.**”

*-John Ackerly, Alliance for Green Heat*



- The fluctuating and high cost of fossil fuels continues to put pressure on households.

August 27, 1990...

[Worcester Journal-World - Aug 27, 1990](#) [Browse this newspaper »](#) [Browse all news](#)

## Fuel worries reviving sales of wood stoves

**BOSTON (AP)** — Sales of wood stoves are heating up again as people worry about the rising cost of fuel for the winter.

Wood stoves have been both maligned and romanticized as having a certain pioneer mystique. While oil price hikes and tensions in the Middle East fanned sales in the 1970s and early 1980s, wood stoves also were the target of pollution restrictions and the source of fatal house fires.

Industry officials say stoves today have more sophisticated designs to remedy the old problems. Now wood stove makers and retailers are hoping to cash

stove sales exceeded 1 million around the start of the 1980s, as large and small manufacturers proliferated around the country.

"Anybody that had a welding shop was putting together a wood stove back then," Hermann said.

But for several reasons, the industry shrank quickly. Annual sales are now estimated around 225,000.

A big factor was the falling price of oil, which meant people no longer were looking for another energy source. Instead, wood stoves increasingly were bought for aesthetic reasons, which meant they were "competing with a new sofa or

December 6, 2012...

The CHRISTIAN SCIENCE  
MONITOR

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ENERGY VOICES INSIGHTS ON THE FUTURE OF FUEL & POWER

## Fighting winter with fire? Wood-burning on the rise.

The number of US homes relying on burning wood for heat is up 24 percent since 2006. But environmental concerns could quash further growth of wood-burning.

By David J. Unger, Correspondent / December 6, 2012



The number of homes relying on wood-burning as a primary heat source is projected to rise 3 percent this winter. Photo Credit: Pat Wellenbach/AP/File

Enlarge

- Wood heat largely an economic decision at the household scale.
- Wood heating **practices**, however, are based on intrinsic **beliefs and attitudes** about the relative harm or safety of wood smoke.
- Behaviors are difficult to modify in light of a thousand-year relationship with fire - food preparation, spiritual and cultural events, and basic survival.

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When we burn wood, the process is called “combustion”.

If the fire isn't hot enough, combustion “fails”, meaning unburnt material turns into **fine ash, smoke and hazardous gases.**



<b>carbon monoxide</b>	80-370	substituted naphthalenes	0.3-2.1
methane	14-25	oxygenated monoaromatics	1-7
<b>VOCs*</b> (C2-C7)	7-27	total particle mass	7-30
<b>aldehydes</b>	0.6-5.4	particulate organic carbon	2-20
substituted furans	0.15-1.7	<b>oxygenated PAHs</b>	0.15-1
<b>benzene</b>	0.6-4.0	Individual PAHs	$10^{-5}$ - $10^{-2}$
alkyl benzenes	1-6	<b>chlorinated dioxins</b>	$1 \times 10^{-5}$ - $4 \times 10^{-5}$
acetic acid	1.8-2.4	normal alkanes (C24-C30)	$1 \times 10^{-3}$ - $6 \times 10^{-3}$
formic acid	0.06-0.08	sodium	$3 \times 10^{-3}$ - $2.8 \times 10^{-2}$
nitrogen oxides	0.2-0.9	magnesium	$2 \times 10^{-4}$ - $3 \times 10^{-3}$
sulfur dioxide	0.16-0.24	aluminum	$1 \times 10^{-4}$ - $2.4 \times 10^{-2}$
methyl chloride	0.01-0.04	silicon	$3 \times 10^{-4}$ - $3.1 \times 10^{-2}$
naphthalene	0.24-1.6	sulfur	$1 \times 10^{-3}$ - $2.9 \times 10^{-2}$
		chlorine	$7 \times 10^{-4}$ - $2.1 \times 10^{-2}$



# Chemical composition of woodsmoke

- Carbon constitutes up to 40% of total PM
- Classified as either Organic Carbon (OC) or Elemental Carbon (EC)
- OC is generally the dominant constituent of PM<sub>2.5</sub> mass – usually present as a vapor – between 10 – 50% of the total mass concentration
- OC **fraction varies** - fuel being burned, combustion conditions.
- EC fraction - approximately **5-20% of woodsmoke particulate**

## Mineral particle

## Carbon aggregate

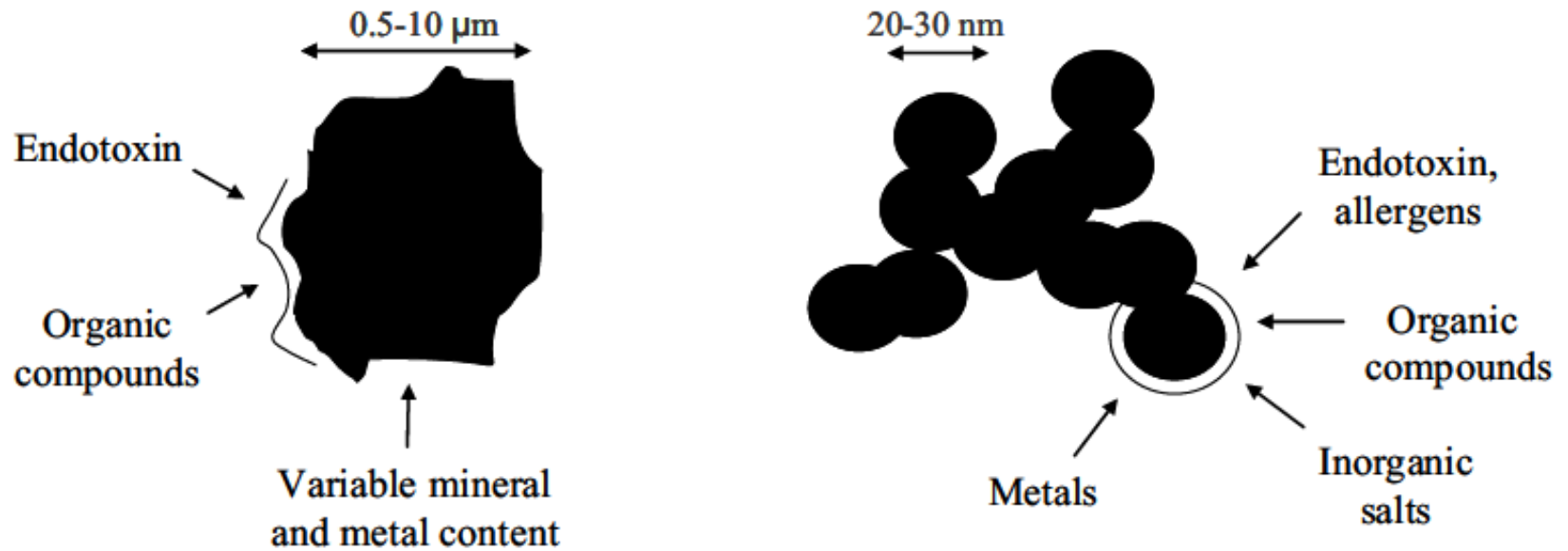


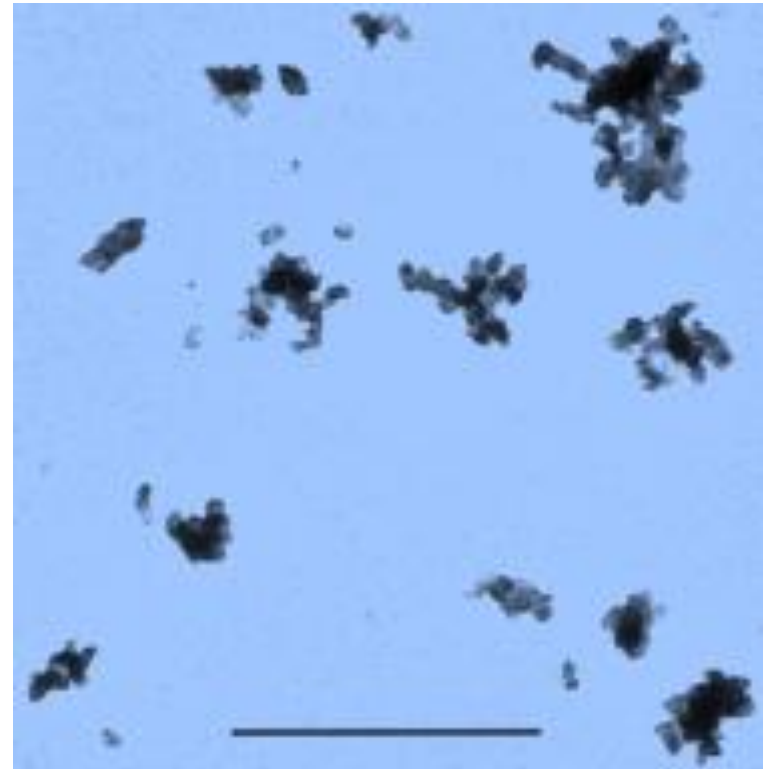
Figure 1: Schematic illustration of the differential characteristics of mineral particles and carbon aggregates.

**“The small diameters of the primary particles provide a large surface area per mass, which allows for adsorption of various compounds such as metals, organic compounds, allergens and endotoxins... Thus, carbon aggregates may act as carriers that transport toxic or biologically active compounds into the lung.**

(Dasch, 1982; Evans et al., 1981; Tesfaigzi et al., 2002). (Kocbach, 2008)

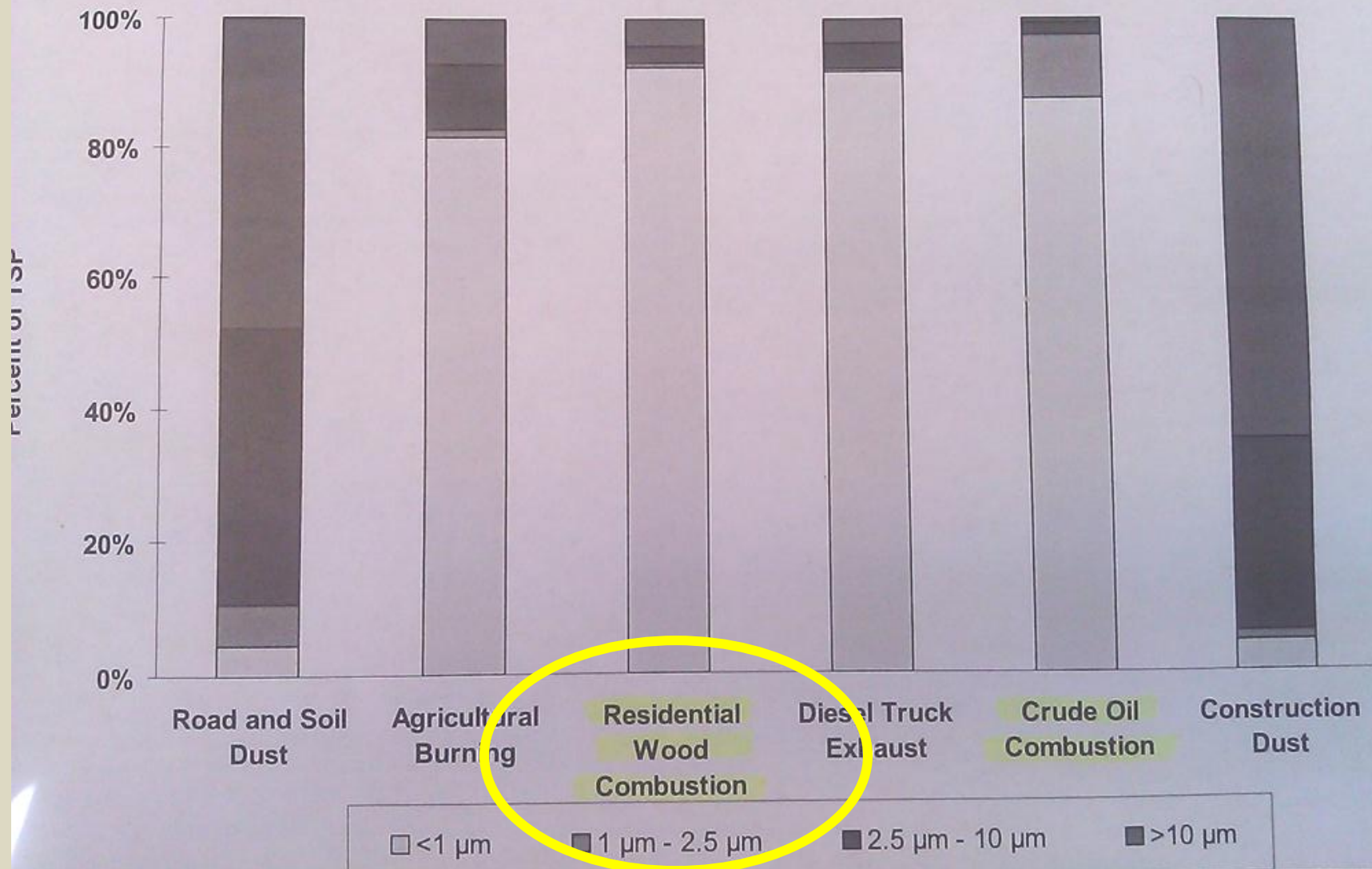
# Physiochemical Properties of Woodsmoke

Over 90% of woodsmoke particles are smaller than **1 micron** - behaving more like a gas than a particle.



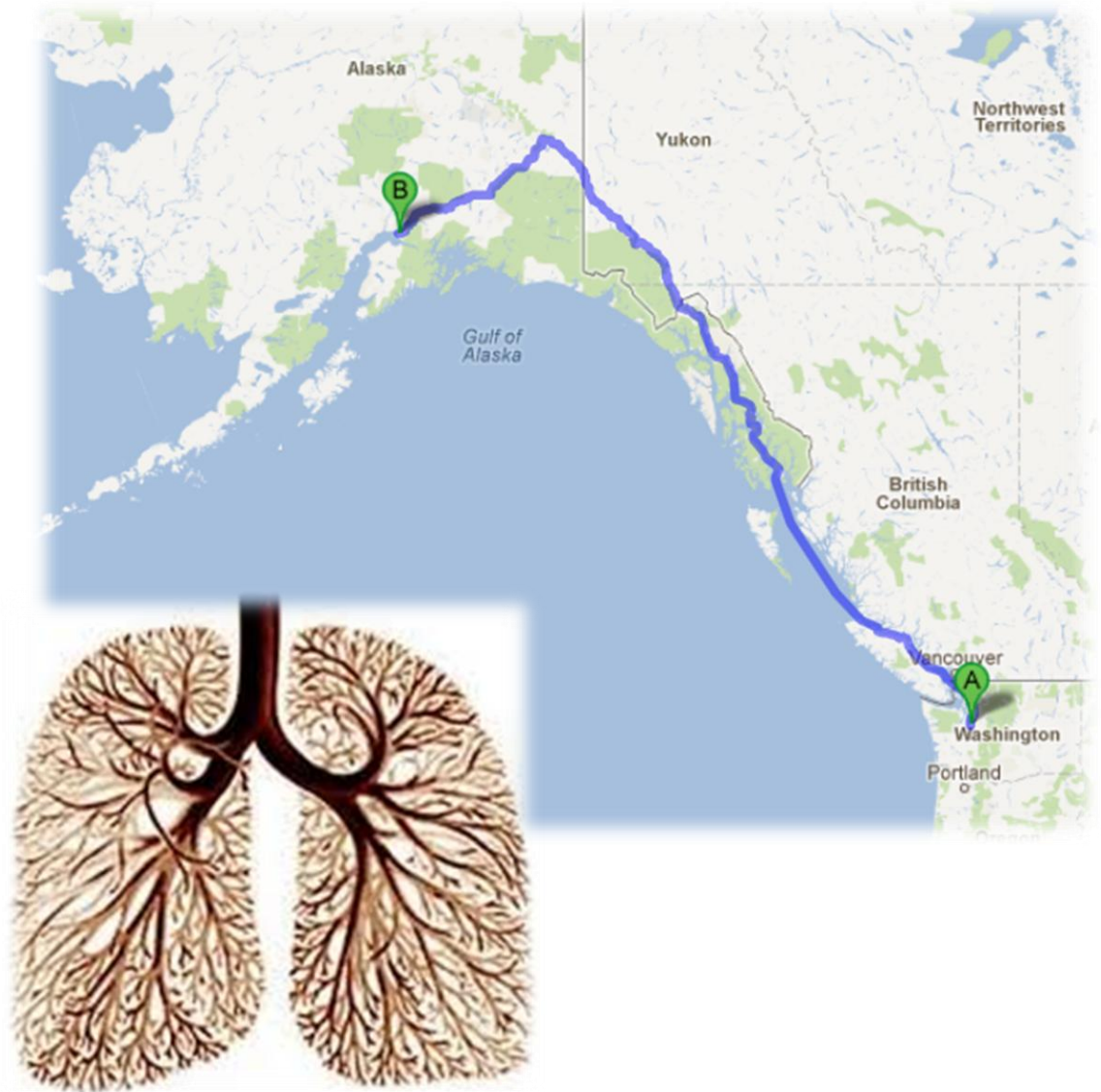
Electron micrograph of wood smoke particles. Bar = 1  $\mu\text{m}$ .

# Size Distributions of Several PM Source Emissions



This network (our “Respiratory System”) is enormous... almost **1500 miles of airways.**

Stretched out, they would reach from Seattle to Anchorage.



At the end of the tubes, we have thousands of tiny air sacs....

If you laid them out flat, they would **cover an entire tennis court,** or about 750 square feet.

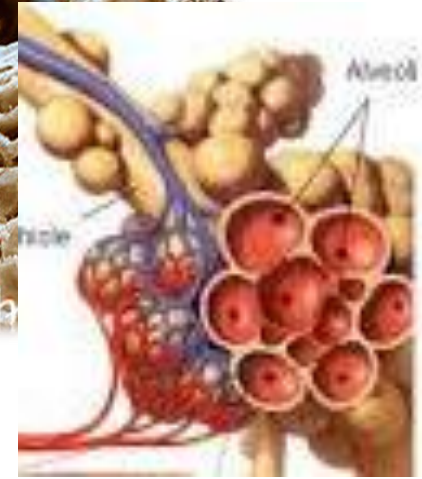


Surface area of the lungs is 80 times greater than the surface area of an average-sized adult's skin.



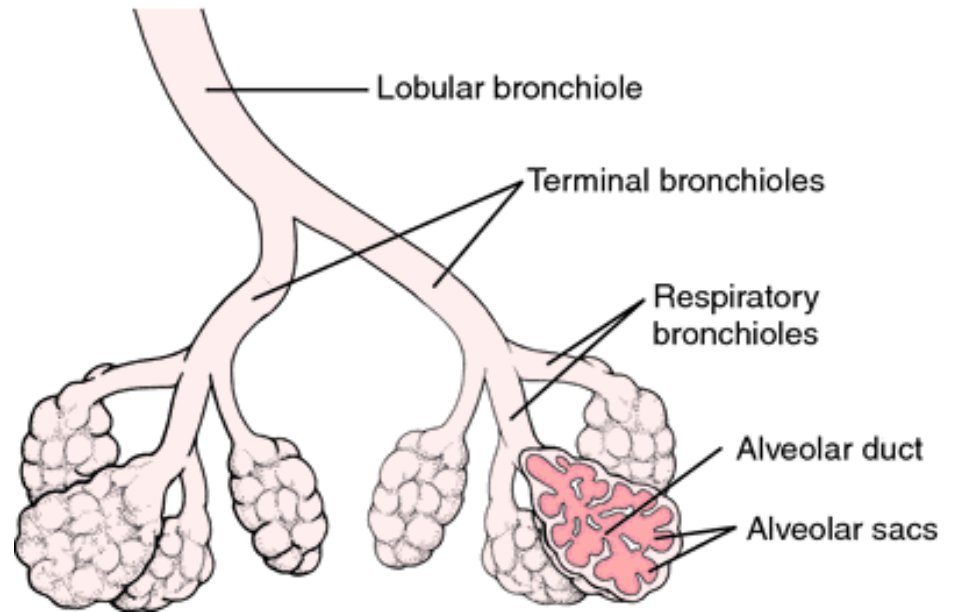


The air sacs are very thin.  
This pictures shows how these sacs look – *and act like* – a “gateway” ...

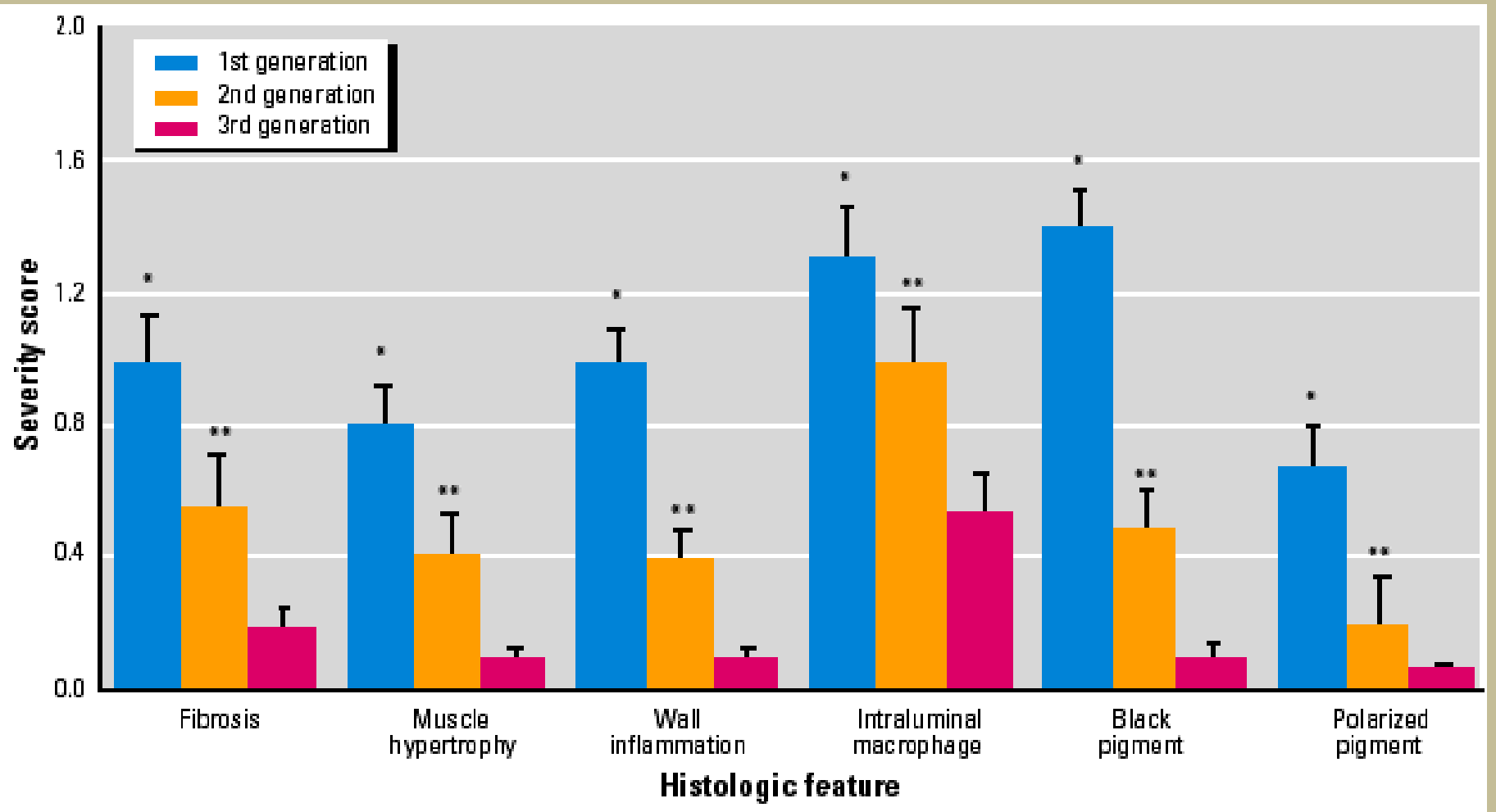


# Chemical composition

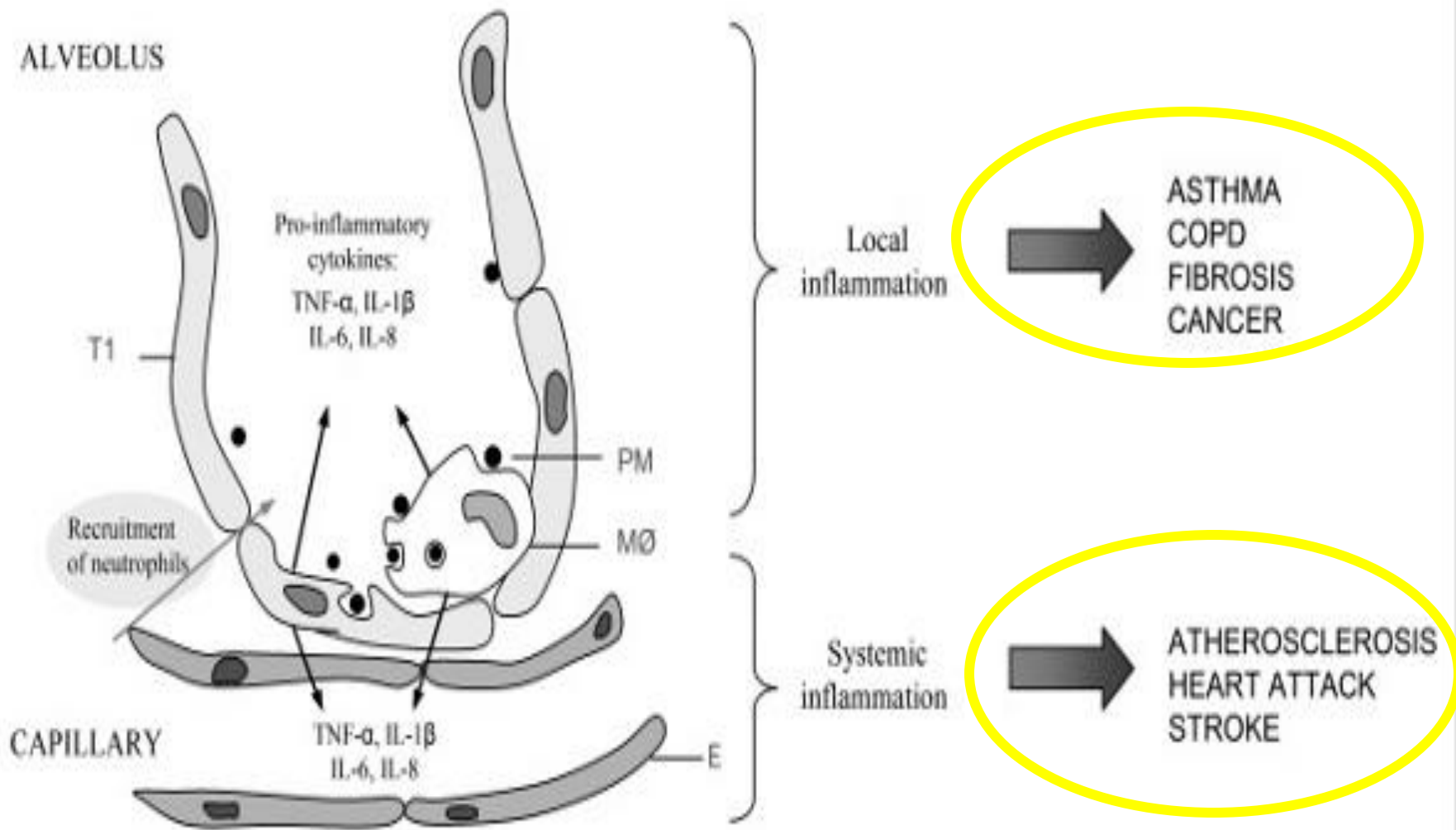
- The adverse health effects of inhaled particles are highly dependent on the **deposition and retention of particles in the lung.**



- Fine particles efficiently evade the mucociliary defense system and are deposited in the peripheral airways where they may exert toxic effects. *(Kirk et al, Berkley study, 2005)*



ALVEOLUS



Pro-inflammatory  
cytokines:  
TNF- $\alpha$ , IL-1 $\beta$   
IL-6, IL-8

T1

Recruitment  
of neutrophils

PM

M $\phi$

CAPILLARY

TNF- $\alpha$ , IL-1 $\beta$   
IL-6, IL-8

E

Local  
inflammation



ASTHMA  
COPD  
FIBROSIS  
CANCER

Systemic  
inflammation



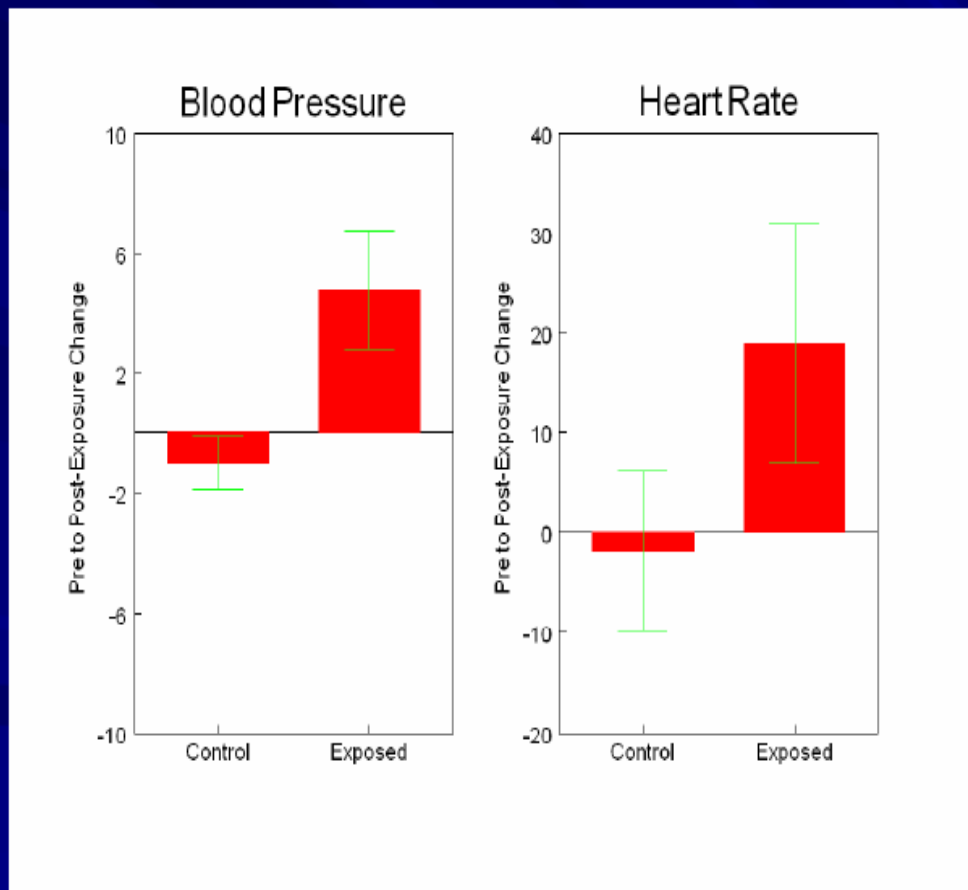
ATHEROSCLEROSIS  
HEART ATTACK  
STROKE

Woodsmoke is present in our bloodstream within **60 seconds** of inhaling it...

Minutes later, **carbon monoxide** can be detected in our blood and **benzene** is in our exhaled breathe.



# Blood Pressure and Heart Rate Were Increased After CAPs Exposures



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5. Cumulative risk

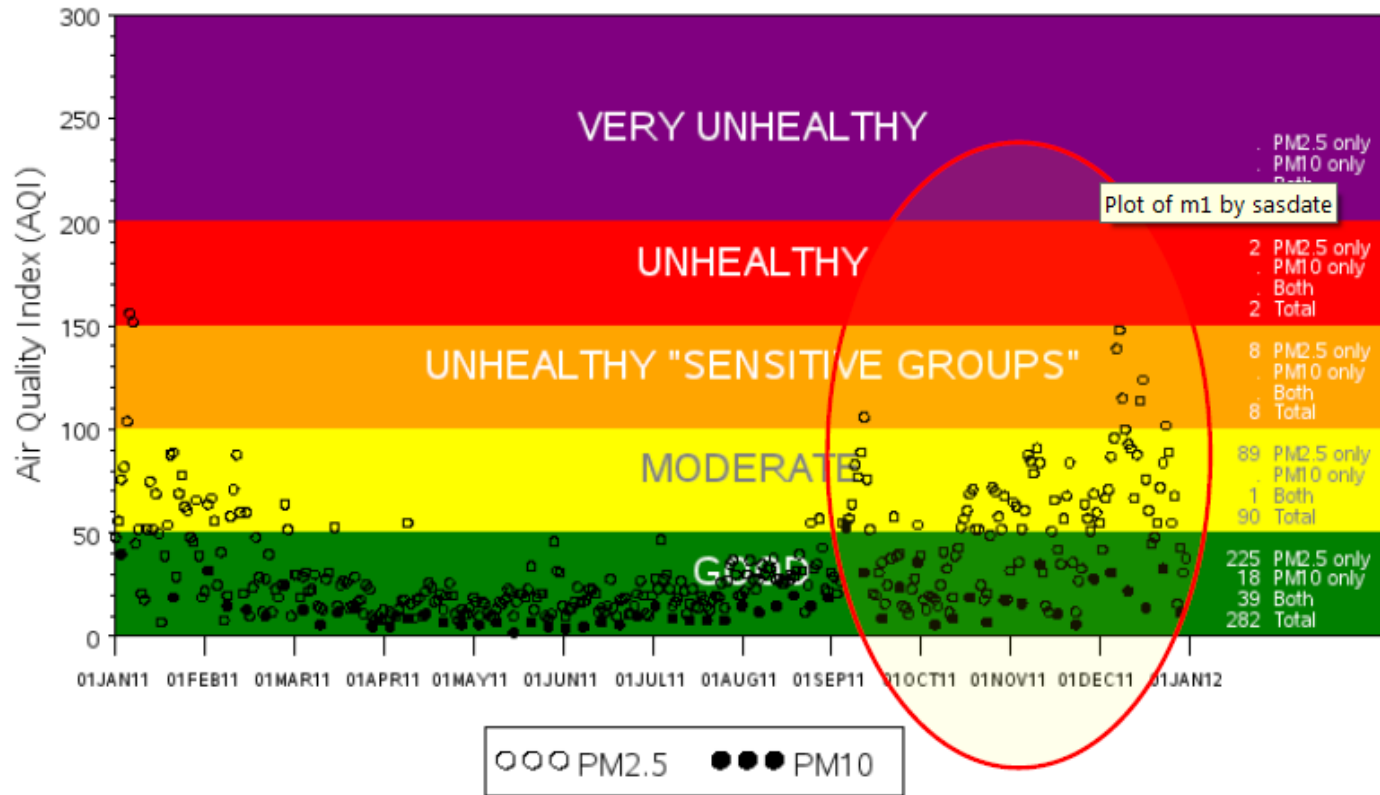


- Literature: Well established association between woodsmoke and asthma exacerbations.
- Epidemiological studies have associated exposure to particles less than 10  $\mu\text{m}$  in diameter with increased pulmonary and cardiovascular morbidity and mortality (*Franklin et al., 2007; Katsouyanni et al., 2001; Metzger et al., 2004; Ostro et al., 2006; Pope III et al., 2002; Zanobetti et al., 2000*)

- A range of pulmonary effects are documented and associated with PM exposure, including: **decreased lung development and function**, exacerbation of **asthma, allergy, chronic obstructive pulmonary disease (COPD)**, pulmonary fibrosis and increased **risk of lung cancer** (Alfaro-Moreno et al., 2007b; Borm and Donaldson, 2007; Kappos et al., 2004).

# Daily PM2.5 and PM10 AQI Values in 2011

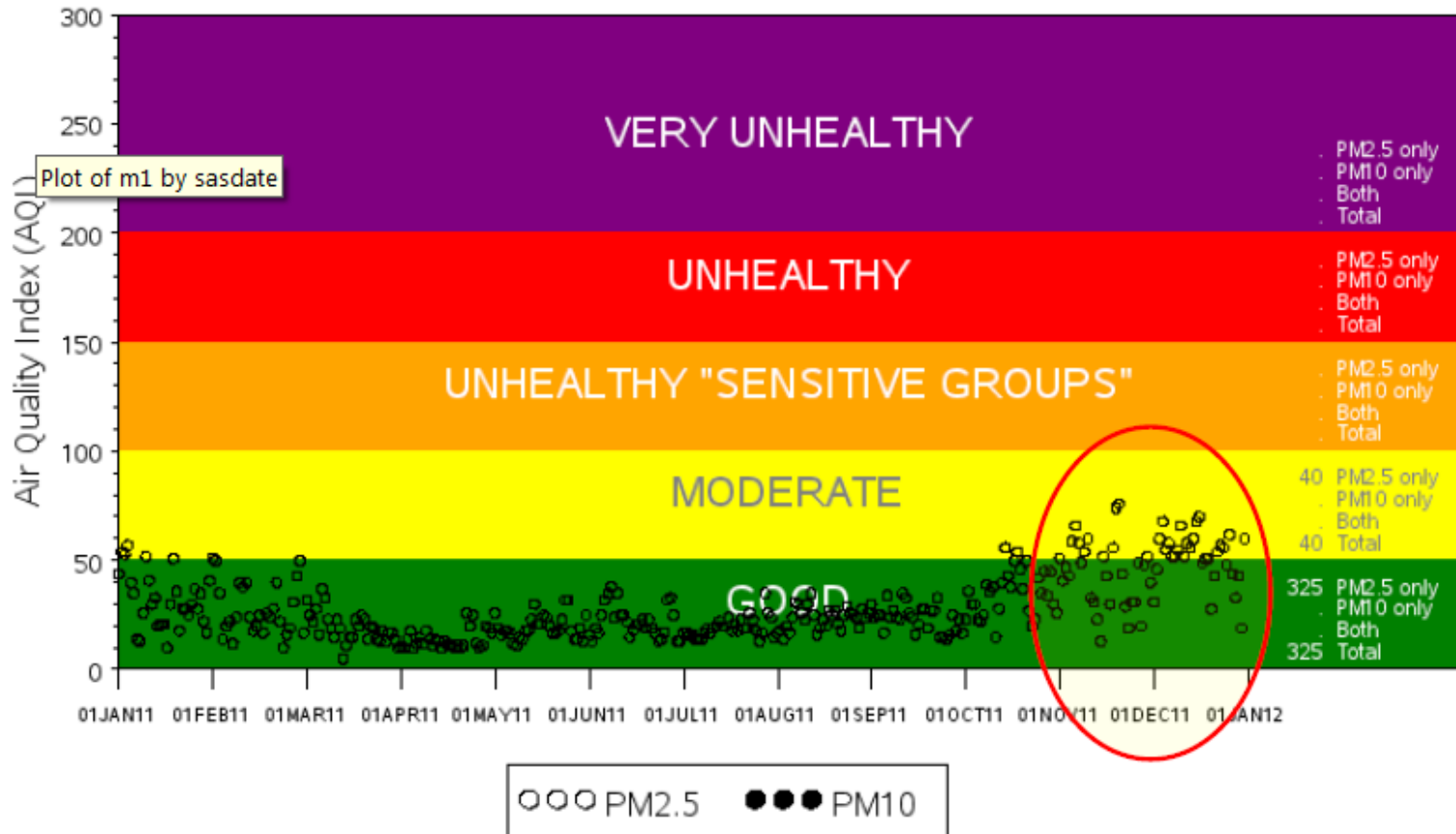
Yakima, WA



Source: U.S. EPA AirData <<http://www.epa.gov/airdata>>  
 Generated: July 30, 2013

# Daily PM2.5 and PM10 AQI Values in 2011

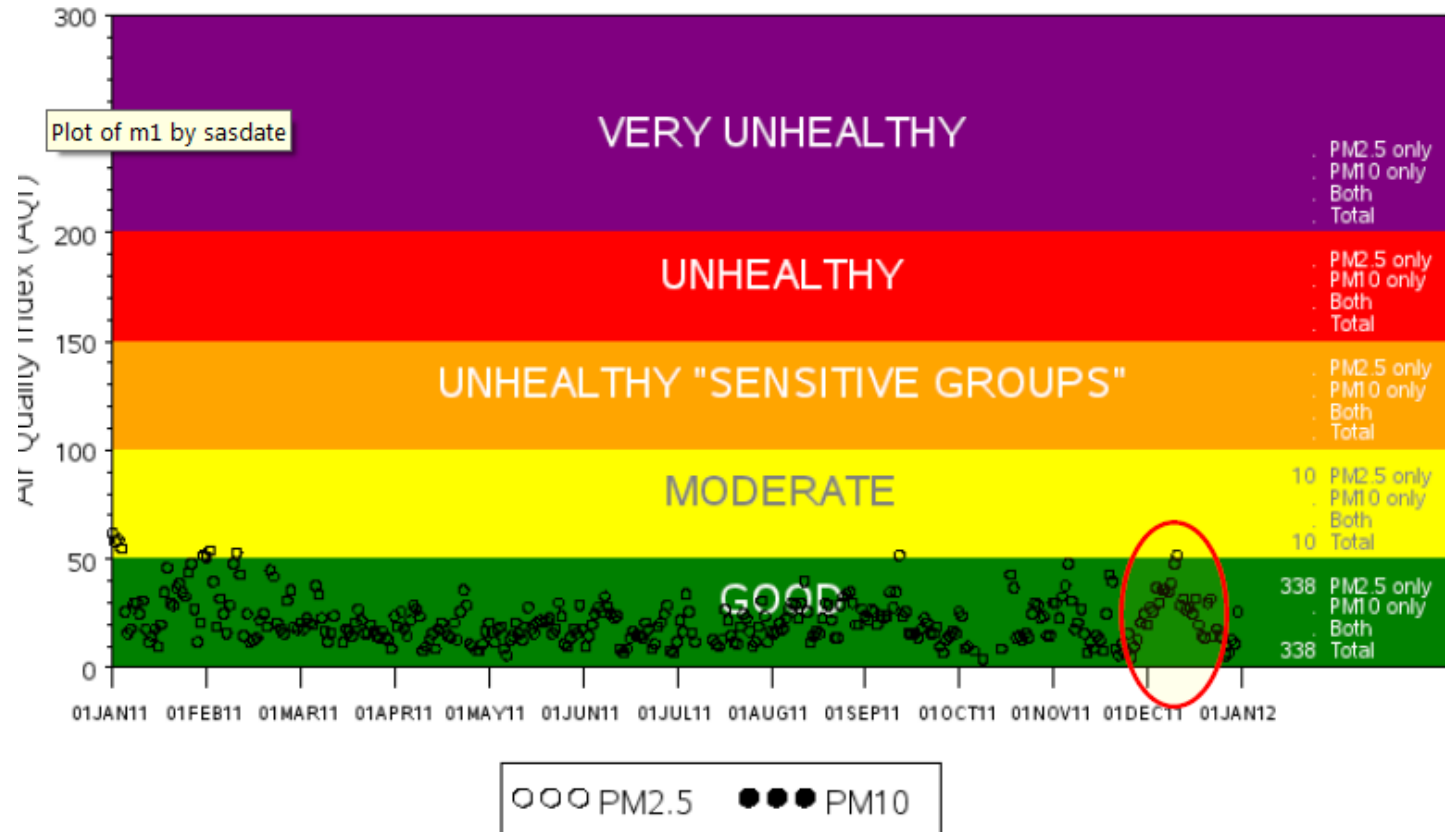
## Port Angeles, WA



Source: U.S. EPA AirData <<http://www.epa.gov/airdata>>

# Daily PM2.5 and PM10 AQI Values in 2011

Bellingham, WA



Source: U.S. EPA AirData <<http://www.epa.gov/airdata>>

202	BRONCHITIS & ASTHMA W CC/MCC	Yakima Valley Memorial Hospital	93	0.006
202	BRONCHITIS & ASTHMA W CC/MCC	Harrison Memorial Hospital	43	0.003
202	BRONCHITIS & ASTHMA W CC/MCC	PeaceHealth Saint Joseph Hospital	58	0.004
203	BRONCHITIS & ASTHMA W/O CC/MCC	Yakima Valley Memorial Hospital	147	0.010
203	BRONCHITIS & ASTHMA W/O CC/MCC	Harrison Memorial Hospital	66	0.005
203	BRONCHITIS & ASTHMA W/O CC/MCC	PeaceHealth Saint Joseph Hospital	107	0.007
204	RESPIRATORY SIGNS & SYMPTOMS	Yakima Valley Memorial Hospital	26	0.002
204	RESPIRATORY SIGNS & SYMPTOMS	Harrison Memorial Hospital	22	0.001
204	RESPIRATORY SIGNS & SYMPTOMS	PeaceHealth Saint Joseph Hospital	16	0.001

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# Immune Suppression and Infectious Outcomes

- Benzene...traditionally studied as carcinogen
- First relationship between asthma and benzene studied in Anchorage (Gordian et al)
- Respiratory morbidity and mortality associated with exposure to biomass combustion (in developing countries)  
– primary health outcome is infectious
- *Could benzene and its metabolites be a contributing but unexamined factor in the high rates of asthma in AI/AN populations?*



- “Our findings indicate that hospital admissions for childhood respiratory diseases, especially pneumonia, are associated with exposure to woodsmoke, PM<sub>2.5</sub> and its constituents.” *Naeher et al, 2007*
- “Despite the direct causes of pneumonia and other respiratory infections being biologic in nature, the effect of air pollution on the development of severe cases requiring hospitalization is especially plausible in children, because particulates likely hamper the ability of an already immature immune system to clear bacteria and other pathogens from the lung.” *Deitert et al, 2002*

....It would take 16,667 cigarettes to emit the same amount of benz(a)anthracene as burning 1 kg of wood. You would have to smoke 16,000 -222,000 cigarettes to produce the equivalent amount of PAH as burning 1 kg firewood in a correctly-operated heater. “- *Australian Air Toxics analysis*

# Benzene and Immune Dysregulation

Modulation of mast cell and basophil functions by benzene metabolites.

Triggiani M, et al.

“Both in vitro and in vivo studies indicate that benzene metabolites alter biochemical and functional activities of other immunocompetent cells and may impair immune responses in the lung. These inhibitory effects of benzene metabolites are primarily mediated by interference with early transduction signals such as PI3 kinase. Together, **currently available studies indicate that benzene metabolites interfere by multiple mechanisms with the role of basophils and mast cells in innate immunity and in chronic inflammation in the lung.**”

## Benzene from Residential Wood Burning

[Kjällstrand J](#), [Petersson G](#). *Phenols and aromatic hydrocarbons in chimney emissions from traditional and modern residential wood burning*. [Environ Technol](#). 2001 Apr;22(4):391-5.

The emissions from a traditional tiled stove consisted mainly of lignin-related methoxyphenols with antioxidant properties, and 1,6-anhydroglucose from cellulose degradation. A wood stove of presently introduced energy-efficient design for residential heating and hot-water supply was shown to emit small amounts of methoxyphenols and anhydrosugars from primary wood pyrolysis.

**Secondary harmful components like benzene and polycyclic aromatic hydrocarbons constituted a major portion of the organic emissions.**

It is concluded that differences in smoke composition are essential to consider in recommendations and rules for proper choices of wood burning devices.

## Benzene/PAH Exposure and LRTIs in Children

Hertz-Picciotto I, Baker RJ, Yap P-S, Dostál M, Joad JP, et al. 2007

Study indicates that “short-term exposures to PAHs may represent a significant public health threat to children...”

“Ambient PAHs and fine particles were associated with early-life susceptibility to bronchitis. Associations were stronger for longer pollutant-averaging periods and, among children > 2 years of age, for PAHs compared with fine particles. Preschool-age children may be particularly vulnerable to air pollution–induced illnesses.”

# Lower Respiratory Tract Infections (LRTI)

- High rates of RSV and LRTIs in AI/AN children < 1 yr/age
- RSV accounted for 14.4 percent of all American Indians/Alaska Native infant hospitalizations.

*American Lung Association State of Lung Disease in Diverse Communities 2010*

# LRTIs in Alaska Native Children

- 1 in 4 AN babies hospitalized each year
- Over 50% of children have Reactive Airway Disease
- Bronchiectasis still common
- High rates of invasive pneumococcal disease



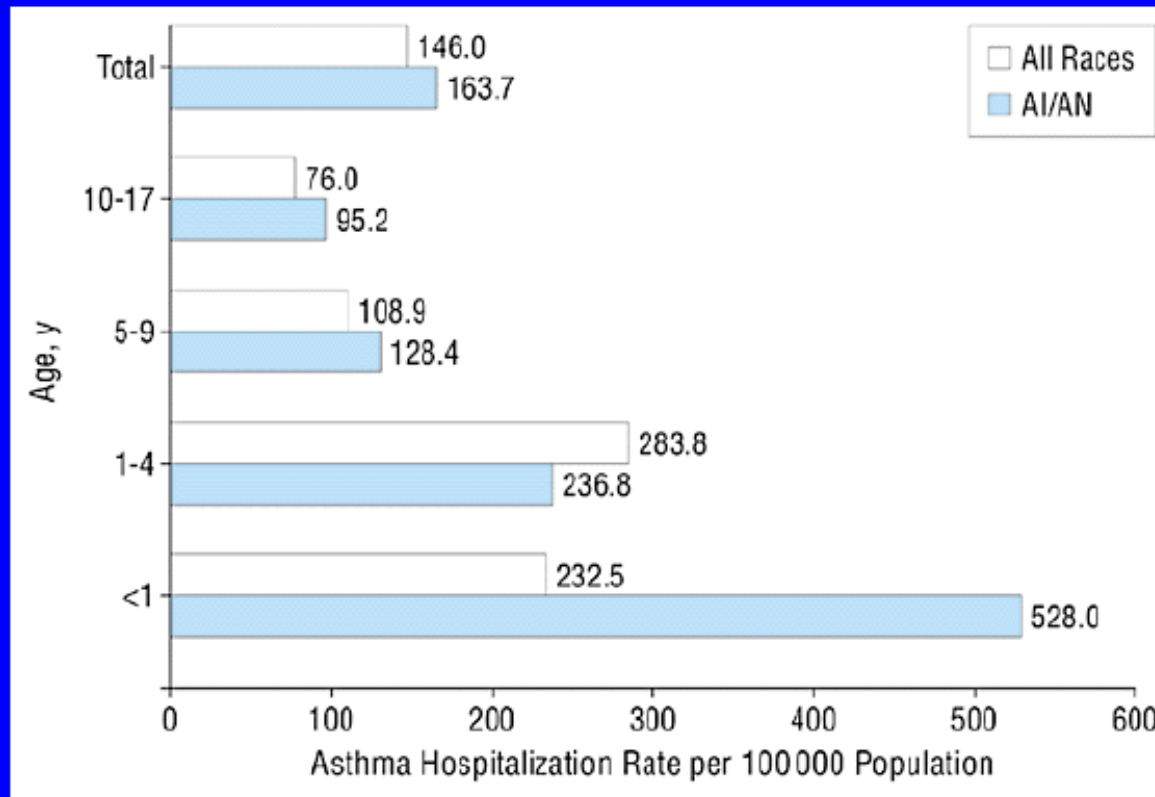
*Data and Photo Source: Yukon-Kuskokwim Delta. T. Ritter, Alaska Native Tribal Health Consortium*

## LRTIs in Native Children

- 58 Navajo children under 2 years with diagnosed pneumonia or bronchiolitis were compared with matched control children. Use of a wood burning stove was associated with a 4 times higher risk of lower respiratory tract infection ( $P < .001$ ). *Hogg JC Apr 1997*



## Asthma hospitalization by age: American Indian & Alaskan Native vs. All WA State children



Liu, L. L. et al. Arch Pediatr Adolesc Med 2000;154:991-996.

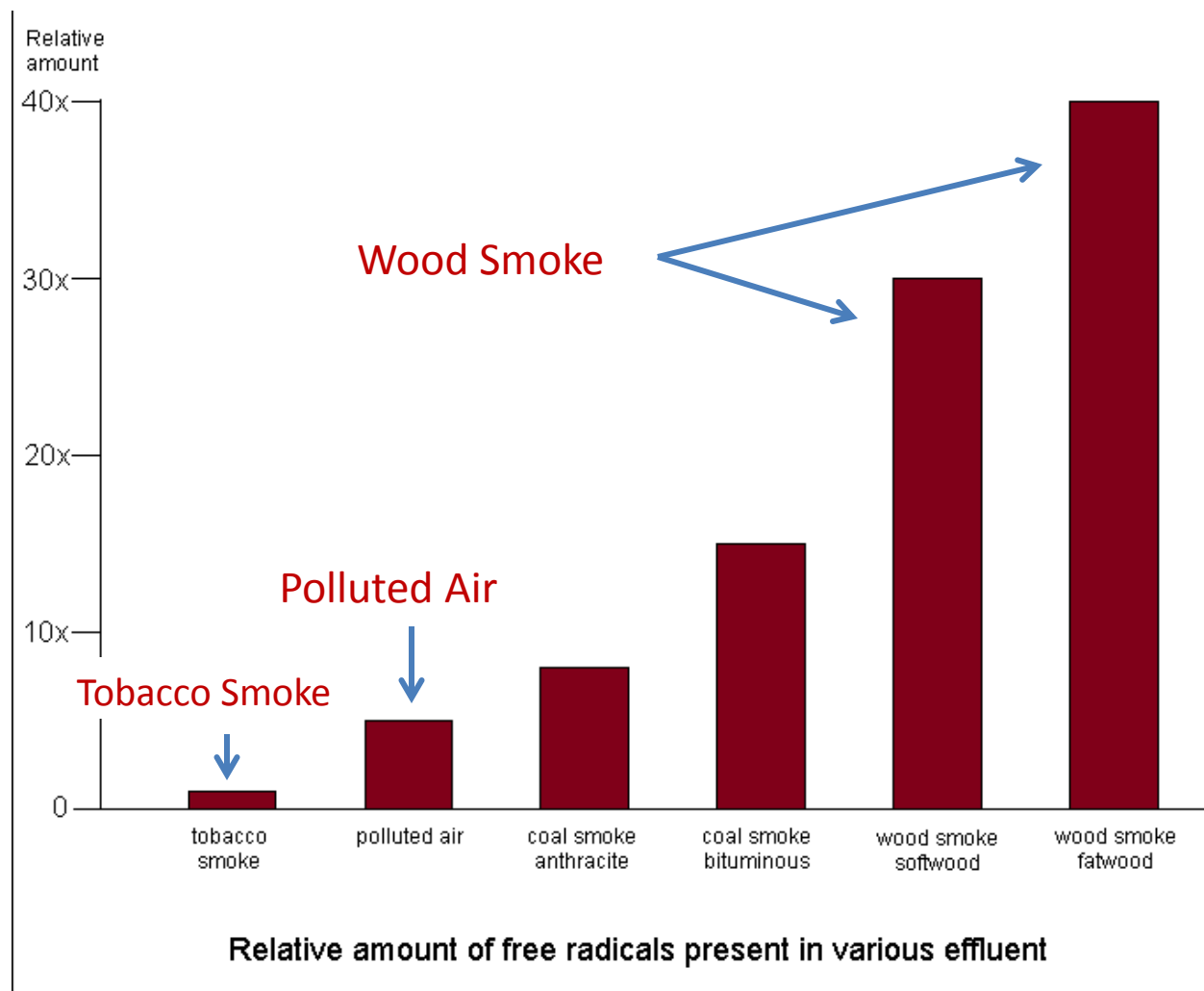
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& ADOLESCENT MEDICINE

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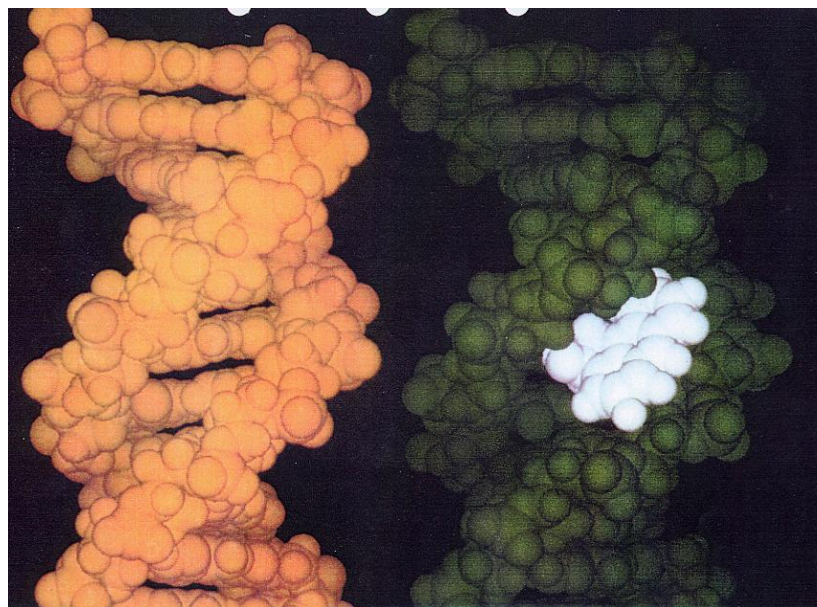
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Compared to other pollution sources, woodsmoke contains **very high levels of DNA-damaging free radicals.**



“...wood smoke particulates were found to be more powerful than other kinds of air pollution in causing potentially cancerous changes to DNA and “activating genes linked to inflammation and oxidative stress, which is a possible mechanism for atherosclerosis, asthma and other diseases.” Journal of [Chemical Research in Toxicology](#) Steffen Loft, researcher at the University of Copenhagen.

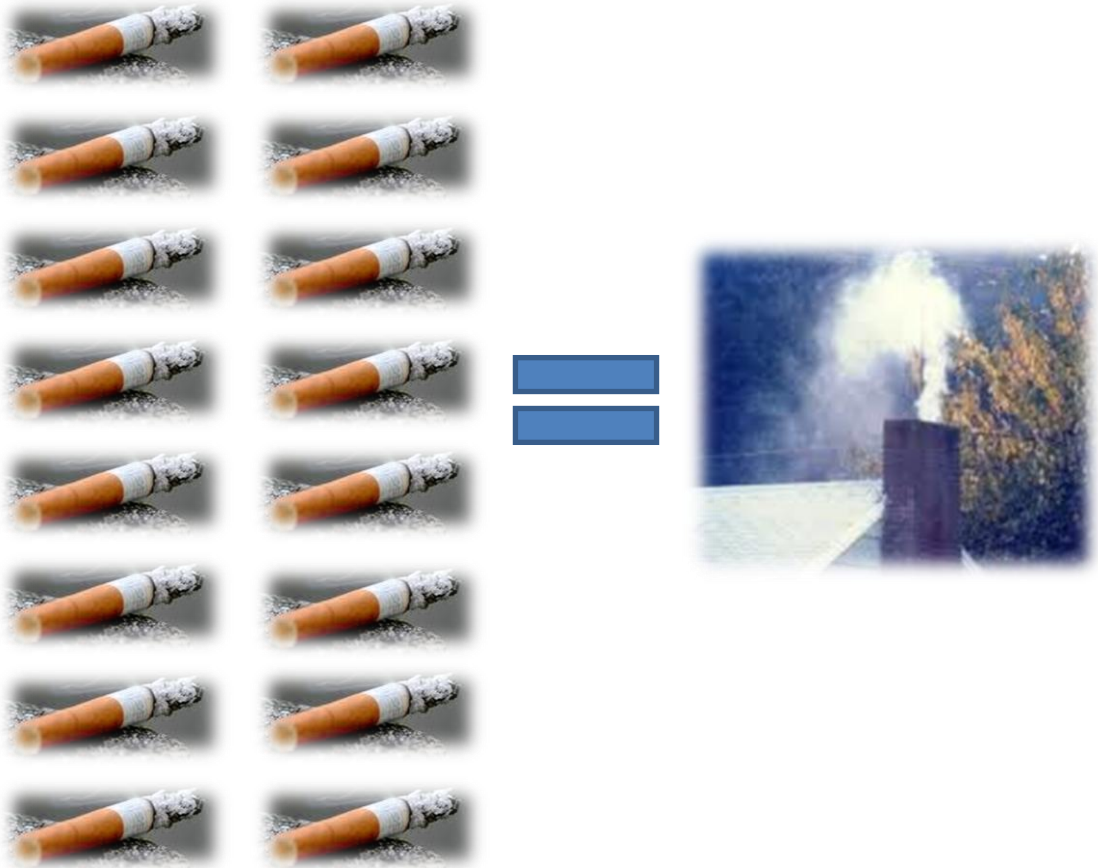
The white area shows where cancer-causing woodsmoke chemicals altered and damaged the DNA in lung cells.



Older woodstoves  
give off over 350  
grams of fine  
particles an hour, or  
20lbs/day...



An EPA study found that **breathing woodsmoke during a high pollution day is the same as smoking 4 to 16 cigarettes.**



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# Cumulative Risk

- Complex mix of coarse, fine and ultrafine particles from combustion of fossil fuels (diesel) and woodsmoke.
- Near-roadway – *strong association with lung impairment*
- Residential and School
- Transportation
- Rural and urban

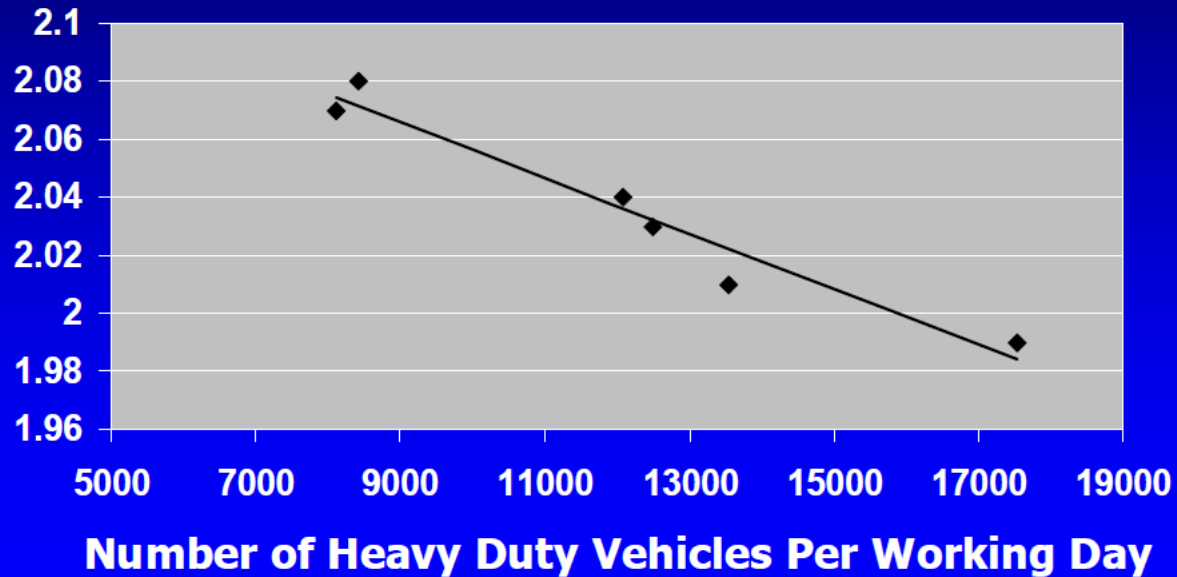


Those with impaired lung function become **highly susceptible to infection**, including **chronic bronchitis, pneumonia, and lung cancer**

Those with “hyper-reactive” airways can be irritated by toxins, but also have greater susceptibility to **permanently remodeled airways - affecting long-term health and life span**

## Local Exposures: Living within 300m of major roadways affects lung function

Lung Function  
FEV1 (Liters)



(Brunekreef et al 1997, Netherlands)



Investigators conducting a study of 756 **inner city children** determined that **exposure to heavy traffic is associated with the ability to achieve and maintain asthma control.**

*Peter N. Huynh, M.D., San Marino, Calif., et al*



## Best Practices to Reduce Risk:

- Drying the Fuel
- Maintaining the Woodstoves
- Ventilating the Homes
- Educating Residents on Effective Burning Practices

## Two Questions to Consider for Cumulative Risk and Future Policy Reform:

1. Are we accurately measuring risk through our current air quality data collection methodology and infrastructure? – (Speciation and composition of PM)
2. Are we reasonably regulating for risk? “Ambient” vs “Household”

# Recommended Reading...

- Breaking Patterns of Environmentally Influenced Disease for Health Risk Reduction: Immune Perspectives [Rodney R. Dietert](#),<sup>1</sup> [Jamie C. DeWitt](#),<sup>2</sup> [Dori R. Germolec](#),<sup>3</sup> and [Judith T. Zelikoff](#)<sup>4</sup>

“The recent identification of major immune-based disease patterns beginning in childhood suggests that the immune system may play an even more important role in determining health status and health care needs across a lifetime than was previously understood.”

## Contact Information:

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