Objective/EKs/Skill

SUGGESTED SKILL

Scientific Experiments

4.E

Explain modifications to an experimental procedure that will alter results.

7.1 Introduction to Air Pollution (Pollutants)

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
STB-2.A Identify the sources and effects of air pollutants.	**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.

Air Pollution Basics

⚠ **Write about air <u>pollutants</u> (specific molecules/particles) not just air "pollution" as an idea**

⚠ **Clean Air Act (1970) identified 6 criteria air pollutants that the EPA is required to set acceptable limits for, monitor, and enforce**

SO_2

Sulfur dioxide

Coal combustion (electricity)
Resp. irr. | smog | acid precip.

NO_x

Nitrogen Oxides (NO & NO_2)

All FF combustion (gas esp.)
O_3 | photochem smog | acid precip.

CO

Carbon Monoxide

Incomplete combustion
O_3 | Lethal to humans

PM

Particulate Matter

FF/biomass combustion
Resp. irr. | smog

O_3

Ozone (tropospheric)

Photochemical oxidation of NO_2
Resp. irr | smog | plant damage

Pb

Lead

Metal plants, waste incineration
Neurotoxicant

Air Pollutants vs. Greenhouse Gasses

⚠ **CO_2 is <u>NOT</u> one of 6 criteria pollutants in Clean Air Act (although 07' SC ruling found EPA could regulate greenhouse gases and it began doing so in 09')**

- CO_2 **<u>does not</u>** *directly** lower air quality from a human health standpoint
  - Not toxic to organisms to breath
  - Not damaging to lungs/eyes
  - Does not lead to smog, decreased visibility
- CO_2 is a <u>greenhouse gas</u>; it does lead to earth warming, and thus env. and human health consequences (basis for SC ruling in 07')

⚠ **Bottom line:** In APES, CO_2 <u>has not</u> typically been included on FRQ scoring guides as an air pollutant

(stick to sure fire air pollutants on FRQs: SO_2, NO_x, O_3, PM)

Coal Combustion

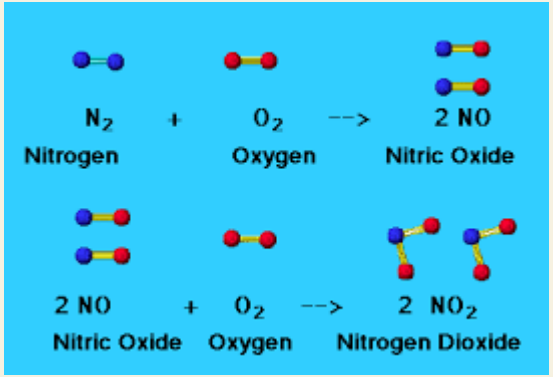
Releases more air pollutants than other FFs; ~35% of global electricity

- Releases CO, CO_2, SO_2, NO_x toxic metals (mercury, arsenic, lead), and PM (often carries the toxic metals)
  - Impacts of SO_2
    - Respiratory irritant (inflammation of bronchioles, lungs), worsens asthma & bronchitis
    - Sulfur aerosols (suspended sulfate particles) block incoming sun, reducing visibility & photosynthesis
    - Forms sulfurous (grey) smog
    - Combines with water & O_2 in atmosphere to form sulfuric acid → acid precip.

Nitrogen Oxides (NO_x)

Released by combustion of anything, especially FFs & biomass

- NO_x refers to nitrogen oxides (both NO, and NO_2)
  - NO forms when N_2 combines with O_2 (esp. during combustion)
  - NO can become NO_2 by reacting with O_3 or O_2
  - sunlight converts NO_2 back into NO



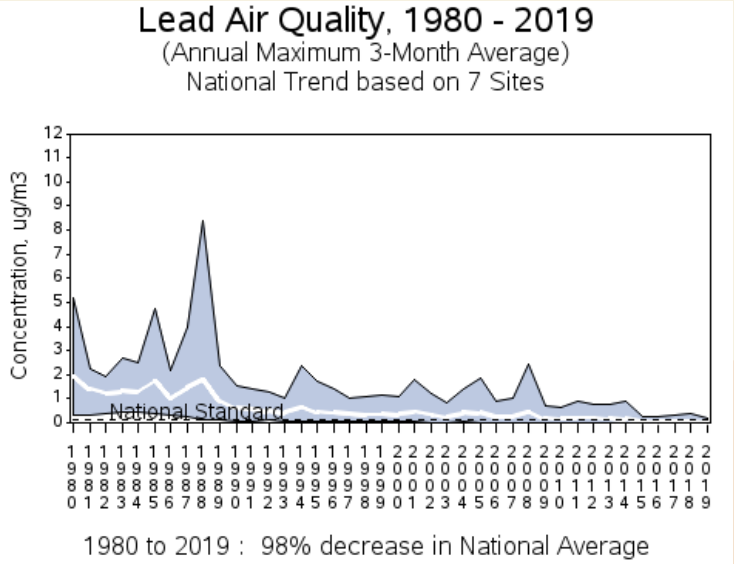
Env. & Human Health Impacts

- Resp. irritant
- Leads to tropospheric ozone (O_3) formation, which leads to photochemical smog
- Combines with water & O_2 in atm. to form nitric acid → acid precipitation

EPA & Lead

Before CAA, lead was a common gasoline additive; EPA began phaseout of lead from gasoline in 1974

- Vehicles made after 1974 are required to have catalytic converters to reduce NO_x, CO and hydrocarbon emissions (lead damages catalytic converters)
  - Also a known neurotoxicant (damages nervous systems of humans)



Primary vs. Secondary Air Pollutants

Primary

- Emitted directly from sources such as vehicles, power plants, factories, or natural sources (volcanoes, forest fires)
- NO_x, CO, CO_2*, VOCs, SO_2, PM, hydrocarbons

Secondary

- Primary pollutants that have transformed in presence of sunlight, water, O_2
- Occur more during the day (since sunlight often drives formation)
- Tropospheric O_3 (Ozone)
- Sulfuric acid (H_2SO_4) & sulfate (SO_4^{2-})
- Nitric acid (HNO_3) & nitrate (NO_3^-)

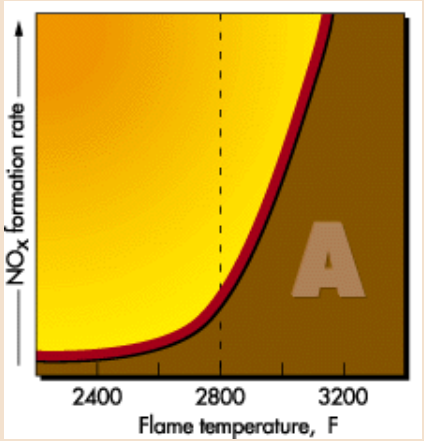
SUGGESTED SKILL

Scientific Experiments

4.E

Explain modifications to an experimental procedure that will alter results.

Practice FRQ 7.1



EPA scientists performed an experiment where coal was burned in different chambers at varying temperatures to see how temperature impacts the amount of NO_x produced by coal combustion.

Explain how the results of the study would be expected to change if the same experiment were repeated with natural gas.

7.2 Photochemical Smog

Objective/EKs/Skill

LEARNING OBJECTIVE

STB-2.B

Explain the causes and effects of photochemical smog and methods to reduce it.

ESSENTIAL KNOWLEDGE

STB-2.B.1

Photochemical smog is formed when nitrogen oxides and volatile organic hydrocarbons react with heat and sunlight to produce a variety of pollutants.

STB-2.B.2

Many environmental factors affect the formation of photochemical smog.

STB-2.B.3

Nitrogen oxide is produced early in the day. Ozone concentrations peak in the afternoon and are higher in the summer because ozone is produced by chemical reactions between oxygen and sunlight.

STB-2.B.4

Volatile Organic Compounds (VOCs), such as formaldehyde and gasoline, evaporate or sublimate at room temperature. Trees are a natural source of VOCs.

STB-2.B.5

Photochemical smog often forms in urban areas because of the large number of motor vehicles there.

ESSENTIAL KNOWLEDGE

STB-2.B.6

Photochemical smog can be reduced through the reduction of nitrogen oxide and VOCs.

STB-2.B.7

Photochemical smog can harm human health in several ways, including causing respiratory problems and eye irritation.

SUGGESTED SKILL

Data Analysis

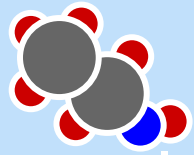
5.B

Describe relationships among variables in data represented.

Photochemical Smog Precursors & Conditions

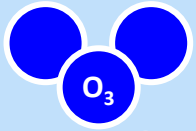
Precursors

NO_2 | Broken by sunlight into NO + O (free O + $O_2 \rightarrow O_3$)



Volatile organic compounds (hydrocarbons) that bind with NO & form photochemical oxidants

- Carbon-based compounds that volatilize (evaporate) easily (this makes them “smelly”)
- Sources: gasoline, formaldehyde, cleaning fluids, oil-based paints, even coniferous trees (pine smell)



O_3 | Forms when NO_2 is broken by sunlight & free O binds to O_2

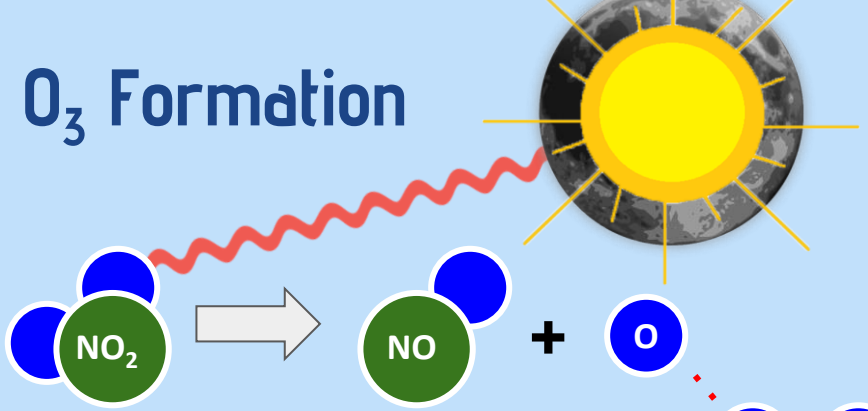
- Resp. irr. in troposphere (@earth’s surface)
- Damaging to plant stomata, limiting growth

Conditions

Sunlight | Drives O_3 formation by breaking down $NO_2 \rightarrow NO + O$; then free O atom binds with O_2

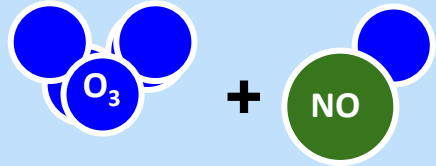
Warmth | Hotter atm. temp. speeds O_3 formation, evaporation of VOCs & thus smog formation

Normal O_3 Formation

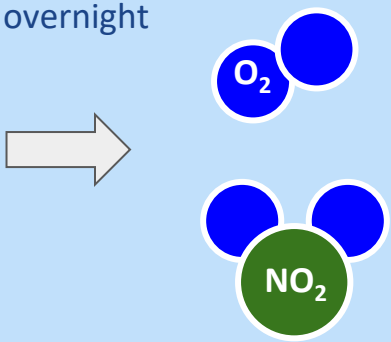


Sunlight breaks NO_2 into NO + O

O bonds with O_2 to form O_3



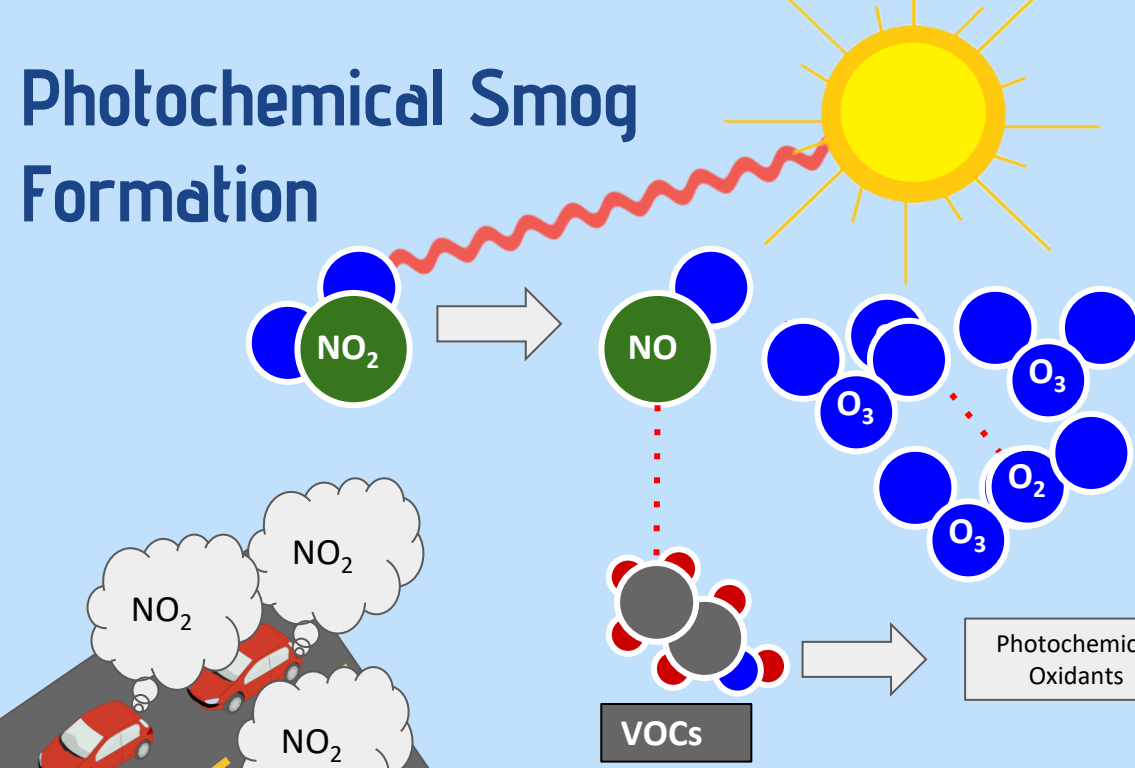
At night, O_3 reacts with NO to form NO_2 and O_2 once again; O_3 levels drop overnight



O_3 formation typically peaks in afternoon when sunlight is most direct and NO_2 emissions from morning traffic have peaked

Morning commute leads to high NO_2 levels from car exhaust

Photochemical Smog Formation



Sunlight breaks NO_2 into NO + O

O bonds with O_2 to form O_3

Without NO to react with, O_3 builds up instead of returning to O_2 & NO_2 overnight

Photochemical Smog

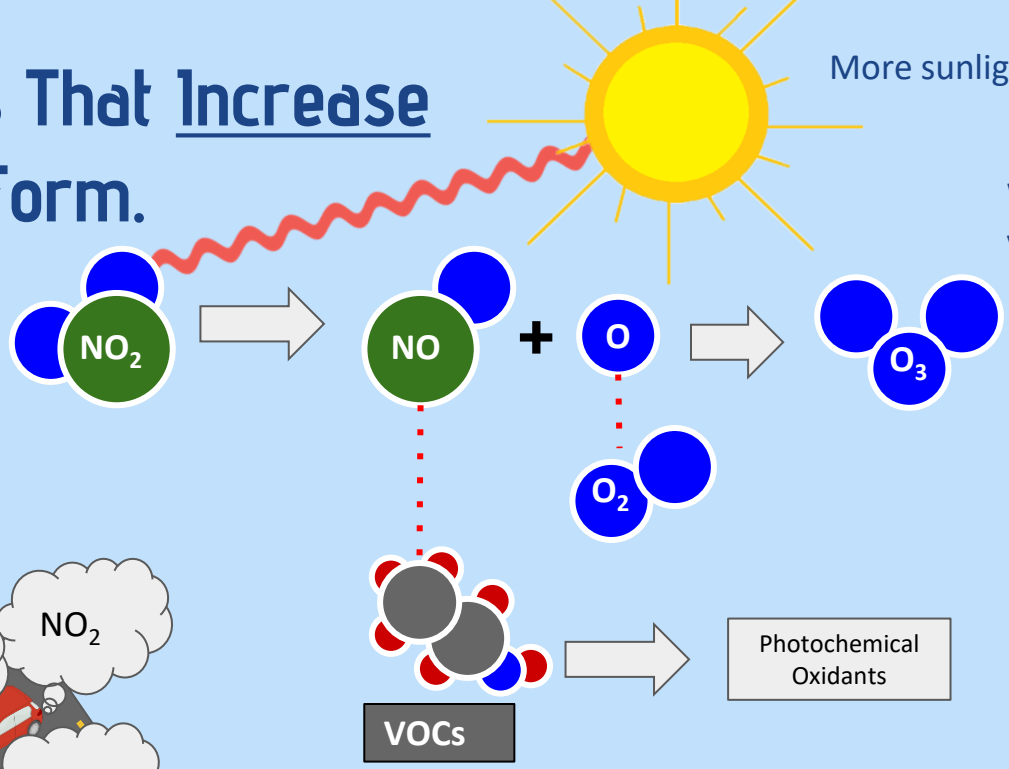
O_3 combines with photochem. oxidants (NO + VOCS) to form photochemical smog

VOCs bond with NO to form photochemical oxidants

Factors That Increase Smog Form.

More sunlight (summer, afternoon) = more O_3

Warmer temperature, speedes evap. of VOCs and rxn that lead to O_3



Photochemical Smog

Higher VOCs emissions (gas stations, laundromats, petrochem. & plastic factories)

Increased vehicle traffic; increases NO_2 emissions & therefore O_3 formation

⚠ **Urban areas have more smog due to all of these factors**

- More traffic → more NO_2
- Hotter temps due to low albedo of blacktop
- More VOCs due to gas stations & factories
- More electricity demand; more NO_x emissions from nearby power plants

Impacts & Reduction of Smog

Impacts

Env. | Reduces sunlight; limiting photosynthesis

O_3 damages plant stomata and irritates animal resp. tracts

Humans | Resp. irritant; worsens asthma, bronchitis, COPD; irritates eyes

Economic | Increased health care costs to treat asthma, bronchitis, COPD

Lost productivity due to sick workers missing work or dying

Decreased ag. yields due to less sunlight reaching crops & damage to plant stomata

Reduction

Vehicles | Decreasing the number of vehicles on the road decreases NO_2 emissions

Fewer vehicles = less gas = fewer VOCs

- Carpooling, public transport, biking, walking, working from home

Energy | Increased electricity production from renewable sources that don't emit NO_x (solar, wind, hydro)

Nat. gas power plants release far less NO_x than coal

SUGGESTED SKILL

Data Analysis

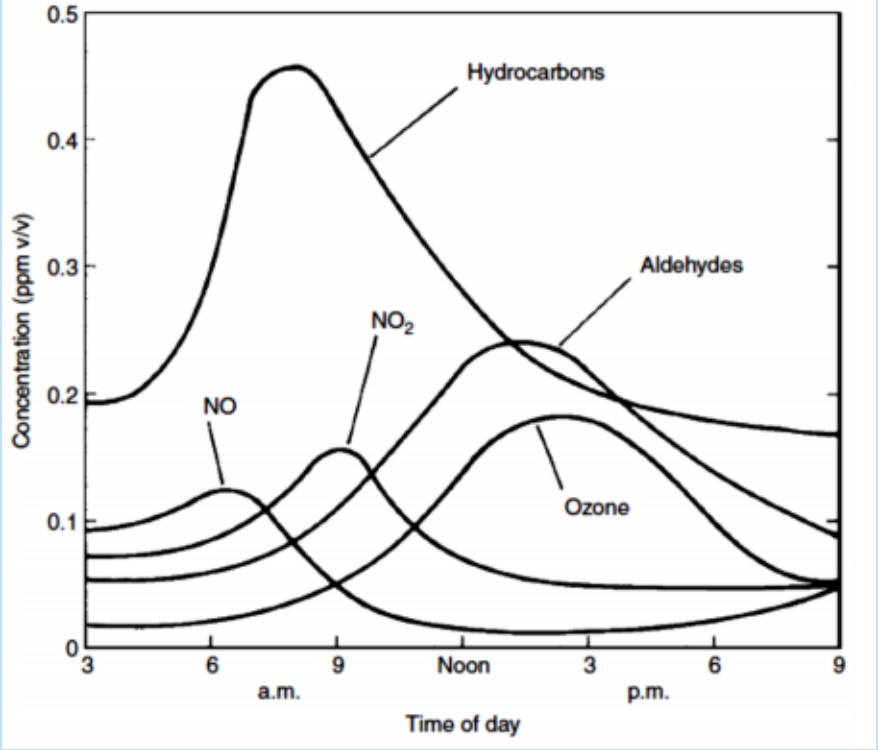
5.B

Describe relationships among variables in data represented.

Practice FRQ 7.2

Explain the relationship between NO_2 concentration and ozone concentration represented in this graph.

Describe how the time of day impacts ozone formation.



7.3
Thermal Inversion

Objective/EKs/Skill

LEARNING OBJECTIVE

STB-2.C

Describe thermal inversion and its relationship with pollution.

ESSENTIAL KNOWLEDGE

STB-2.C.1

During a thermal inversion, the normal temperature gradient in the atmosphere is altered as the air temperature at the Earth's surface is cooler than the air at higher altitudes.

STB-2.C.2

Thermal inversion traps pollution close to the ground, especially smog and particulates.

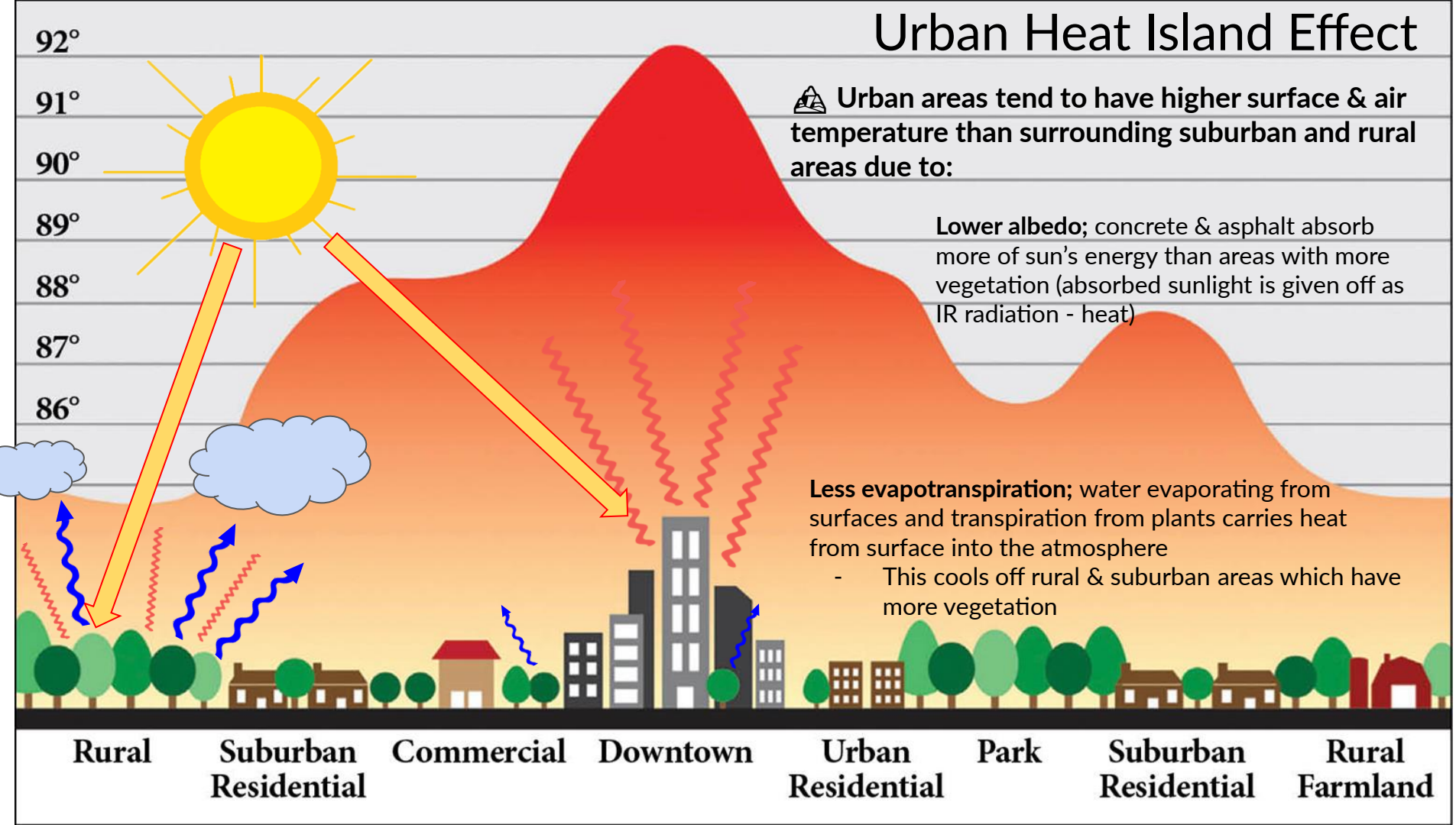
SUGGESTED SKILL

Visual Representations

2.C

Explain how environmental concepts and processes represented visually relate to broader environmental issues.

Urban Heat Island Effect



⚠ **Urban areas tend to have higher surface & air temperature than surrounding suburban and rural areas due to:**

Lower albedo; concrete & asphalt absorb more of sun's energy than areas with more vegetation (absorbed sunlight is given off as IR radiation - heat)

Less evapotranspiration; water evaporating from surfaces and transpiration from plants carries heat from surface into the atmosphere

- This cools off rural & suburban areas which have more vegetation

Thermal Inversion

Normally, the atmosphere is warmest at earth's surface, and cools as altitude rises

Because cold air at the surface is trapped beneath the warmer mass above, convection doesn't cary pollutants up & away

During a thermal inversion, a cooler air mass becomes trapped near earth's surface (Inverting normal gradient)

- **Due to a warm front moving in over it**
- **Or due to hot urban surfaces cooling overnight while IR radiation absorbed during the day is still being released**

Because warm air rises, air convection carries air pollutants away from earth's surface & distributes them higher into the atmosphere

Effects of Thermal Inversion

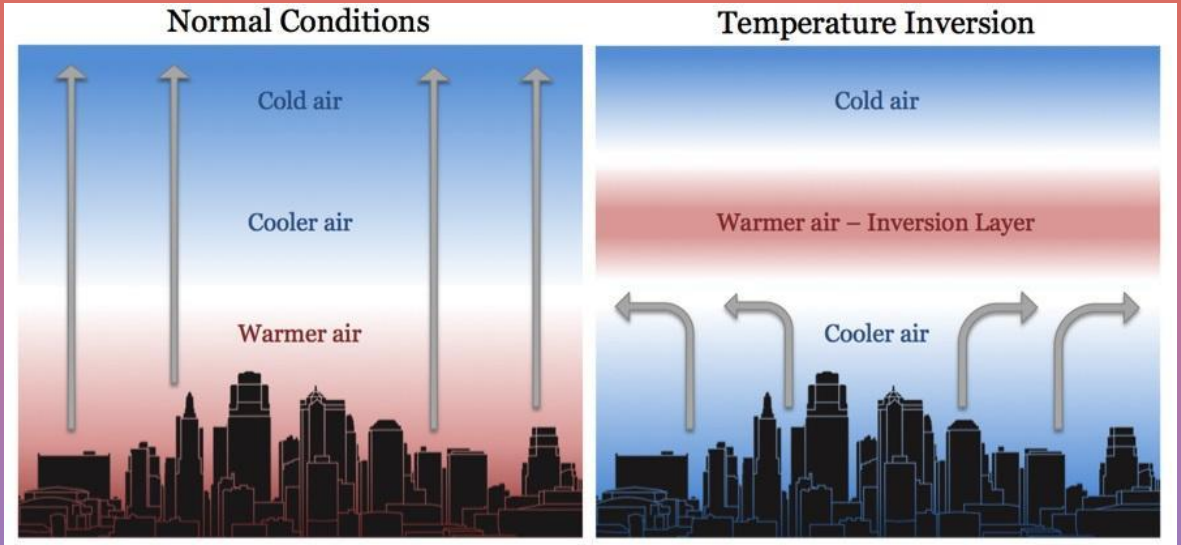
Air pollutants (smog, PM, ozone, SO_2 , NO_x) trapped closer to earth

Respiratory irritation: asthma flare ups leading to hospitalization, worsened COPD, emphysema

Decreased tourism revenue

Decreased photosynthetic rate

Practice FRQ 7.3



SUGGESTED SKILL

Visual Representations

2.C

Explain how environmental concepts and processes represented visually relate to broader environmental issues.

Explain what the arrows in each diagram illustrate about the impacts of a temperature inversion on air pollutants such as smog.

7.4 Atmospheric CO_2 & PM

Objective/EKs/Skill

LEARNING OBJECTIVE

STB-2.D

Describe natural sources of CO_2 and particulates.

ESSENTIAL KNOWLEDGE

STB-2.D.1

CO_2 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.

SUGGESTED SKILL

Scientific Experiments

4.C

Describe an aspect of a research method, design, and/or measure used.

Natural Sources of Air Pollutants

Lightning Strikes

Convert N_2 in atm. to NO_x

Forest Fires

CO, PM, NO_x

Combustion of biomass also releases CO_2 & H_2O vapor (greenhouse gasses)

Plants (esp. conifers)

Plants emit VOCs

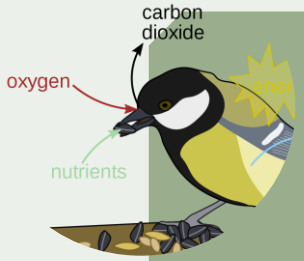
Ex: terpenes & ethylene from pine, fir, spruce trees

This forms natural photochemical smog in Smoky Mountains

Volcanoes

SO_2, PM, CO, NO_x

Natural Sources of CO_2 & PM



Respiration

All living things (plants included) release CO_2 through respiration

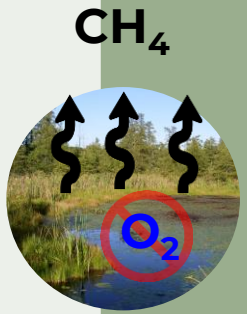
Natural PM Sources

Sea salt, pollen, ash from forest fires & volcanoes dust (windborne soil)

Leads to haze (scattering of sunlight & reduced visibility)

Aerobic Decomposition

Decomposition of organic matter by bacteria & decomposers in the presence of oxygen → **releases CO_2**

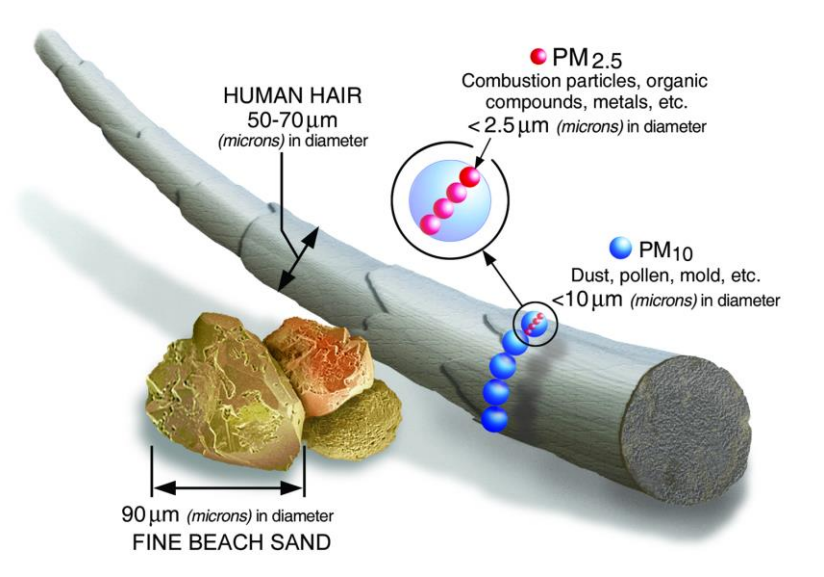


Anaerobic Decomposition

Decomposition of organic matter by bacteria & decomposers in low or oxygen-free conditions → **releases CH_4 (methane)**

PM_{10} vs. $PM_{2.5}$

Particulate Matter: solid or liquid particles suspended in air (also referred to as “particulates)



PM_{10} (<10 micrometers)

- Particles or droplets like dust, pollen, ash, or mold
- Too small to be filtered out by nose hairs and trachea cilia; can irritate respiratory tract & cause inflammation

$PM_{2.5}$ (<2.5 micrometers)

- Particles from combustion (especially vehicles) smaller dust particles
- More likely to travel deep into the lungs due to smaller size
- Associated with chronic bronchitis and increased risk of lung cancer

Practice FRQ 7.4

Students want to conduct an experiment to determine how road construction impacts the amount of PM in the air. They spread vaseline onto the bottom of six petri dishes and placed them at various distances from a road construction site and an existing road. The first three dishes were placed 50, 100, and 200 yards from the road construction site. The second group of dishes were placed 50, 100, and 200 yards from an active road (not under construction).

SUGGESTED SKILL

Scientific Experiments

4.C

Describe an aspect of a research method, design, and/or measure used.

Identify the control group used in this experiment.

Identify the likely dependent variable the students are measuring and **describe** how they could measure this variable.

7.5 Indoor Air Pollutants

Objective/EKs/Skill

SUGGESTED SKILL

Data Analysis

5.C

Explain patterns and trends in data to draw conclusions.

LEARNING OBJECTIVE

STB-2.E

Identify indoor air pollutants.

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.

ESSENTIAL KNOWLEDGE

STB-2.E.7

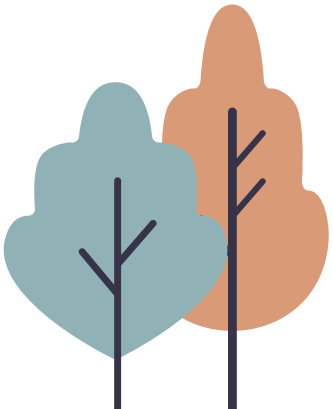
Radon-222 is a naturally occurring radioactive gas that is produced by the decay of uranium found in some rocks and soils.

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.



Developing vs. Developed Countries

- Developing nations use more subsistence fuels such as wood, manure, charcoal (biomass)
  - These biomass fuels release CO, PM, NO_x, VOCs (can also cause deforestation)
  - Often combusted indoors with poor ventilation, leading to high concentrations
  - Est. 3 billion people globally cook with subsistence fuels, resulting in est. 3.5 - 4.3 million deaths annually

- Developed nations use more commercial fuels (coal, oil, natural gas) supplied by utilities
  - Typically burned in closed, well ventilated furnaces, stoves, etc.

⚠ **Major indoor air pollutants in developed nations come from chemicals in products: adhesives in furniture, cleaning supplies, insulation, lead paint**

PM & Asbestos

- Particulates (PM) 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 (since been linked to lung cancer & asbestosis)**

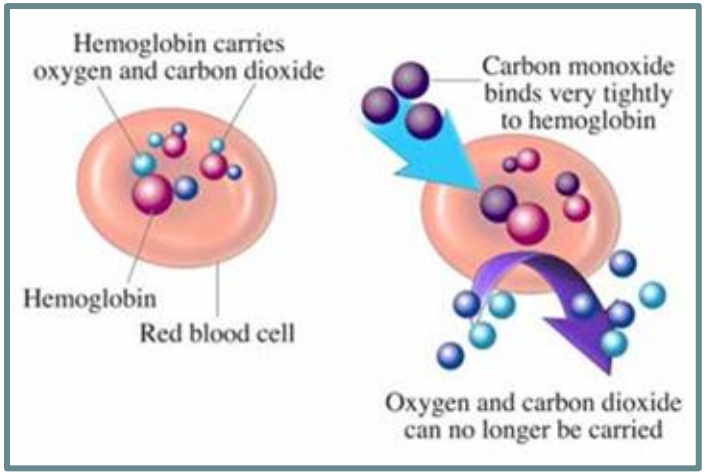
- Phased out of use, but still remains in older buildings
  - Not dangerous until insulation is disturbed and asbestos particles enter air & then resp. tract
  - Should be removed by trained professionals with proper respiratory equipment, ventilation in the area it's being removed from, plastic to seal off area from rest of the building

CO (Carbon Monoxide)

- CO is produced by <u>incomplete combustion</u> of basically any fuel
  - Not all the fuel is combusted due to low O_2 or temp.

⚠ **CO is an asphyxiant: causes suffocation due to CO binding to hemoglobin in blood, displacing O_2**

- Lethal to humans in high concentrations, especially with poor ventilation (odorless and colorless - hard to detect)
  - **Developed nations:** CO released into home by malfunctioning natural gas furnace ventilation
    - Can be detected by carbon monoxide detectors (similar to smoke detectors)
  - **Developing nations:** CO emitted from indoor biomass combustion for heating/cooking



VOCs
(Volatile Organic Compounds)

- Chemicals used in variety of home products that easily vaporize, enter air, and irritate eyes, lungs, bronchioles

Adhesives/sealants: chemicals used to glue carpet down, hold furniture together, seal panels

Formaldehyde is a common adhesive in particle board and carpet glues (new carpet smell)

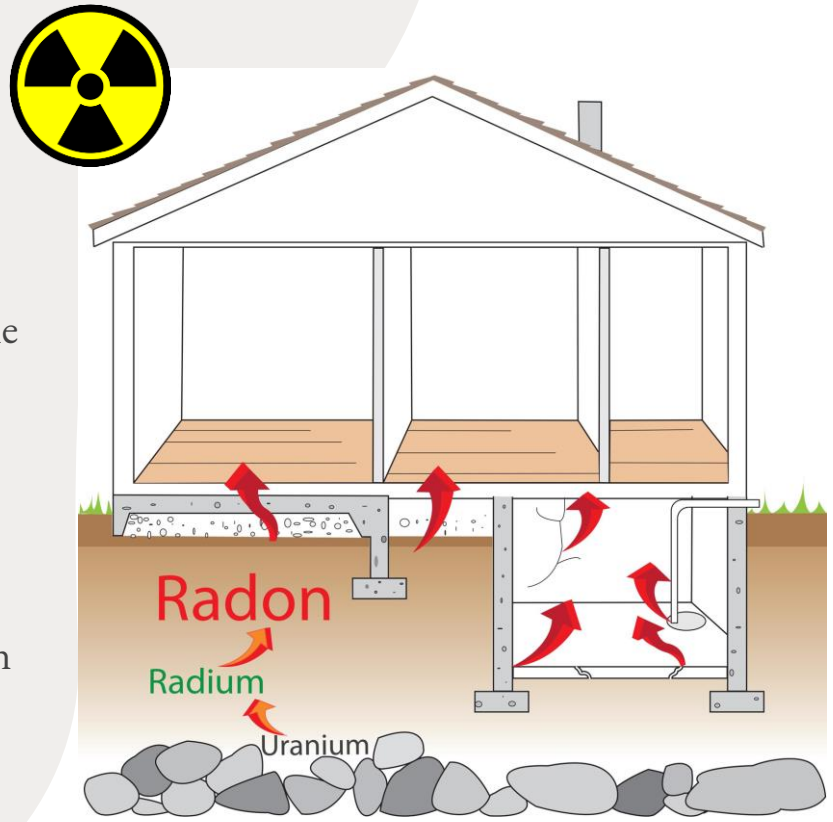
Cleaners: Common household cleaners and deodorizers such as febreeze

Plastics and Fabrics: both can release VOCs themselves, or from adhesives used in production

Radon Gas

☢ 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
- 2nd leading cause of lung cancer after smoking
    - EPA recommends testing homes with airborne Radon monitor
    - Sealing cracks in foundation can prevent it from entering and increasing ventilation in the home can disperse it if it's detected



Dust & Mold

⚠ **Natural indoor air pollutants that can worsen asthma, bronchitis, COPD, emphysema**

- Dust settles in homes naturally, is disturbed by movement, entering air and then respiratory tract

- Mold develops in areas that are dark and damp and aren't well ventilated (under sinks/showers, behind panels in walls and ceiling)
  - Black mold is a class of mold that releases spores into air
    - Especially harmful to resp. system
  - Can be removed by physically cleaning mold out and fixing the water leak or ventilation issue that lead to mold forming

Lead

⚠ **Found in paint in old homes (EPA banned lead 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) 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 by cities with copper pipes

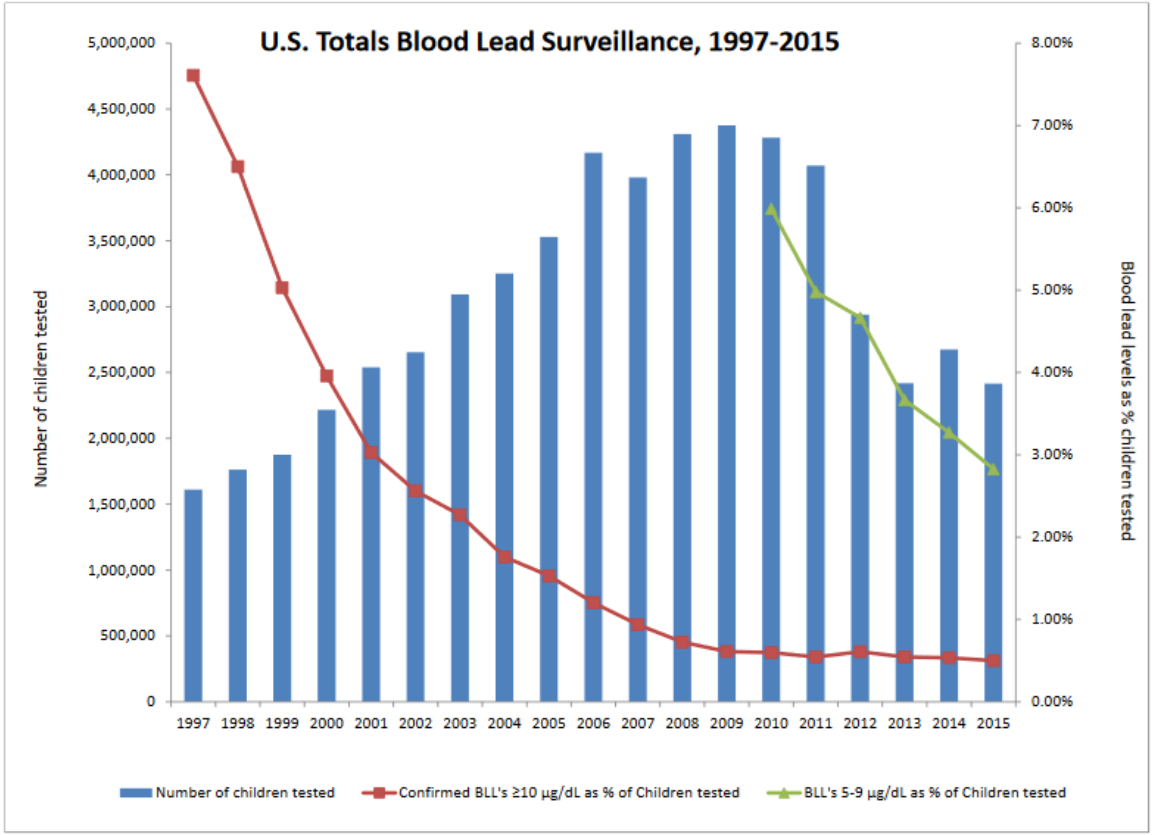
Practice FRQ 7.5

SUGGESTED SKILL

Data Analysis

5.C

Explain patterns and trends in data to draw conclusions.



Explain a cause for the trend in the confirmed BLLs (blood lead levels) above 10 micrograms/dL as a % of children tested from 1997 to 2015.

7.6 - Reduction of Air Pollutants

Objective/EKs/Skill

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
STB-2.G Explain how air pollutants can be reduced at the source.	**STB-2.G.1** Methods to reduce air pollutants include regulatory practices, conservation practices, and alternative fuels. **STB-2.G.2** A vapor recovery nozzle is an air pollution control device on a gasoline pump that prevents fumes from escaping into the atmosphere when fueling a motor vehicle. **STB-2.G.3** A catalytic converter is an air pollution control device for internal combustion engines that converts pollutants (CO, NO*x*, and hydrocarbons) in exhaust into less harmful molecules (CO_2, N_2, O_2, and H_2O). **STB-2.G.4** Wet and dry scrubbers are air pollution control devices that remove particulates and/or gases from industrial exhaust streams. **STB-2.G.5** Methods to reduce air pollution from coal-burning power plants include scrubbers and electrostatic precipitators.

SUGGESTED SKILL

Environmental Solutions

7.D

Use data and evidence to support a potential solution.

Reducing Emissions

Reducing emissions = reducing air pollutants

- Drive less, walk/bike/bus more
- Conserve electricity (smart appliances)
- Eat more plants, less meat
- Renewable, non-pollution emitting energy (solar, wind, hydro)

Laws/Regulations

Clean Air Act

- Allows EPA to set acceptable levels for criteria air pollutants
    - Monitor emissions levels from power plants and other facilities
    - Tax/sue/fine corporations that release emissions above levels

CAFE Vehicle Standards

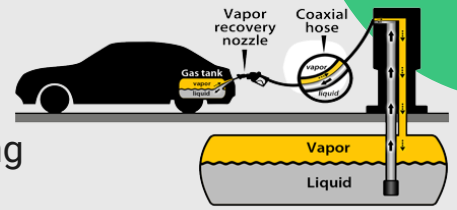
- (**C**orporate **A**verage **F**uel **E**conomy) standards require the entire US “fleet” of vehicles to meet certain average fuel
    - Requires vehicle manufacturers to work to make more efficient vehicles
    - More efficient vehicles burn less gasoline and release less NO_x, PM, CO, and CO_2

Pollution Credits

- Similar to ITQs for fish
- Companies that reduce emissions well below EPA-set levels earn pollution credits
    - They can sell these to companies that release more than acceptable levels

Reducing Vehicle Air Pollutants

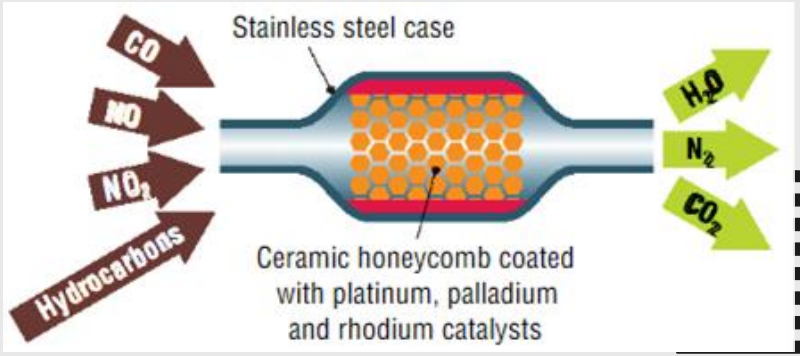
Vapor Recovery Nozzle



- Capture hydrocarbon VOCs released from gasoline fumes during refueling
  - Separate tube inside nozzle captures vapors & returns them to underground storage tank beneath the gas station
  - Reduces VOCs, which contribute to smog & irritate resp. tracts
  - Also reduces benzene (carcinogen) released from gasoline vapors

Catalytic Converter (CC)

- Required on all vehicles after 1975
- Contains metals (platinum & palladium) that bind to NO_x and CO
  - CC converts NO_x, CO, and other hydrocarbons into CO_2, N_2, O_2, and H_2O



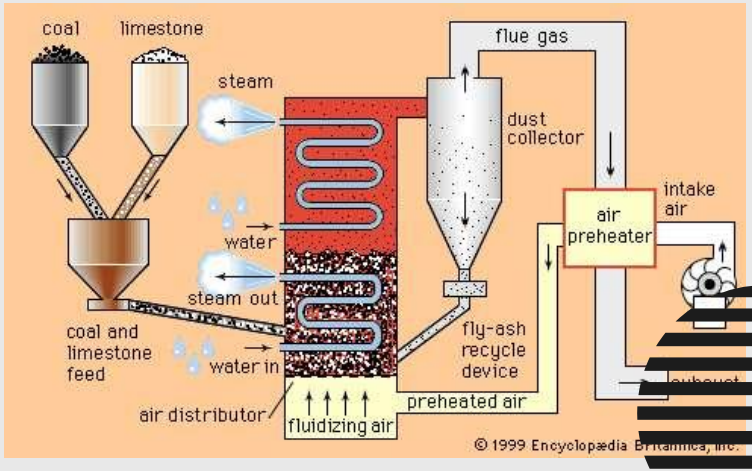
Reducing SO_x & NO_x

Crushed Limestone (SO_2)

- Used to reduce SO_2 from coal power plants
  - Crushed coal mixed with limestone (calcium carbonate) before being burned in boiler
  - Calcium carbonate in limestone combines with SO_2 to produce calcium sulfate, reducing the SO_2 being emitted
  - Calcium sulfate can be used to make gypsum wallboard or sheetrock for home foundations

Fluidized Bed Combustion (NO_x)

- Fluidizing jets of air pumped into combustion “bed”
- Jets of air bring more O_2 into rxn, making combustion more efficient and bringing SO_2 into more contact with calcium carbonate in limestone
  - Also allows coal to be combusted at lower temp, which emits less NO_x



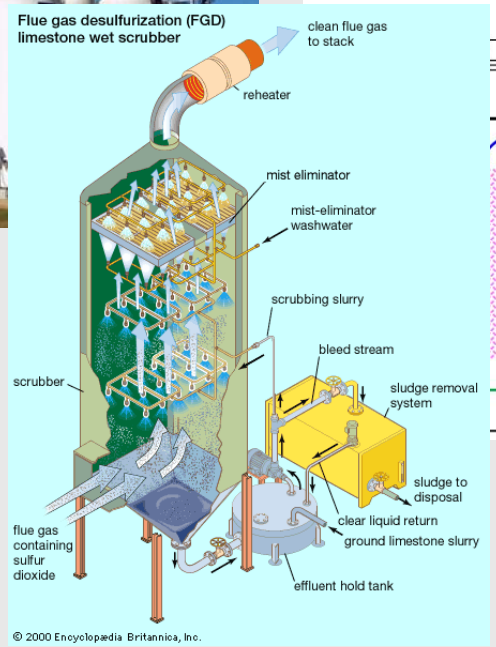
Wet & Dry Scrubbers

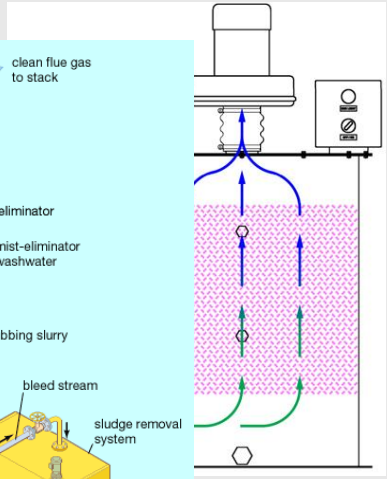
Dry Scrubbers (NO_x, SO_x, VOCs)

- Large column/tube/pipe filled with chemicals that absorb or neutralize oxides (NO_x, SO_x, VOCs) from exhaust streams (emissions)
    - Calcium oxide is a common dry scrubber additive which reacts with SO_2 to form calcium sulfite

Wet Scrubbers (NO_x, SO_x, VOCs + PM)

- May involve chemical agents that absorb or neutralize NO_x, SO_x, VOCs, but also include mist nozzles that trap PM in water droplets as well
    - Mist droplets with pollutants and PM trapped in them fall to bottom of scrubber or get trapped @ top by mist eliminator
    - Sludge collection system traps polluted water for disposal

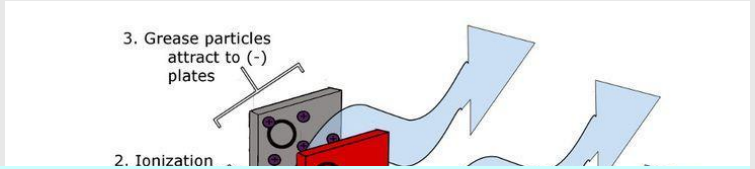




Reducing PM

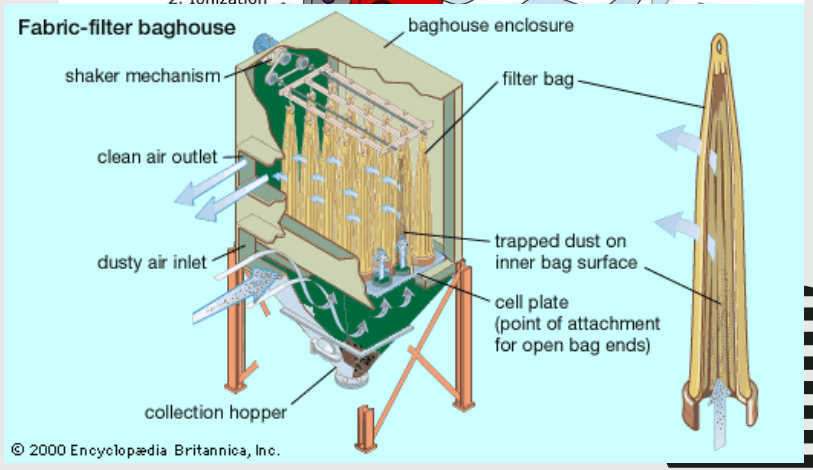
Electrostatic Precipitator

- Power plant/factory emissions passed through device with a neg. charged electrode, giving particles a neg. Charge
- Neg. charged particles stick to pos. charged collection plates, trapping them
- Plates discharged occasionally so particles fall down into collection hopper for disposal in landfills



Baghouse Filter (PM)

- Large fabric bag filters that trap PM as air from combustion/industrial process passes through
- Shaker device knocks trapped particles loose into collection hopper below
    - PM collected & taken to landfill



Practice FRQ 7.6

SUGGESTED SKILL

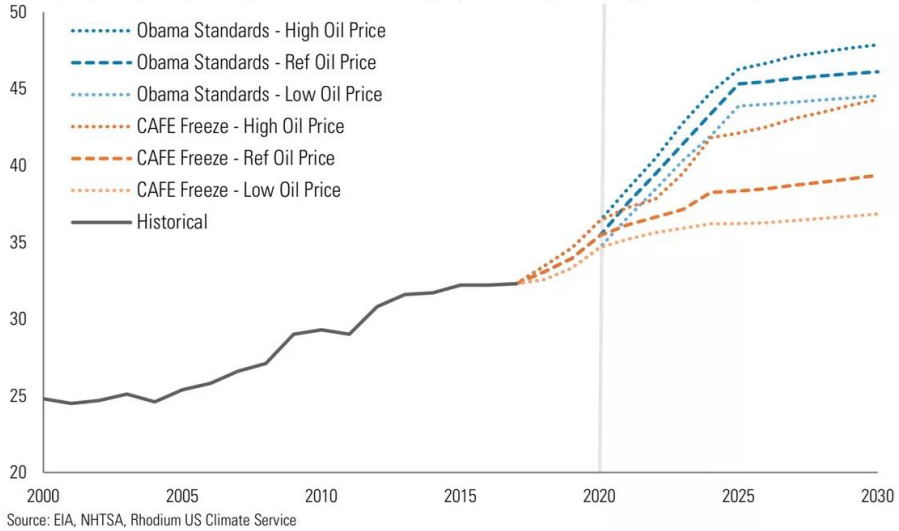
Environmental Solutions

7.D

Use data and evidence to support a potential solution.

Figure 1: Impact of CAFE rollbacks on fleetwide fuel economy

Miles per gallon, new passenger vehicle fleet average (cars and light trucks), AEO2018 oil price scenarios



Source: EIA, NHTSA, Rhodium US Climate Service

Make a claim about the effectiveness of the Obama CAFE standards as an effort to reduce the levels of NO_x in urban areas. **Justify** your claim with data from figure 1.

7.7
Acid Rain

SUGGESTED SKILL

Scientific Experiments

4.B

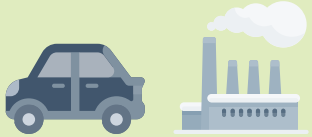
Identify a research method, design, and/or measure used.

Objective/EKs/Skill

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
STB-2.H Describe acid deposition.	**STB-2.H.1** Acid rain and deposition is due to nitrogen oxides and sulfur oxides from anthropogenic and natural sources in the atmosphere. **STB-2.H.2** Nitric oxides that cause acid deposition come from motor vehicles and coal-burning power plants. Sulfur dioxides that cause acid deposition come from coal-burning power plants.
STB-2.I Describe the effects of acid deposition on the environment.	**STB-2.I.1** Acid deposition mainly affects communities that are downwind from coal-burning power plants. **STB-2.I.2** Acid rain and deposition can lead to the acidification of soils and bodies of water and corrosion of human-made structures. **STB-2.I.3** Regional differences in soils and bedrock affect the impact that acid deposition has on the region—such as limestone bedrock's ability to neutralize the effect of acid rain on lakes and ponds.

Sources of NO_x & SO_2

NO_x and SO_2 are the primary pollutants that cause most acid precipitation

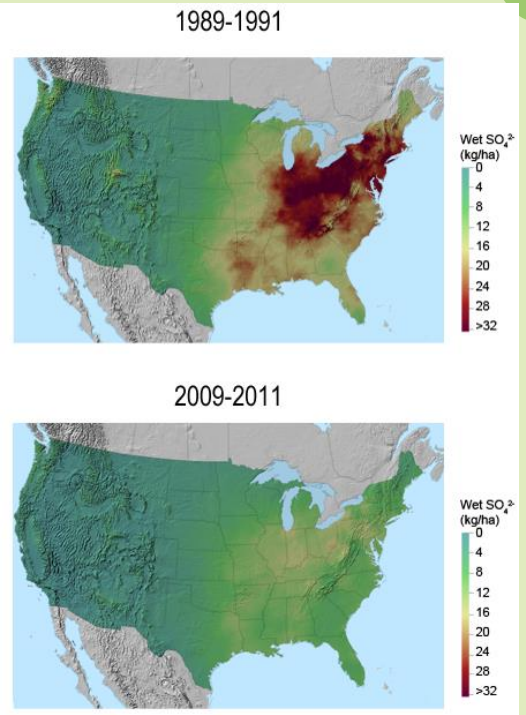


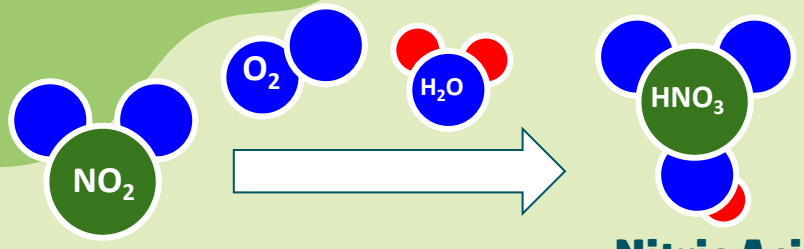
Major Sources

- **SO_2** - Coal fired power plants, metal factories, vehicles that burn diesel fuel
- **NO_x** - vehicle emissions, diesel generators coal power plants

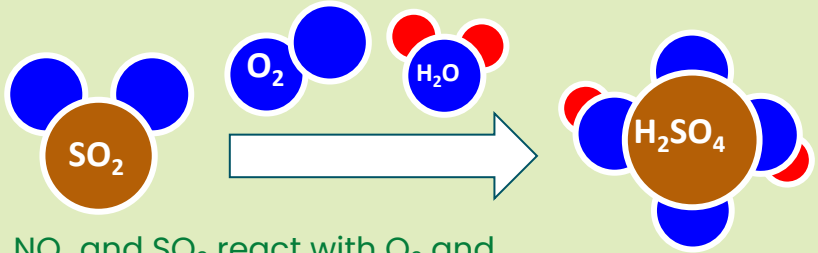
Limiting Acid Rain

- Reducing NO_x & SO_2 emissions reduces acid deposition
  - Higher CAFE Standards
  - More public transit
  - Renewable energy sources
  - More efficient electricity use
- Since passage of Clean Air Act, acid deposition has decreased significantly

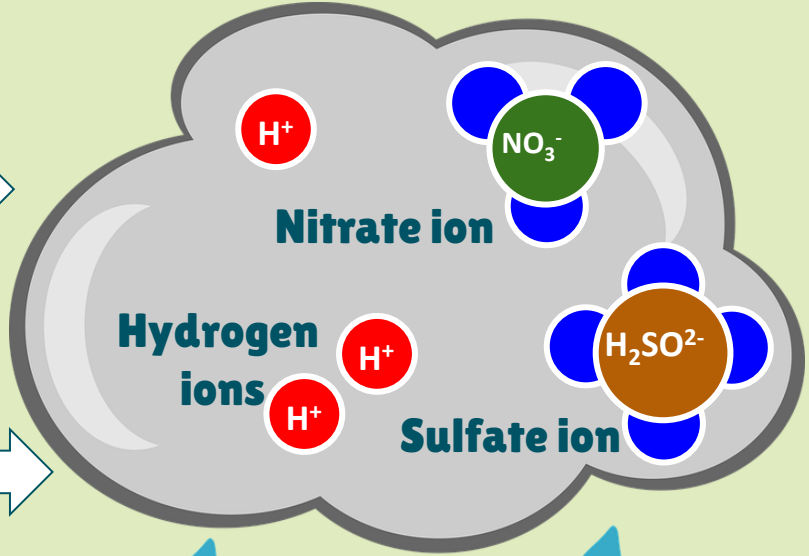




Nitric Acid

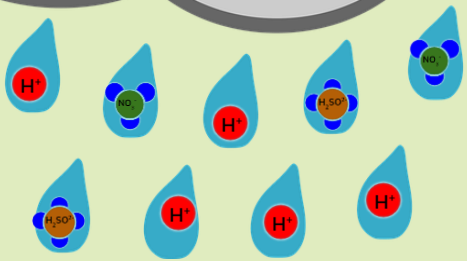


Sulfuric Acid



NO_x and SO_2 react with O_2 and H_2O in the atmosphere, forming nitric and sulfuric acid

Sulfuric acid and nitric acid dissociate in the presence of water into sulfate and nitrate ions, and hydrogen ions (H^+)



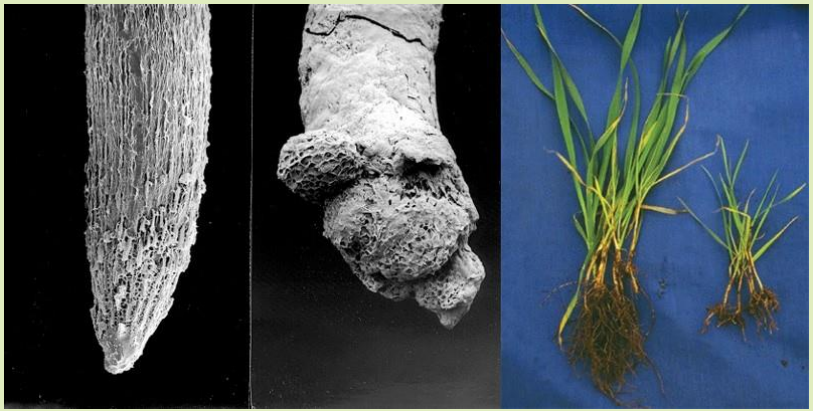
Acidic rain water (higher H^+ conc.) deceases soil and water pH; can limit tree growth in forests down wind from major SO_2 & NO_x sources

Env. Effects of Acid Rain

⚠ **Acidity = higher H^+ ion concentration, lower pH**

Soil/Water Acidification

- H^+ ions displace or leech other pos. charged nutrients (Ca^{2+}, K^+) from soil
- H^+ ions also make toxic metals like aluminum and mercury more soluble in soil and water
    - This can slow growth or kill plants and animals living in the soil or water



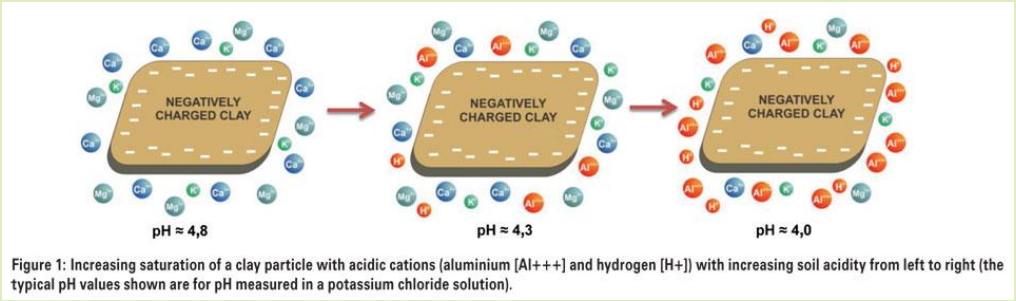


Figure 1: Increasing saturation of a clay particle with acidic cations (aluminium [Al+++] and hydrogen [H+]) with increasing soil acidity from left to right (the typical pH values shown are for pH measured in a potassium chloride solution).

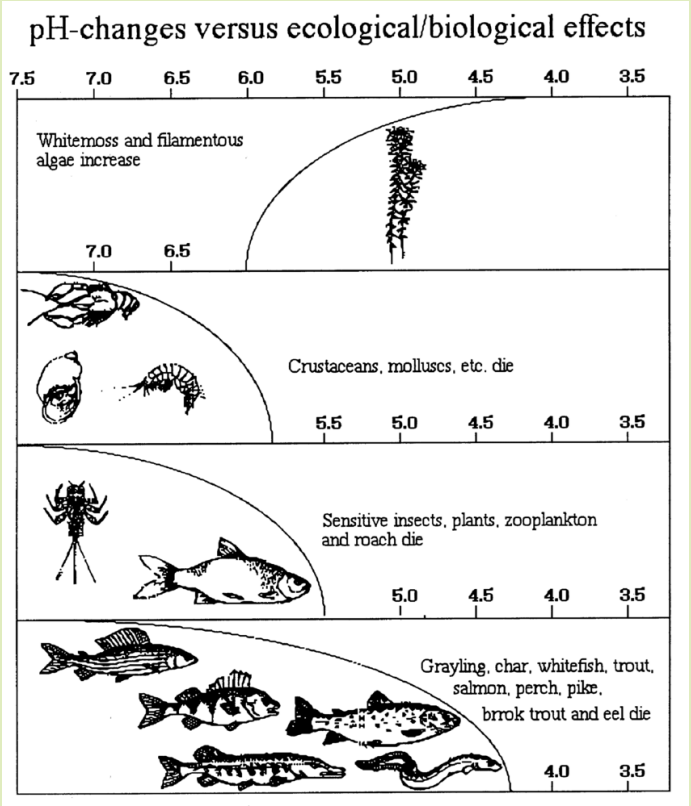
Env. Effects of Acid Rain

⚠Aquatic species have diff. pH tolerances

pH Tolerance

- As pH decreases (more acidic) outside optimal range for a species, pop. declines
  - When pH leaves range of tolerance, they cannot survive at all, due to:
    - Aluminum toxicity
    - Disrupted blood osmolarity (Na^+/Cl^- balance disrupted at low pH)

- **Indicator species** can be surveyed and used to determine conditions of an ecosystem (soil, water, etc.)
  - Ex: high whitemoss/filamentous algae pop. indicates pH < 6.0
  - High crustacean pop. indicates pH > 6.0



Mitigating Acid Rain

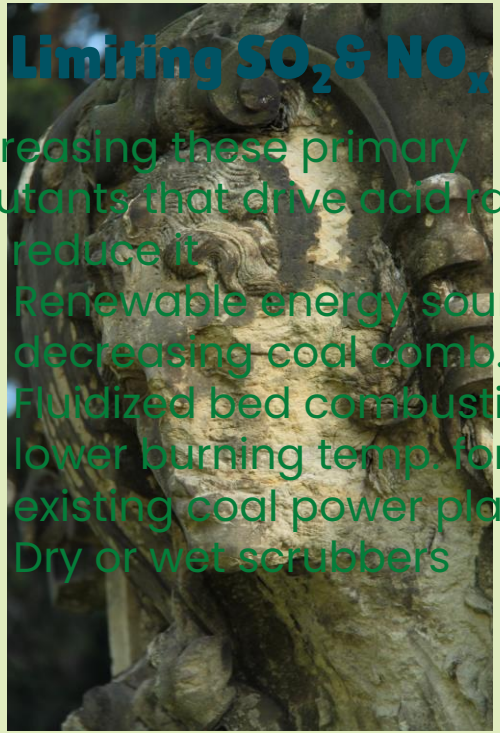
⛰️Limestone (calcium carbonate) is a natural base that can neutralize acidic soil/water

Limestone

- Calcium carbonate ($CaCO_3$) reacts with H^+ ions, forming HCO_3 and giving off Ca^{2+}
  - This “neutralizes” acidic water/soil, moving it closer to a pH of 7
- Regions with limestone bedrock have some natural buffering of acid rain
  - Humans can also add crushed limestone to soils/waters to neutralize
- Acid rain can corrode human structures, especially those made from limestone

Limiting SO_2 & NO_x

- Decreasing these primary pollutants that drive acid rain can reduce it
  - Renewable energy sources, decreasing coal comb.
  - Fluidized bed combustion & lower burning temp. for existing coal power plants
  - Dry or wet scrubbers



SUGGESTED SKILL

Scientific Experiments

4.B

Identify a research method, design, and/or measure used.

Practice FRQ 7.7

Scientists want to examine how acid deposition impacts crustacean organisms, such as isopods (rolly pollies) in the soil of temperate forests. To explore this question, they collect rainwater with different pH values and mist the different rainwater samples onto pots of soil taken from a temperate forest.

Throughout the experiment, the scientists record the number of living and dead crustaceans found in each pot of soil.

a) **Identify** a likely hypothesis for this experiment.

b) **Identify** the independent variable for this experiment.

c) **Explain** how the results of this experiment would change if crushed limestone were added to each soil pot.

7.8 NOISE POLLUTION

OBJECTIVE/EKS/SKILLS

SUGGESTED SKILL

Text Analysis

3.C

Describe the author's reasoning (use of evidence to support a claim).

LEARNING OBJECTIVE

STB-2.J

Describe human activities that result in noise pollution and its effects.

ESSENTIAL KNOWLEDGE

STB-2.J.1

Noise pollution is sound at levels high enough to cause physiological stress and hearing loss.

STB-2.J.2

Sources of noise pollution in urban areas include transportation, construction, and domestic and industrial activity.

STB-2.J.3

Some effects of noise pollution on animals in ecological systems include stress, the masking of sounds used to communicate or hunt, damaged hearing, and causing changes to migratory routes.

Urban Noise Pollution

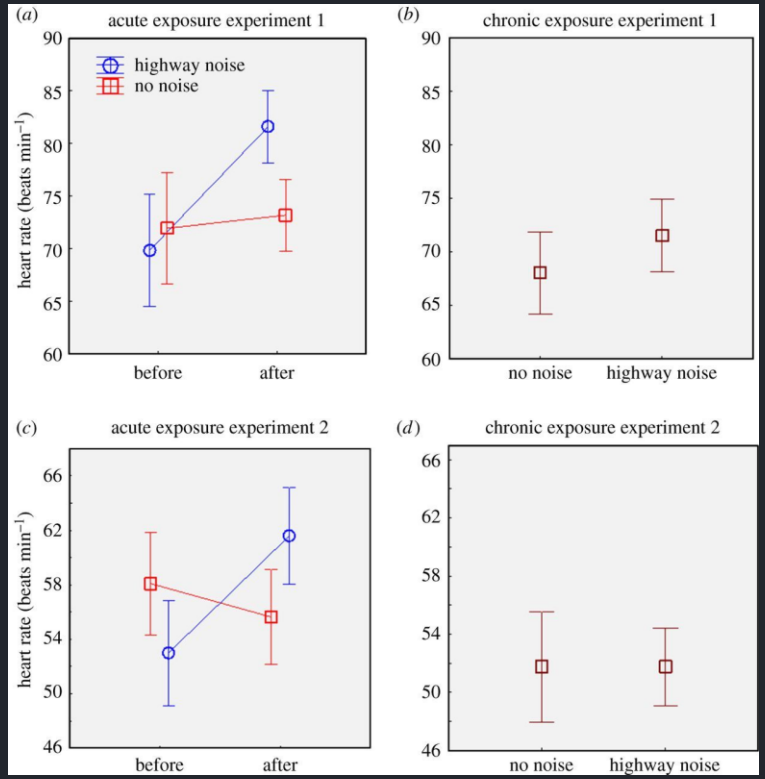
⚠ Any noise at great enough volume to cause physiological stress (difficulty communicating, headaches, confusion) or hearing loss

- Construction: jack hammers, trucks, concrete pouring
- Transportation: cars, busses, trains
- Industrial activity: manufacturing plants
- Domestic activity: neighbor's music, lawn mowing, home projects

WILDLIFE EFFECTS (LAND)

⚠ **Noise pollution can disrupt animal communication, migration, and damage hearing**

- **Physiological stress**: caterpillar hearts beat faster when exposed to simulated highway noise pollution
    - Could drive pollinator species decline
- **Hearing:** can prevent predators from hearing prey and vice versa; can prevent mates from locating each other (both of these decrease chances of survival)

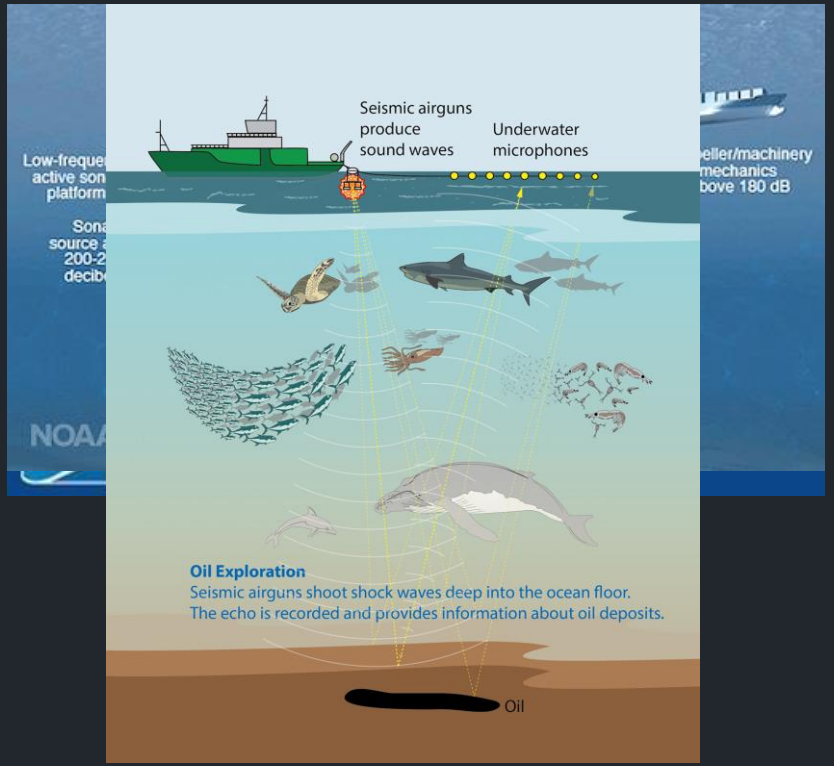


Wildlife effects (aquatic)

⚠ **Aquatic noise pollution comes from the noise of ship engines, military sonar, and seismic air blasts from oil & gas surveying ships**

- **Physiological stress**: hearing loss, disrupted communication, mating calls, predator and prey navigation
    - Whales are especially prone to having migration routes disrupted as their vocal communication is disrupted

- **Seismic surveying** ships send huge air blasts down into the water, searching for oil by recording how the echo is returned from ocean floor
    - So loud that researchers off the coast of Virginia can detect blasts from coast of



practice 7.8

SUGGESTED SKILL

Text Analysis

3.C

Describe the author's reasoning (use of evidence to support a claim).

Read the passage from NAMEPA (North American Marine Environment Protection Association)

👇 link 🔗 in the description 👇

Describe the reasoning behind the author's claim that whales may be able to adapt to the increased levels of aquatic noise pollution.