

Study Questions

1. Compare and contrast primary vs. secondary pollutants, giving examples of each.
2. Compare and contrast indoor vs. outdoor pollution, listing specific examples and sources of each.
3. Briefly explain the pH scale. What is the pH of natural rainwater and why?
4. What causes acid rain? What are some of its effects?
5. What can be done to reduce acid rain?
6. Describe the causes and effects of the thinning ozone layer.

Air Pollution



Developed Countries have reduced emissions recently

- increased efficiency of cars, factories, power plants
- pollution-control technologies

Developing Countries still struggling

- dust, smoke, dirt 10x higher than safe levels

“Asian Brown Cloud”



www.nasaimages.org/luna/servlet/detail/nasaNA...

Primary pollutants: chemicals released directly into the air in a harmful form



Examples of Primary Pollutants:

- Car exhaust, smokestacks (CO, SO₂, NO)
- Particulate material (soot, ash)
- Toxic metals (lead, mercury)
- Volatile organic compounds (VOCs)
(methane, propane, CFCs, etc.)

Secondary pollutants: chemicals released into air that become hazardous after reacting with substances in the air

Examples of secondary pollutants:

- Atmospheric acids ($\text{H}_2\text{SO}_4, \text{HNO}_3$)
- Photochemical oxidants (NO_2)

The Conventional (Criteria) Pollutants

- Sulfur dioxide (SO_2)
- Nitrogen oxides (NO_x)
- Carbon monoxide (CO)
- Particulate material
- VOCs
- Lead
- Ozone

Sulfur dioxide (SO_2)

- Colorless, corrosive gas
- Reacts to form SO_3
- Reacts to form H_2SO_4 , (sulfuric acid)
- Major component of industrial smog



Nitrogen Oxides (NO_x)

- Very reactive gases
- $\text{NO} \rightarrow \text{NO}_2$ (photochemical smog)
- Combine with water to form HNO_3 (nitric acid)



Carbon monoxide (CO)

- Colorless, odorless toxic gas
- Produced by combusting coal, oils charcoal, wood, gas

Particulate Matter

- Ash, soot, dust, pollen
- Asbestos fibers
- Cigarette smoke

Volatile organic compounds (VOCs)

- Natural sources (bogs, termites, plants)
 - Methane (CH_4), isoprenes, terpenes
 - Converted to CO and CO_2 in atmosphere
- Man-made sources (vehicles, power/chemical plants, petroleum refineries)
 - Formaldehyde, toluene, chloroform, phenols

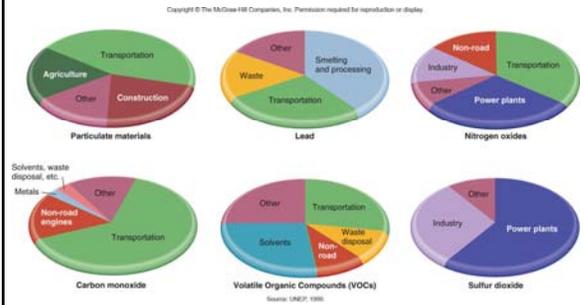
Lead and other Toxic Elements

- Metals (lead, mercury, arsenic, etc.)
- Halogens (fluorine, chlorine, bromine, iodine)
- Come from mining, manufacturing



gaussing.wordpress.com/2009/08/page/2/

Anthropogenic sources of 6 of the Conventional Pollutants



Indoor Pollution

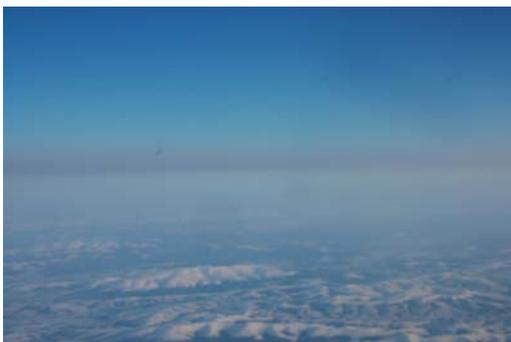


- Higher concentrations of toxic air pollutants inside
- People spend more time inside than out

Examples:

- Cigarette smoke (400,000 deaths per year in U.S.)
- Formaldehyde
- Mold
- Cooking/heating fires (over 1/3 of world population)

Haze over the Arctic



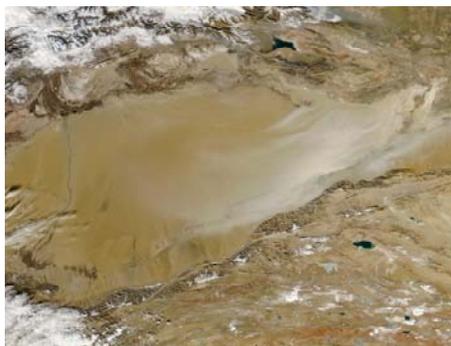
www.esrl.noaa.gov/.../photos/inter_dc8.php?num=1

Pollutants accumulate in food chains, especially at poles



www.feetofgreen.com/hggallery/page-216/page-15/

Dust storm over China



visibleearth.nasa.gov/view_rec.php?id=8302

Ozone Depletion

Ozone, O₃, is a pollutant in lower atmosphere but is necessary in upper atmosphere

Natural formation of Ozone:

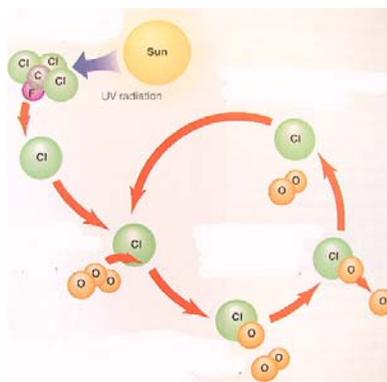
- 1) $O_2 + UV \rightarrow O + O$
- 2) $O + O_2 \rightarrow O_3$

Ozone "hole:" a depletion or thinning of ozone concentration in stratosphere

Depletion caused by chlorine-based aerosols, such as chlorofluorocarbons (CFCs)



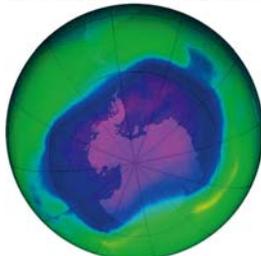
Ozone Destruction by CFCs



Ozone thinning is most severe over the arctic and Antarctic, due to the extremely cold temperatures

Seasonal depletion occurs, destroying 50% of ozone each spring, only some of which is regenerated

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Effects of Ozone Depletion

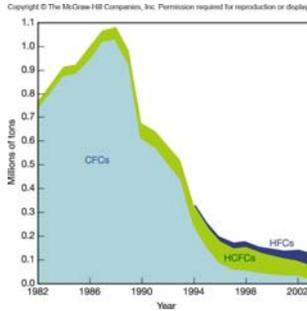
Ozone absorbs UV radiation, protecting organisms at earth's surface from these harmful rays

- Increased skin cancer
- Reduced crop yield
- Reduced phytoplankton, disrupted food chain
- Increased smog, acid deposition



What's Being Done?

- Reduce production of ozone-depleting chemicals
- The Montreal Protocol 1987



Acid Rain

Acid: substance that donates H⁺, pH less than 7

Base: substance that accepts H⁺, pH greater than 7

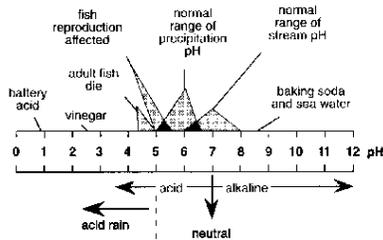
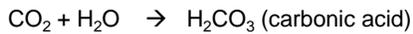
Pure water:

- pH 7 (neutral)
- Equal amounts of H⁺ and OH⁻

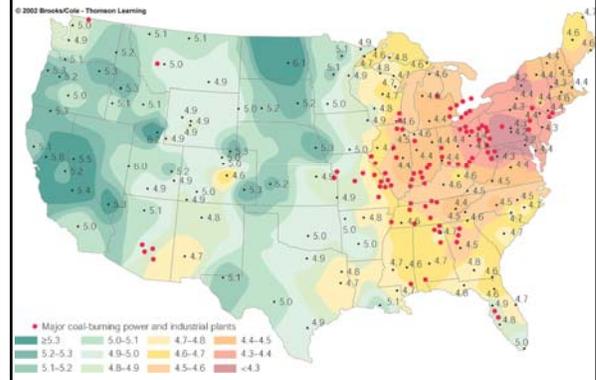


Rain water has a pH of about 5.6!

Rain water reacts with CO₂ in the air



"Acid rain" can have pH values below 4.3!



Sources of Acid Deposition

Air pollutants combine with water in air to form acids:

Sulfur dioxide (SO₂) → sulfuric acid (H₂SO₄)

Nitric oxide (NO) → nitrous acid (HNO₂)

Nitrous oxide (NO₂) → nitric acid (HNO₃)

These air pollutants come from:

automobiles, factories and power plants

Effects of Acid Deposition

- Reduced or destroyed aquatic life
- Damaged and dying forests
- Damaged/destroyed buildings and art
- Cause or worsen human illnesses



Sudbury, Ontario

Nickel, copper mining created acid precipitation

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1975

2005

