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Ch 15: Air Pollution

chapter 15: air pollution

Big ideas: air is shared by everyone on the planet, crosses international borders without consent, impacts innocents with little power.

6 major pollutants: "criteria pollutants"

- Sulfur dioxide: SO2
- Nitrogen oxides:NOx
- Carbon monoxide: CO
- Particulate matter: PM (PM 2.5, PM 5, PM10)
- Ozone: O3
- Lead: Pb

Mnemonic: SOX/NOX, CO/O3, PM/Pb

2007 added CO2, VOC, Hg

TABLE 46.1 Major air pollutants

Compound	Symbol	Human-derived sources	Effects/Impacts
Criteria air pollutants			
Sulfur dioxide	SO_2	• Combustion of fuels that contain sulfur, including coal, oil, gasoline	• Respiratory irritant, can exacerbate asthma and other respiratory ailments • SO_2 gas can harm stomata and other plant tissue • Converts to sulfuric acid in atmosphere, which is harmful to aquatic life and some vegetation
Nitrogen oxides	NO_X	• All combustion in the atmosphere including fossil fuel combustion, wood, and other biomass burning	• Respiratory irritant, increases susceptibility to respiratory infection • An ozone precursor, leads to formation of photochemical smog • Converts to nitric acid in atmosphere, which is harmful to aquatic life and some vegetation • Contributes to over-fertilization of terrestrial and aquatic systems
Carbon monoxide	CO	• Incomplete combustion of any kind • Malfunctioning exhaust systems and poorly ventilated cooking fires	• Bonds to hemoglobin, thereby interfering with oxygen transport in the bloodstream • Causes headaches at low concentrations • Can cause death with prolonged exposure at high concentrations
Particulate matter	PM_{10} (smaller than 10 micrometers) $PM_{2.5}$ (2.5 micrometers and smaller)	• Combustion of coal, oil, and diesel, and of biofuels such as manure and wood • Agriculture, road construction, and other activities that mobilize soil, soot, and dust	• Can exacerbate respiratory and cardiovascular disease and reduce lung function • May lead to premature death • Reduces visibility and contributes to haze and smog
Lead	Pb	• Gasoline additive, oil and gasoline, coal, old paint	• Impairs central nervous system • At low concentrations, can have measurable effects on learning and ability to concentrate
Ozone	O_3	• A secondary pollutant formed by the combination of sunlight, water, oxygen, VOCs, and NO_X	• Reduces lung function and exacerbates respiratory symptoms • Degrades plant surfaces • Damages materials such as rubber and plastic

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Other air pollutants			
Volatile organic compounds	VOC	• Evaporation of fuels, solvents, paints • Improper combustion of fuels such as gasoline	• A precursor to ozone formation
Mercury	Hg	• Coal, oil, gold mining	• Impairs central nervous system • Bioaccumulates in the food chain
Carbon dioxide	CO_2	• Combustion of fossil fuels and clearing of land	• Affects climate and alters ecosystems by increasing greenhouse gas concentrations

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SOx: Sulfur Dioxide (SO2) and other SOx versions

From Methionine (amino acid in living things) in fossil fuels

Combines with water in the air to make H2SO4 (sulfuric acid)

NOx: Nitric oxide (NO2) and other NOx versions

Various forms of oxidized nitrogen, which alone is inert and makes up 78% of the atmosphere at sea level

From high temperature combustion (e.g. auto engines, esp. high efficiency ones, which burn at higher temps)

Also from decomposition of fertilizers (e.g. Ammonium Nitrate)

CO: Carbon monoxide

Emission from car exhaust, or other incomplete combustion:

C + O2 —> CO2

If not enough O2, then CO forms, like in a closed space (tent, hut, cold house in Texas)

Toxic, permanently attaches to your hemoglobin rendering it useless for respiration. 30 day life cycle for hemoglobin

See also CO2 and climate change, > 400ppm since 2012, 420+ppm today (look this up)

Air Quality monitoring: Purple Air:

https://www.purpleair.com/map?&zoom=12&lat=20.03156357084113&lng=-155.69287088607177&clustersize=30&inc=313230|313232&orderby=L&latr=0.2806209732295741 3&lngr=0.3714752197265625

Check out other locations...

PM: Particulate Matter

PM2.5 is 2.5 microns in size, PM10 is 10 microns in size

PM2.5 is most dangerous, smaller particles lodge deep in the lungs, beyond ability of pulmonary cilia to flush out

PM5, PM10 larger particles

Main cause: coal fired power plants, diesel engines, oil fired power plants (soot)

See also vog: PM2.5 particles of ash with SO2 dissolved in water droplets: physical abrasive + corrosive acid = respiratory damage

Ozone

Ozone in stratosphere is good, in troposphere bad

Ozone (O3) blocks UV radiation, while Oxygen (O2) does not

Stratospheric ozone is necessary to filter UV radiation. CFC (chloro-fluro-carbons) destroy this layer this way:

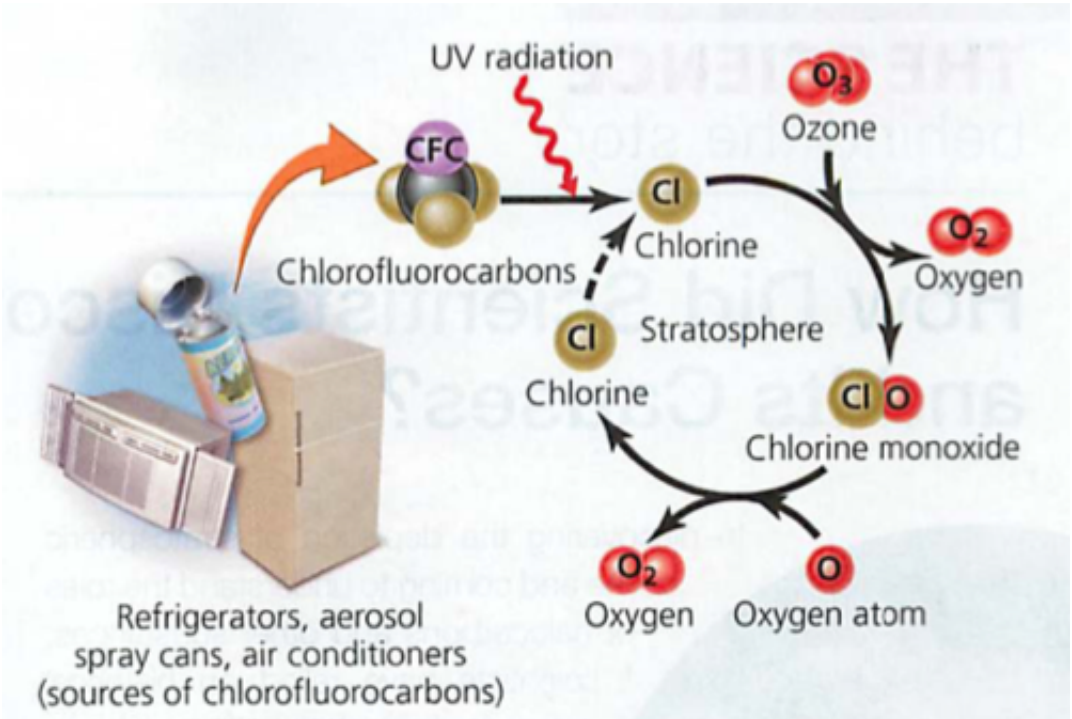

FIGURE 17.24 CFCs destroy ozone in a multistep process, repeated many times. A chlorine atom released from a CFC molecule in the presence of UV radiation reacts with an ozone molecule, forming one molecule of oxygen gas and one chlorine monoxide (ClO) molecule. The oxygen atom of the ClO molecule then binds with a stray oxygen atom to form oxygen gas, leaving the chlorine atom to begin the destructive cycle anew.

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This caused an ozone hole over antarctica:

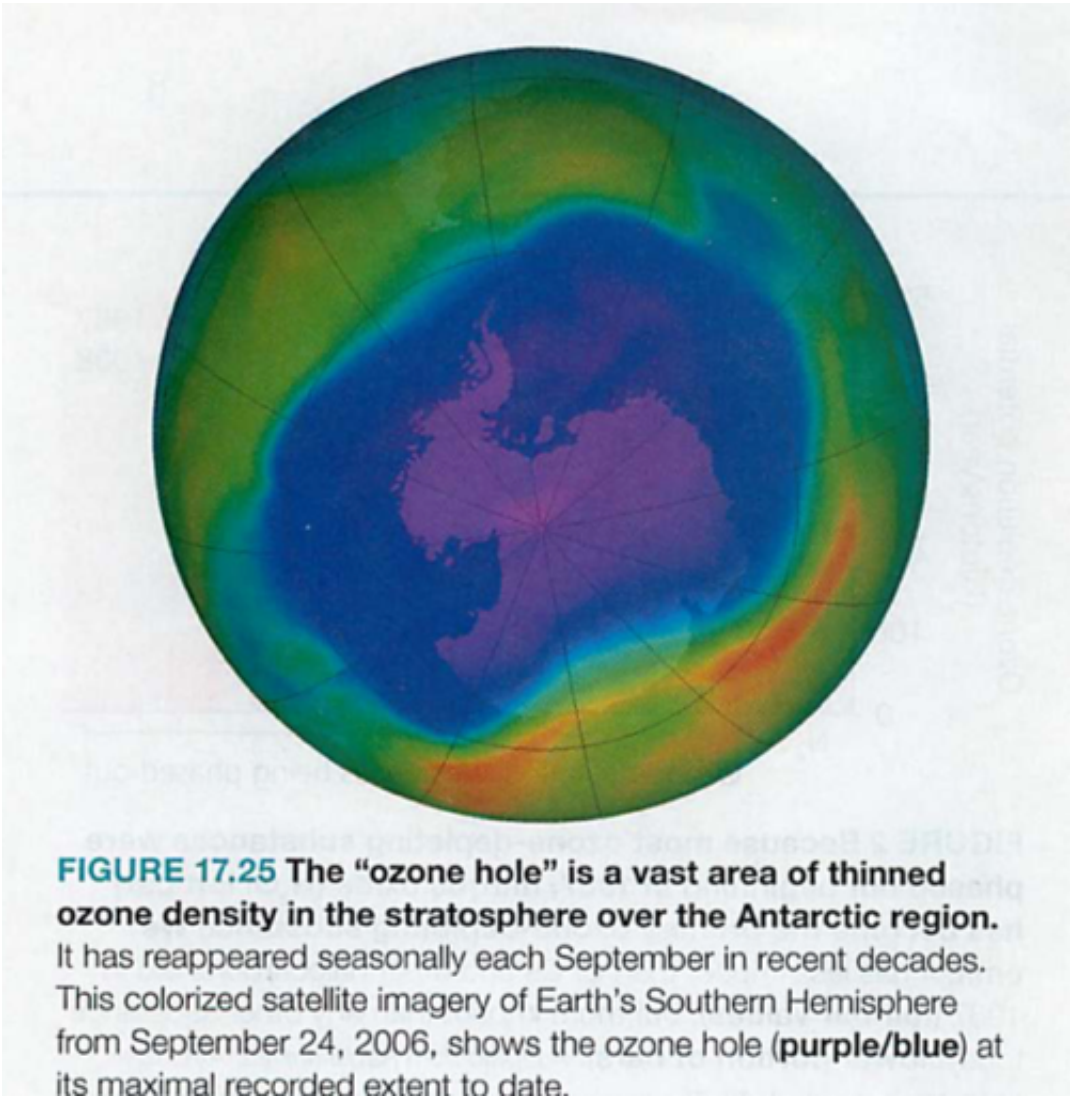

FIGURE 17.25 The "ozone hole" is a vast area of thinned ozone density in the stratosphere over the Antarctic region. It has reappeared seasonally each September in recent decades. This colorized satellite imagery of Earth's Southern Hemisphere from September 24, 2006, shows the ozone hole (**purple/blue**) at its maximal recorded extent to date.

Click for full-size image

How did we solve this? The 1987 Montreal Protocol:

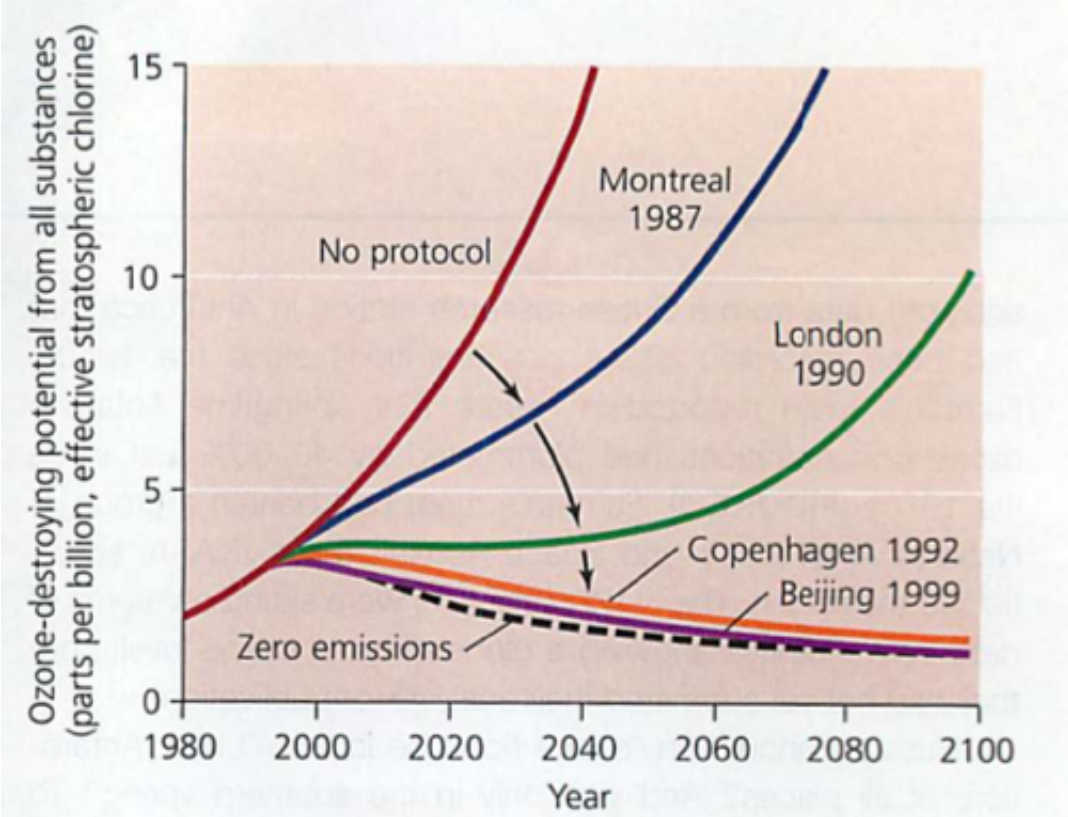

FIGURE 17.26 The Montreal Protocol reduced atmospheric concentrations of pollutants that destroy stratospheric ozone, and follow-up agreements in London, Copenhagen, and Beijing reduced them still more. In this graph, *y*-axis values give a collective measure of ozone-destructive potential from all substances, and most data indicate future projected values. *Data from Emmanuelle Bournay, UNEP/GRID-Arendal, http://maps.grida.no.*

Click for full-size image

Tropospheric ozone causes lung and eye irritation, and is toxic to some organisms

You may have heard of ozone generators used in hotel rooms to absorb smoke

Pb: Lead

Gasoline additive (tetraethyl lead, improves octane rating cheaply), replaced by other worse carcinogenic (cancer causing) chemicals like MTBE:

https://en.wikipedia.org/wiki/Methyl_tert-butyl_ether

Decreases mental capacity (e.g. Roman insanity theory)

Found in coal smoke, along with Mercury and other heavy metals. Sludge from mining is worse.

VOC: Volatile Organic Compounds

Volatile organic compounds, e.g. gasoline vapors (why your gas cap must be on or you get a dashboard warning):

https://en.wikipedia.org/wiki/Volatile_organic_compound

Smog and other photochemical reactions:

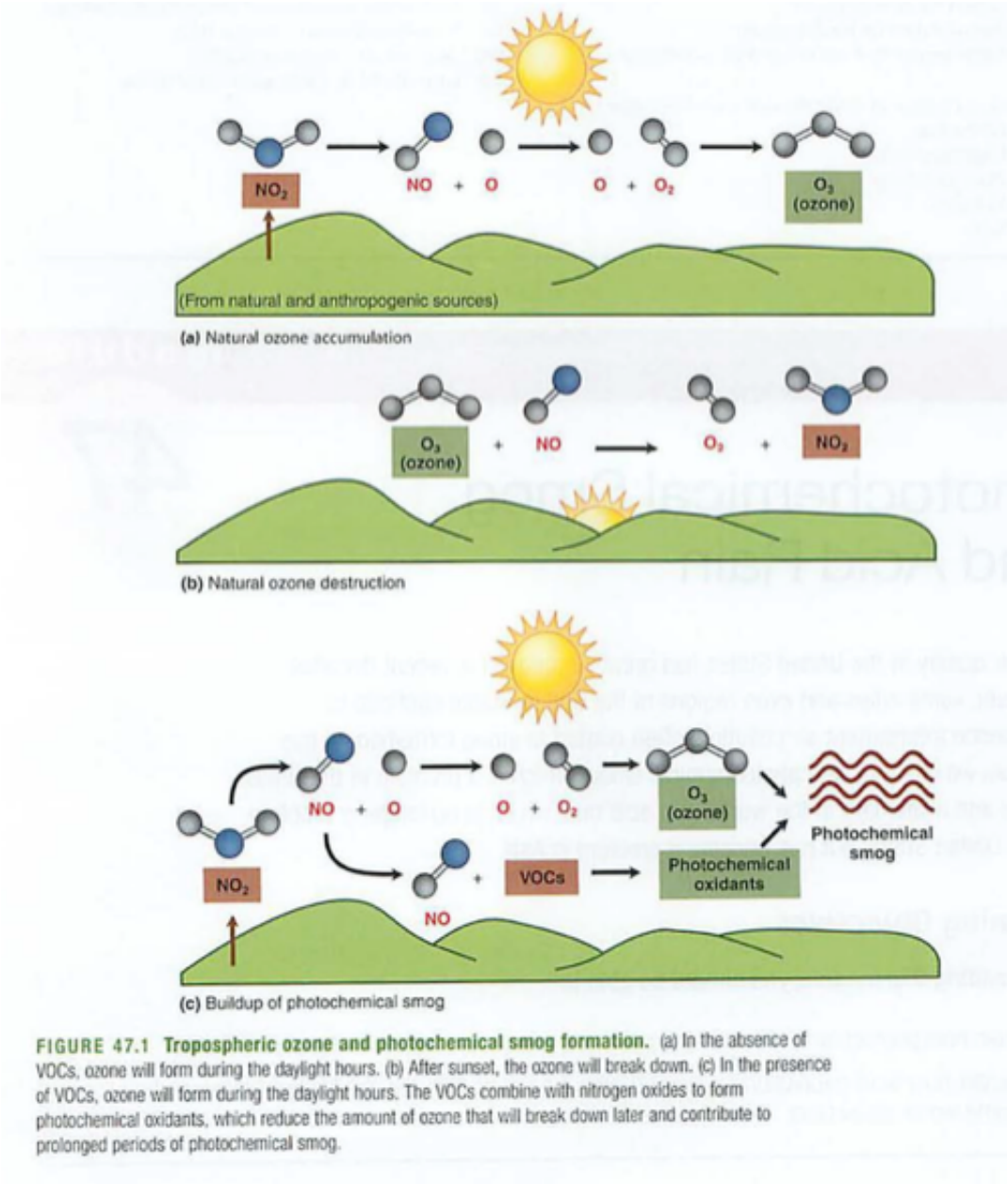

FIGURE 47.1 **Tropospheric ozone and photochemical smog formation.** (a) In the absence of VOCs, ozone will form during the daylight hours. (b) After sunset, the ozone will break down. (c) In the presence of VOCs, ozone will form during the daylight hours. The VOCs combine with nitrogen oxides to form photochemical oxidants, which reduce the amount of ozone that will break down later and contribute to prolonged periods of photochemical smog.

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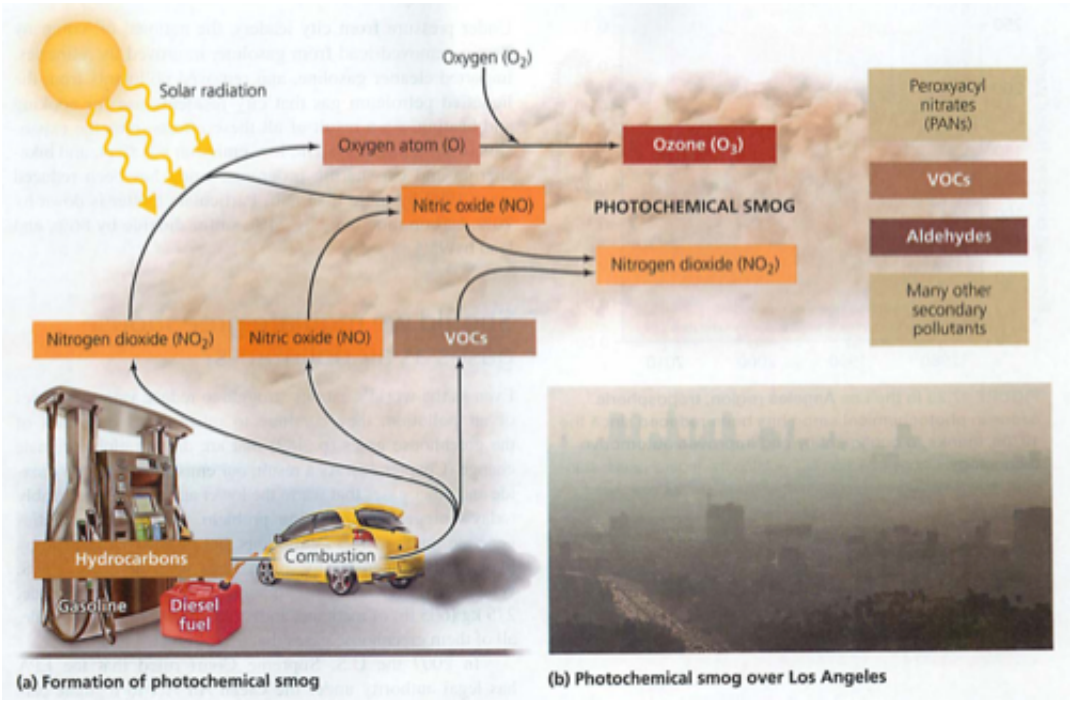

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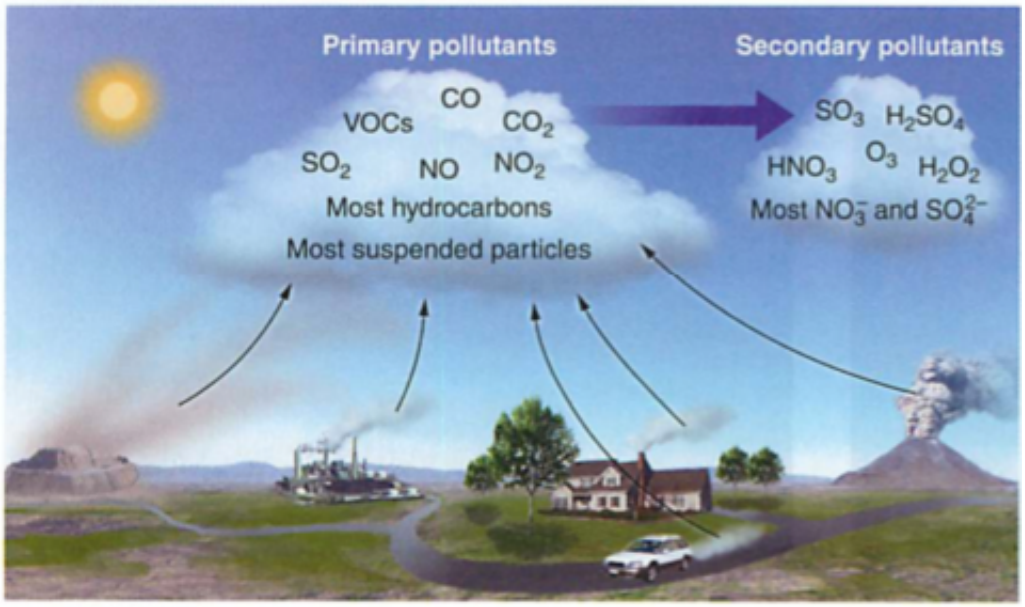
Primary and secondary pollutants:



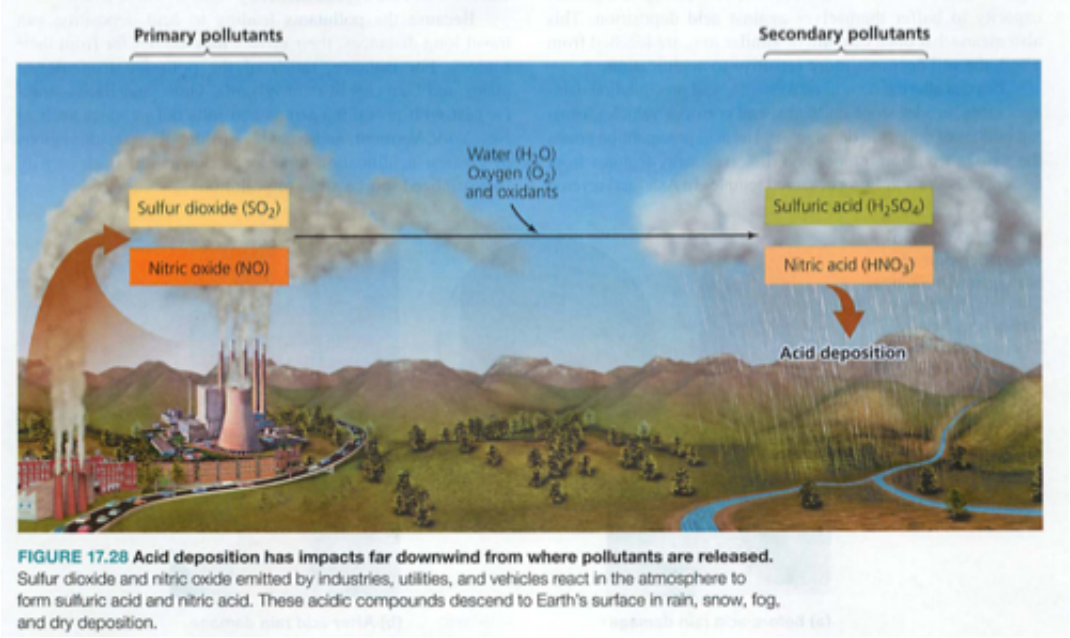


FIGURE 17.28 Acid deposition has impacts far downwind from where pollutants are released.
Sulfur dioxide and nitric oxide emitted by industries, utilities, and vehicles react in the atmosphere to form sulfuric acid and nitric acid. These acidic compounds descend to Earth's surface in rain, snow, fog, and dry deposition.

Click for full-size image

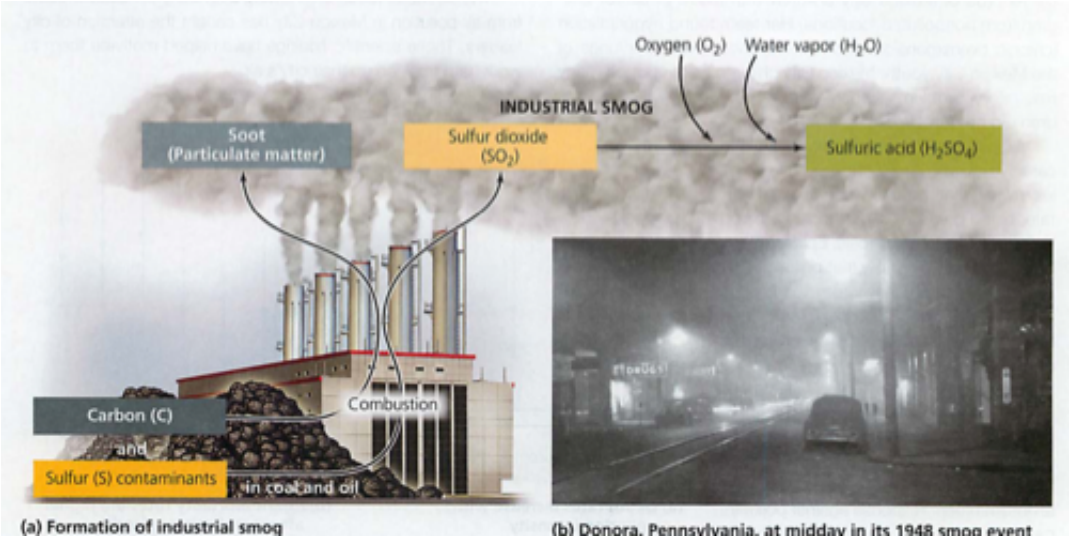
Secondary pollutants: need a chemical reaction (often energy from sunlight) to form (see figures above)

Example: PhotoChemical Smog: Photo (light) Chemical (reaction) smog

See PANs: Peroxyacyl nitrates: formed from VOCs, NOx

https://en.wikipedia.org/wiki/Peroxyacyl_nitrates

Thermal inversions: London fog, US, Donora, PA 1948 k.20, sick 7000



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1952 London 4000-12,000 dead, three nights

Mexico city 1996 300 dead, 400K sick

How?

Normally, the sun heats the surface, warming the air there, which rises. Cooler air aloft then falls to replace this rising air.

In an inversion, warmer air aloft traps the air at the surface (no temperature difference, so no mixing), causing the pollution to be trapped in the lower levels. Most dangerous in valleys or bowl shaped cities (London, Mexico City, Denver, Donora).

Los Angeles has severe smog in the daytime, when hotter air draws in ocean air ("onshore breeze"), but the cycle reverses at night when the water is warmer than the land, so they have an "offshore breeze". Surfers like the first one.

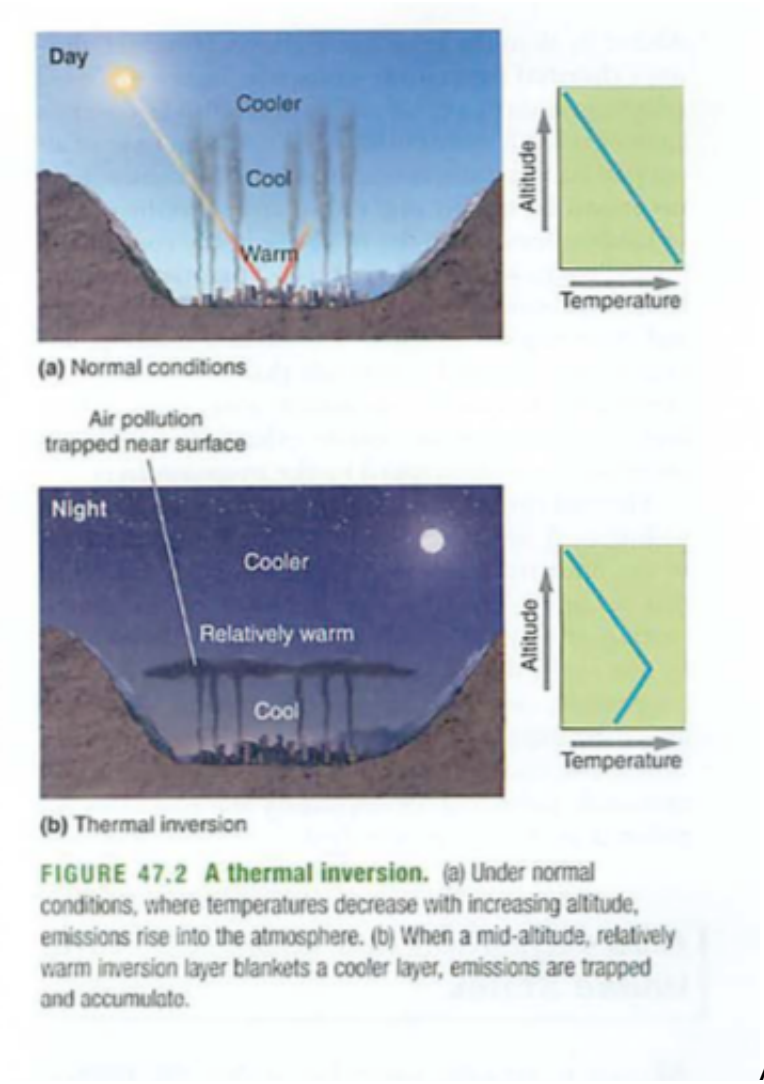
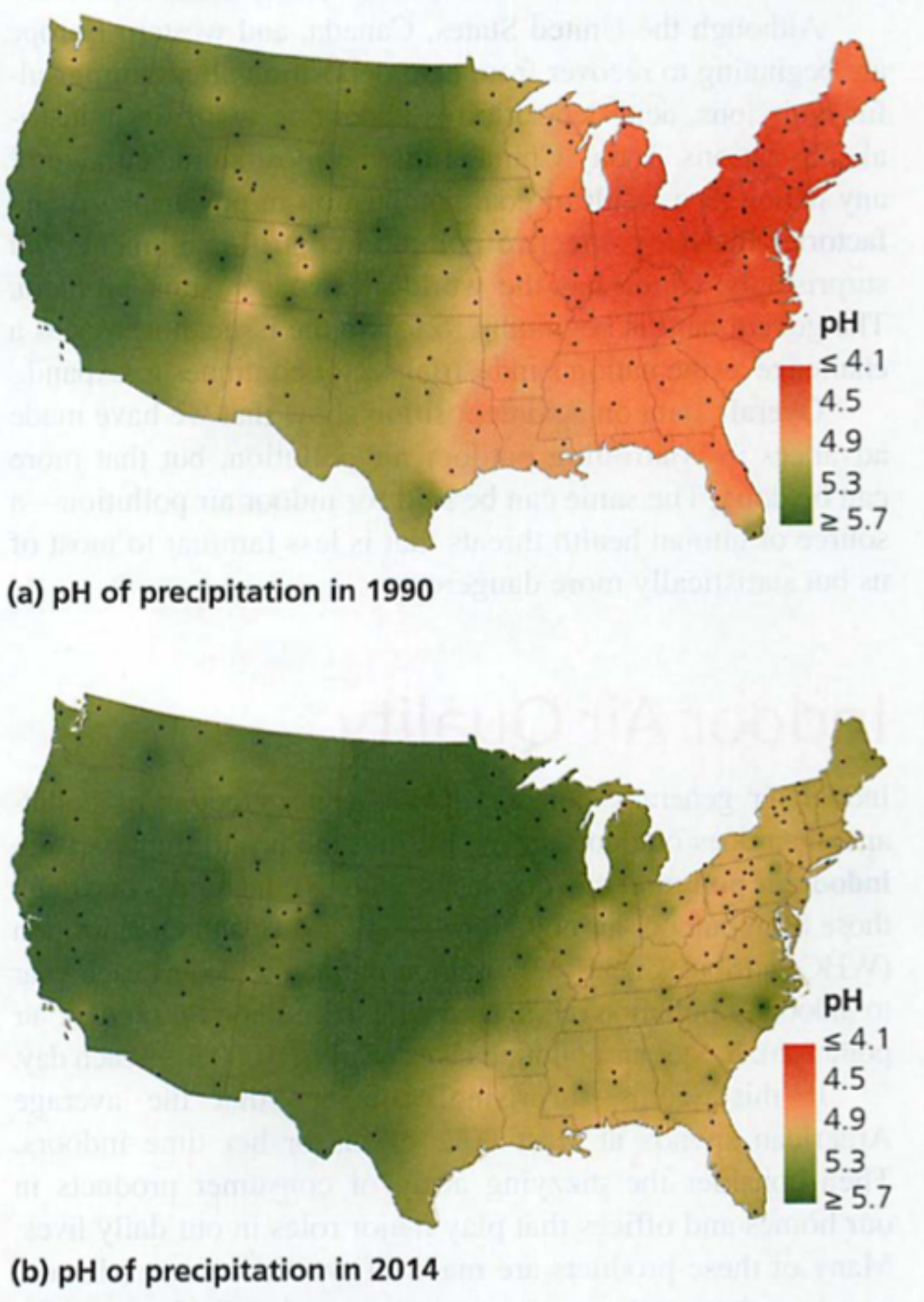


FIGURE 47.2 A thermal inversion. (a) Under normal conditions, where temperatures decrease with increasing altitude, emissions rise into the atmosphere. (b) When a mid-altitude, relatively warm inversion layer blankets a cooler layer, emissions are trapped and accumulate.

Acid rain: plants, fish, structures. Check this out:



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$SO_2 + O_2$, water = H_2SO_4 (sulfuric acid)

$NO_3 + O_2$, water = HNO_3 (nitric acid)

“Acid snow” yes, acid snow...

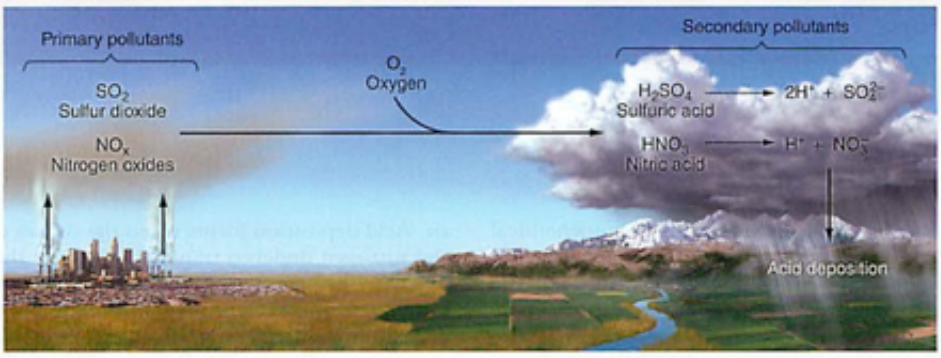

FIGURE 47.3 Formation of acid deposition. The primary pollutants sulfur dioxide and nitrogen oxides are precursors to acid deposition. After transformation to the secondary pollutants—sulfuric and nitric acid—dissociation occurs in the presence of water. The resulting ions—hydrogen, sulfate, and nitrate—cause the adverse ecosystem effects of acid deposition.

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W. VA had rain more acidic than stomach acid in the 1970's

Important: Know how a power plant air scrubber works (just like the nuclear plant diagram)

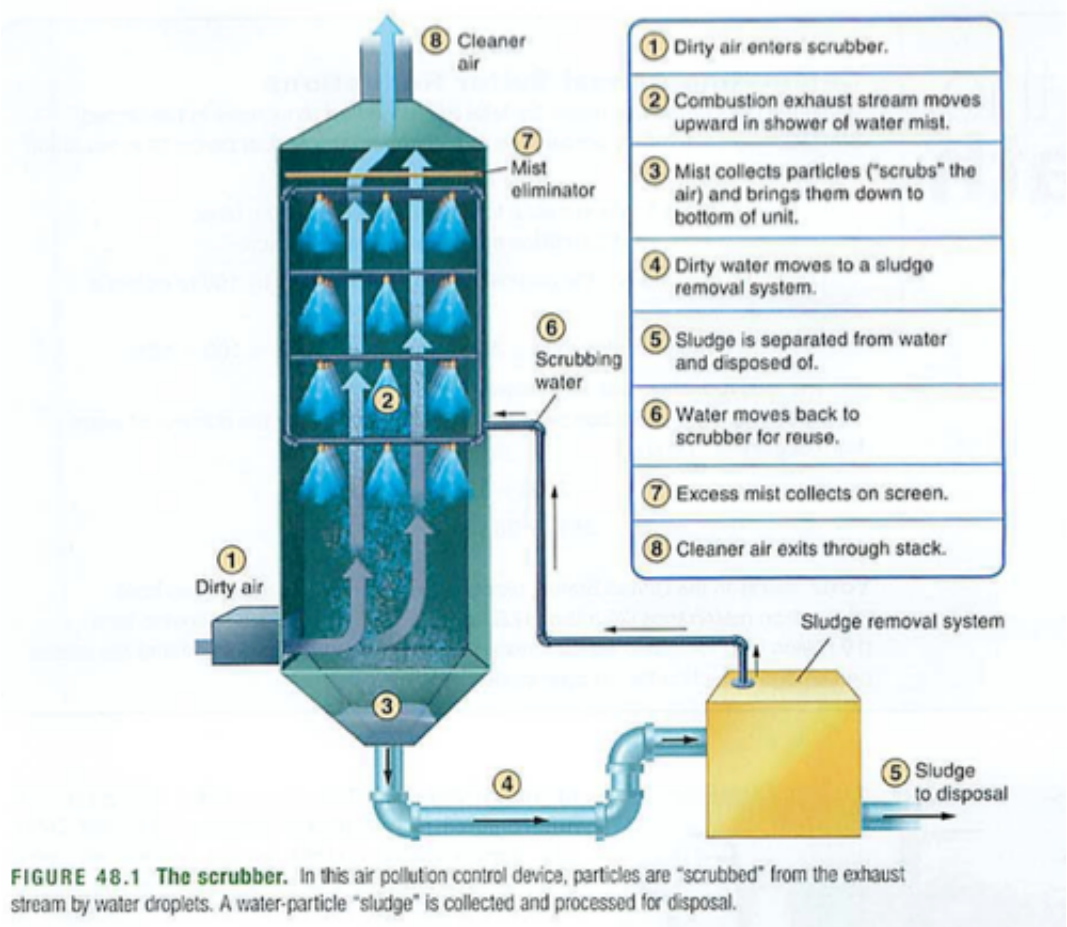

FIGURE 48.1 The scrubber. In this air pollution control device, particles are "scrubbed" from the exhaust stream by water droplets. A water-particle "sludge" is collected and processed for disposal.

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IAP-indoor air pollution

Leading cause of death in LDC (women). LDC is the latest term for "Lesser Developed Countries"

Burning manure for fuel, open pit fires, CO, PM10

Sick building syndrome: formaldehyde, CO2, VOC

Check out the Living Building Challenge and LEED Platinum in the elab hallway

Main culprits:

- VOC (paints, aerosols, vaporizers)
- CO (burning), Radon (radioactive rocks)
- Lead (paint, gasoline)
- Formaldehyde (adhesives, wood products, carpet glue)
- Asbestos (insulation, tiles, flooring)
- PM10 (soot from burning)

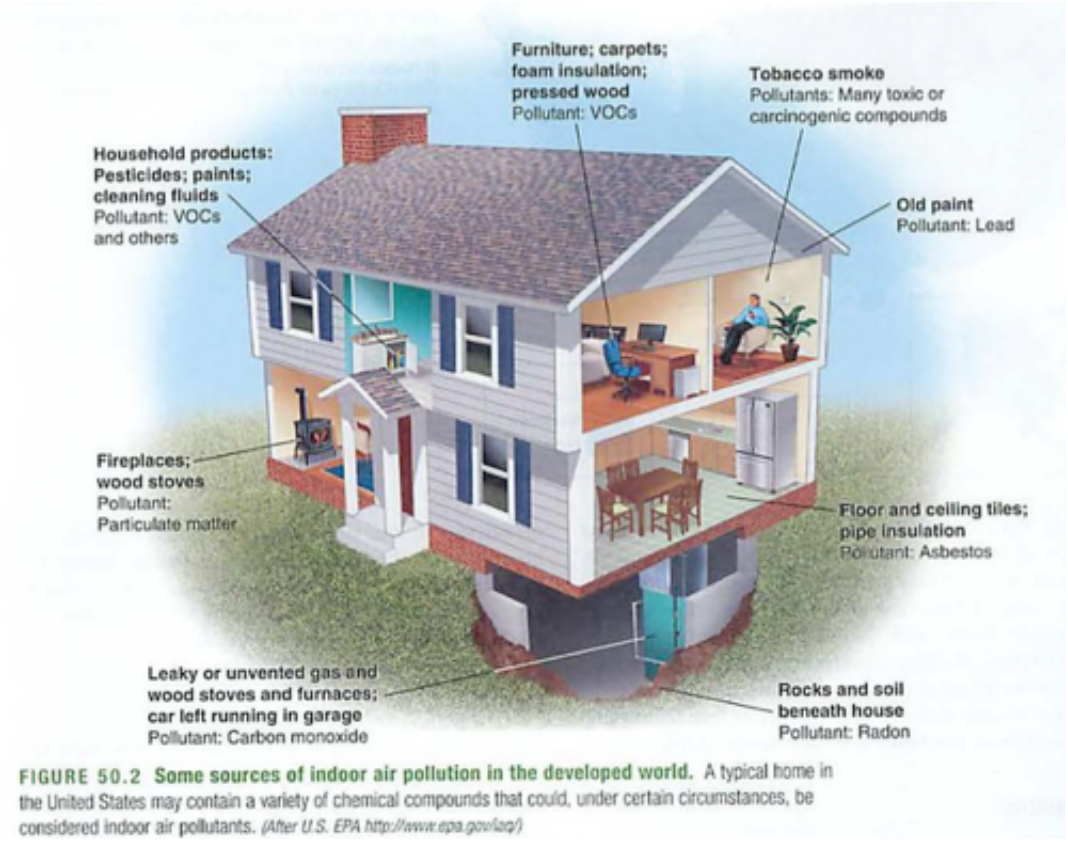

FIGURE 50.2 **Some sources of indoor air pollution in the developed world.** A typical home in the United States may contain a variety of chemical compounds that could, under certain circumstances, be considered indoor air pollutants. *(After U.S. EPA http://www.epa.gov/iaq/)*

Click for full-size image

FIGURE 17.34 **The typical home contains many sources of indoor air pollution.** Shown are common sources, the major pollutants they emit, and some of the health risks they pose.

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Asbestos-asbestosis, mesothelioma (like the ads on TV, usually aimed at Military folks or shipyard workers)

Radon 222-lung cancer (smoke demo-lungs)-#2 cause of lung cancer in the US (behind smoking of course)

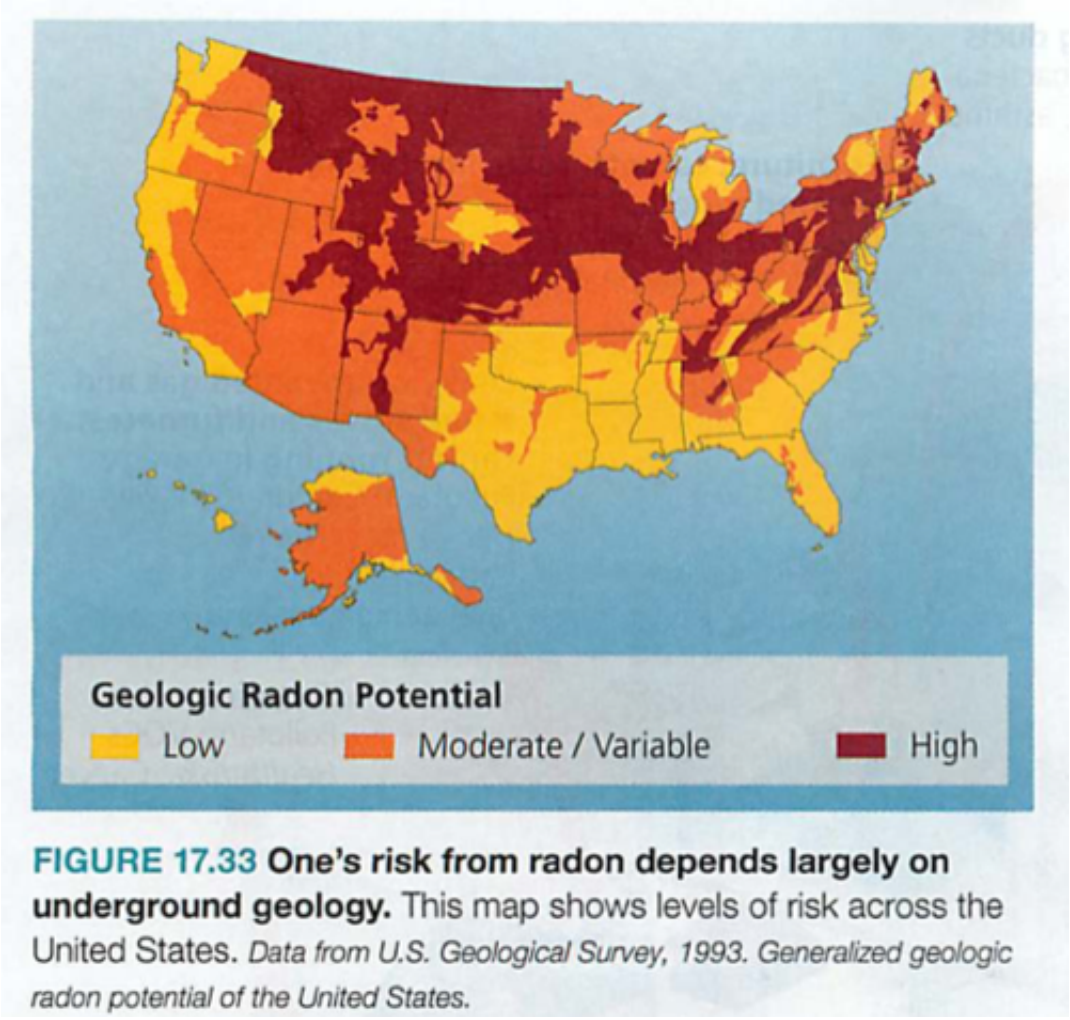

FIGURE 17.33 One's risk from radon depends largely on underground geology. This map shows levels of risk across the United States. *Data from U.S. Geological Survey, 1993. Generalized geologic radon potential of the United States.*

Click for full-size image

AIR QUALITY LABS-From the AP exam folks

• **Air Quality:** Air quality can be assessed using various methods.

• **Particulates:** Sticky paper can be used to collect air particulates from various sources, and then the paper can be examined under a microscope. It is not possible to see the smallest particulates, but they do color the white paper.

• **Ozone:** In this lab, an ecobadge or a homemade potassium iodide gel sampler is hung or worn in

order to collect data on tropospheric ozone. The badge or KI sample changes color in the presence of ozone and becomes more intensely colored as the amount of ozone increases.

- **Carbon dioxide:** In this lab, a commercial sampling device is used to determine the amount of carbon dioxide in an air sample. Car exhaust, burning tobacco, or other pollutants can also be sampled.

Pollution roundup:

Chapter 8 of Princeton Review for AP:

http://physics.hpa.edu/physics/apenvsci/apes_exam_prep/apes_princeton/ch08-pollution.pdf

http://physics.hpa.edu/physics/apenvsci/apes_exam_prep/apes%205%20steps%20to%20a%205/18-pollution.pdf

https://en.wikipedia.org/wiki/Peroxyacyl_nitrates