



7.1 INTRODUCTION TO AIR POLLUTION, CO₂, PM, AND INDOOR AIR QUALITY

College Board Topics 7.1, 7.4, and 7.5

Related Reading Ch. 17


Learning Objectives and Essential Knowledge

LEARNING OBJECTIVE

STB-2.A

Identify the sources and effects of air pollutants.

SUGGESTED SKILL

 *Scientific Experiments*

4.E

Explain modifications to an experimental procedure that will alter results.

ESSENTIAL KNOWLEDGE

STB-2.A.1

Coal combustion releases air pollutants including carbon dioxide, sulfur dioxide, toxic metals, and particulates.

STB-2.A.2

The combustion of fossil fuels releases nitrogen oxides into the atmosphere. They lead to the production of ozone, formation of photochemical smog, and convert to nitric acid in the atmosphere, causing acid rain. Other pollutants produced by fossil fuel combustion include carbon monoxide, hydrocarbons, and particulate matter.

STB-2.A.3

Air quality can be affected through the release of sulfur dioxide during the burning of fossil fuels, mainly diesel fuels.

STB-2.A.4

Through the Clean Air Act, the Environmental Protection Agency (EPA) regulated the use of lead, particularly in fuels, which dramatically decreased the amount of lead in the atmosphere.

STB-2.A.5

Air pollutants can be primary or secondary pollutants.

LEARNING OBJECTIVE

STB-2.D

Describe natural sources of CO₂ and particulates.

ESSENTIAL KNOWLEDGE

STB-2.D.1

CO₂ appears naturally in the atmosphere from sources such as respiration, decomposition, and volcanic eruptions.

STB-2.D.2


There are a variety of natural sources of particulate matter.

LEARNING OBJECTIVE

STB-2.E

Identify indoor air pollutants.

SUGGESTED SKILL

 *Data Analysis*

5.C

Explain patterns and trends in data to draw conclusions.

ESSENTIAL KNOWLEDGE

STB-2.E.1

Carbon monoxide is an indoor air pollutant that is classified as an asphyxiant.

STB-2.E.2

Indoor air pollutants that are classified as particulates include asbestos, dust, and smoke.

STB-2.E.3

Indoor air pollutants can come from natural sources, human-made sources, and combustion.

STB-2.E.4

Common natural source indoor air pollutants include radon, mold, and dust.

STB-2.E.5

Common human-made indoor air pollutants include insulation, Volatile Organic Compounds (VOCs) from furniture, paneling and carpets; formaldehyde from building materials, furniture, upholstery, and carpeting; and lead from paints.

STB-2.E.6

Common combustion air pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, and tobacco smoke.

STB-2.F

Describe the effects of indoor air pollutants.

STB-2.F.1

Radon gas can infiltrate homes as it moves up through the soil and enters homes via the basement or cracks in the walls or foundation. It is also dissolved in groundwater that enters homes through a well.

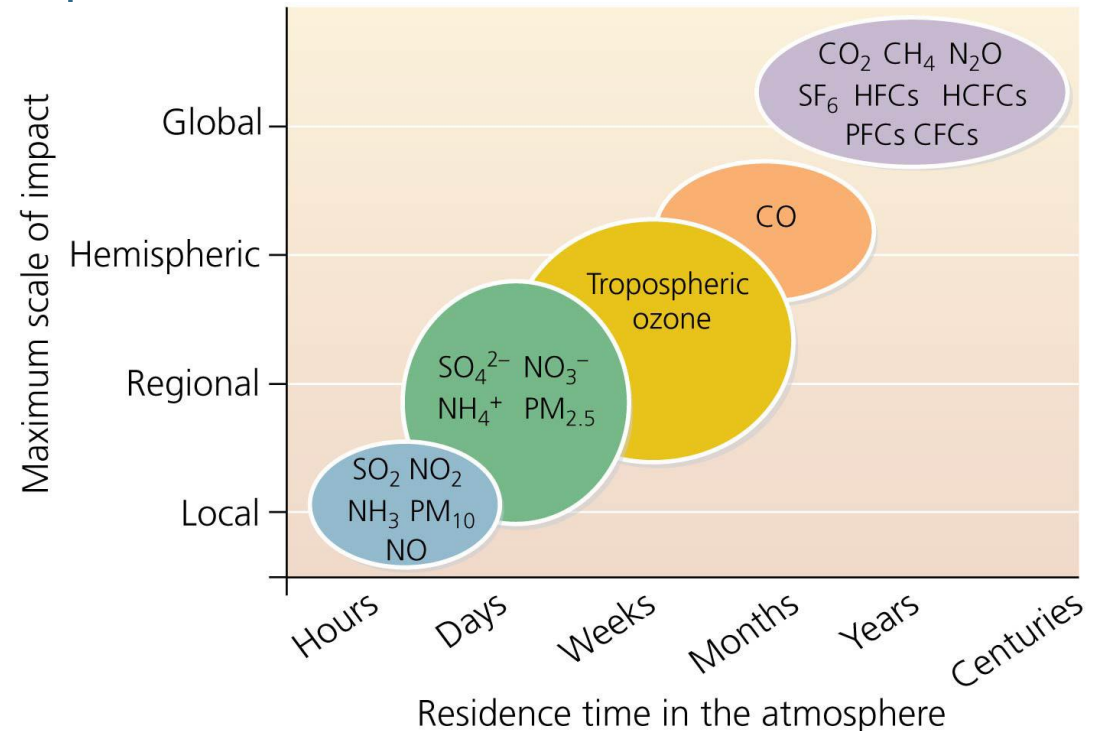
STB-2.F.2

Exposure to radon gas can lead to radon-induced lung cancer, which is the second leading cause of lung cancer in America.

Air pollutants cause air pollution

- **Air pollutants** are gases and particulate material added to the atmosphere
- **Primary pollutants** are pollutants that are directly harmful and can react to form other harmful substances.
 - NO_x, SO_x, PM, CO
- **Secondary pollutants** are pollutants that form when primary pollutants interact or react with components of the atmosphere
 - Tropospheric ozone (O₃) and sulfuric acid (H₂SO₄)

- **Residence time** is the time a pollutant stays in the atmosphere.
 - Pollutants with brief residence times exert localized impacts over short time periods (smog forming chemicals, acid rain precursors)
 - Pollutants with long residence times exert regional or global impacts
 - Pollutants causing climate change or ozone depletion.

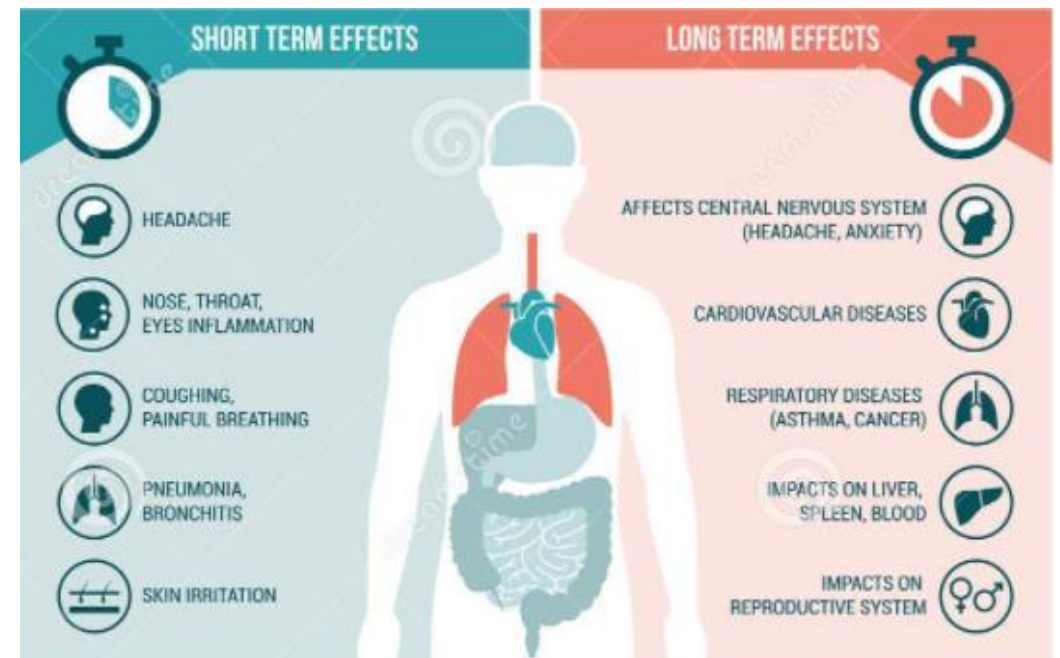
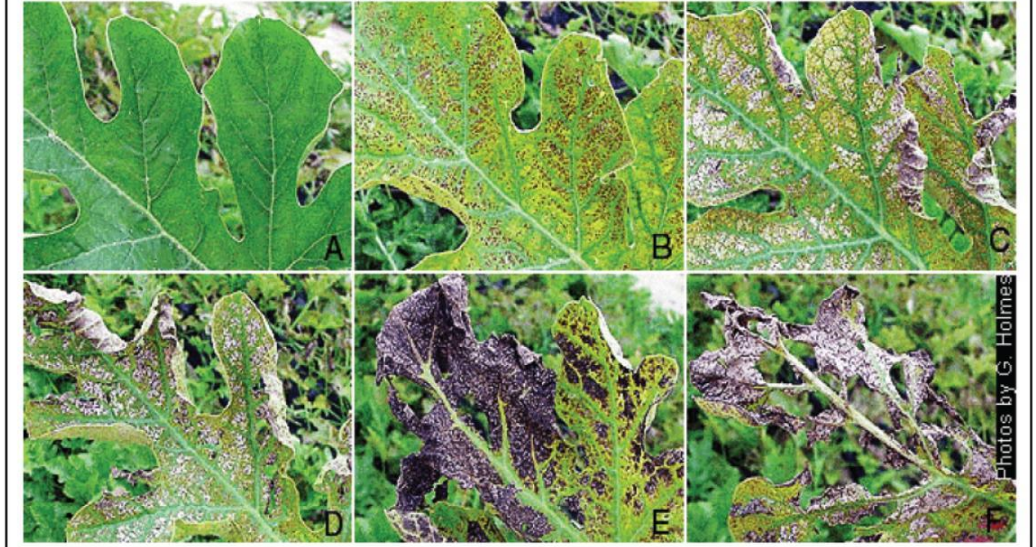


General Effects of Pollution

- Reduction of visual quality
 - Reduced range and clarity
 - Alteration of color, reduction in color contrast
- Damage to vegetation
 - Damage leaf tissue, needles and fruits
 - Reduction of germination and growth rates
 - Increased susceptibility to diseases and pests
- Soil and Water Contamination
 - Deposition of airborne chemicals and particles can toxify soils, alter pH, and reduce productivity
- Human health effects
 - Irritation of eyes, nose, throat (mucous membranes)
 - Increased lung disease (asthma, lung cancer, emphysema, COPD, pneumonia, bronchitis)

Fig. 2 Progression of ozone damage (A=none to F=severe) on watermelon foliage.

Photo courtesy of G. J. Holmes, NCSU



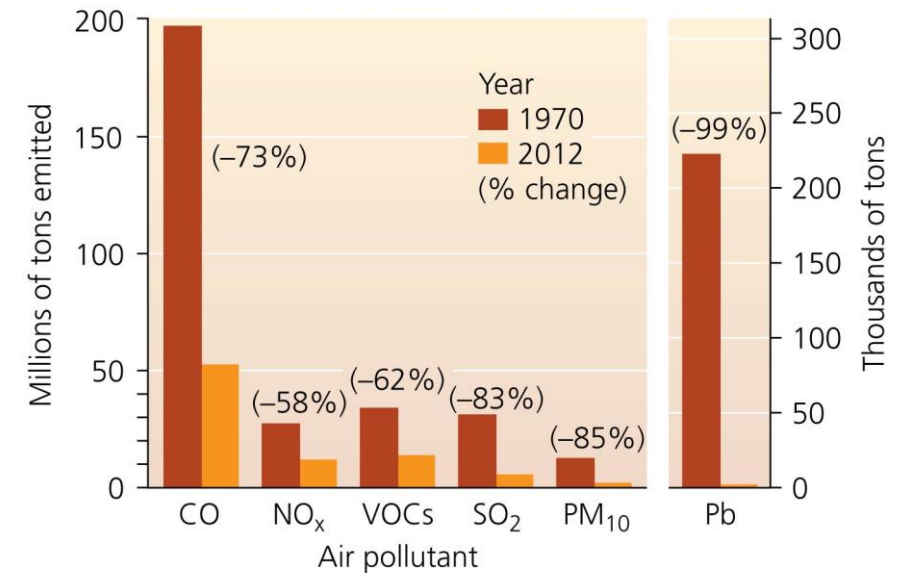
Clean Air Act identifies and regulates pollutants

- **Clean Air Act (1970)** identified that the Environmental Protection Agency (EPA) is required to set acceptable limits for. **6 criteria air pollutants**
 - States monitor and enforce EPA guidelines. If states fail to meet federal guidelines, the EPA can withhold money for future transportation projects.

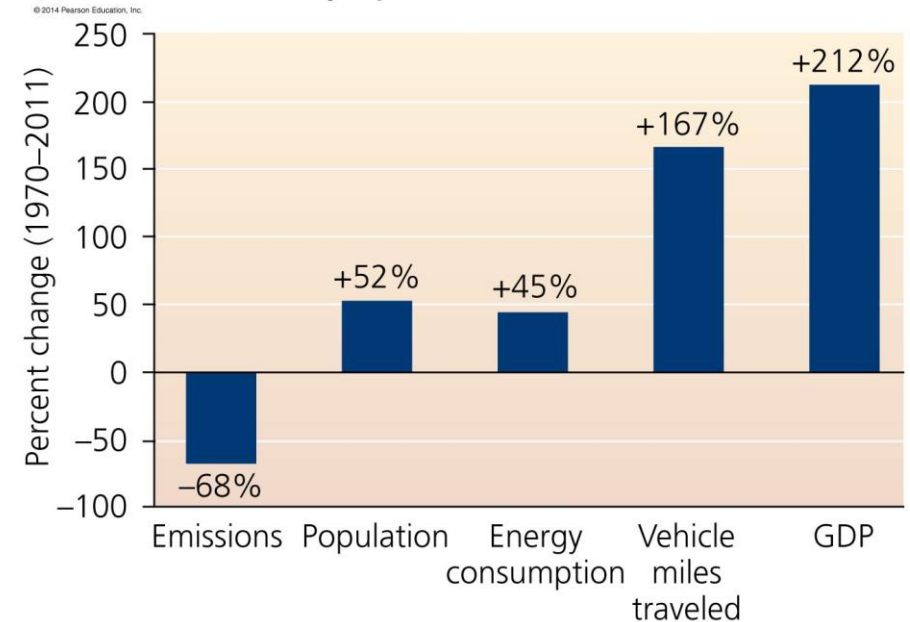
Air Pollutant	Source	Consequence
Sulfur Dioxide (SO ₂)	Coal Combustion	Respiratory irritant, smog, acid deposition
Nitrogen Oxides (NO _x)	All fossil fuel combustion, especially gasoline in automobiles	O ₃ Formation, Smog, and acid deposition
Carbon Monoxide (CO)	Incomplete combustion of fossil fuels, especially engines and biomass	Smog / O ₃ formation, lethal to humans (binds to hemoglobin, leads to suffocation)
Particulate Matter (PM _{2.5} and PM ₁₀)	Fossil Fuel and Biomass combustion	Respiratory Irritant, smog formation, Mercury deposition
Tropospheric Ozone (O ₃)	Photochemical oxidation of NO _x	Respiratory Irritant, smog
Lead (Pb)	Metal plating and waste incineration. Previously from leaded gasoline	Neurotoxin

The Clean Air Act has lowered emissions of the 6 criteria pollutants

- Total emissions of the six monitored pollutants have declined substantially since the Clean Air Act of 1970.
 - Stopped the practice of adding Tetramethyl and tetraethyl lead to gasoline, thereby almost eliminating Pb as an air pollutant.
 - Ozone is the criteria pollutant most frequently exceeded today.
- Despite increased population, energy consumption, miles traveled, and gross domestic product.
- Most other industrialized nations have also reduced their emissions.
- Air pollution in developing nations is a growing concern.



(a) Declines in six major pollutants



(b) Trends in major indicators

Fossil Fuel Emissions = Pollutants and GHG's

- Extraction, refining, and combustion of fossil fuels is the leading source of most major air pollutants.
 - Combustion of coal and gas for electricity.
 - Gasoline and diesel combustion in engines.
 - Various industrial processes that rely on combustion of fossil fuels.
- Fossil fuels are associated with the following emissions
 - CO, CO₂, CH₄, Volatile Organic Compounds (VOCs), PM_{2.5} and PM₁₀, NO_x and N₂O, SO₂ (mainly from coal), Mercury (mainly from coal)
- Several secondary pollutants are formed from these primary pollutants:
 - Tropospheric O₃, Peroxyacyl Nitrates (PAN's), HNO₃⁻, H₂SO₄
- CO₂, CH₄, and other Greenhouse gases (GHG's) are not listed in the Clean Air Act.
 - Concern over greenhouse gases was mostly nonexistent in 1970 when Clean Air Act was passed.
 - In 2007 a Supreme Court ruling found EPA could regulate greenhouse gases and it began doing so in 09').
- CO₂ does not *directly* lower air quality from a human health standpoint. Not toxic.
- CO₂ is a **greenhouse gas**; it leads to earth warming.
 - As a result, a number of risks to human health increase (basis of the 2007 SC ruling).
 - Extreme heat, severe storms, flooding, expanding ranges of tropical diseases

Natural Sources of Outdoor Air Pollution

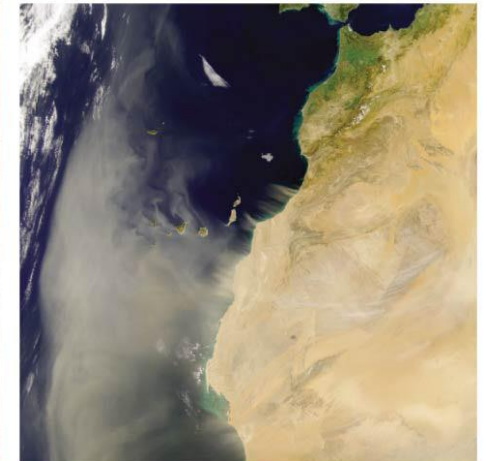
- Respiration & decomposition produce CO_2 .
 - CO_2 produced by these sources, represents CO_2 that was recently removed from the atmosphere by photosynthesis.
 - Cellular respiration and photosynthesis are balanced.
 - Anaerobic decomposition releases CH_4
- Fires pollute the atmosphere with particulate matter and gases.
 - Over 150 million acres/yr of forests and grasslands burn annually.
 - Human influence makes fires more severe
 - Fuel buildup from fire suppression
 - Development in fire-prone areas (such as chaparral)
 - “Slash-and-burn” agriculture.
- Volcanoes release ash and gases that can remain in the air for months or years
 - Particulate matter
 - Aerosols = fine droplets of sulfur dioxide, water, oxygen
- Dust storms occur when wind sweeping over arid land sends huge amounts of dust aloft
 - Unsustainable farming and grazing contribute by promoting erosion and desertification and the drying up of water sources through overuse



(a) Natural fire in California

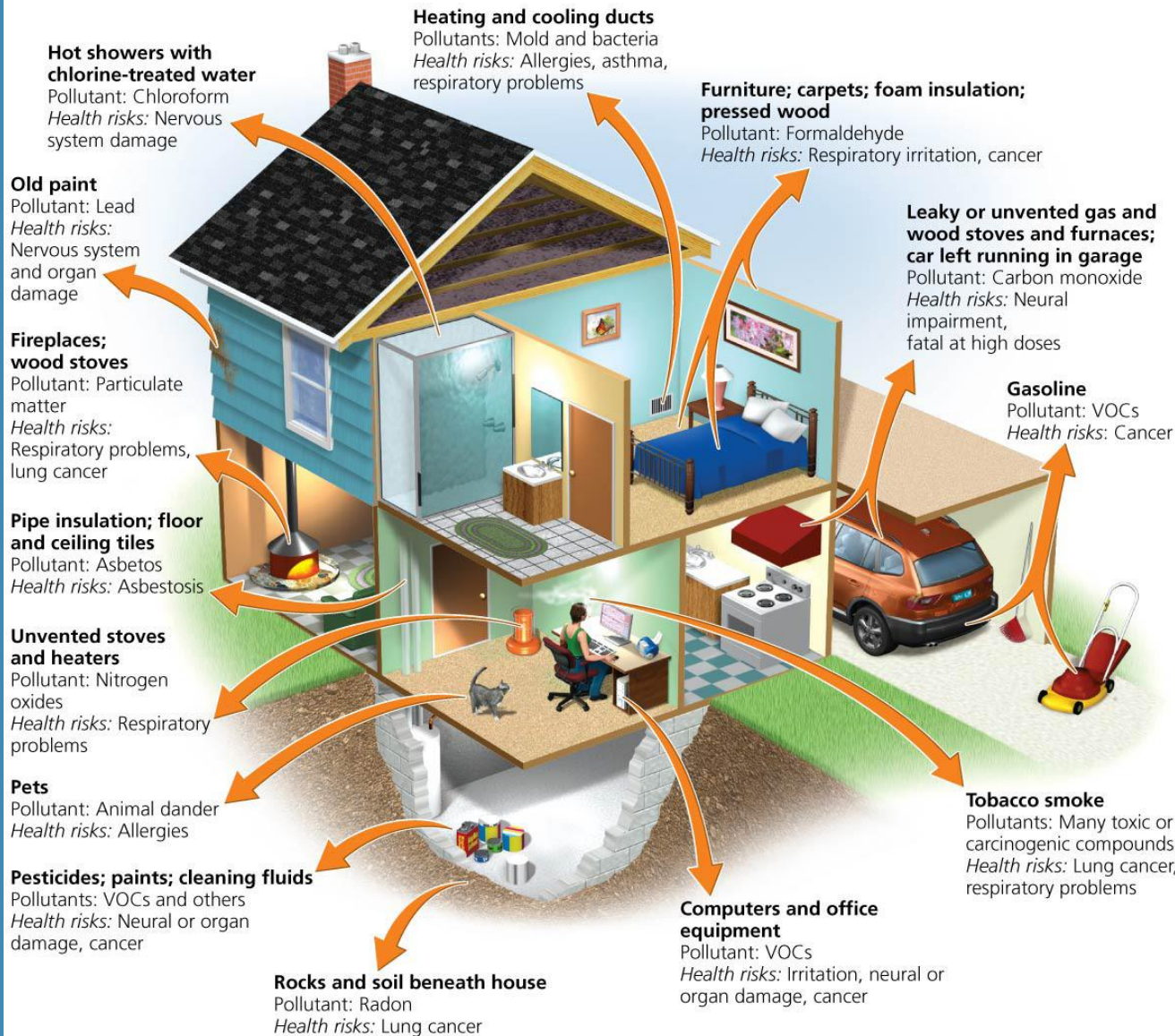


(b) Mount Saint Helens eruption, 1980



(c) Dust storm blowing dust from Africa to the Americas

Indoor air pollution

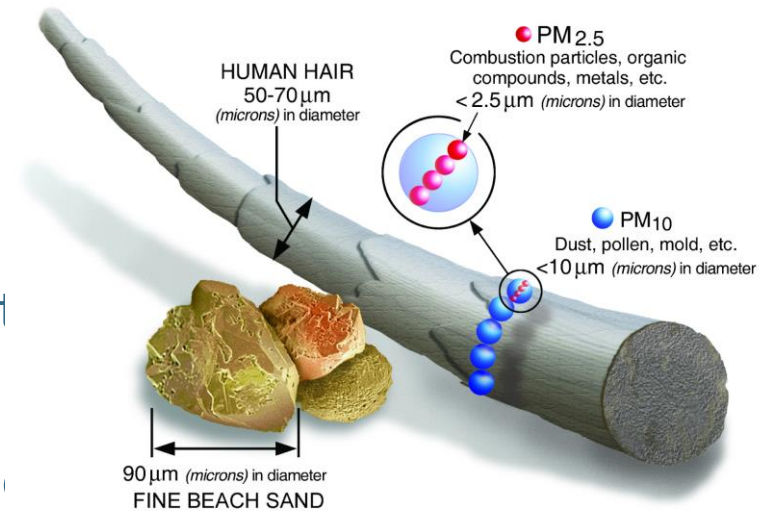


• Indoor air pollution

- Air pollution within workplaces, schools, and homes.
- In developed nations, the greatest risk from indoor pollution comes from exposure to synthetic materials.
 - Furniture (adhesives, paint, foam, flame retardants)
 - Building materials (adhesives, paints, insulation, flooring)
 - Cigarette smoke
- To improve efficiency of heating /cooling, and conserve energy, buildings are now more air tight.
 - Pollutants produced indoors now reach higher concentrations causing greater risk.
- The average U.S. citizen spends 90% of their time indoors.

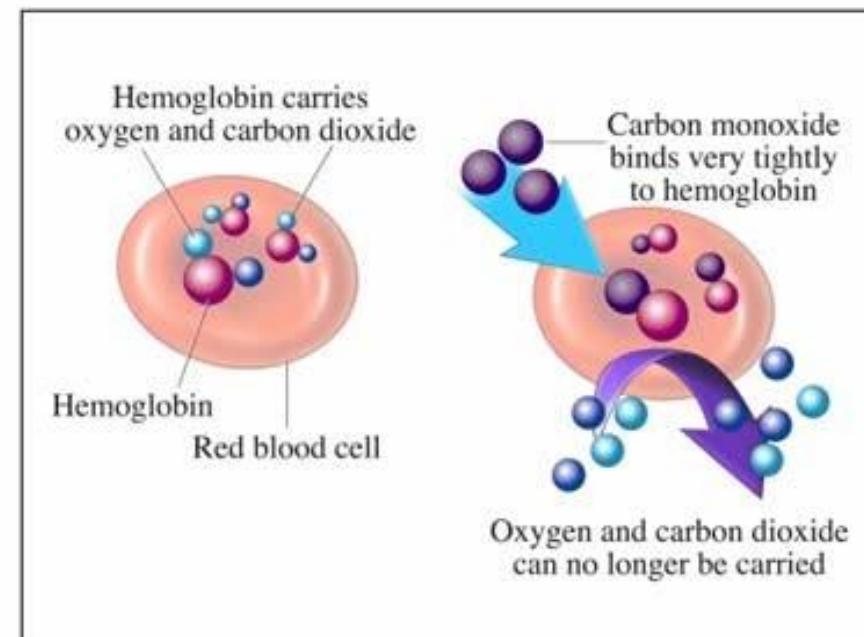
Particulate Matter and Asbestos

- Particulates (PM₁₀ and PM_{2.5}) are a common indoor air pollutant.
 - Ex: Smoke (from indoor biomass combustion or cigarettes), dust and asbestos.
- **Asbestos** is a long, silicate particle previously used in insulation.
 - Asbestos has since been linked to lung cancer & asbestosis
 - Phased out of use, as part of an amendment to the clean air act, but still remains in older buildings.
 - Not dangerous until insulation is disturbed and asbestos particles enter air & then resp. tract
 - Should be removed by trained professionals with proper respiratory equipment, ventilation in the area it's being removed from, plastic to seal off area from rest of the building



- CO is produced by *incomplete combustion* of basically any fuel containing carbon.
 - Not all the fuel is combusted due to low O₂ or temp.
- CO is an *asphyxiant*
 - causes suffocation due to CO binding to hemoglobin in blood, displacing O₂
 - Can be lethal to humans, especially with poor ventilation (odorless and colorless - hard to detect)
- Developed nations
 - CO released into home by malfunctioning natural gas furnace ventilation or vehicle left running in the garage.
 - Can be detected by carbon monoxide detectors (similar to smoke detectors) which are now required by law
- Developing nations
 - CO emitted from indoor biomass combustion for heating/cooking

Carbon Monoxide (CO)



Volatile Organic Compounds (VOC's)

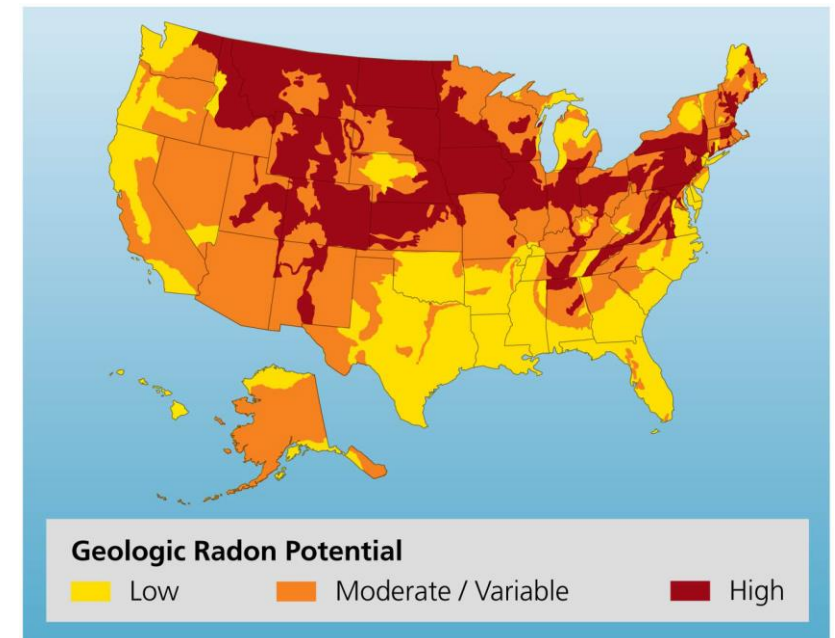
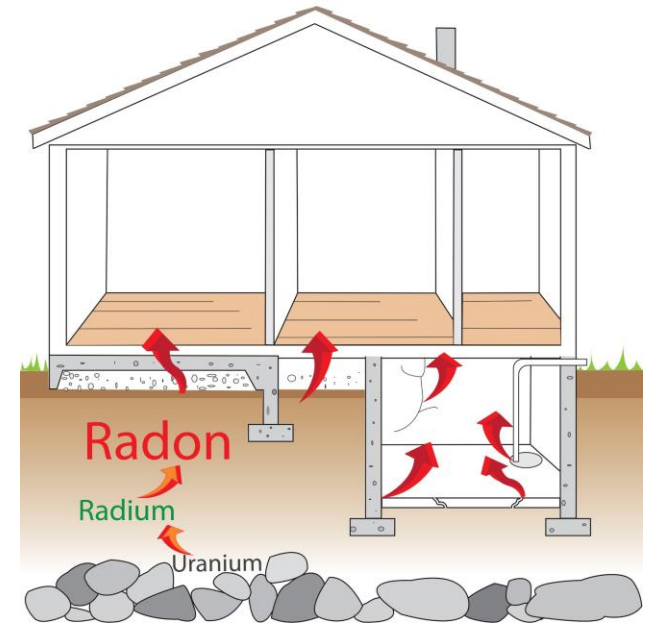
- Diverse group of chemicals used in variety of home products that easily vaporize and enter the air
- Furniture: Foam, adhesives, upholstery treated with flame retardants or stain guards
- Building Materials: Adhesives, wall paint, insulation, particleboard/OSB/MDF/plywood, vinyl flooring,
 - **Formaldehyde** is a common VOC released by adhesive in manufactured wood products and carpet glues (new carpet smell)
- Cleaners: Common household cleaners, deodorizers, moth repellants, aerosol sprays, dry cleaning chemicals, pesticides.
- Office Supplies: Printer and copier ink/toner, permanent markers, liquid white out, carbon paper
- Plastics : Just about everywhere
- Health Effects
 - Eyes, nose, throat irritation
 - Dizziness, nausea, light headed
 - Damage to liver, Kidney, central nervous system
 - Many VOC's are suspected or known carcinogens



Radon Gas (Radon-222)

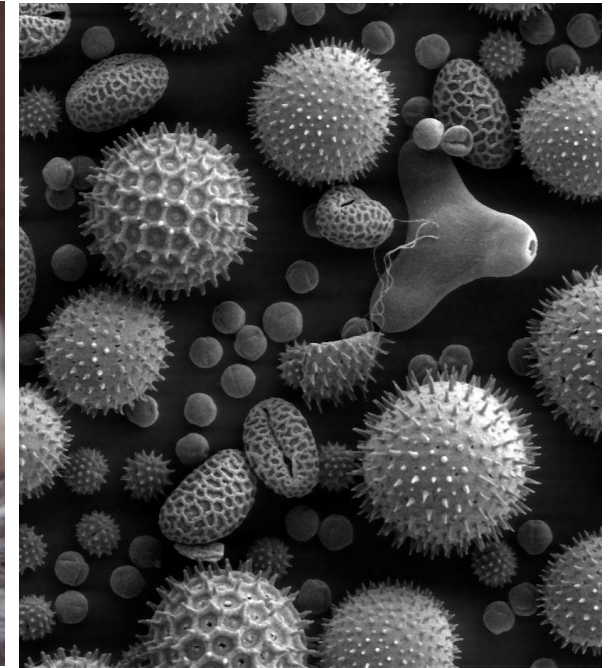


- Radioactive gas released by decay of uranium naturally found in rocks underground (granite especially)
 - Usually enters homes through cracks in the foundation & then disperses up from basement/foundation through home
 - Can also seep into groundwater sources & enter body through drinking water.
- EPA recommends testing homes with airborne Radon monitor if geologic radon potential is high.
- 2nd leading cause of lung cancer after smoking.
- Estimated 21,000 deaths/year in the U.S.
- Sealing cracks in foundation can prevent it from entering and increasing ventilation in the home can disperse it if it's detected.
- New construction methods make homes radon resistant



Dust and Mold

- Natural indoor air pollutants that can worsen asthma, bronchitis, COPD, emphysema
- Dust mites, pollen, and animal dander settles in homes naturally, is disturbed by movement, entering air and then respiratory tract
- Fungi, molds, and mildews develop in areas that are dark and damp and poorly ventilated (under sinks/showers, behind panels in walls and ceiling)
 - Can be removed by physically cleaning mold out and fixing the water leak or ventilation issue that lead to mold forming.



Lead (Pb)

- Found in paint in old homes (EPA banned lead in paint in 78')
- Paint chips off walls/windows and is eaten by small children (due to curiosity & sweet taste) or inhaled as dust
- Lead water pipes can also release lead into drinking water sources (as in Flint, MI) but it's less common than lead paint
- Damages central nervous system of children due to smaller size and still developing brain
- Can be removed from home by stripping lead paint and replacing with non-lead based paint
- Lead water pipes can be replaced with copper plastic or cast iron pipes.



Indoor air pollution in the developing world

- People in the developed world are exposed to a greater variety of indoor air pollutants
- But the human health impacts are greatest in the developing world.
 - Millions burn wood, charcoal, dung, crop wastes inside homes for heating and cooking with little ventilation.
 - Primarily affects women and children who are the ones most often at home and working around the fire.
 - Produces particulate matter, carbon monoxide, NO_x and VOC's
 - Increasing risk of pneumonia, bronchitis, lung cancer, allergies, asthma, COPD
- Fuel-burning pollution causes 3.5 million deaths/year (nearly 7% of all deaths)



Video Resources

- Paul let me down on this topic 😞