Air Pollution:
Its History and Influence on Health

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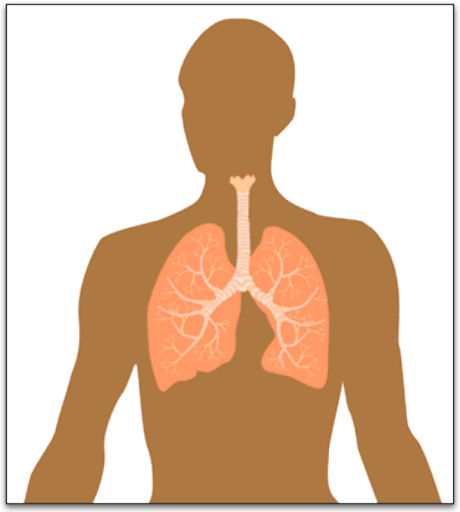
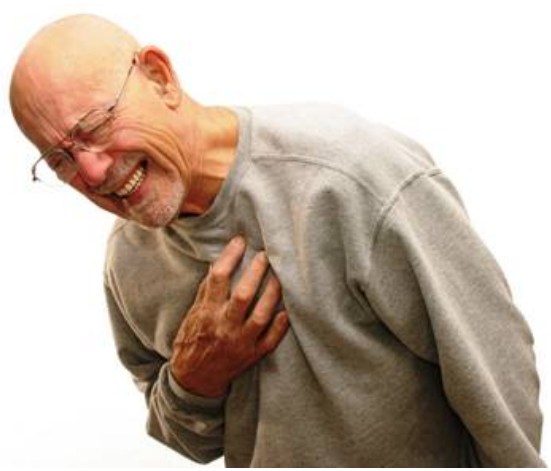
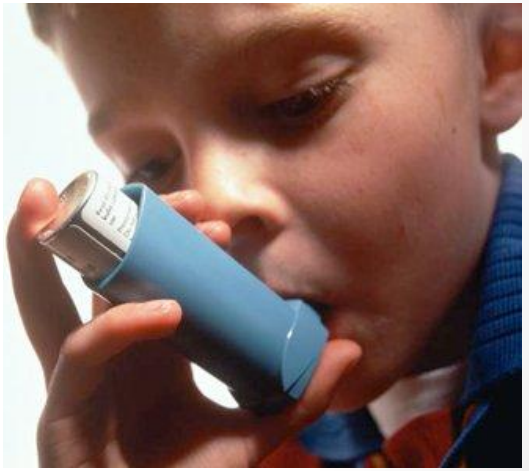
Everyone is exposed!

What are we concerned about?

- Air pollutants have been demonstrated to influence lung function and asthma, airway inflammation, cancers, heart attacks, stroke, birth defects… Air pollutants can influence a lot of factors







Air Pollution and Health

- Today
  - A history of air pollution, from caves to suburbia
  - Gov't response with protective legislation, how do we know what's safe? Risk Assessment of air pollutants
  - Ozone
- Thursday
  - Fine Ambient Particulate Matter
  - Current Research at UW on air pollution and cardiovascular health

Prosperity, Development, & Health

- Symbol of national pride and prosperity was the smoke stack
- Pollution meant industrial development, which meant jobs, economy, growth, and a future!
- Thus evolved a complexity between the balance between industrial development, our environment, and our health
- Led to public outcry about the environment, and a call for gov't to protect

Let's go way back…

- Air pollution used to be limited to the microenvironment, wood smoke pollution in cave and hut dwelling people

http://www.scoutingny.com/?p=2401

Native populations in Utah, fires burned within their living quarters, creating a high concentration of wood smoke in a small area

Ventilation of settlements moved the wood smoke from inside to outside

- This fundamentally changed the issue of air pollution
- By ventilating the smoke outdoors, smoke combined with those of their neighbors, creating an additive level of pollution
- Air pollution was no longer limited to the microenvironment

http://www.env.gov.yk.ca/monitoringenvironment/wood_burning_tips.php

Development, a change of fuel source, and an change of pollution

- As the population increased, cities formed, the available wood as a fuel source plummeted
- With energy demands continuing to increase, there was a shift to burn a large amount of cheap coal
- Changing the air pollution from wood smoke (still hazardous) to sulfurous, sooty, coal smoke (even worse)

- Seneca, Roman philosopher AD 61
  - *"As soon as I had gotten out of the heavy air of Rome, and from the Stink of the chimneys thereof, which being stirred, poured forth whatever pestilential vapors and soot they had enclosed in them, I felt an alteration to my disposition"*

Public outcry against air pollution

- Efforts to regulate air pollution began in the time of ancient Greece and Rome, where there were, although rare, examples of successful civil suits against polluters
- In 13th century London, community based outcries about the air pollution led to a ban on "sea coal" for use in lime kilns and domestic heaters, from King Edward I, but was not enforced
  - "Sea Coal" was coal that washed up on the beach, predominantly found in Scotland and Northern Britain

17th-18th Century England

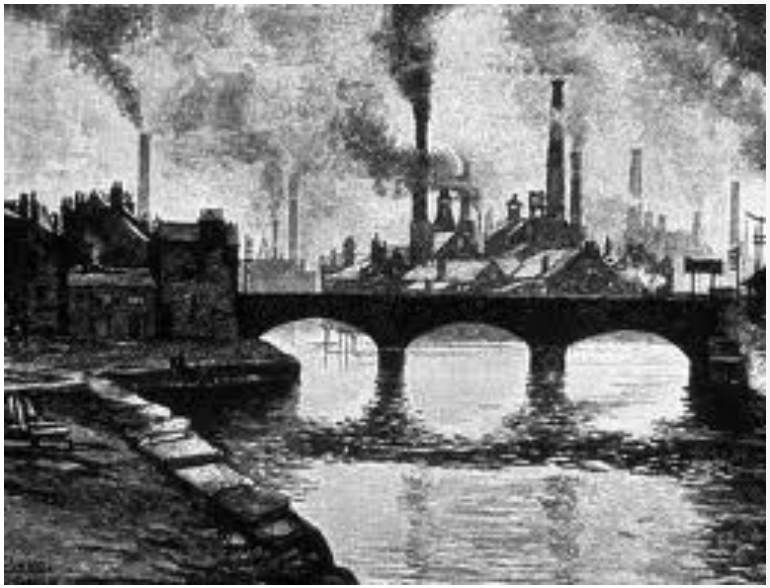
- Further reductions in wood harvests increased the reliance on sea coal for domestic heating
- Percival Pott discovered that chimney sweeps had an increased risk of scrotal and nasal cancers, he attributed this to exposure to coal soot

- The health community had little to offer, only a simple recommendation:
  - *"Fly the city, shun its turbid air; breathe not the chaos of eternal smoke"*

Percival Pott, London Surgeon, 1714-1788

Industrial Revolution

- Late 18th century, was powered by "cleaner" mined coal
- Emissions were more acidic, and hung in the air longer than the fluffy soot of the cheaper sea coal
- Caused a soiling of buildings and damage to nearby crops
- Brought community boards to address sanitary reforms to cut the worse of the pollution peaks
- Any gains in controlling the air pollution was quickly offset by growth and the increased burning of coal
- By the end of the 19th century, power plants were built to provide energy for factories and eventually to light homes

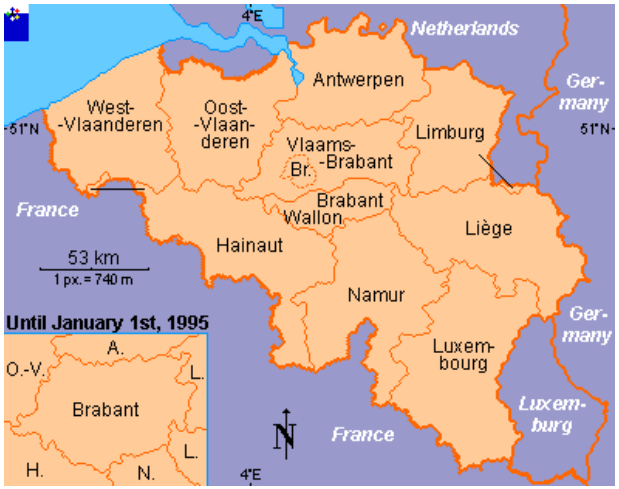


The past 100 years…

- By 1925, air pollution was common to all industrialized nations
- But people grew less tolerant of the nuisance of acidic-soot corrosion of all exposed surfaces and the general discomfort that came with the smoky air
- Public surveys were initiated to bring political attention to the problem and promote the implementation of controls (i.e. Salt Lake City, 1926; New York City, 1937; Leicester, Great Britain, 1939), but little was accomplished
- It was not until air pollution disasters occurred that air pollution was indicted primarily as a health issue
  - Meuse Valley, Belgium, 1930
  - Donora, Pennsylvania, 1948
  - London Fog, 1952

Meuse Valley, Belgium, 1930

- Between December 3rd, 4th, and 5th, 1930
- Thousands of individuals began suffering from acute pulmonary attacks, 60 people died
- Attributed to poisonous products of waste gas from the industries in the valley (SO_x, fluorine gas)



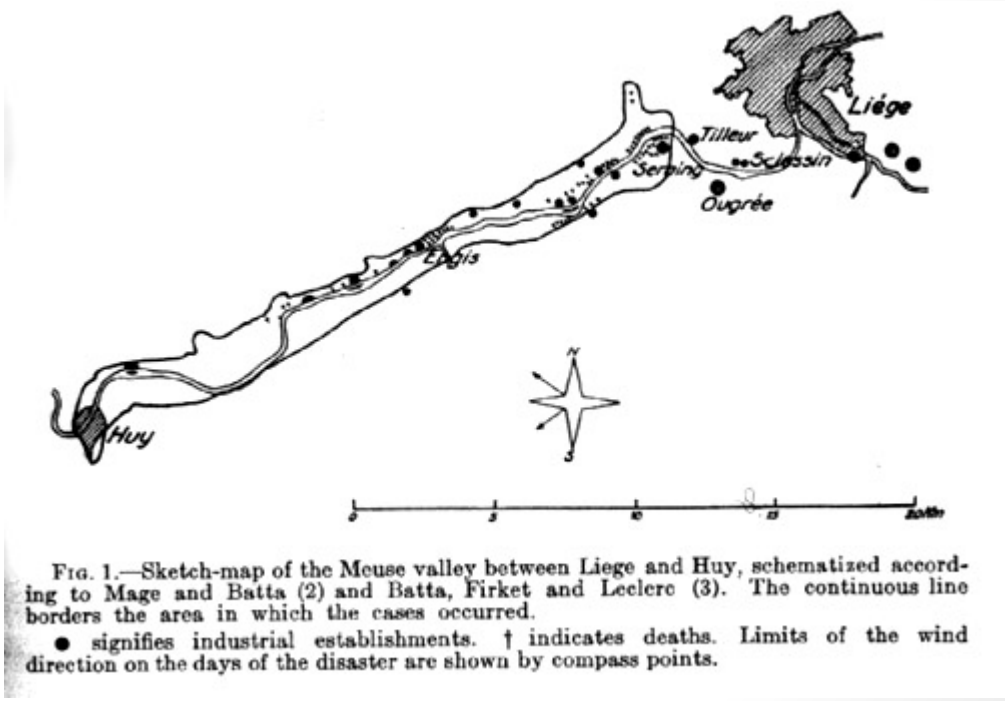


FIG. 1.—Sketch-map of the Meuse valley between Liege and Huy, schematized according to Mage and Batta (2) and Batta, Firket and Leclerc (3). The continuous line borders the area in which the cases occurred.

● signifies industrial establishments. † indicates deaths. Limits of the wind direction on the days of the disaster are shown by compass points.

Donora, Pennsylvania, 1948

- October 27th, 1948, fog rolled in to Donora
- Over 7000 residents along the Monongahela River Valley quickly began suffering from coughing, asthma symptoms, respiratory distress
- 20 people died, and mortality rates in Donora continued to be elevated for decades
- U.S. Steel's Donora Zinc Works and its American Steel and Wire Plant frequently released large amounts of sulfur dioxide (SO_2)
- Killed nearly all the vegetation within a ½ mile radius of the industrial plant

http://toxipedia.org/display/toxipedia/Donora+smog

London Fog Incident, December 5th-9th, 1952

More coal burned when the temperature drops

- Estimated 12,000 people died

Air pollution was associated with mortality

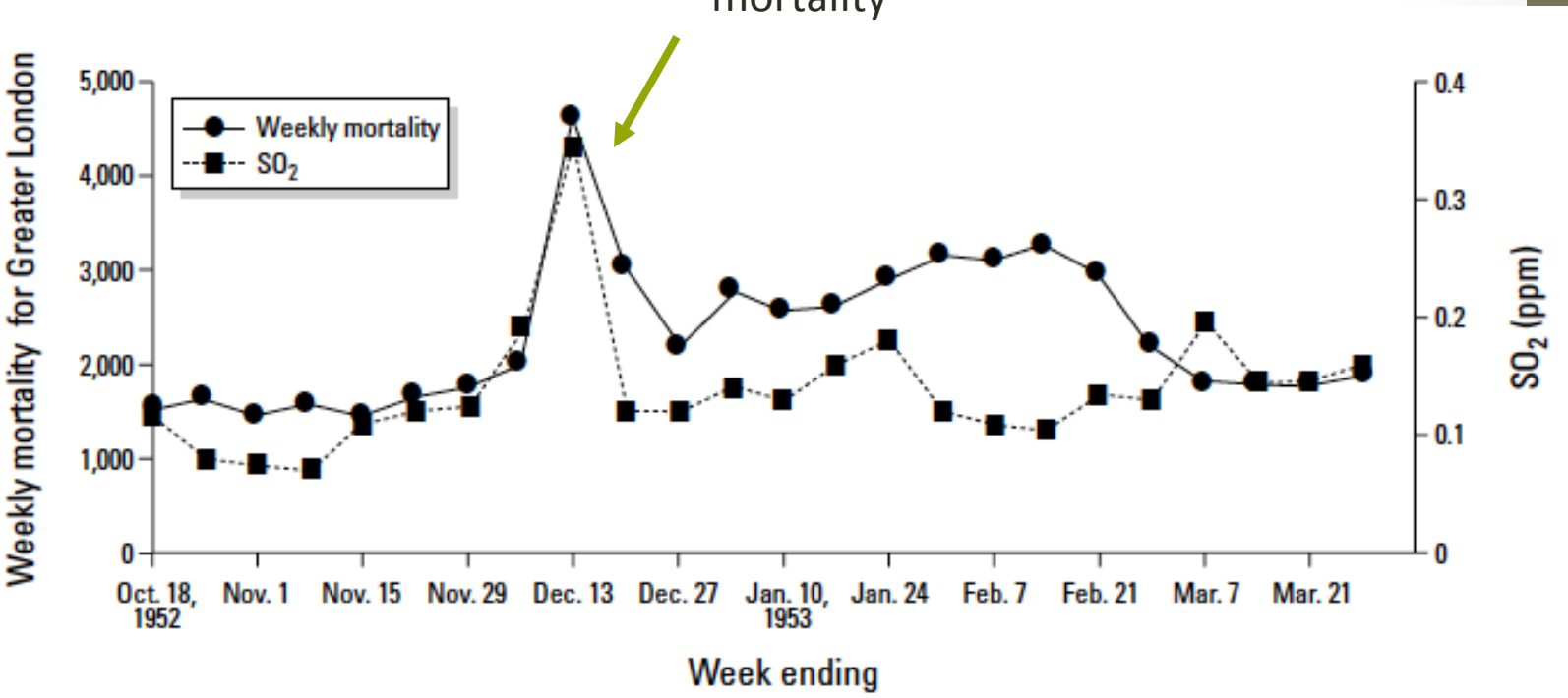


Figure 1. Approximate weekly mortality and SO_2 concentrations for Greater London, 1952–1953.

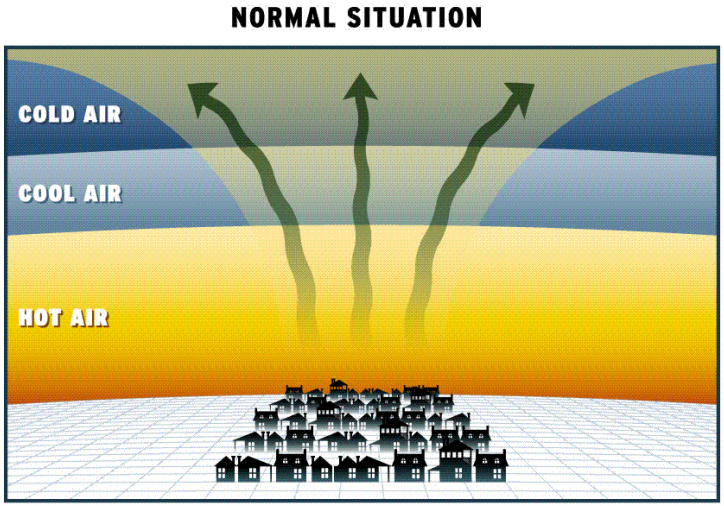
What's with the dates?

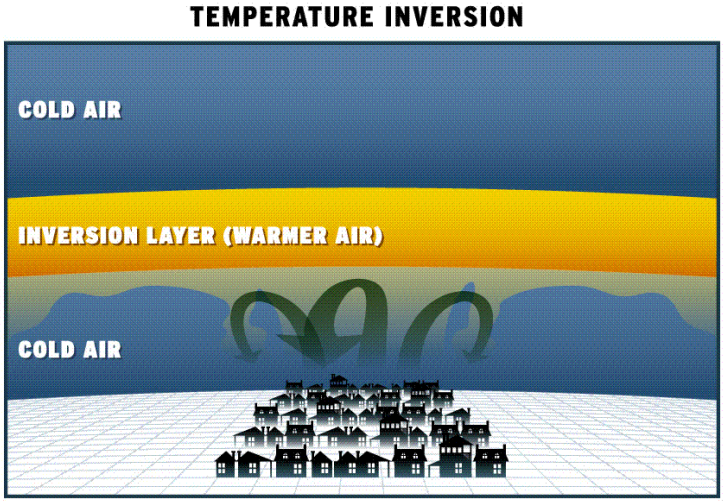
- Meuse Valley, Belgium, December 3-5th, 1930
- Donora Pennsylvania, October 27th-30th, 1948
- London Fog, December 5th-9th, 1952

- Winter! It's cold:
  - So more burning of coal (important for London Fog)
  - But more importantly, winter is a time that temperature inversions are more likely to occur

Weather inversions are important to air pollution

- Under normal circumstances, temperatures decrease as height increases
- When temperatures increase as height increases, this is called a ‘temperature inversion’
- Creates a layer that prevents mixing of air pollutants with air from above





In response to these events, public called for gov't intervention

- California Air Pollution Control Act, 1947
  - Controlled for 'opaque smokes'
- President Harry Truman created a federal impetus to deal with air pollution, which ultimately led to the passing of the Air Pollution Control Act, 1955, under Dwight Eisenhower, providing funds for air pollution research

- These new regulations were aimed at targeting stationary sources of air pollution (i.e. smoke stack), but a new source of air pollution was underway…

After WWII, suburban sprawl of the 1950's

- In an attempt to get away from the dirty and polluted life of the cities, many people moved away from the city, creating the suburban lifestyle, and with it, the commute
- With the car becoming a family fixture, coupled with the daily commute to work, automobile emissions quickly became a major source of air pollution

Smoke + fog = Smog?

- Originally coined to describe the mixture of smoke and fog that blanketed cities like London, was adopted to describe the eye-irritating photochemical reaction products of auto exhaust that blanketed cities like LA
- The rapid increase in smog further causes alarm among communities, leading to further governmental regulations to control the worsening air pollution

L.A. 1947

L.A. 2002

Early federal legislation was expanded to include automobiles

- Clean Air Act (CAA), 1963, empowered the Secretary of the Federal Health, Education, and Welfare to define air quality criteria based on scientific studies, established a new program within U.S. Public Health Service and authorized research into techniques for monitoring and controlling air pollution
- CAA was amended with the Motor Vehicle Pollution Control Act, 1965, Department of Health, Education, and Welfare was directed to establish auto emission standards
- 1966, Auto tailpipe emission standards were adopted by the California Motor Vehicle Pollution Control Board
- 1967, Federal Air Quality Control Act, established a framework for defining “air quality control regions”

Clean Air Act, 1970

- Under President Nixon, Monumental legislation, though it was only an amendment
- Recognized air pollution as a national issue, and set forth a program to control it
- Established the U.S. Environmental Protection Agency, charged with the responsibility to protect the public from hazards of polluted outdoor air
- US EPA listed 7 “criteria air pollutants”
  - Ozone (O_3)
  - Sulfur dioxide (SO_2)
  - Particulate matter (PM)
  - Nitrogen Dioxide (NO_2)
  - Carbon Monoxide (CO)
  - Lead (Pb)
  - Total hydrocarbons (ultimately dropped)
- These were specified as significant health hazards in need of individual National Ambient Air Quality Standards (NAAQS)

What's with those 'Criteria Pollutants'?

- Sulfur Dioxide, Carbon Monoxide, Nitrogen Dioxide, Ozone, Particulate Matter, Lead (Pb)
- Found all over the United States and can cause harm to human health, the environment, and property
- They are called "criteria" air pollutants because the EPA regulates them by developing human health-based or environmentally-based criteria (science based guidelines) for setting permissible levels
- Set limits based on human health are called "Primary Standards"
- Set limits based on environmental or property damages are called "Secondary Standards"
- Of the 6 pollutants, Particle Pollution, and ground level Ozone are of the most concern to human health

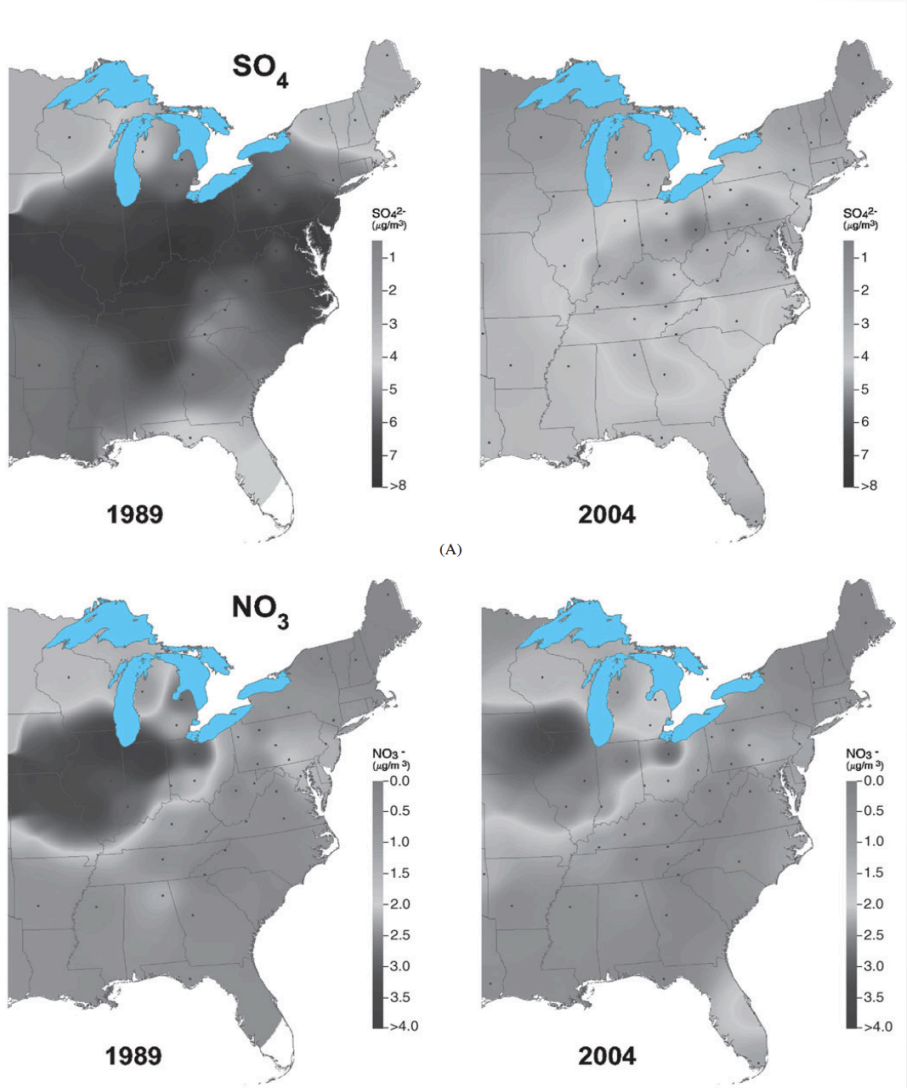
U.S. National (Primary) Ambient Air Quality Standards (NAAQS)

- Mandated to be reviewed every 5 years as to the adequacy of the existent standard to protect human health,
- **Economic impact not to be involved!**

Pollutant	Unit	Averaging Time	Concentrations	Statistic
SO_2	ug/m^3 (PPM)	Annual, 24h	80 (0.03), 365 (0.14)	Annual Mean, Maximum
CO	ug/m^3 (PPM)	8h, 1h	10 (9), 40 (35)	Maximum, Maximum
O_3	ug/m^3 (PPM)	1h, 8h	235 (0.12) 157 (0.08)	Maximum, Maximum
NO_2	ug/m^3 (PPM)	Annual	100 (0.053)	Annual Mean
PM_{10}	ug/m^3	Annual, 24h	150, 50	Annual Mean, 24h Mean
Lead (Pb)	ug/m^3	3 months	1.5	Quarterly Average

What are the results of these policies and regulations?

- There have been many successes from these regulations!
- But we still have a long way to go…
- Over half of the American population lives in counties that are not in compliance with current NAAQS standards



Great disparity in the world regarding air pollution control

These developing countries are repeating the exact steps in air pollution that the now Established Market Economies (EME) took over the past 100 years

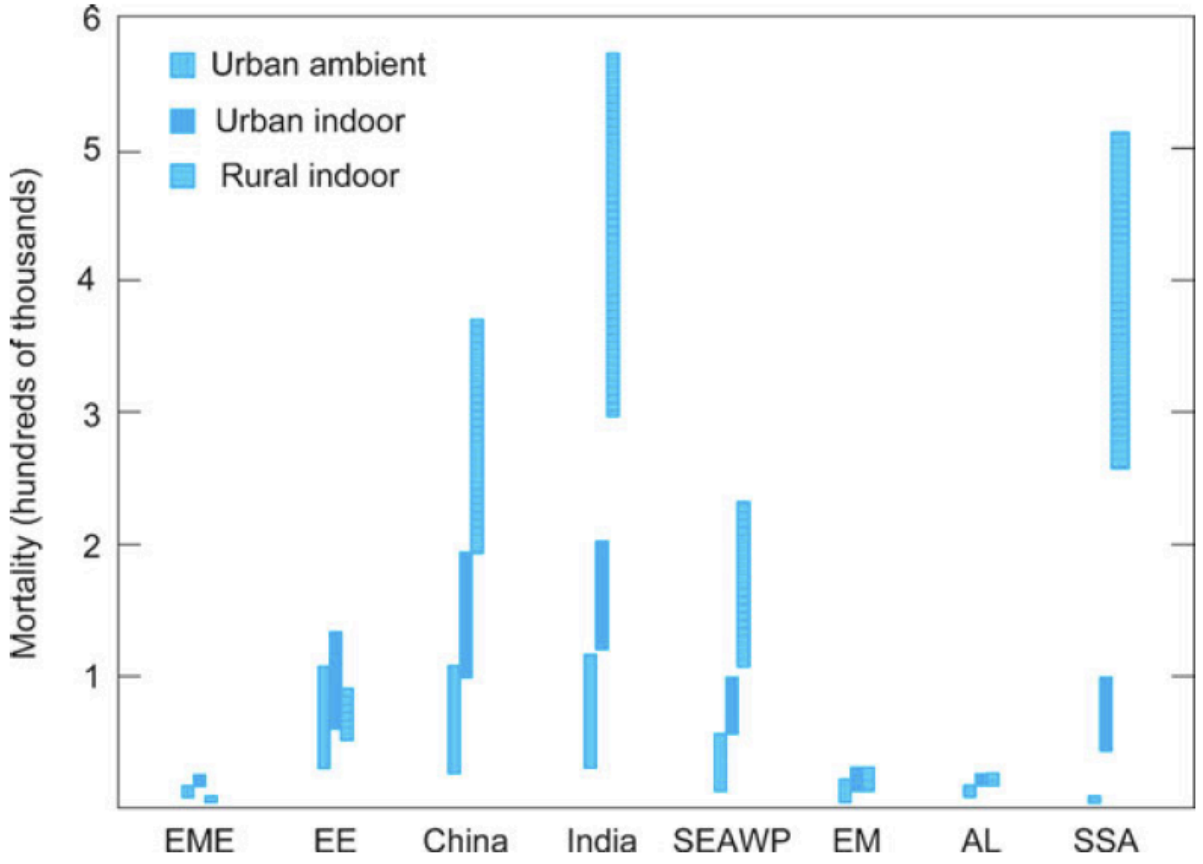


Figure 28-2. Excess mortality due to outdoor and indoor particulate matter in various international economic groupings.

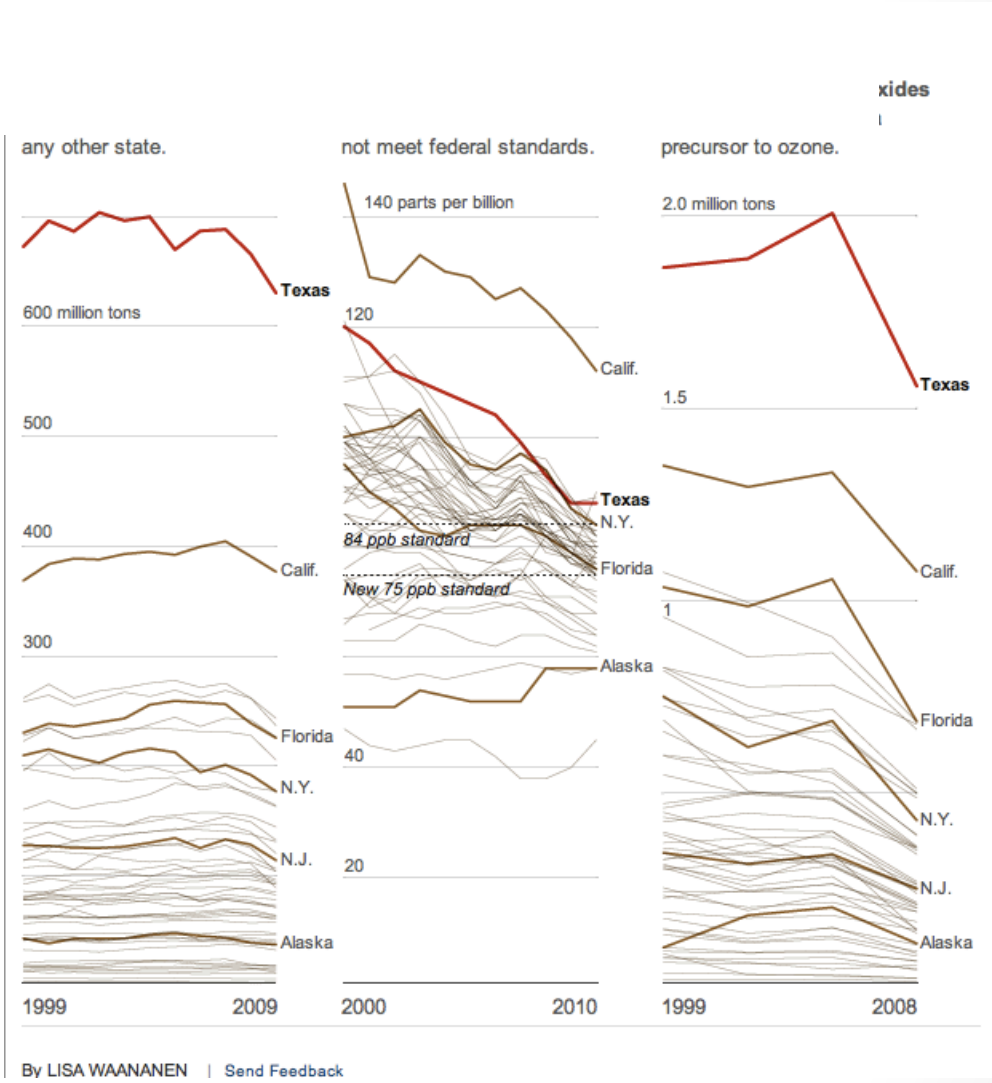
Established market economies, Eastern Europe, China, India, Southeast Asia/Western Pacific, Eastern Mediterranean, Latin America, Sub-Saharan Africa

Perry Promises Increased Drilling and Decreased Regulation

By RICHARD A. OPPEL Jr.
Published: October 14, 2011

Many candidates for the presidency have called for decreased regulation. One is particular is Gov. Rick Perry, who claims that his states has reduced regulations and has improved air quality

But in reality his state has some of the worst air quality for Ozone and NO_2, as well as the highest CO_2 emissions in the country



NY Times, September 29th, 2011, "Texas Air Pollution to Other States" by Lisa Waananen

How do we make sure we are protecting human health?

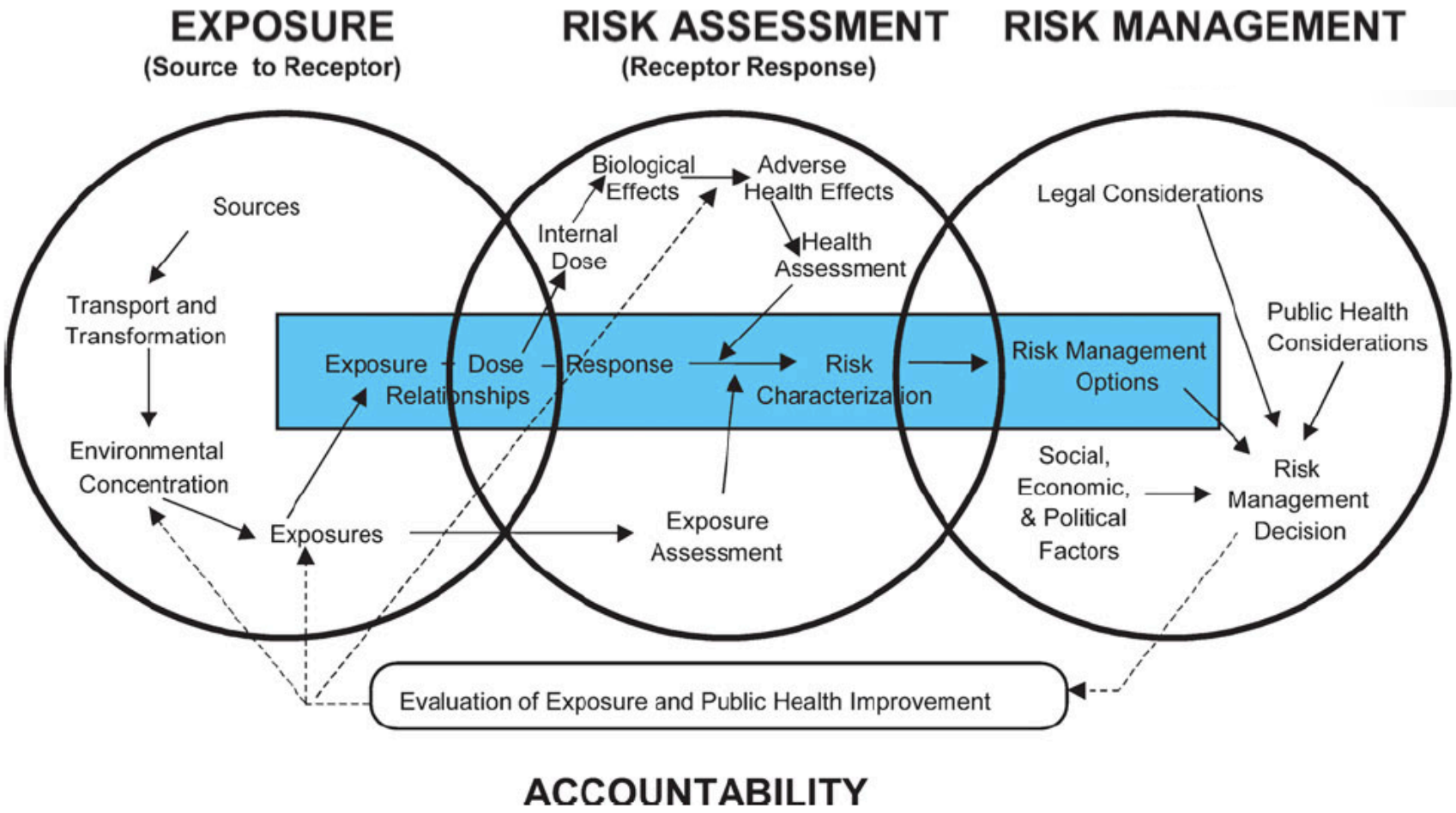


Figure 28-4. NRC risk assessment paradigm.

Basics of risk assessment

- Risk = Hazard x Exposure

- so, if toxicant has no hazard, there is no risk
- if there is no exposure, there is no risk
- The risk is the combination of the two

How air pollution research can lead to EPA standards

- 3 Broad methods of research:

- Epidemiology
- Clinical Studies
- Toxicology

- This research leads to the understanding of how air pollutants can cause harm to human health, and allows for careful determination of what level of exposures would be expected to increase risk of adverse health effects

Ozone (O_3)

- Primary Pollutant – Toxic directly following its release into the environment
- Secondary Toxicant – Not directly released into the environment, but rather it is formed in the environment, usually after photochemical oxidation of primary toxicants to generate a new molecule
- Ozone is a secondary pollutant of most concern

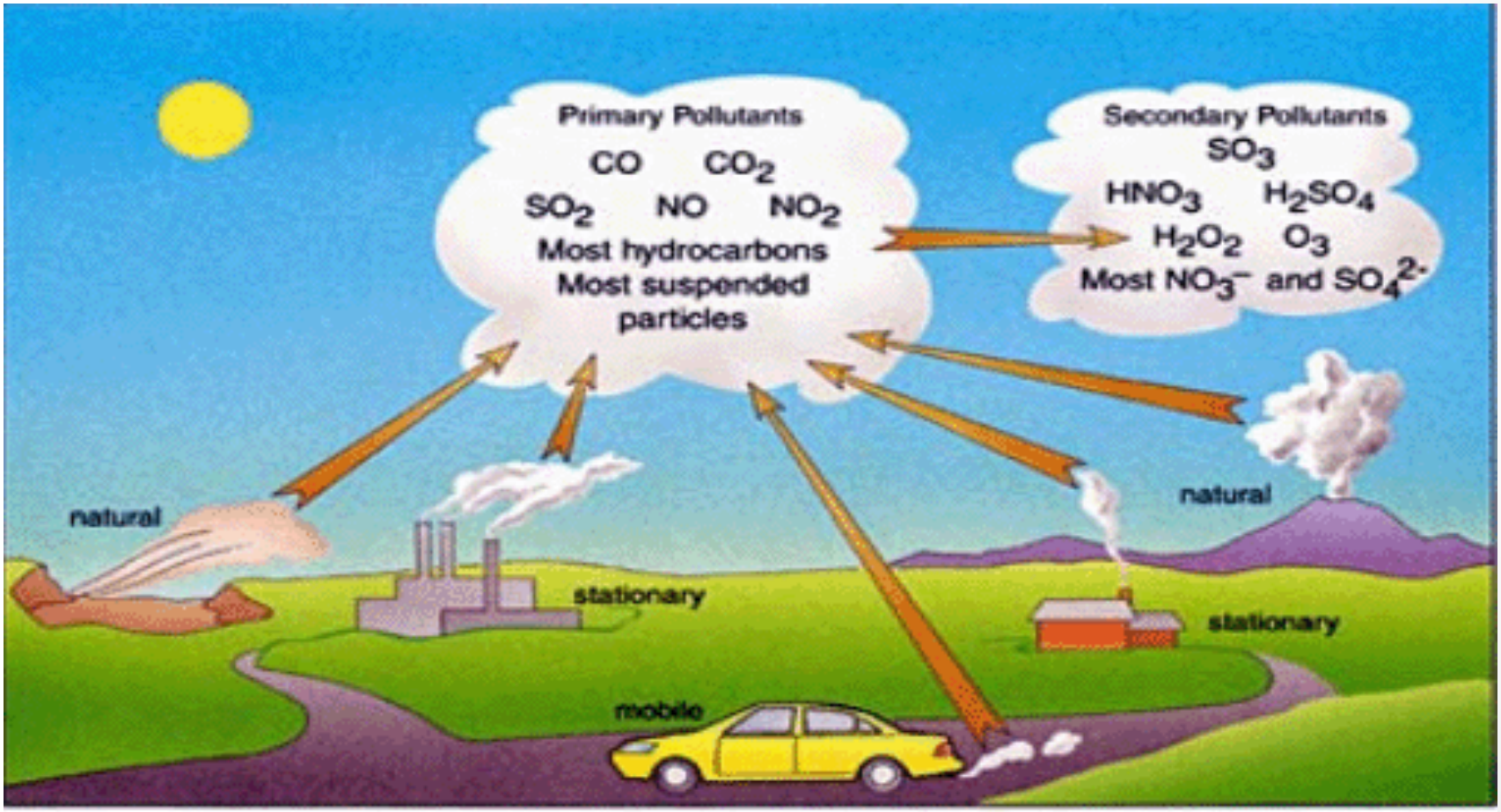
$$NO_2 + h\nu \text{ (UV light)} \rightarrow O^{\bullet} + NO^{\bullet}$$

$$O^{\bullet} + O_2 \rightarrow O_3$$

$$O_3 + NO^{\bullet} \rightarrow NO_2$$

Casarett & Doull's Toxicology, 7th Edition, Pg 1142

Of many secondary pollutants, O_3 is of most concern

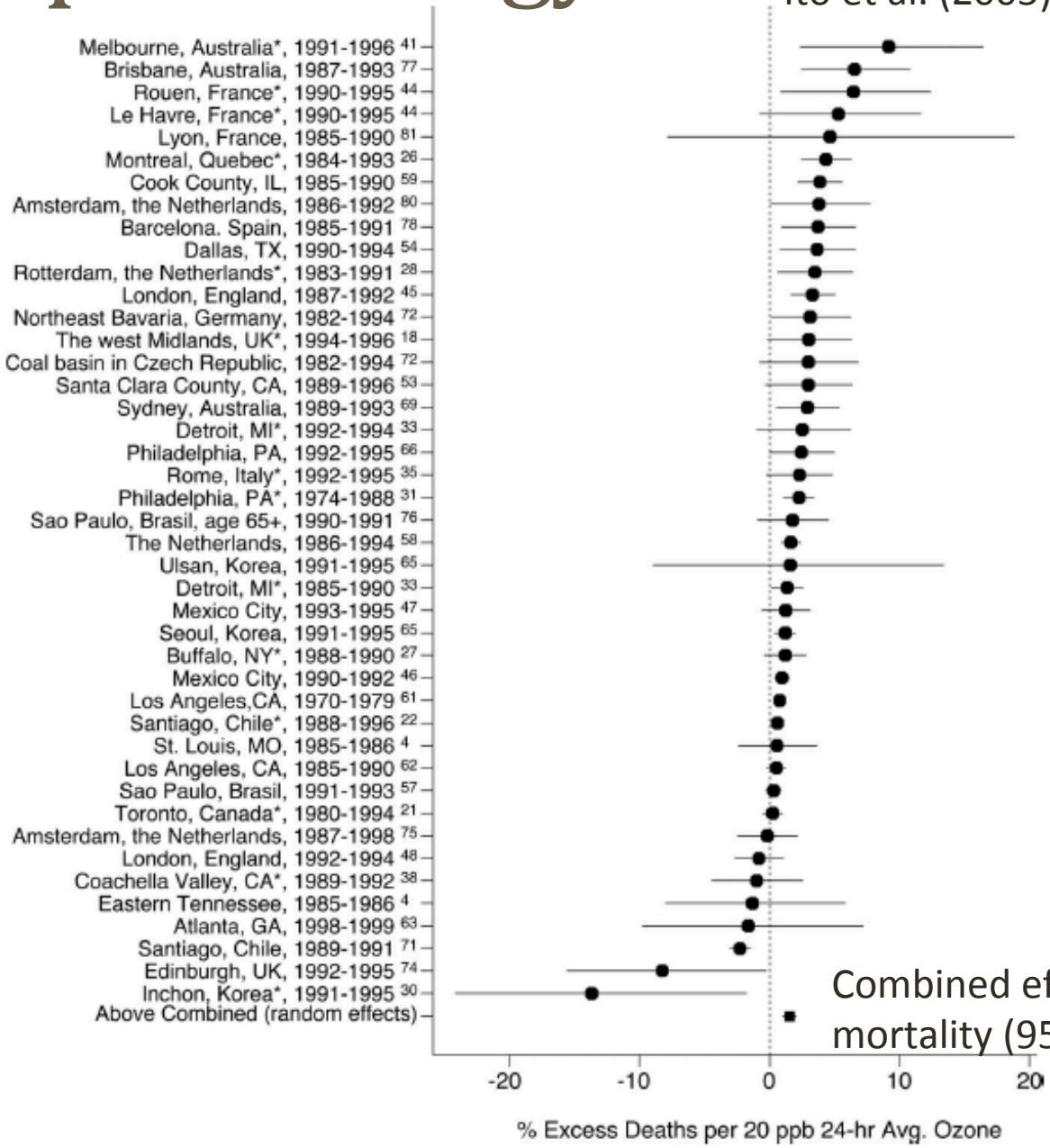


Types and sources of air pollutants

google images

Epidemiology

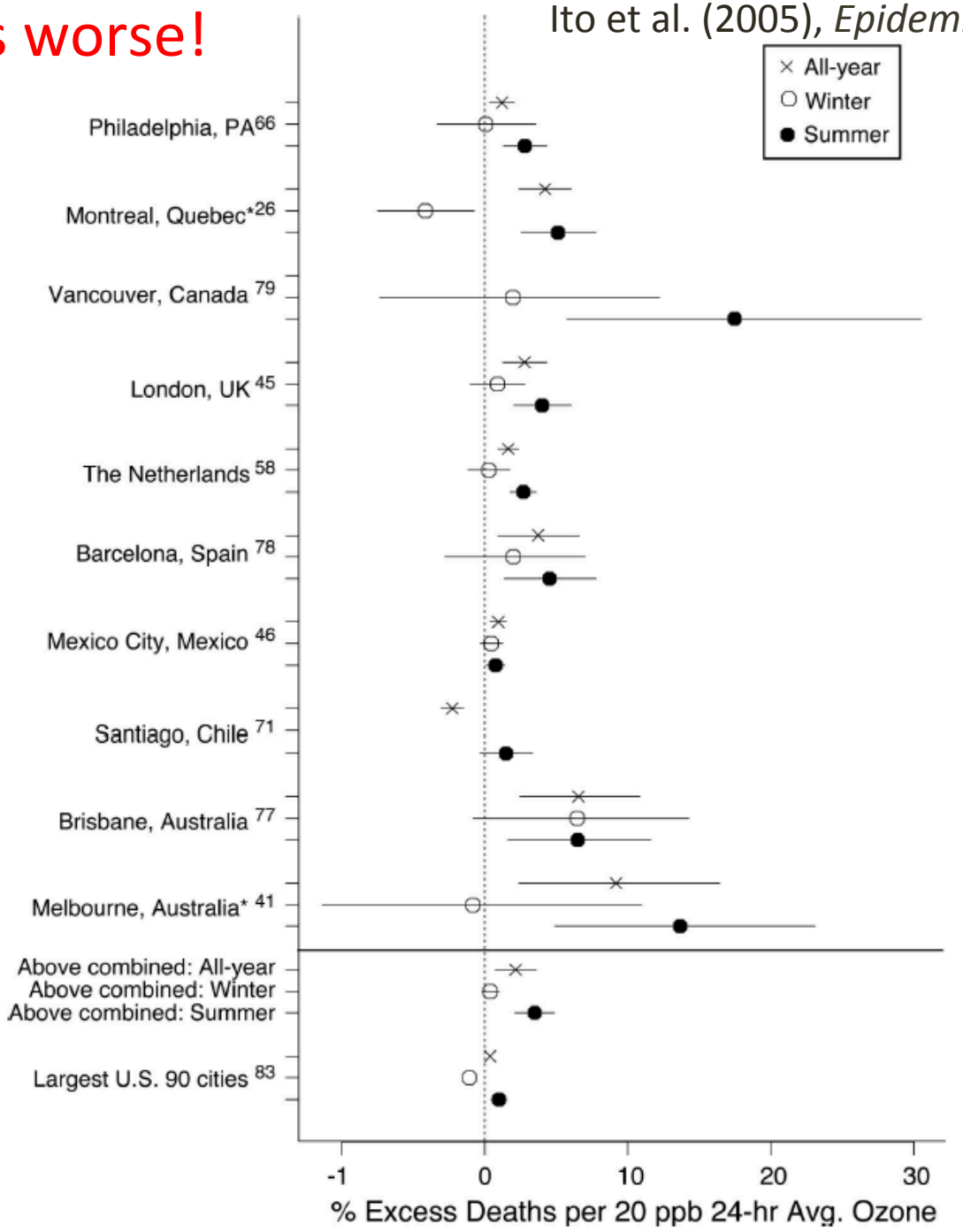
Ito et al. (2005), *Epidemiology,* Vol. 16



Combined effect: 1.6% Excess mortality (95% CI=1.1-2.0%)

Summer is worse!

Ito et al. (2005), *Epidemiology,* Vol. 16



Why can't we set regulations using epidemiology data alone?

- Difficult to control for confounding variables
  - Genetic diversity
  - lifestyle differences
  - population mobility
- Lack of adequate exposure data
  - Difficult to separate a single pollutant from correlated co-pollutants
- Only association, and not causality, can be drawn from broad-based exposure data and effects

Human Exposures

- Since these are pollutants that humans are exposed to everyday, it is ethical to expose humans in highly controlled environments to pollutants for short periods of time, monitoring for biological effect
- These studies can give extremely valuable information into the health effects of air pollutants

First question, does O_3 even get into the lung?

- Not a crazy question!
- O_3 is extremely reactive, it could easily be scrubbed out of the air by the nasal cavity and upper respiratory tract, and not even touch the lung
- Remember, Risk = Hazard x Exposure, we need to understand the exposure

Extrathoracic and intrathoracic removal of O_3 in tidal-breathing humans

J. Appl. Phys. 1988

TIMOTHY R. GERRITY, RICHARD A. WEAVER,
JON BERNTSEN, DENNIS E. HOUSE, AND JOHN J. O'NEIL

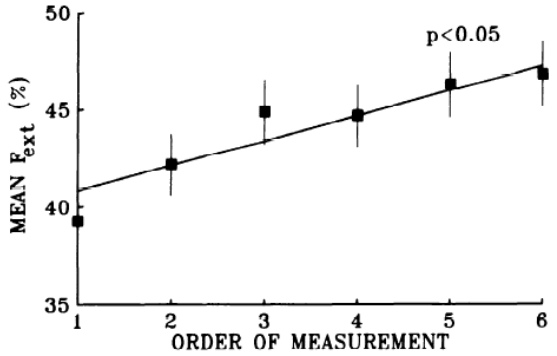


FIG. 3. Regression of measured extrathoracic O_3 removal efficiency (Fext) vs. measurement order. Each point represents mean of all measurements obtained at that particular position in sequence of 6 measurements. ——, Best linear fit of data obtained from an analysis of covariance. Regression equation is given by Fext = 39.6% + 1.27% (order).

TABLE 2. *Mean intrathoracic O_3 removal efficiency by effects*

	n	Fint, %
Target O_3 concn, ppm		
0.1	108	89.4±0.8
0.2	107	90.9±0.8
0.4	108	92.5±0.8*
Mode of breathing		
Nasal	108	90.7±0.4
Mouth	108	91.1±0.4
Oronasal	107	91.0±0.4
Breathing frequency, breaths/min		
12	161	92.6±0.2
24	162	89.3±0.2†

Values are means ± SE. Fint, intrathoracic O_3 removal efficiency. * Significantly greater than value for 0.1 ppm ($P < 0.05$). † Significantly less than value for 12 breaths/min ($P < 0.001$).

- About 40-50% of ozone inhaled is removed by the upper respiratory tract
- But of the ozone that makes it into the lung, ~90% doesn't come back up

Ozone Dose and Effect in Humans and Rats

A Comparison Using Oxygen-18 Labeling and Bronchoalveolar Lavage

GARY E. HATCH, RALPH SLADE, LINDA P. HARRIS, WILLIAM F. MCDONNELL, ROBERT B. DEVLIN, HILLEL S. KOREN, DANIEL L. COSTA, and JOHN MCKEE

Pulmonary Toxicology Branch, Environmental Toxicology Division and Clinical Research Branch, Human Studies Division, Health Effects Research Laboratory, EPA, and Mantech Environmental, Research Triangle Park, North Carolina

TABLE 1

PULMONARY FUNCTION MEASUREMENTS AFTER EXPOSURE TO AIR AND OZONE

	FEV_1 (*ml BTPS*)				FVC (*ml BTPS*)				SRaw (*cm H_2O/s*)			
	Before	After	Δ	Δ%	Before	After	Δ	Δ%	Before	After	Δ	Δ%
Air												
Mean	4,857	4,806	−51	−1.10	5,850	5,774	−76	−1.26	3.66	3.78	0.12	9.74
± SE	210	249.4	107	2.25	172	190	130	2.29	0.59	0.50	0.17	4.89
p Value			0.67				0.60				0.54	
0.4 ppm $^{18}O_3$												
Mean	4,613	4,099	−515	−11.4	5,792	5,170	−622	−15.5	4.93	6.58	1.65	33.7
± SE	152	253	165	3.66	119	180	178	6.2	0.48	0.81	0.57	10.1
p Value			0.02				0.01				0.02	

n = four air-exposed and eight O_3-exposed.

- 2h Ozone exposure to humans causes a reduction is lung function and increased lung inflammation
- Can't breath in as deeply, and can't breath out as quickly
- Lung inflammation is associated with lung cancer, as well as systemic impairments in cardiovascular function

Am. J. Resp. Crit. Care Med. 1994

How does it translate to rat exposures?

- Ozone is a unique toxicant in that rat exposures are not very comparable
- About 1/5 of the amount of ozone that incorporates into the lung tissue in humans, incorporates into the lung tissue of rats
- But higher doses in rats show the same effects as seen in humans

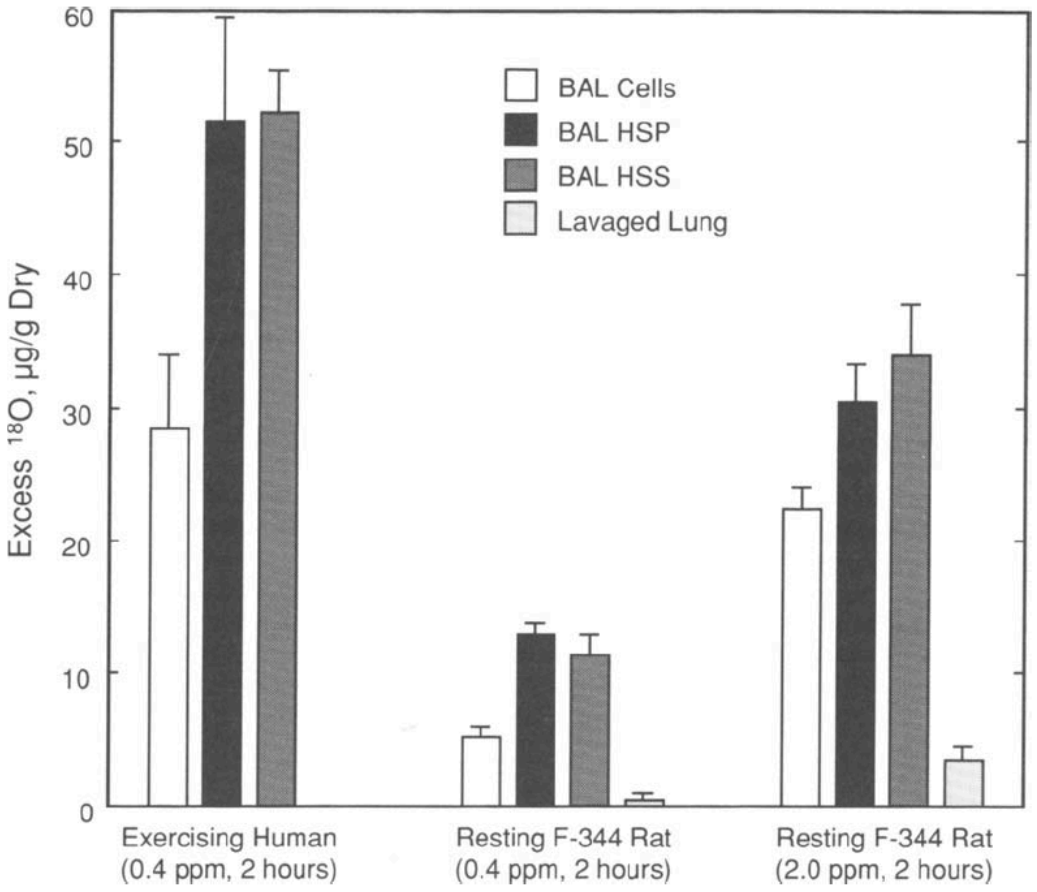
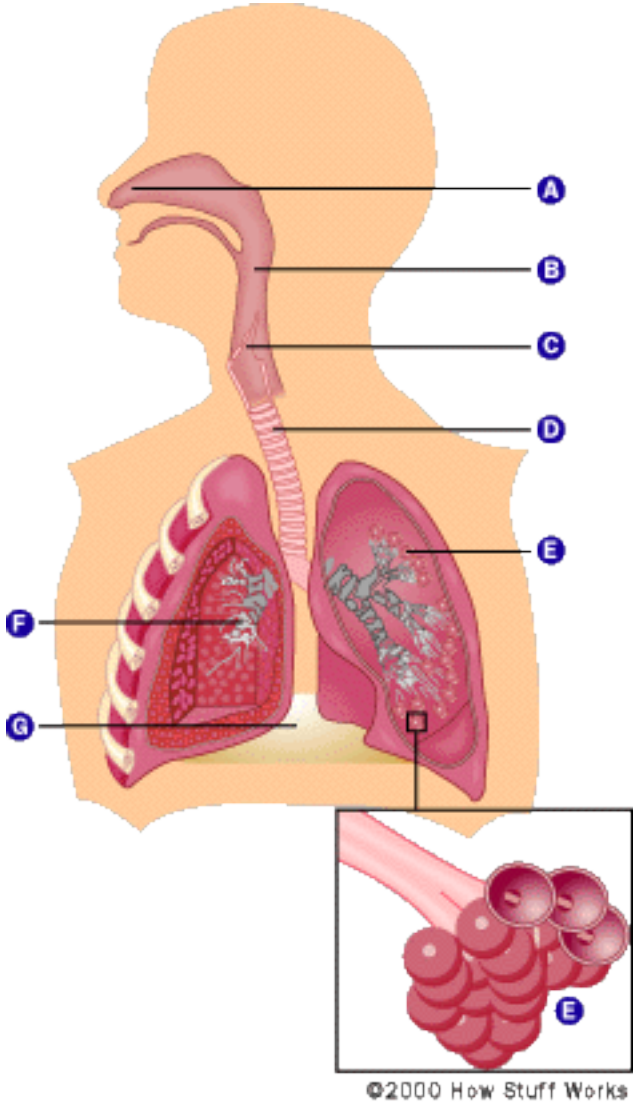


Figure 1. Oxygen-18 incorporation into different fractions of bronchoalveolar lavage fluid from humans and rats exposed to 0.4 and 2.0 ppm $^{18}O_3$. The excess ^{18}O in each fraction is expressed relative to the dry weight of that fraction. Fractions assayed include cells, high speed pellet (HSP), high speed supernatant (HSS), and lavaged lung homogenates.

Am. J. Resp. Crit. Care Med. 1994

So how is it toxic?



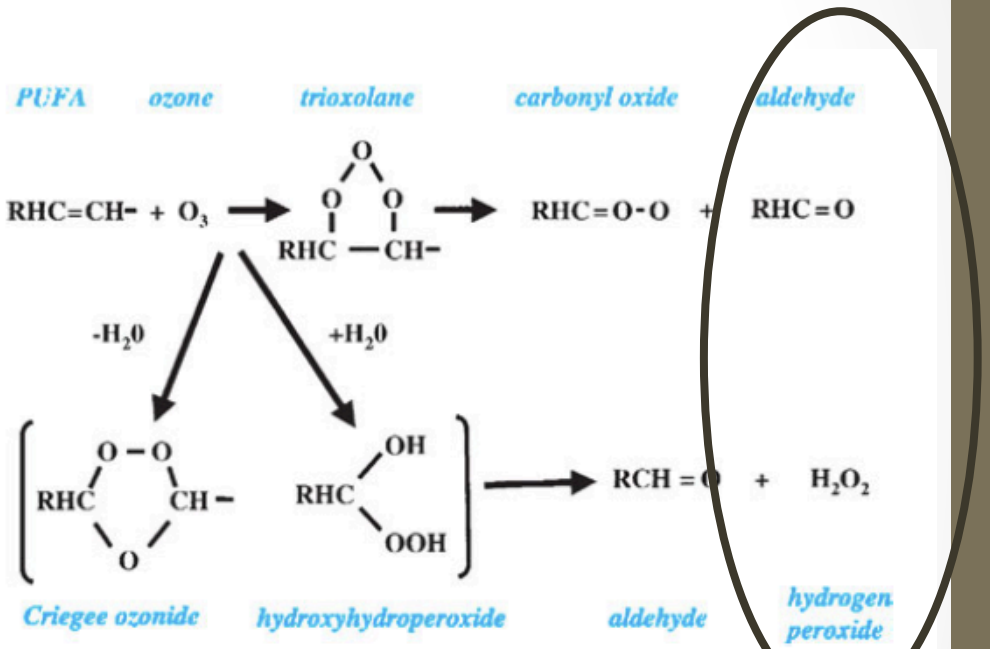


Figure 28-12. Major reactions pathways of O_3 with lipids in lung lining fluid and cell membranes. (Adapted with permission from the Air Quality Criteria Document for Ozone and Photochemical Oxidants, 600/P-93/004cF, NCEA Research Triangle Park, NC: U.S. EPA, 1996).

Modification of lipids and general oxidative stress incite strong inflammatory responses!

EPA Will Enforce Bush-Era Ozone Limit, Agency Chief Says

By GABRIEL NELSON of Greenwire

Published: September 22, 2011

U.S. EPA plans to enforce smog rules that were put in place under George W. Bush, now that President Obama has asked the agency to wait until 2013 to move on still-stricter air quality standards for ozone, Administrator Lisa Jackson told lawmakers on Capitol Hill this morning.

Jackson had spent the past two years reconsidering the limit of 75 parts per billion, which was finalized in 2008, because it was higher than the range of 60 to 70 ppb recommended by the agency's science advisers.

Her recommendation was 70 ppb, she told members of the House Energy and Commerce Committee this morning, in her first public disclosure of EPA's final proposal to the White House.

But now that Obama has stopped the reconsideration, based on concerns that the rule could hold back the struggling economy, the entire country is legally required to ratchet down air pollution limits from the previous standard of 84 ppb, Jackson told members of the committee. Air quality officials will be given new instructions in the days ahead, she said.

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- As Solyndra Execs Prepare to Take the Fifth, Company Blames DOE for Its Demise
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- DNC Members Latest on Left to Pressure Obama on Canada-To-U.S. Pipeline

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OXFORD
AMERICAN
THE SOUTHERN MAGAZINE OF GOOD WRITING
WINNER: NATIONAL MAGAZINE AWARD FOR VIDEO 2011

Toxic Trash: The Burn Pits of Iraq and Afghanistan

Published on August 24 2011

98

Billy McKenna and Kevin Wilkins survived Iraq—and died at home. The Oxford American sent filmmaker Dave Anderson and journalist J. Malcolm Garcia to Florida to investigate this deadly threat to American soldiers.