

Smoke gets in your Eyes, and Lungs, and...

Harriet M. Ammann Ph.D.

**Diplomate of the American
Board of Toxicology**

Smoke makes such a pretty picture!





Smoke, even from “controlled burns” adds to the smoke burden of the air shed and impacts the health of people who breathe it

Controlled Field Burning



Wild Fire Smoke/ Controlled Burn



08/10/2005

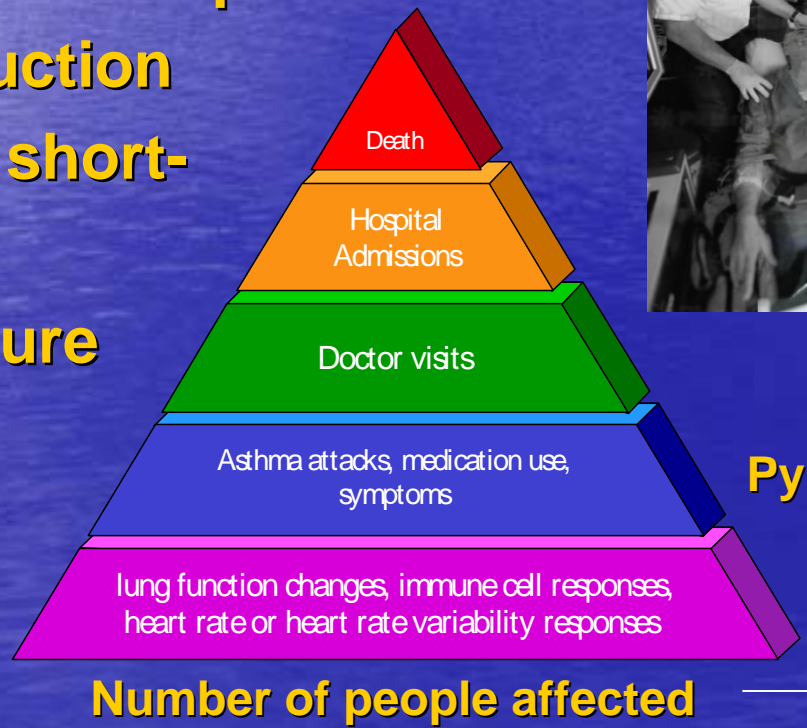
**Those most at risk:
children, elder, ill people with
heart disease, diabetes, lung
disease.**





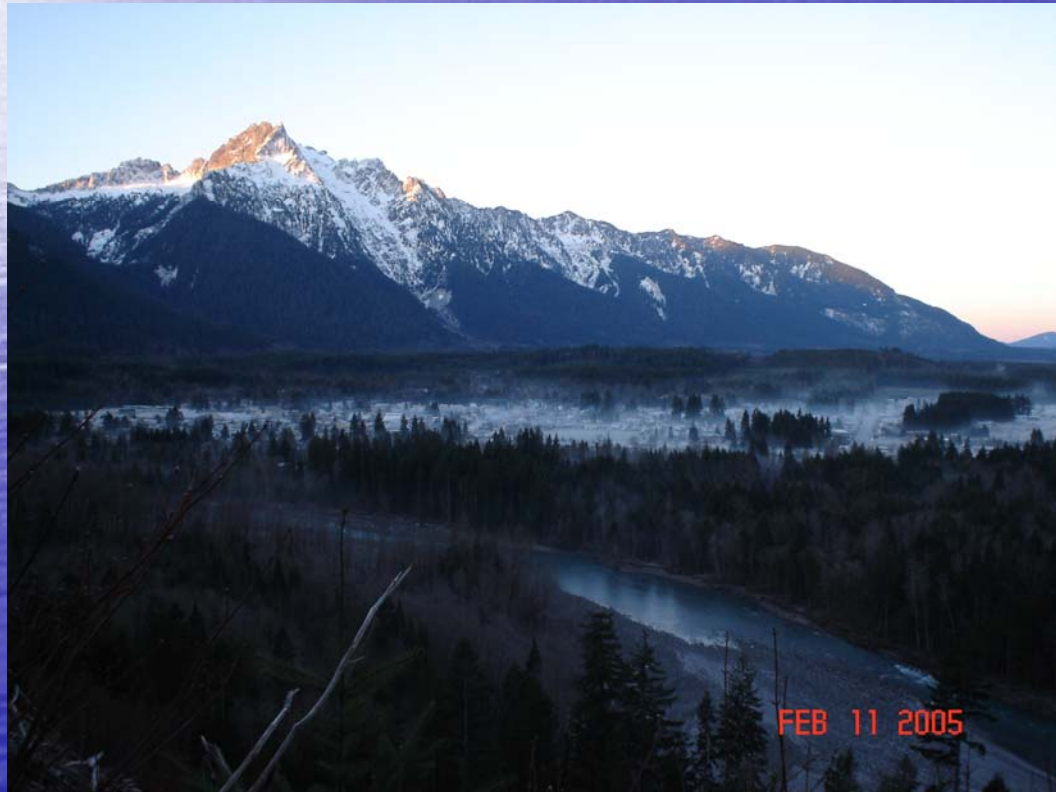
Over-all Effects:

- Watery eyes
- Irritated respiratory tract
- Reduced lung function
- Increased hospitalization for lung and heart problems
- Cancer induction
- Death from short- and long-term Exposure



Pyramid of Effects

Weather and time-of-day effects

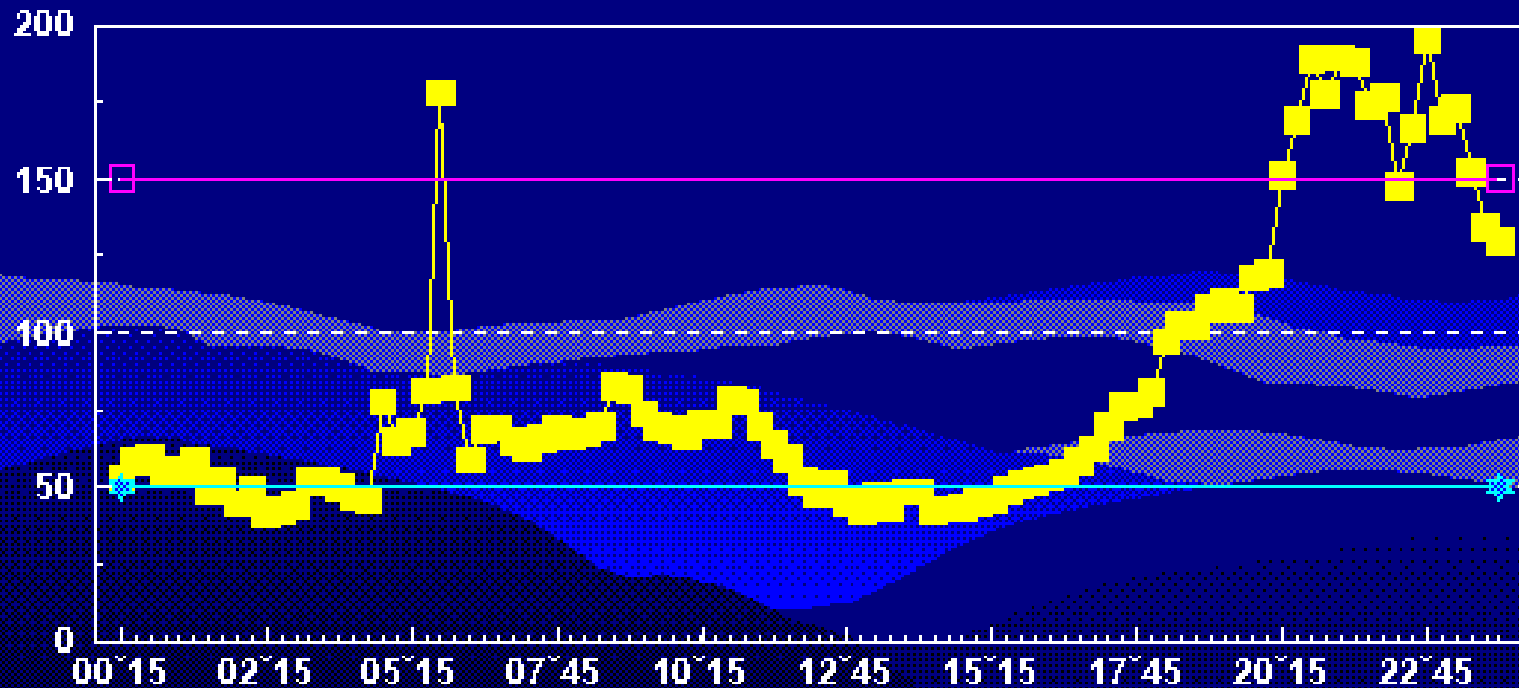


- The colder the day, the more woodstove/fireplace use and emissions
- The less atmospheric circulation, the higher the PM levels
 - Residential wood smoke in Olympia accounted for 50% to 85% days of PM on clear days
- 80-90% of the PM measured in the PS area ambient air was due to use of wood burning devices during nighttime hours

Nighttime Burning - Jan. 9, 1992

Particulates

Micro Grams / Cubic Meter



Smoke is a local and regional problem: accumulates in low areas



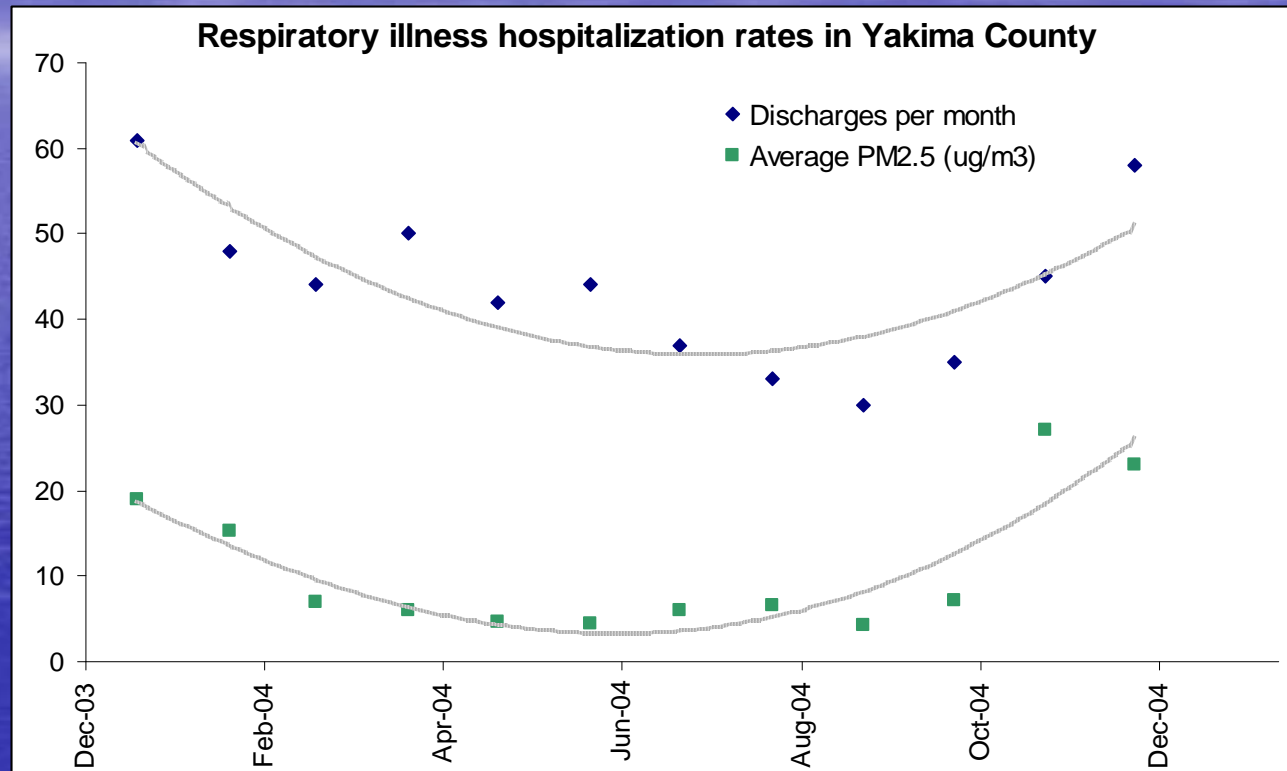
Topography effects

**Wood Smoke
concentrates
near valley
floors with a
consistent
factor of two or
three times
between
ridgeline and
valley smoke
levels**



The Yakima area is especially prone to high PM levels

A close association between PM_{2.5} levels and days in hospital for respiratory illnesses is evident



Inversions put the Lid on

- Lower-lying areas have much higher smoke values during temperature inversions: the cold air layer acts like a lid and lack of wind won't let smoke blow away



What's in Smoke and What are the Impacts?

- **Smoke particles:** small, less than one micron in diameter; behave like a gas
- Penetrate indoors and deep into the lung
- **Have high surface area:** adsorb other combustion products, catalytic surface
- **Gaseous pollutants:** CO, NO_x, SO_x, irritant gases (i.e., aldehydes)



What is smoke made of?

- **Gaseous pollutants: CO, NO_x, SO_x, irritant gases (such as aldehydes)**
- **Particles are a complex mixture of extremely small solids and liquid droplets; behave like a gas and have high surface area: adsorb other combustion products act as a catalytic surface for Free Radical formation**

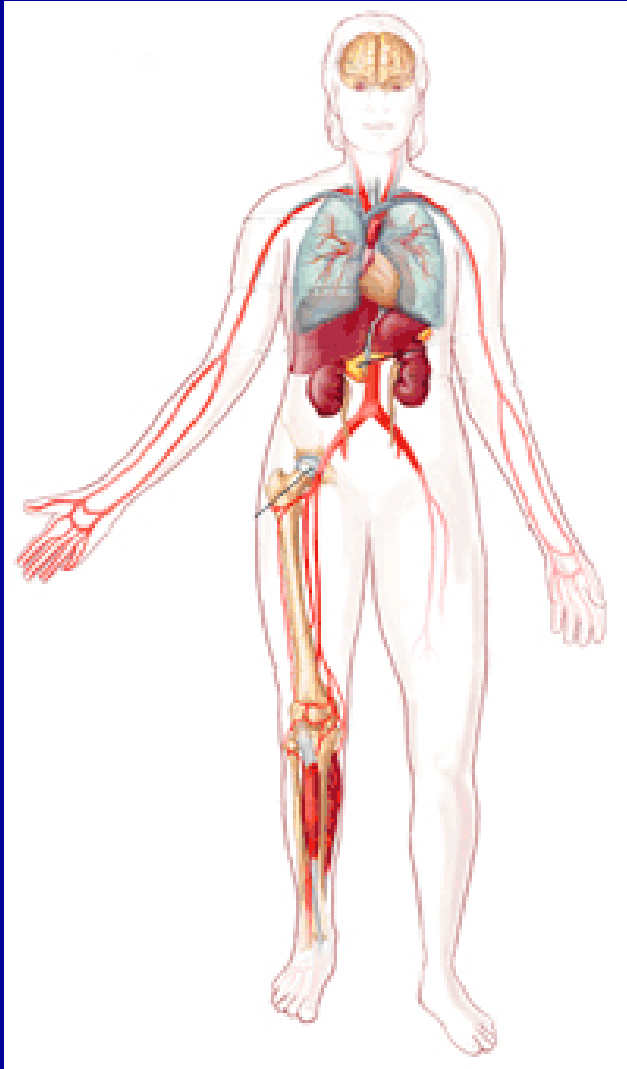
Fine particle health effects

- Smoke particles of 1 micron and smaller enter indoors, and penetrate deep into lungs, where defenses are few
- More than 2000 toxicological and epidemiological studies: **FINE PARTICLES** cause death and illness from both long term low level concentrations as well as air pollution episodes

Volatile and Semivolatile Organic Compounds

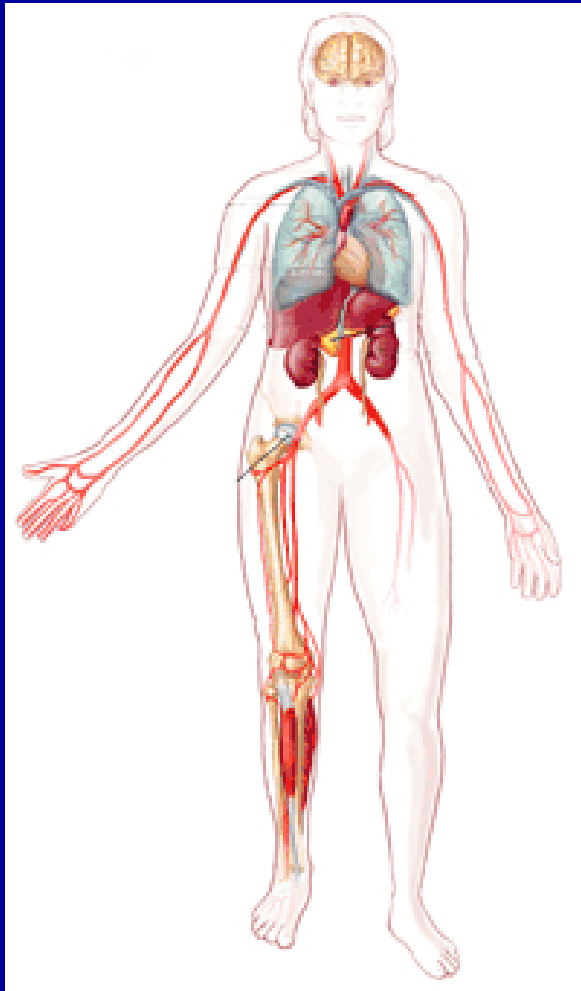
- **Semivolatiles: Formaldehyde, acrolein**
 - highly irritating to eyes and respiratory membranes
- **Volatiles:**
 - **BTEX = benzene, toluene, ethylbenzene, xylenes**

Acrolein (an aldehyde)



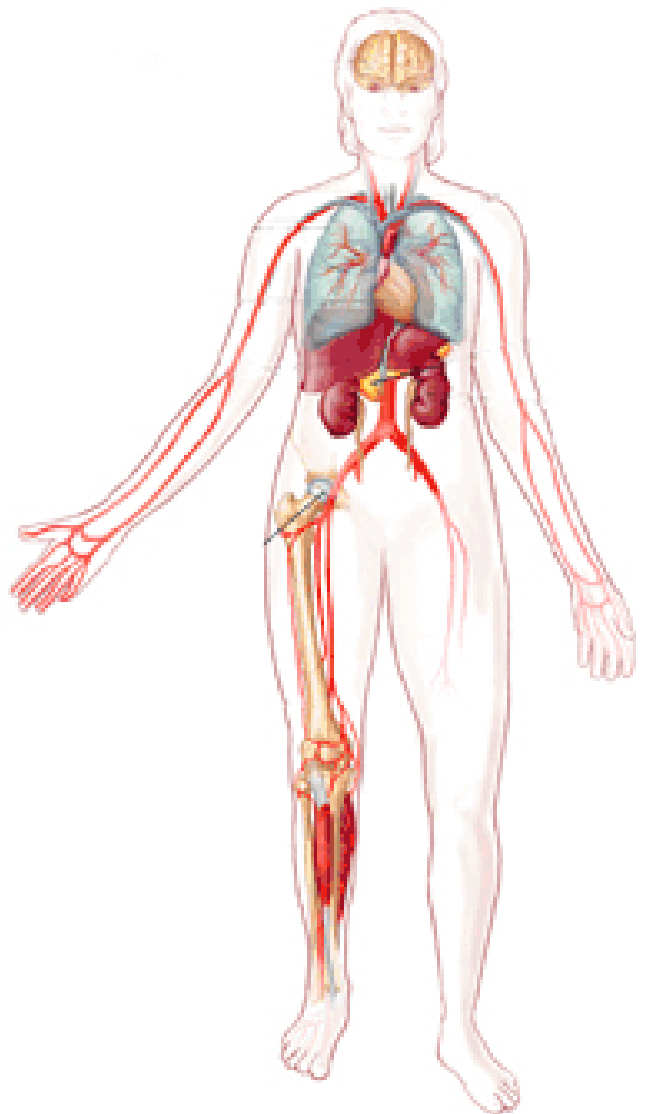
- Short term symptoms include stinging and tearing eyes, nausea and vomiting.
- Long term exposure risk is: Chronic respiratory disease

Formaldehyde



- Short term symptoms include irritated eyes, nose and throat.
- Inflammation of mucous membranes
- Long term exposure risk is nasal and nasopharyngeal cancer.

Benzene



- Short term symptoms are headaches, dizziness, nausea and breathing difficulties respiratory , eye irritation
- Long term exposure risks are anemia, liver and kidney damage, and cancer, especially leukemia, changes in blood cell ratios.

Carbon Monoxide

- **Binds to hemoglobin 240 times more avidly than oxygen**
- **Affects *high demand organs* most: brain = one-fiftieth body weight, uses one fifth of body oxygen**
- **Heart :heart and circulatory system patients most sensitive**

Carbon Monoxide: the Great Imitator

- **Headache, malaise, nausea**
- **Irritability, decreased attention, memory loss, sleep deficits, increased aggressiveness**
- **More frequent chest pain in cardiac patients**
- **Loss of consciousness, coma, death**

Nitrogen Dioxide

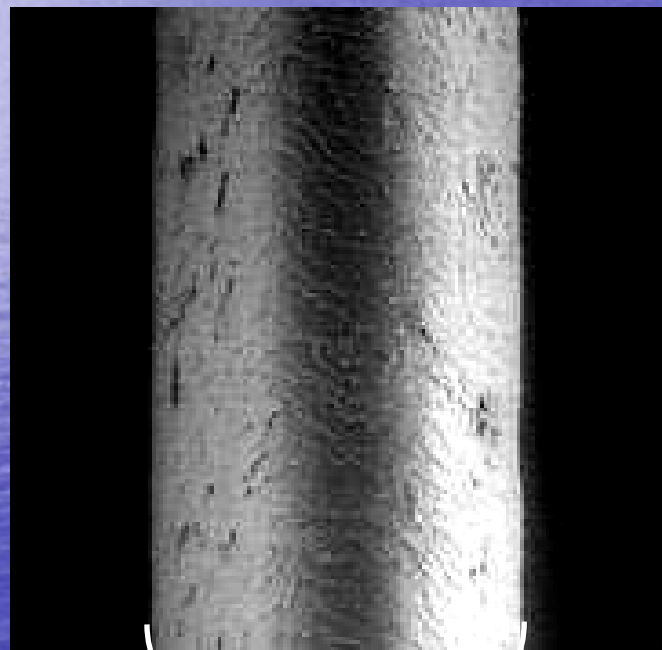
- Results from high temperature flames: gas, tobacco, diesel hot wild fires
- Respiratory, eye irritant
- Immune suppresser
- Decreases mechanical respiratory defenses (mucociliary escalator)

Combustion Particles

- **Most closely related to health effects (may act as surrogate for many air pollution effects)**
- **Very small (less than a tenth of a micron); distribute widely (NAAQS); go indoors**
- **Adsorb and carry other toxic combustion products on their surface and deep into the lung.**
- **Measured as and called PM_{2.5} (but are mostly very much smaller, < 1 micron)**

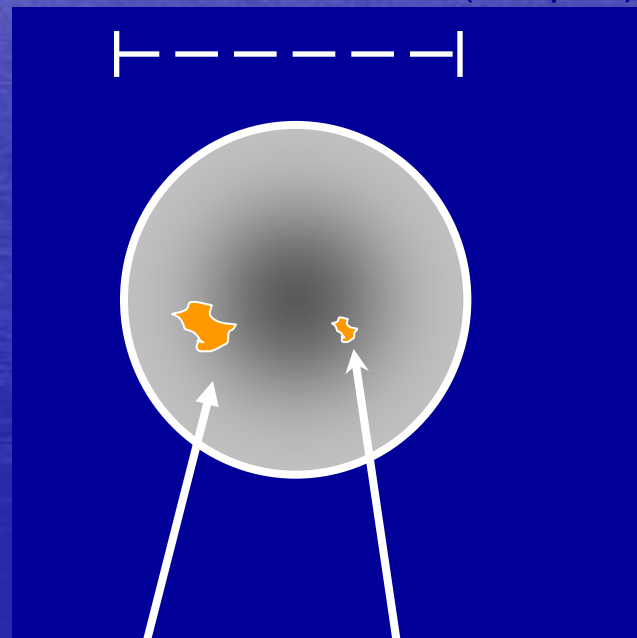
Particles: What Are They?

Airborne particles are a complex mixture of extremely small solids and liquid droplets



Human Hair (70 μm diameter)

Hair cross section (70 μm)



PM₁₀
(10 μm)

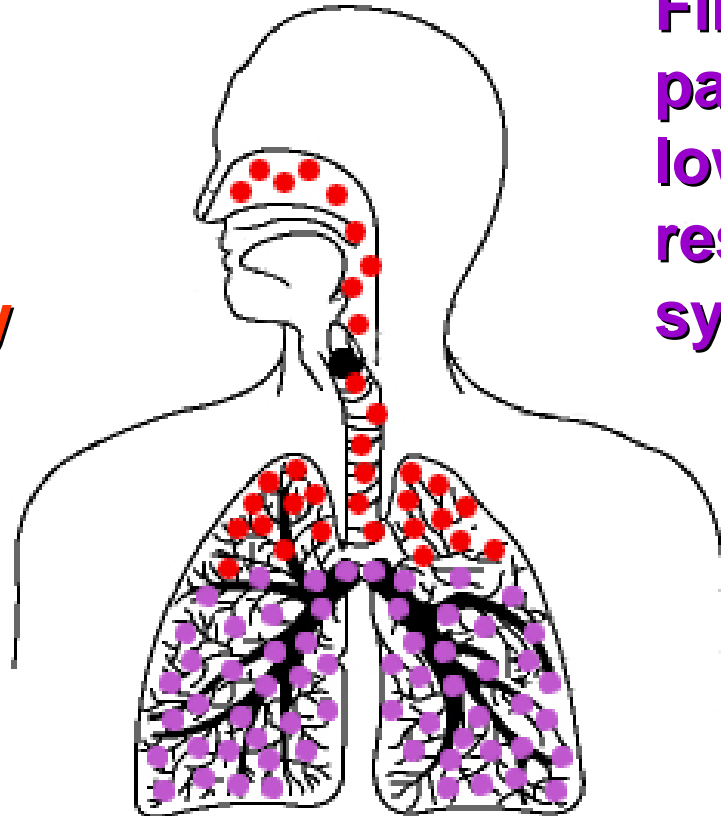
PM_{2.5}
(2.5 μm)

Size matters

- **Fine and ultra-fine particles behave like a gas:**
 - penetrate indoors from outside air**
 - penetrate deep into lungs**
- **Fine particles have greater aggregate surface area**
- **Adsorb toxic combustion products, metals, atmospheric air toxics, carry them deep into the lung; are a catalytic surface for free radical, reactive oxygen species formation**

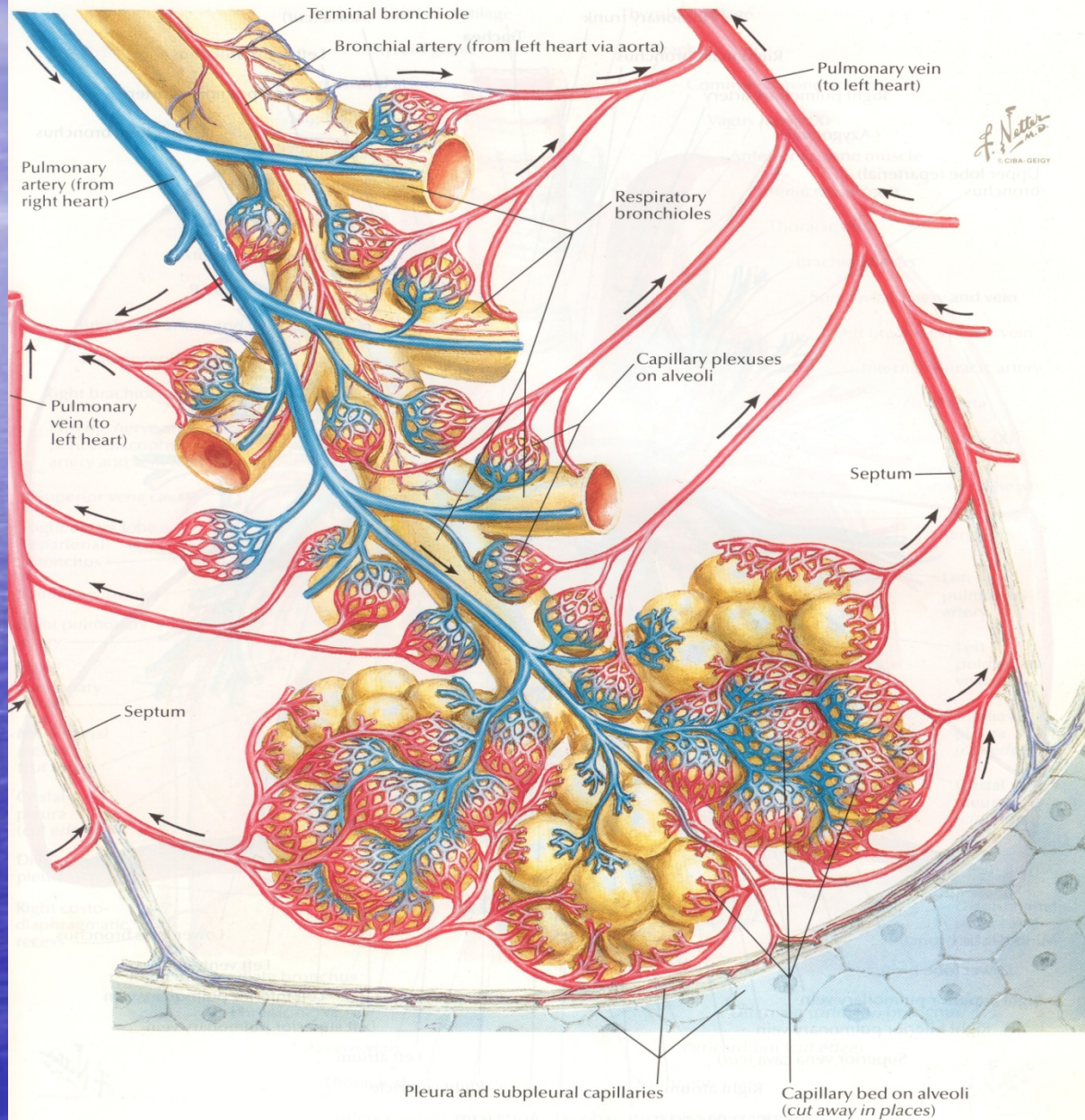
Respirable Particles

**Coarse
particles =
upper
respiratory
system**



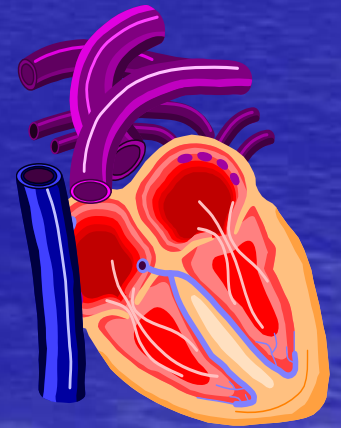
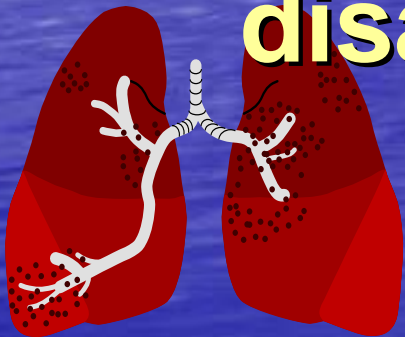
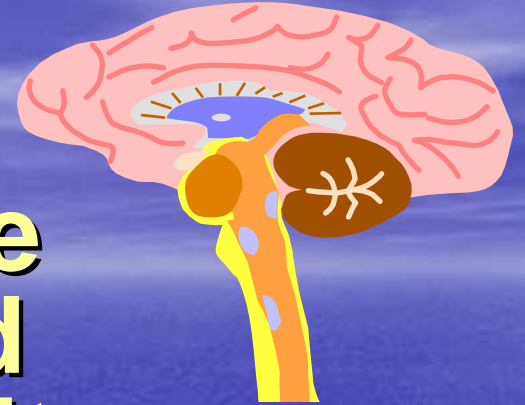
**Fine
particles =
lower
respiratory
system**

Main Branch Intrapulmonary Blood Circulation: Schema



Health Effects

Can range from those that are **transient** and only affect productivity to those that are long-term and **produce chronic or severe effects or even disability, and death**



Health effects from air pollution episodes

Death (from cardiopulmonary disease and cancer)

Illness

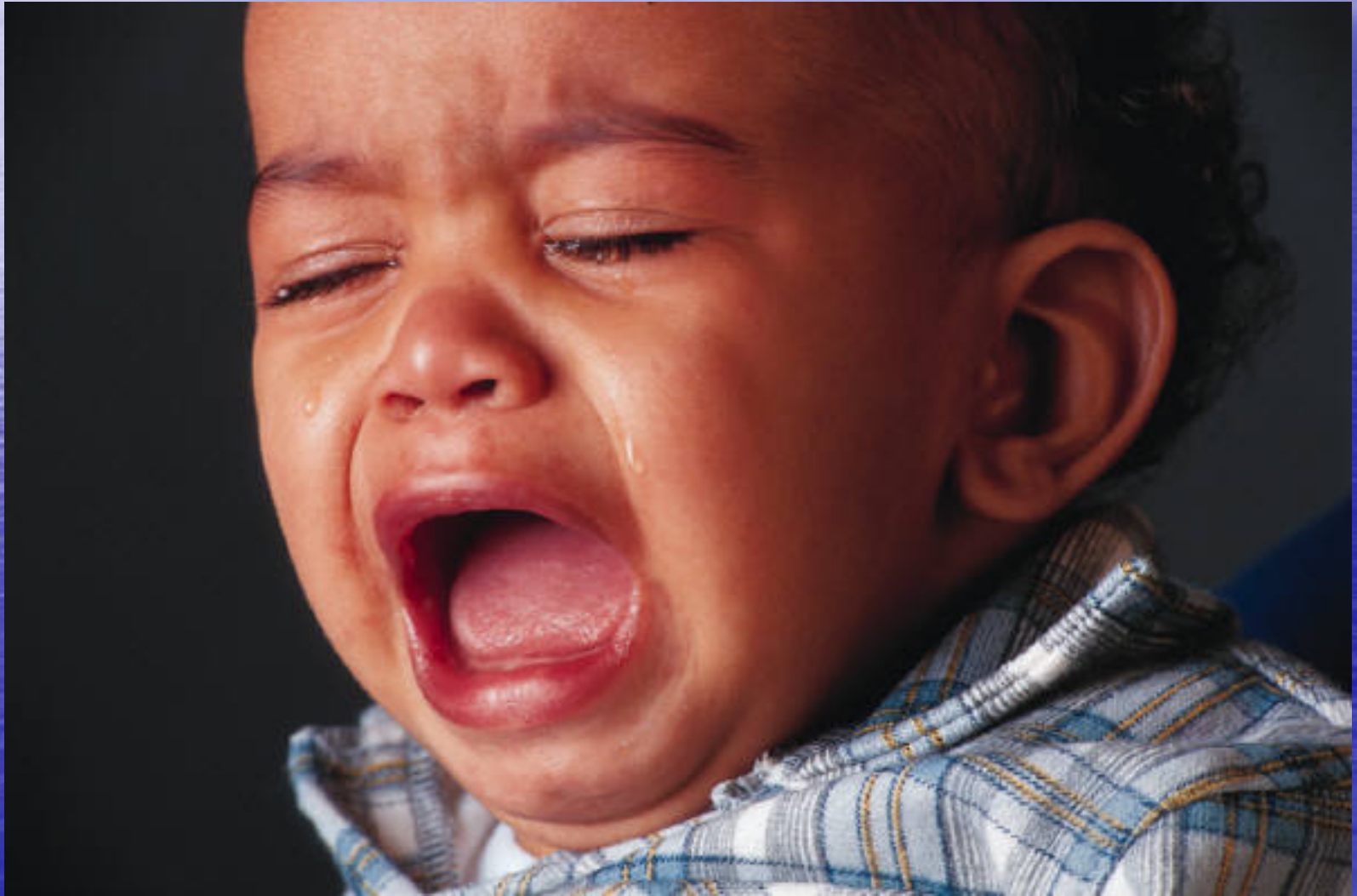
- increase in respiratory symptoms**
- increase ER visits**
- increase in hospitalizations**
- decrease lung function (children)**
- decreased lung growth (children)**
- increased medication use**

Who is Affected?

People are affected

- **Because of who they are:**
age, state of health, genetic predisposition
- **Because of the level of exposure**
higher level of exposure: greater effect
(proximity to source may determine level)

Children More Exposed, More Susceptible



Children

- **Breathe more air per body weight than adults**
- **Tend to be active, breathe more**
- **Mouth breathe when active, crying**
- **Lungs still developing in infants, small children (smoke affects growth and function of lung)**
- **Respiratory, immune, brain defenses not fully formed**

Short Term Exposure Effects in Children

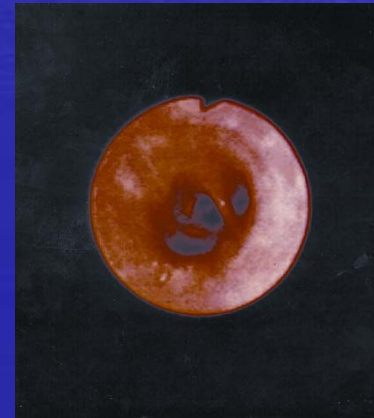
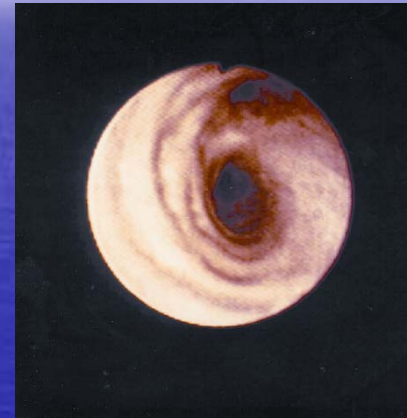
- **declines in asthmatic children's pulmonary functions;**
- **increased rates of emergency department admissions for asthma in children;**
- **increased rates of asthma symptoms among asthmatic children 5-13**

Infant respiratory symptoms

- **Prospective cohort study (Triche et al., 2002. Am J Respir Crit Care Med 166: 1105-1111)**
- **Association with Indoor heating sources**
 - **total days cough: wood stove use**
 - **episodes, days of wheeze: gas space heater**
 - **episodes cough: kerosene heaters**

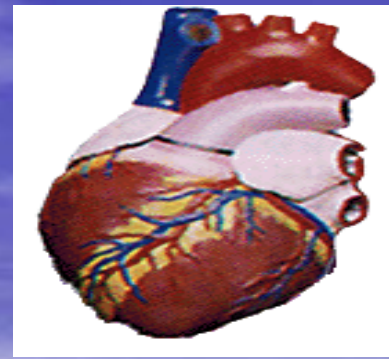
Observations of chronic particle health effects

- **aggravation of asthma**
- **inflammation of respiratory membranes**
- **bronchoconstriction**
- **impaired respiratory defense**
- **decreased heart rate variability**
- **accumulation of particles in lungs**





... and the Heart



- **Cardiovascular system effects**
 - **Changes in heart rate and heart rate variability (autonomic control and resiliency of heart)**
 - **Blood component changes: decreased clotting time**
 - **Cardiac arrhythmias**
 - **Heart attacks, congestive heart failure**
 - **Atherosclerosis (hardening of arteries)**

Older adults

- **May have Lung Injury from work or other exposures, smoking**
- **Lose Immune, Respiratory Defenses with Aging**
- **May have Atherosclerosis, other Heart or Circulatory Illness, Diabetes**

Short-term Effects in Elders

- increased rates of hospital admissions among people < 65 for asthma;
- increased rates of hospital admissions among people ≥ 65 for any cardiovascular problem;
- increased rates of hospital admissions for respiratory disease among people > 65
- increased rates of emergency department visits among persons < 65 for asthma



Who dies from short-term exposures to fine particles?

- **individuals with chronic pulmonary disease**
 - bronchitis, emphysema, asthma
- **individuals with cardiovascular disease**
- **individuals with infections**
 - flu, pneumonia
- **elderly**
- **infants**

Health effects from long-term, low level exposures

Illness

- increase in chronic respiratory illness
- decrease lung function in children
(predisposes children to Chronic Obstructive Pulmonary Disease as adults)

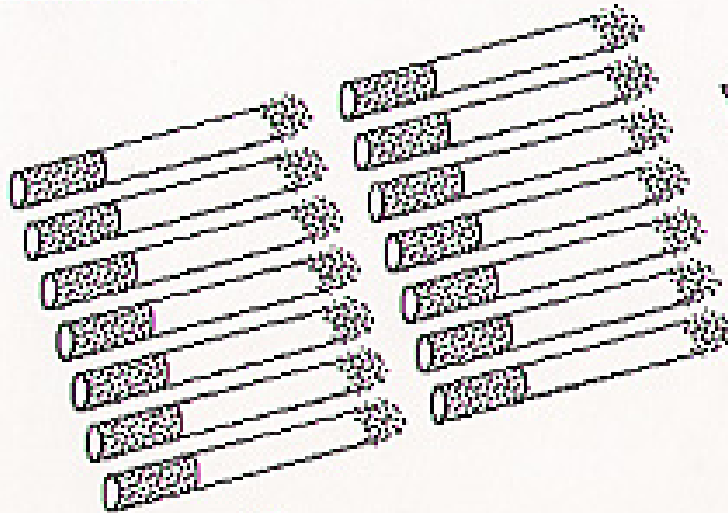
Death

- increases overall death rate (not just in individuals near death)

Smoke is carcinogenic

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)

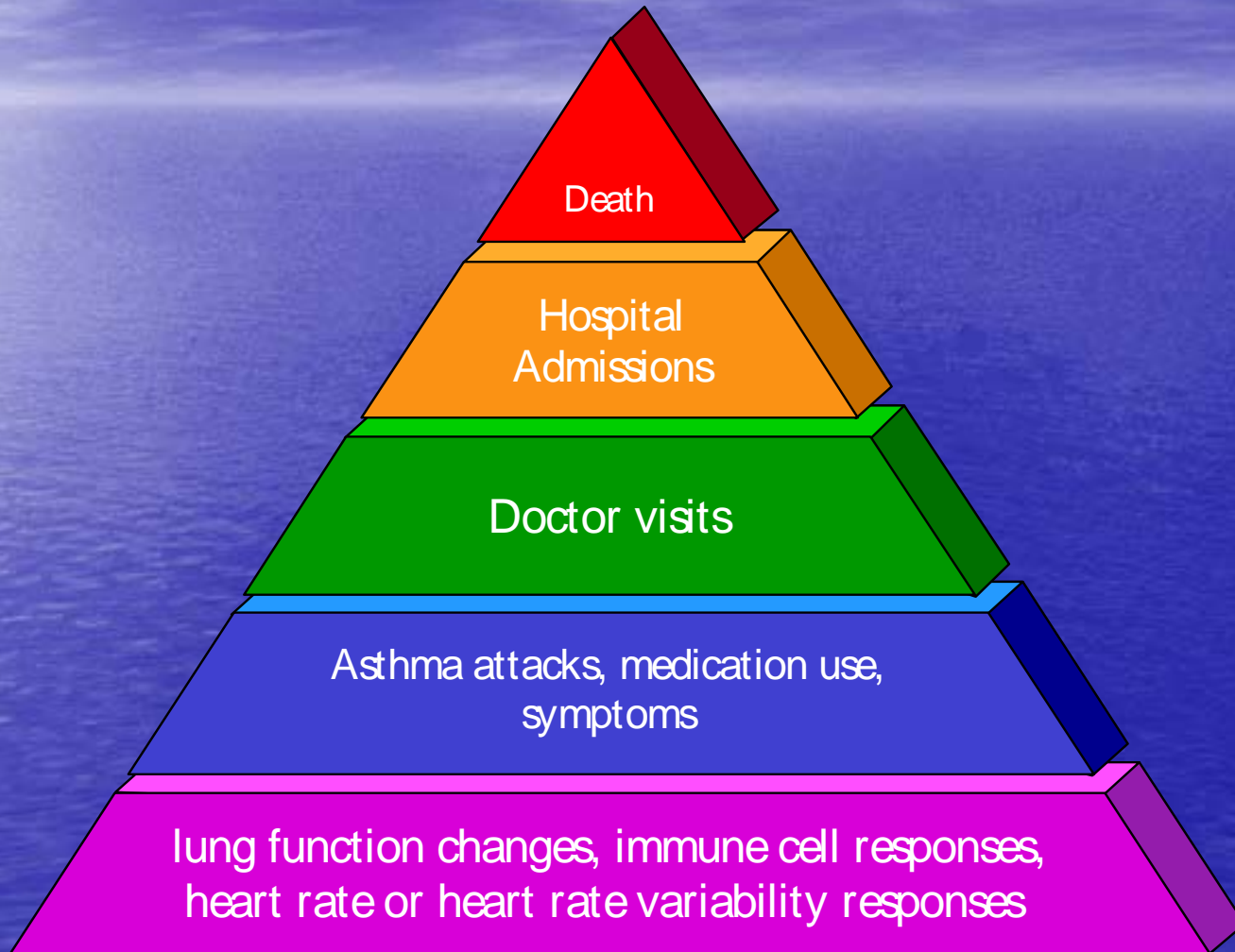
Particulate
Pollution
Project

The Dangers of Particulates

Recent studies on cancer re wood smoke exposure

- **Pinto et al., 1998 Brazil: cancer of mouth pharynx, larynx linked with use of wood stoves (case-control study in Int J Epi 27: 936-940)**
- **Delgado et al., 2005. Lung cancer pathogenesis 39 % of lung cancer pts studied , cancer associated with wood smoke; wood smoke induced same enzymes as tobacco smoke. (Chest 128[10]: 124-131)**

Pyramid of Effects



Wood smoke may be dear to our hearts, but it hurts them, our lungs, and is to die for





From the Klamath Reservation, 1885, by A. S. W. Smith

KLAMATH CHILD

Citations

- Anderson. *Final Report: Risk assessment document for residential wood combustion emissions*. Maine Department of Health Services, Environmental Toxicology Program, Environmental Health Unit, Division of Diseases Control, Bureau of Health. October 1989.
- Butterfield, Edmundson, LaCava and Penner. 1989. Woodstoves and indoor air. *I. Environ. Health* 59:172-173
- CEPA/FPAC Working Group on Air Quality Objectives and Guidelines. *Part 1: Science Assessment Document National Ambient Air Quality Objectives for Particulate Matter*. 1998. http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/98ehd220.pdf
- Chow and Watson. *Western Washington 1996-97 PM2.5 Source Apportionment Study*. Puget Sound Air Pollution Control Agency. Final Report No. 98-0 1, June 1998
- Collings, Martin and Sithole. 1990. Indoor woodsmoke pollution causing lower respiratory disease in children. *Trop Doctor* 2:151-155
- Delgado, Martinez, Sánchez, Ramirez, Iturria and González-Avila. 2005. Lung Cancer Pathogenesis Associated With Wood Smoke Exposure. *Chest* 128(10):124-131
- Dockery, Pope, Xu, Spengler, Ware, Fay, Ferris and Speizer. 1993. An association between air pollution and mortality in six U.S. cities. *N Engl J Med* 329:1753-9
- Honicky and Osborne. 1991. Respiratory effects of wood heat: clinical observations and epidemiologic assessment. *Environ Health Perspect* 95:105-9
- Honicky, Akpom and Osborne. 1983. Infant respiratory illness and indoor air pollution from a wood burning stove. *Pediatrics* 71:126-128
- Honicky, Osborne and Akpom. 1985. Symptoms of respiratory illness in young children and the use of wood-burning stoves for indoor heating. *Pediatrics* 75(3):587-93
- Kammen, Wahhaj, and Yiadom. 1998. *Acute respiratory infections (ARI) and indoor air pollution (with emphasis on children under five in developing countries)*. EHP Activity No. 263-CC, USEPA
- Keill and Maykut. *Final Report: Puget Sound Air Toxics Evaluation*. Puget Sound Clean Air Agency in conjunction with Washington State Department of Ecology. October 2003
- Kelly. *A Comparison of Local and National Air Toxics Emissions Estimates: Regional Importance of Selected Source Categories*. Olympic Region Clean Air Agency, Olympia. 2003
- Koenig. 1998. Human health risk from woodsmoke. *Toxicol Sci* 42(Suppl 1-S):354
- Larson and Koenig. *A summary of the chemistry, emissions, and non cancer respiratory effects of wood smoke*. EPA 453/R-9-008. 1993
- Larson and Koenig. 1994. Wood smoke: emissions and non-cancer respiratory effects. *Ann Rev Public Health* 15:133-56
- Larson, Kalman, Wang and Nothstein. *Urban air toxics mitigation study*. Rep. submitted to Puget Sound Air Pollut. Control Agency, June 1990
- Larson, Yuen and Maykut. "Weekly Composite Sampling of PM2.5 for Total Mass and Trace Element Analysis", in *Transactions, PM10 Standards and Non-Traditional Particulate Source Controls*. Chow and Ono, Eds. Air & Waste Management Association, Pittsburgh, PA., pp. 39-50, 1992
- Lewtas. 1988. Genotoxicity of complex mixtures: Strategies for the identification and comparative assessment of airborne mutagens and carcinogens from combustion sources. *Fund & Appl Tox* 10:571-589
- Maykut, Lewtas, Kim and Larson. 2003 Source Apportionment of PM2.5 at an Urban IMPROVE Site in Seattle, WA *Environ Sci Tech* 37(22):5135-42
- Morris, Morgenlander, Coulehan, Gahagen, Arena and Morganlander. 1990. Wood-burning stoves and lower respiratory tract infection in American Indian Children. *Am J Dis Child* 144:105-108
- Pintos, Franco, Kowalski, Oliveira and Curado. 1998. Use of wood stoves and risk of cancers of the upper aero-digestive tract: A case-control study. *Int J Epi* 27(6):936-40
- Rajpandey. 1984. Domestic smoke pollution and chronic bronchitis in a rural community of the Hill Region of Nepal. *Thorax* 39:337-339
- Tarnai. *Wood burning stove survey for Idaho, Oregon and Washington State*. Washington State University. Social and Economic Sciences Research Center. August 2001