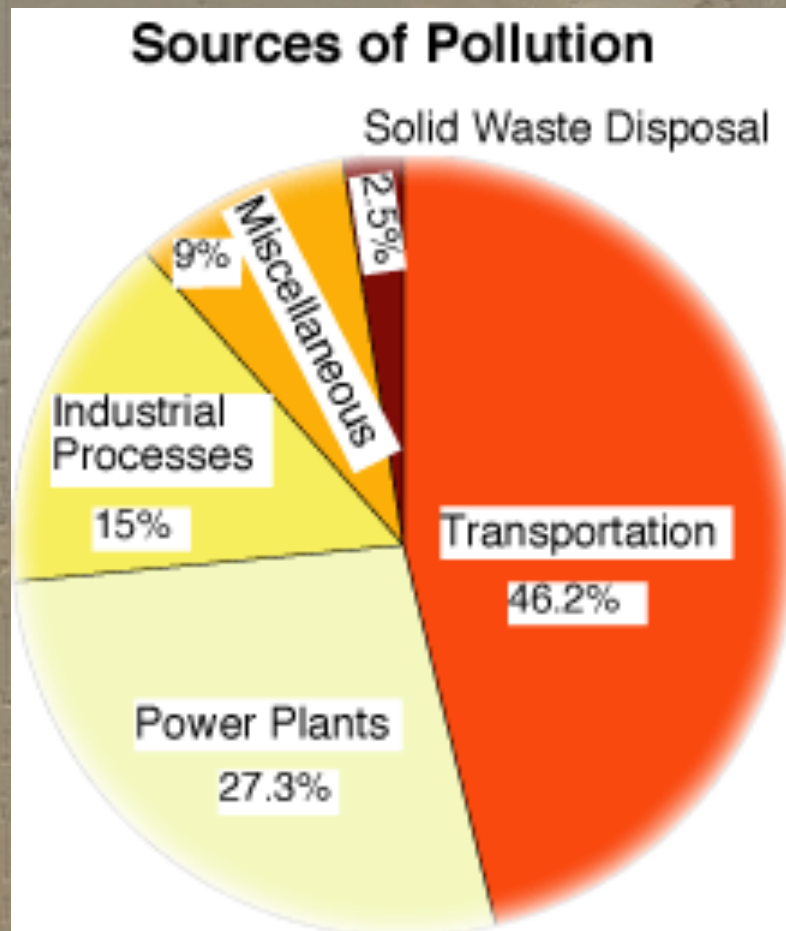
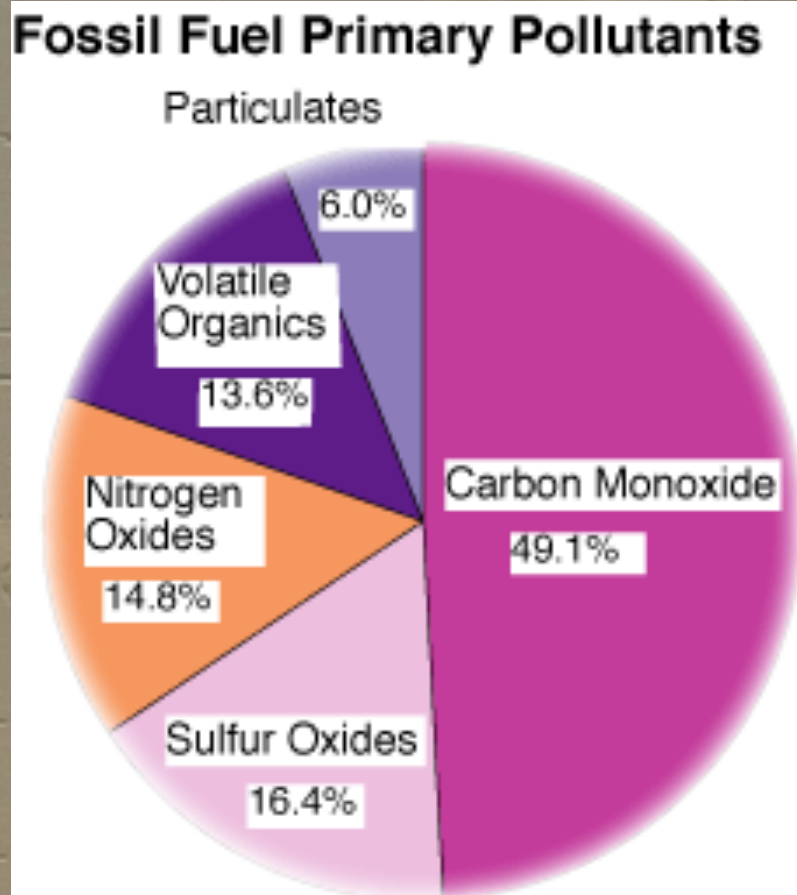


Air Pollution and Acid Rain



- transportation (majority)
- power plants
- industry

Air Pollution and Acid Rain

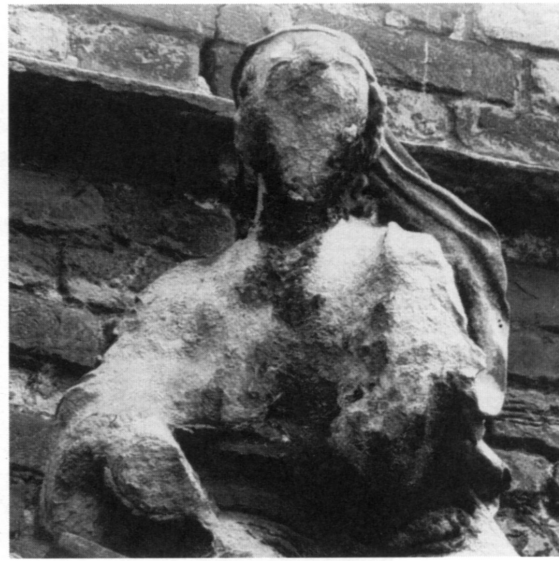


CO₂ considered greenhouse gas but not a pollutant

- CO from burning fossil fuels
- NO_x with sunlight → O₃
- NO_x from car engines (with rain nitric acid)
- SO₂ from coal burning (with rain sulfuric acid)

**volatile organics are carcinogenic
particulates cause respiratory ailments**

Acid Rain and Coal Burning



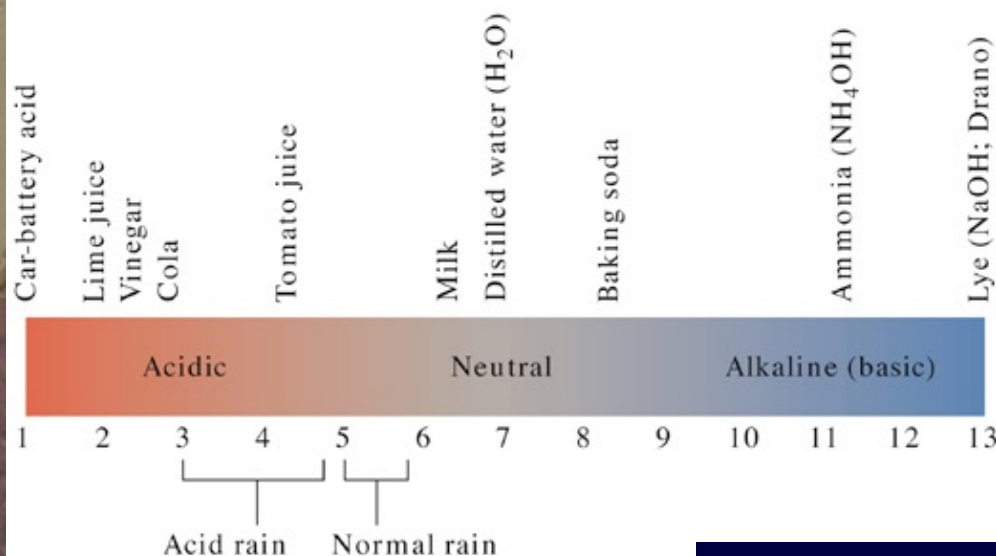
**statues at the
Cologne/D
cathedral**

(1248)

Image: “Understanding Earth” by Press/Siever

- massive fish kills in freshwater lakes (Scandinavia, Canada, NE U.S.)
- about 50% of Canada's fallout has U.S. source
- mountain forests damaged, particular at higher elevations
- \$1 billion damage each year to buildings and monuments
- relationship between acid rain and coal burning firmly established
- > Clean Air Act in 1991: reduce SO_2 and NO_2 production!

Acid Rain and Fish Kill



- pH of normal rain: 5-6
- pH of acid rain: 3-5

**East burns low-grade coal
(has more FeS_2 /Pyrite)**

**Southwest has traffic!!
(NO_x emission)**

Acid Rain



**75% of lakes
50% of streams acidified**



Image: <http://en.wikipedia.org>

**fish cannot hatch at pH < 5
fish die at pH < 5
e.g. brook trout in Appalachians**

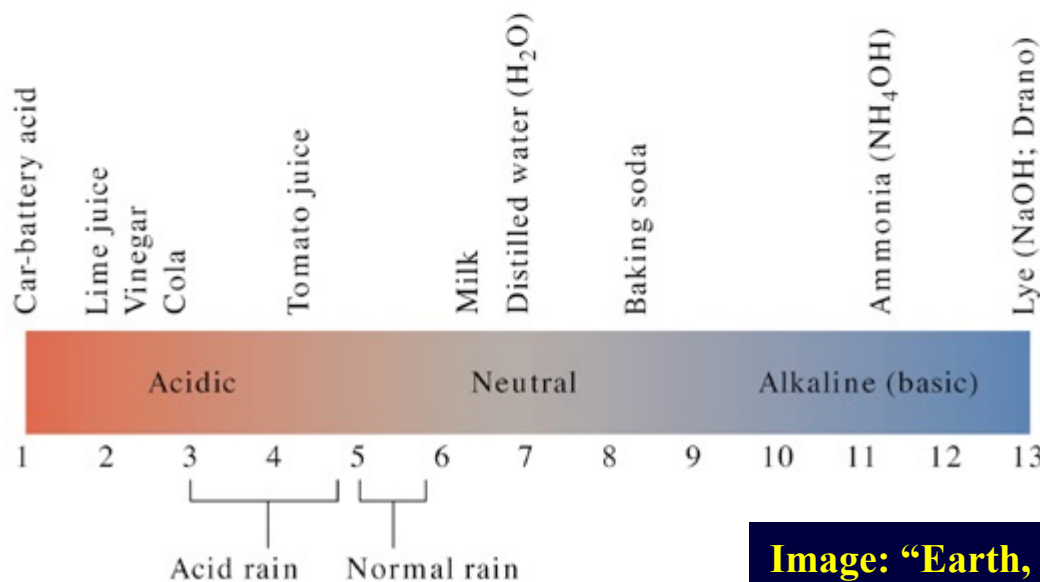


Image: "Earth, Portrait of a Planet" by Marshak Changes: The Atmosphere

Canadian Lakes: Long-term Effects

Canadian Lakes 'Jellified' by Acid Rain

November 28, 2014



Decades of acid rain that have made many Canadian freshwater lakes more acidic have also profoundly altered the ecological balance and turned some lake bottoms to jelly.

Even though pollution controls have long since diminished the amount of acid rain, some affected lakes have not recovered from the pollution and have become home to expanding populations of a tiny, slimy crustacean called the *Holopedium*.

The invertebrate is surrounded by a bulbous coating of jelly.

Swimmers in affected lakes often emerge from the water with the caviar-like balls clinging to their arms and backs.

Writing in the journal *Proceedings of the Royal Society B*, researchers document that decades of acid rain have flushed away much of the calcium in the lakes, which *Holopedium*'s biggest competitor, the *Daphnia* water flea, needs to create an exoskeleton.

With the formerly dominant *Daphnia* now deprived of enough calcium to bulk up, and gradually disappearing, *Holopedium* has been able to reproduce unchecked since it needs far less calcium to make its gooey shell.

This competitive edge is creating a jellied mess that threatens to clog water intake systems in the lakes for residential and commercial use.

Photos: Ron Ingram/Ontario Ministry of the Environment and Climate Change



Top: Microphotograph of the *Holopedium*. Bottom: Researcher holds a handful of the small invertebrates, which have slimed some Canadian lakes.

Acid Rain and Tree Kill in Europe

Tree Kill in German Forest



Image: wikipedia



acid rain -> acidified soil
harm roots -> no water/nutrient uptake
free aluminum -> toxin

1980s: from high smoke stacks;
lignite burning in Eastern Europe
2006: 75% of German forest now affected
(how much of this is global warming?)
- pest infestation

Particulate Matter

tiny pieces of solid or liquid matter in atmosphere
suspended in air - > aerosol

Radiative forcing:
lower atm: positive
upper atm: negative

- biological
- dust
- particulate contaminants (soot, smog)
- gas molecules (e.g. SO_2)

Aerosol Optical Depth

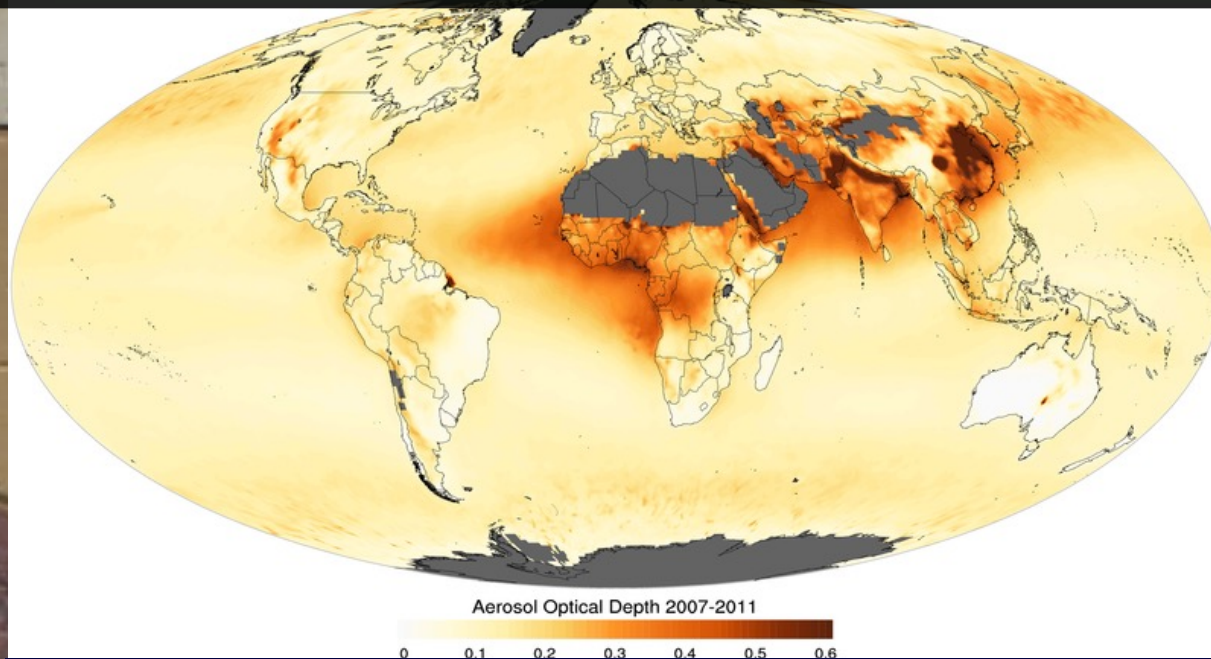


Image: wikipedia/ NASA

Changes: The Atmosphere

Particulate Matter

tiny pieces of solid or liquid matter in atmosphere
suspended in air - > aerosol

Radiative forcing:
lower atm: positive
upper atm: negative

PM $\mu\text{g}/\text{m}^3$ (2004)	City
169	Cairo, Egypt
150	Dehli, India
128	Calcutta, India
125	Taiyuan, China
123	Chongqing, China
109	Kanpur, India
109	Lucknow, India
104	Jakarta, Indonesia
101	Shenyang, China

EU PM₁₀ legislation limits:
yearly average: $20\mu\text{g}/\text{m}^3$
daily average: $50\mu\text{g}/\text{m}^3$
days: 7

Black Carbon in the Lower Atmosphere



- RF of CO₂ 1.7
- RF of black carbon: 0.34 – 1.1
- short-lived
- reduction would have instant effect

6% residential coal burning
10% industrial; power generation
10% diesel engines, industrial
14% diesel engines, transportation
18% residential biofuel burning
42% open biomass burning

work done at SIO (Ramanathan)