Air Pollution

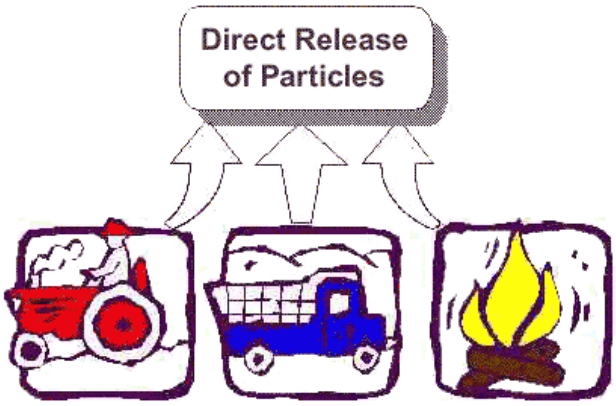
Seven Main Air Pollutants of Concern:

1. P_____
2. S_____ Oxides (SO_X)
3. O_____
4. N_____ Oxides (NO_X)
5. Carbon M_____ (CO and other hyrdrocarbons)
6. Volatile O_____ Compounds (VOCs)
7. L_____ (mercury, other inorganic metals, radon)

Particulates:

– released d_____ into the air
– largely a result of s_____ sources
– a nearly ubiquitous u_____ pollutant.

"Although particulate levels in North America and Western Europe rarely exceed 50 micrograms of particulate matter per cubic meter (μμg/m^3) of air, levels in many Central and Eastern European cities and in many developing nations are much higher, often exceeding 100 μg/m^3 (http://www.wri.org/wr-98-99/urbanair.htm)."



http://www.epa.gov/air/urbanair/pm/what1.html

Size of Particulates:

– $PM_{2.5-100}$: 2.5 to 100 μ in diameter, usually comprise s_____ and d_____t from industrial processes, agriculture, c_____, and road traffic, p_____ and other natural sources.
– $PM_{2.5}$: particles less than 2.5 μ in diameter generally come from combustion of f_____ fuels.
  – vehicle exhaust s_____, which is often coated with various chemical contaminants
  – fine sulfate and nitrate a_____ that form when SO2 and nitrogen oxides condense in the atmosphere.
  – largest source of fine particles is c_____-fired power plants, but auto and diesel e_____ are also prime contributors, especially along busy transportation corridors.

Health Effects:

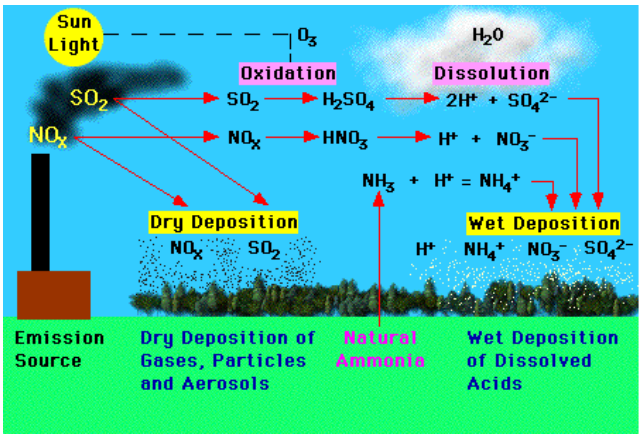
– s_____ particulates most damaging ($PM_{2.5}$)
– $PM_{2.5}$ aggravate existing h_____ and lung diseases
– changes the body's defenses against i_____ materials, and damages l_____ tissue.
– e_____ children and those with chronic lung or heart disease are most sensitive
– lung impairment can persist for 2-3 weeks after e_____ to high levels of $PM_{2.5}$
– c_____ carried by particulates can also be toxic

National Ambient Air Quality Standards (NAAQS)

Criteria Pollutants	Standard Type	Avg. Time	Conc.	Health Risks and Concerns	Anthropogenic Sources	Natural Sources
Carbon monoxide	Primary	8 h 1 h	9 ppm 35 ppm	carboxy-hemoglobin (blood)	incomplete combustion from mobile and stationary sources	intermediate in breakdown of methane by hydroxyl radicals (OH·)
Hydrocarbons (measured as CH_4)	Primary	3 h	240 ppb	photochemical smog	incomplete combustion from mobile and stationary sources	see graph
Lead	Primary	24 h 3 month	18 ppb 6 ppb	CNS	leaded gasoline (obsolete?), smelters and refineries	volcanic activity and soils
Nitrogen dioxide	Primary	annual 1 h	53 ppb 250 ppb	health risks, visibility (NO_2 has a brown color)	high temperature combustion	bacterial processes in soil release nitrous oxide N_2O
Ozone	Primary	1 h 8 h	120 ppb 80 ppb	eye irritation, breathing difficulties	formed in nitrogen oxide photolytic cycle (NO_X + sunlight)	
Sulfur dioxide	Primary	annual 24 h	30 ppb 140 ppb	respiratory disease	sulfur in fuel	sulfur released in biological processes
Sulfur dioxide	Secondary	3 h	500 ppb	plant damage, material damage		
Total suspended particulates (TSP)	Primary	annual 24 h	75 μg/m^3 150 μg/m^3	visibility and respiratory effects	combustion of fossil fuels and industrial activity	soil, sea salt, sand, forest fires, volcanoes
Particulates (PM_{10})	Primary	annual 24 h	50 μg/m^3 365 μg/m^3	visibility and respiratory effects		
Particulates ($PM_{2.5}$)	Primary	24 h	65 μg/m^3	visibility and respiratory effects		

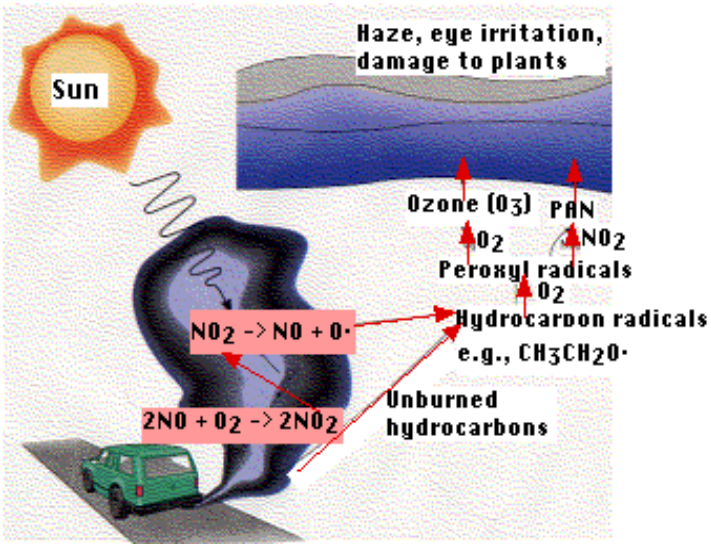
Sulfur Oxides (SO_X, mainly SO_2)

- emitted largely from burning c_____, high-sulfur o_____, and d_____ fuel.
- usually found in association with p_____
- SO2 is the p_____ for fine sulfate particles (separating the health effects of these two pollutants is difficult)
- SO_2 and particulates make up a major portion of the pollutant l_____ in many cities, acting both separately and in c_____ to damage health.
- concentrations are higher by a factor of _____ in a number of cities in Eastern Europe, Asia, and South America, where residential or industrial coal use is still prevalent and diesel traffic is heavy
- major component of a_____ r_____



Health Effects:

- SO_2 affects people q_____, usually within the first few minutes of e_____
- SO_2 exposure can lead to the kind of a_____ health effects typical of particulate pollution.
- Exposure is linked to an increase in h_____ and deaths from respiratory and cardiovascular causes, especially among a_____ and those with preexisting r_____ diseases
- severity of these effects increases with rising SO_2 levels, and e_____ enhances the severity by increasing the volume of SO_2 inhaled and allowing SO_2 to penetrate deeper into the respiratory t_____
- Asthmatics may experience w_____ and other symptoms at much lower SO_2 levels than those without asthma.
- When o_____ is also present, asthmatics become even more sensitive to SO_2 indicating the potential for s_____ effects among pollutants



Ozone

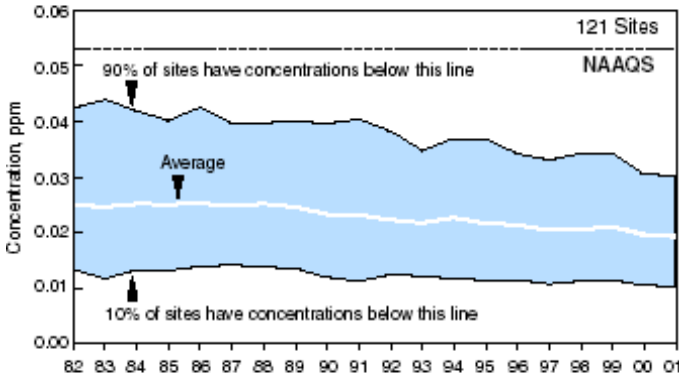
- major component of p_____ smog
- formed when N_____ from fuel combustion react with V_____
- s_____ and heat stimulate ozone formation, peak levels occur in the s_____
- w_____ in cities in Europe, North America, and Japan as auto and industrial emissions have increased. Many cities in d_____ countries also suffer from high ozone levels
- powerful o_____, can react with nearly any biological tissue.

– concentrations of 0.012 ppm can irritate the respiratory tract and impair l_____ function, causing coughing, shortness of breath, and c_____ pain.
– Exercise increases these effects, and heavy e_____ can bring on symptoms even at low ozone levels (0.08 ppm).
– ozone exposure l_____ body's defenses, increasing susceptibility to respiratory infections
– hospital a_____ and emergency room visits for respiratory illnesses such as asthma, increase proportionally with ozone levels
– hospital admissions rise roughly 7 to 10 percent for a 0.05 ppm increase in ozone levels.
– in 13 cities where ozone levels e_____ U.S. air standards, the American Lung Association estimated that high ozone levels were responsible for approximately 10,000 to 15,000 extra hospital admissions and 30,000 to 50,000 additional emergency room v_____ in 1993-94

Nitrogen Oxides (NO_X, mainly NO_2)

– principal p_____ component of photochemical smog
– component of a_____ rain (NO_X is oxidized to NO_3^- in the atmosphere, NO_3^- reacts with moisture to form nitric acid H_2 NO_4)
– formed i_____ due to high temperature of combustion of atmospheric nitrogen

NO_2 Air Quality, 1982–2001
Based on Annual Arithmetic Average

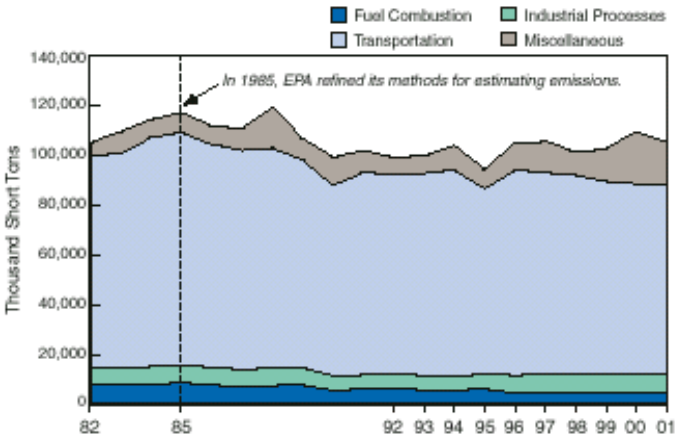


1982–01: 24% decrease
1992–01: 11% decrease

Carbon Monoxide

– H_____ has an affinity for CO that is 200 to 250 times its affinity for oxygen - this reduces its affinity for oxygen, disrupts release of oxygen.
– Blood level of 0.4% is maintained by CO produced by b_____.
– Blood is cleared of 50% of CO in 3-4 hours after e_____.
– Global emissions of CO are 350 million tons per year, 20% from m_____ sources.
– CO concentration in c_____ smoke is 200-400 ppm.
– 24% of emergency room patients complaining of f_____-like symptoms in one study showed carbon monoxide poisoning

CO Emissions, 1982–2001



1982–01: 0% change
1992–01: 6% increase

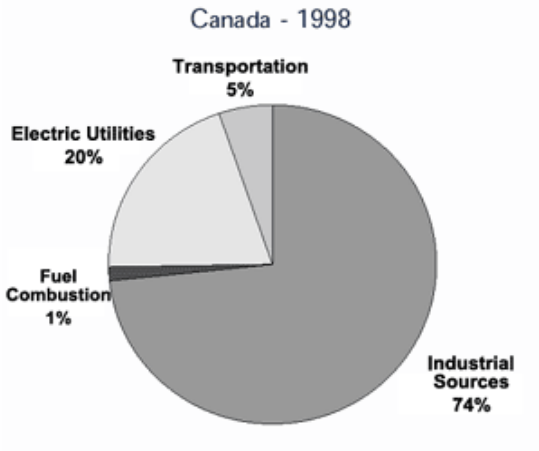
Volatile Organic Compounds (VOCs)

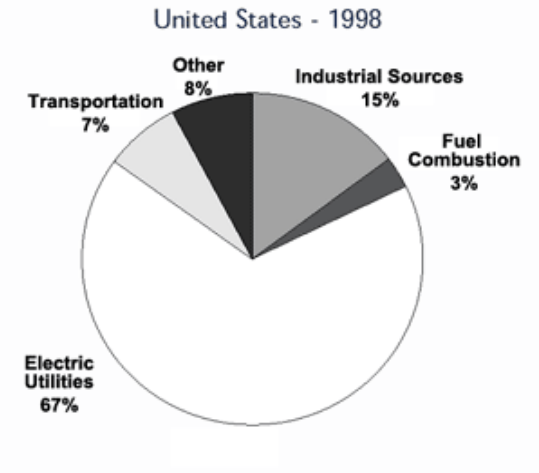
– contribute to o_____ generation
– many are subject to NESHAPS (benzene from gasoline vapors)
– significant i_____ emissions (e.g., perchloroethylene from d_____ cleaners)
– many are c_____ or suspected carcinogens

ACID RAIN

What is acid rain?

- More accurate term may be acid d_____
- Occurs in two forms
  - w_____ deposition (acidic rain, fog, and snow)
  - d_____ deposition (acidic gases and particles)
- Principal c_____ are SO_X and NO_X
- About _____ of SO_X and _____ of NO_X comes from power plants (most are coal burning)





http://www.ec.gc.ca/acidrain/acidfact.html

How do we measure?

- pH of "natural" rain water is _____ (pK_{a1} H_2CO_3 is 6.35)
- m_____ by two networks, both supported by EPA
  - The National Atmospheric Deposition Program measures w_____ deposition, and its Web site (http://nadp.sws.uiuc.edu/) features maps of pH
  - The Clean Air Status and Trends Network (CASTNET) measures d____deposition (http://www.epa.gov/castnet/)

Effects of acid rain:

- damage to forests and soils, fish and other living things, materials, and human health.
  - acidification of l_____ and s_____

In a National Surface Water Survey (NSWS)

– effects of acidic deposition in over 1,000 lakes larger than 10 acres and in thousands of miles of streams believed to be sensitive to a_____

– acid rain caused acidity in _____ percent of the acidic lakes

– acid rain caused acidity in about _____ percent of the acidic streams

– U.S. regions containing many of the s_____ w_____ sensitive to acidification include:

– the Adirondacks and Catskill Mountains in New York state,

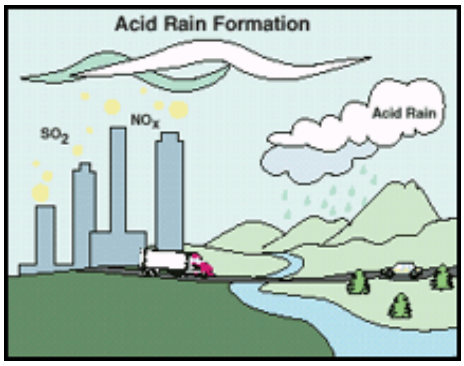
– the mid-Appalachian highlands along the e_____ c_____,

– the upper M_____, and mountainous areas of the Western United States.

– In areas like the Northeastern United States, where s_____ buffering capacity is poor, some lakes now have a pH value of less than _____.

– One of the most acidic is Little Echo Pond in Franklin, NY with a pH of__ ____.

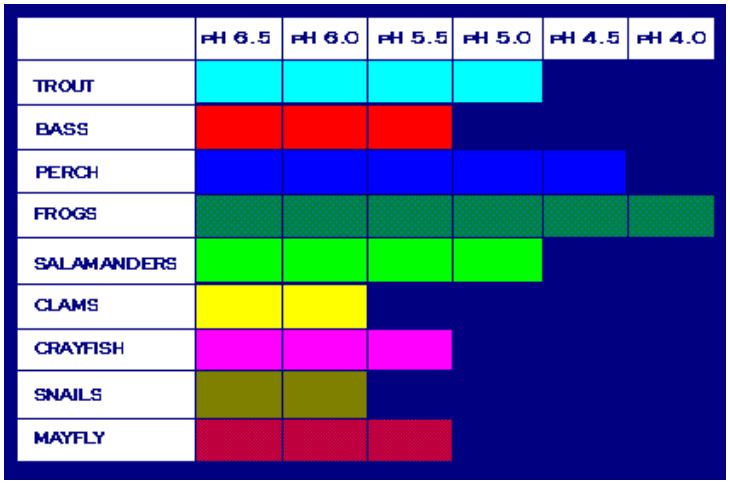
– also a problem in lakes smaller than 10 acres that were not included in the NSWS (may increase the number up to f_____ - fold).



- approximately _____ percent of sensitive lakes in the Adirondacks are at risk of e_____ acidification (brief periods of low pH)
- low b_____ streams: _____ of the streams in the Mid-Atlantic Coastal Plain

are acidic, in the New Jersey Pine Barrens, over _____ percent of the streams are acidic (highest rate of acidic streams in the nation), and over _____ of the streams in the Mid-Atlantic Highlands (mid-Appalachia) are acidic, primarily due to acidic deposition.

- Canadian government has estimated that _____ lakes in eastern Canada are acidic.



Affects Fish and Aquatic Species

- acid rain causes a c_____ of effects that harm or k_____ individual fish, reduce fish p_____ numbers, e_____ fish species, and decrease b_____
- increased a_____ levels cause chronic stress that may not kill individual fish, but leads to lower body weight and smaller size and makes fish less able to compete for food and habitat.
- generally, the y_____ of most species are more sensitive to environmental conditions than adults. At pH 5, most fish e_____ cannot hatch. At lower pH levels, some adult fish die.

Tree and Forest Damage

- damage of trees at high e_____ (for example, red spruce trees above 2,000 feet) and many sensitive forest soils.

Water Quality Impacts

- n_____ impacts on water quality due to eutrophication (o_____ depletion, a_____ blooms, d_____ in the health of fish and shellfish, loss of s_____ beds and c_____ reefs, and ecological changes in food webs): 10-45 percent of the nitrogen produced by various human activities that reaches e_____ and coastal e_____ is transported and deposited via the atmosphere. _____% of nitrogen in the Chesapeake Bay comes from atmospheric deposition.

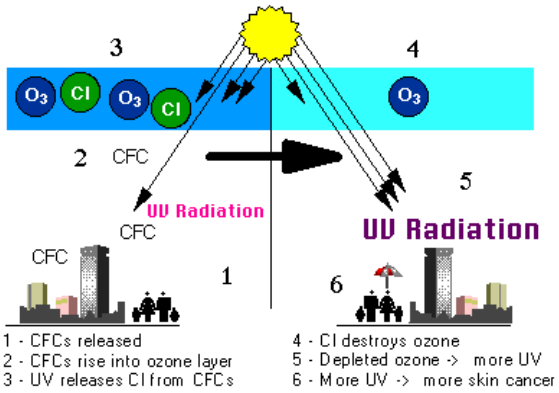
Materials and Building Decay

- a_____ the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage.
- acid rain can s_____ automotive coatings
- Acid rain and the dry deposition of acidic particles contribute to the c_____ of metals (such as bronze) and the deterioration of paint and s_____ (such as marble and limestone).
- some car manufacturers use acid-resistant paints, at an average cost of $_____ for each new vehicle ($61 m total/y)

Air Quality Concentrations
1981–00 50% decrease
1991–00 37% decrease
1999–00 4% decrease
Emissions
1981–00 27% decrease
1991–00 21% increase
1999–00 6% increase

Worth Noting:
SO2 concentrations have been reduced by over 50% over the past 20 years (1982-2001) and approximately 35% over the more recent 10-year period (1992-2001) nationwide. Reductions in SO2 concentrations since 1990 are due, in large part, to controls implemented under EPA's Acid Rain Program beginning in 1995.

- **Affects visibility** (as in photochemical smog from NO_X) Sulfate particles account for _____ percent of the visibility reduction in the eastern part of the United States



Acid Rain Reductions

- EPA's Acid Rain Program caps SO_2 emissions from power plants at _____ million tons/yr
- 1990 Acid Rain Program under the Clean Air Act set goal to achieve reductions of _____ million tons of sulfur dioxide (SO_2) and _____ million tons of nitrogen oxides (NO_X).
- When fully implemented by the year 2010, the public health benefits of the Acid Rain Program are estimated to be valued at $_____ billion annually, due to decreased m_____, h_____ admissions, and emergency room visits.

(for more details see: http://www.epa.gov/airmarkets/progress/arpreport/acidrainprogress.pdf)

Ozone Depletion

– _____ % of the planet's ozone is in the ozone layer in the statosphere (10-50 kilometers above the Earth's surface)
– Stratospheric ozone is a naturally-occurring g____ that filters the sun's ultraviolet (UV) radiation
– d_____ ozone layer allows more UV to reach the Earth
– overexposure to UV rays can lead to s_____ cancer, c_____, and weakened i_____ systems.
– Increased UV can also lead to reduced c_____ yield and disruptions in the m_____ food chain.
– ozone destruction occurs when the release of c_____ (CFCs) and other ozone-depleting substances (ODS), widely used as refrigerants, insulating foams, and solvents.
– CFCs are heavier than air, can take as long as _____ years to reach the stratosphere
– Stratospheric measurements are made from b_____, aircraft, and satellites.
– When CFCs reach the stratosphere, the U___ from the sun causes them to break apart and release c_____ atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer.
– One chlorine atom can break apart more than _____ ozone molecules.
– Other chemicals that damage the ozone layer include:
  – m_____ bromide (used as a pesticide)
  – h_____ (used in fire extinguishers)
  – m_____ chloroform (used as a solvent in industrial processes).
– As methyl bromide and halons are broken apart, they release bromine atoms, which are 40 times more destructive to ozone molecules than chlorine atoms.
– Halon-1301 has _____ times depleting potential as CFC-11
– total chlorine is d_____, while bromine from industrial halons is increasing
– v_____ and o_____ release large amounts of chlorine, the chlorine from these sources is easily dissolved in water and washes out of the atmosphere in rain.
– CFCs are not broken down in the lower atmosphere and do not d_____ in water.

– the increase in stratospheric c_____ since 1985 matches the amount released from CFCs and other ozone-depleting substances produced and released by human activities.
– In 1978, the use of CFC p_____ in spray cans was banned in the U.S.
– In the 1980s, the Antarctic "o_____ hole" appeared and an international science assessment more strongly linked the release of CFCs and ozone depletion.
– 1987, the Montreal Protocol was signed and the signatory nations committed themselves to a r_____ in the use of CFCs and other ozone-depleting substances.
– Since that time, the treaty was amended to ban CFC production after 1995 in d_____ countries, and later in developing countries.
– Today, over 160 countries have signed the treaty. Since January 1, 1996, only re_____ and stockpiled CFCs have been available for use in developed countries
– This production phaseout is possible because of efforts to ensure that there will be s_____ chemicals and technologies for all CFC uses.
– but provided that we stop producing ozone-depleting substances, n_____ ozone production reactions should return the ozone layer to normal levels by about _____