Air Pollution

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Definition of Air Pollution

Air pollution is the presence in the atmosphere of substances put there by the acts of man in concentrations sufficient to interfere with :

- Health
- Comfort
- Safety
- Full use & enjoyment of property

Sources of Air Pollution

Mobile sources: Vehicles

Stationary sources: Power plants/ Factories

Other sources: Open burning

Factors Affecting Air Pollution

- Wind
- Atmospheric Stability
- Topography
- Type of Plumes

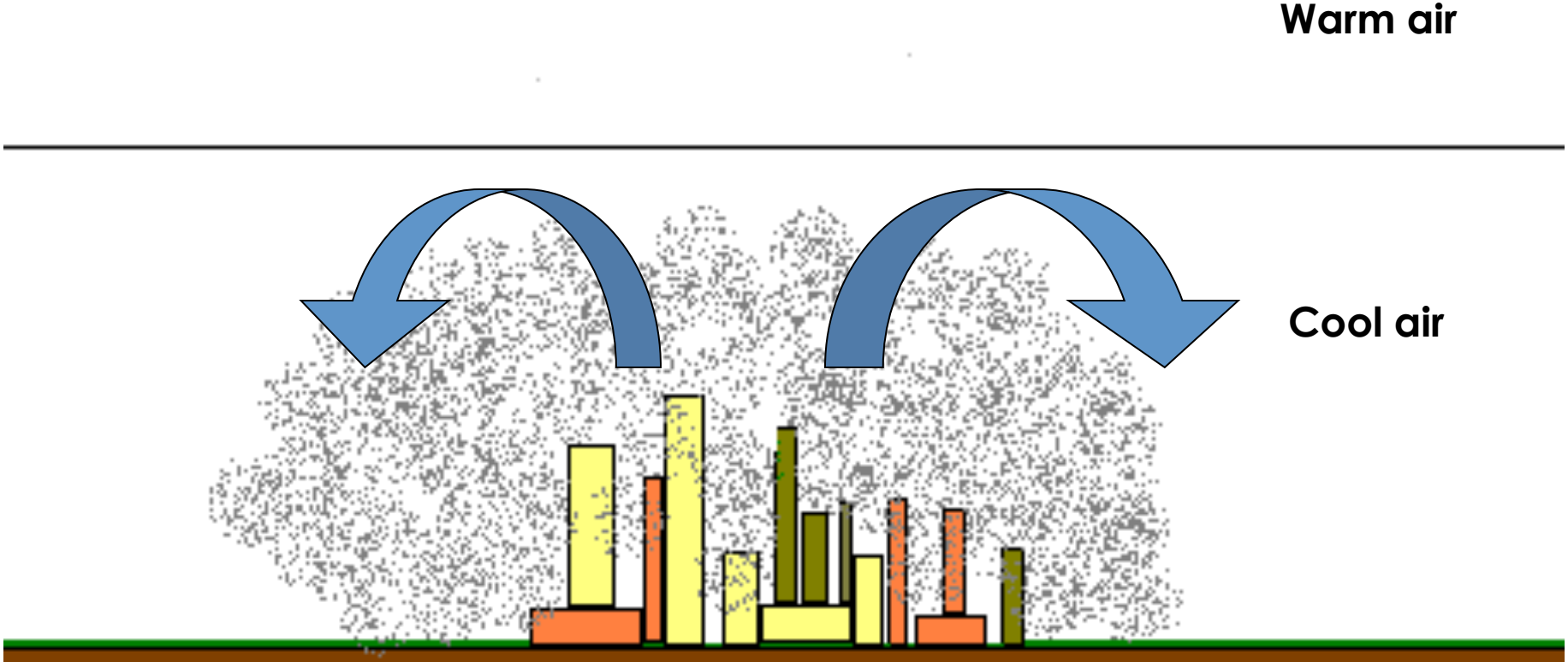
Wind

- Horizontal dispersion of air pollutants depends upon wind speed and direction
- Concentration of pollutants decreases with increasing wind speed
- Buildings in cities can also obstruct wind flow thus further aggravating air pollution problems.

Atmospheric Stability

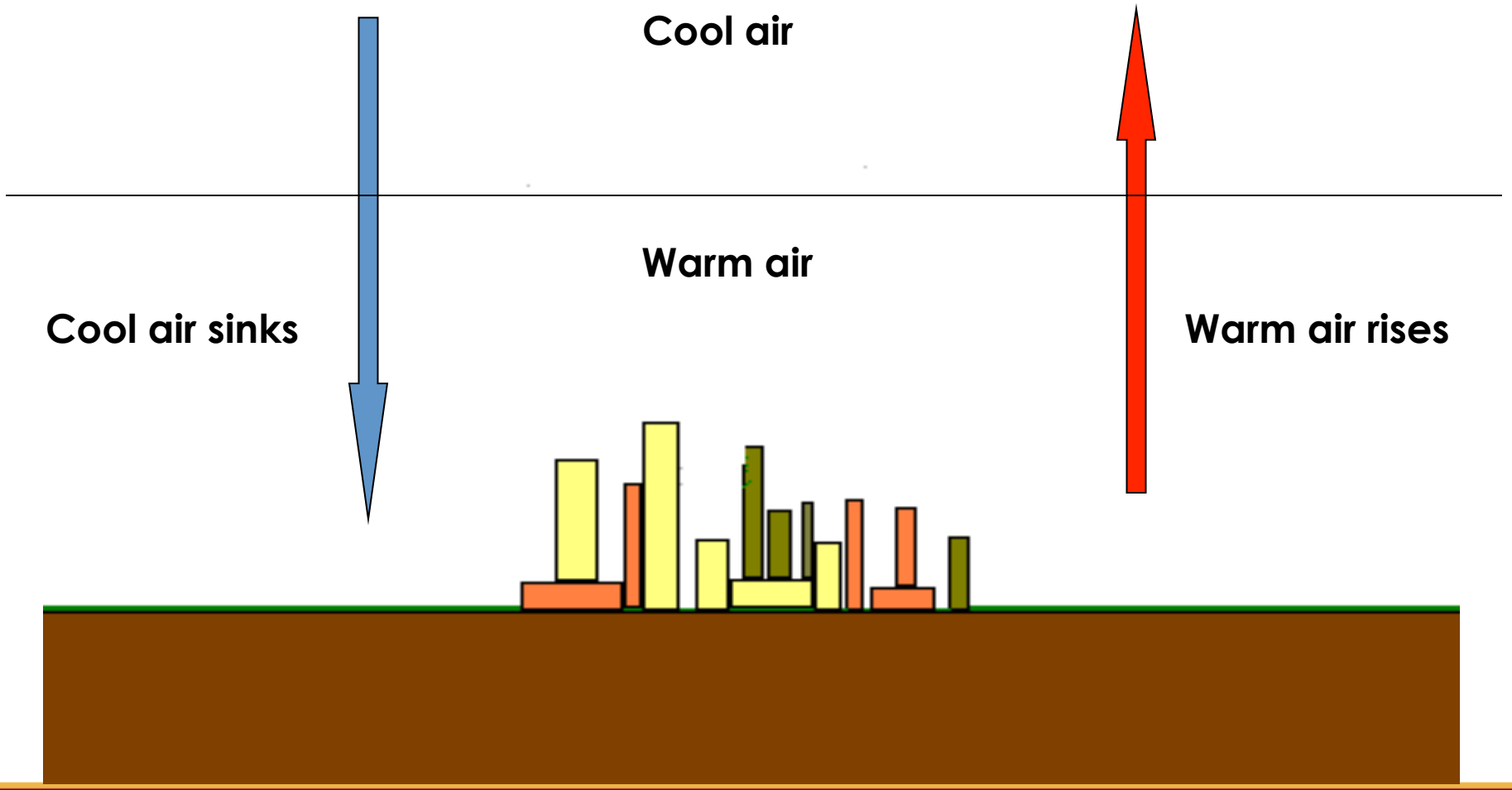
- Atmospheric stability depends upon relationship between air, temperature and altitude occurs at particular time and place.
- Tendency of air to remain at its original position (stable) or to rise (unstable)
- Atmospheric stability affects vertical movements of air.

STABLE Atmospheric Stability

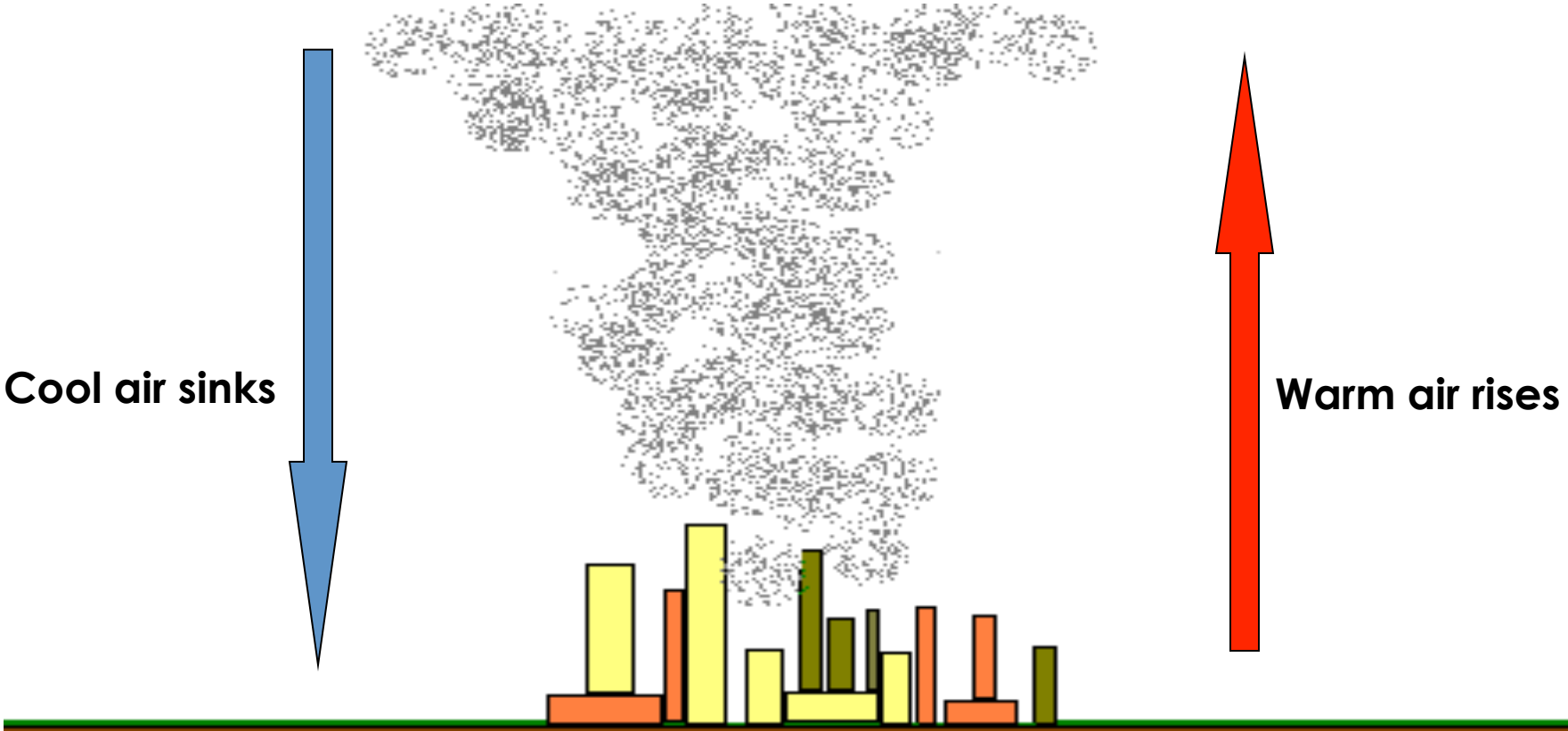


Little or no vertical movement of air masses. As a result, there is no mixing of air pollutants in the vertical direction, and pollutants tend to accumulate near the ground.

UNSTABLE Atmospheric Stability



UNSTABLE Atmospheric Stability (Cont')



Air masses move naturally in a vertical direction, and carry pollutants upward, away from the ground

Topography

- Certain topographical and atmospheric stability conditions may aggravate air pollution problems

- Less obstruction type of topographical condition can lower the risk of air pollution

Type of Plumes

- Stack's emission becomes a plume in the atmosphere.
- The plume is an area of concentrated waste emissions that slowly become diluted with the other atmospheric gases.

Type of Plumes (Cont')

- Plume types are important because they help us understand under what conditions there will be higher concentrations of contaminants at ground level.
  - ❖Looping plume
  - ❖Coning plume
  - ❖Fanning plume
  - ❖Lofting plume
  - ❖Fumigation plume

Looping Plume

- High degree of convective turbulence
- Super-adiabatic lapse rate-- strong instabilities
- Associated with clear daytime conditions accompanied by strong solar heating & light winds
- High probability of high concentrations sporadically at ground level close to stack.

Coning Plume

- Stable with small-scale turbulence
- Associated with overcast moderate to strong winds
- Roughly 10°cone
- Pollutants travel fairly long distances before reaching ground level in significant amounts

Fanning Plume

- Occurs under large negative lapse rate
- Strong inversion at a considerable distance above the stack
- Extremely stable atmosphere
- Little turbulence
- If plume density is similar to air, travels

Lofting Plume

- Favorable in the sense that fewer impacts at ground level.
- Pollutants go up into environment
- They are created when atmospheric conditions are unstable above the plume and stable below

Fumigation Plume

- Most dangerous plume: contaminants are all coming down to ground level
- They are created when atmospheric conditions are stable above the plume and unstable below
- This happens most often after the daylight sun has warmed the atmosphere, which turns a night time fanning plume into fumigation for about a half an hour

Types of Air Pollutants

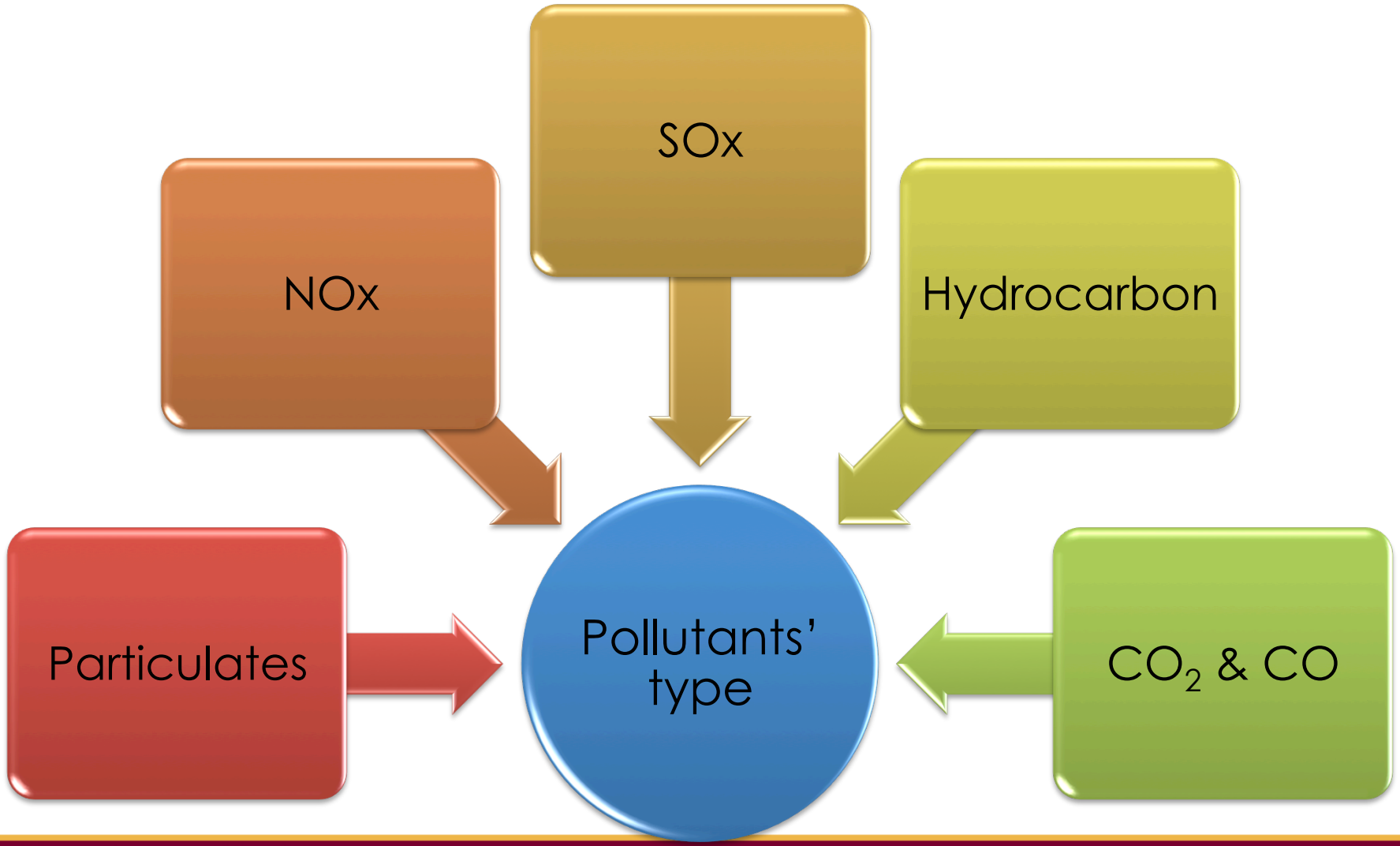
Primary air pollutant

- Enters directly into the atmosphere from natural events or human activities
- CO, CO_2, SO_2, NO (nitric oxide), most hydrocarbons, most particulates

Secondary air pollutant

- Is formed in the atmosphere through chemical reaction and solar reaction (also by hydrolysis or oxidation)
- NO_2, SO_3, HNO_3(nitric acid), H_2SO_4, H_2O_2, O_3, PAN (peroxyacetyl nitrate) – from oxidation of HC.

Types of Air Pollutants (Cont')



Particulate Matters

- Particulate matter in the atmosphere (either solids or liquid form)
- Includes wind-blown soil, smoke, aerosol, dust, fly ash, fumes and fog
- Size: 0.0002μm~500μm
- Sources: Factories, power plants, cars, construction activities, fires, and agricultural activities

Particulate Matters (Cont')

	Coarse Particles (PM_{10})	Fine Particles ($PM_{2.5}$)
What	• smoke, dirt and dust from factories, farming, and roads • mold, spores, and pollen	• toxic organic compounds • heavy metals
Source	• crushing and grinding rocks and soil blown by wind • **burning plants** (brush fires and forest fires or yard waste)	• driving automobiles • **burning plants** (brush fires and forest fires or yard waste) • smelting (purifying) and processing metals

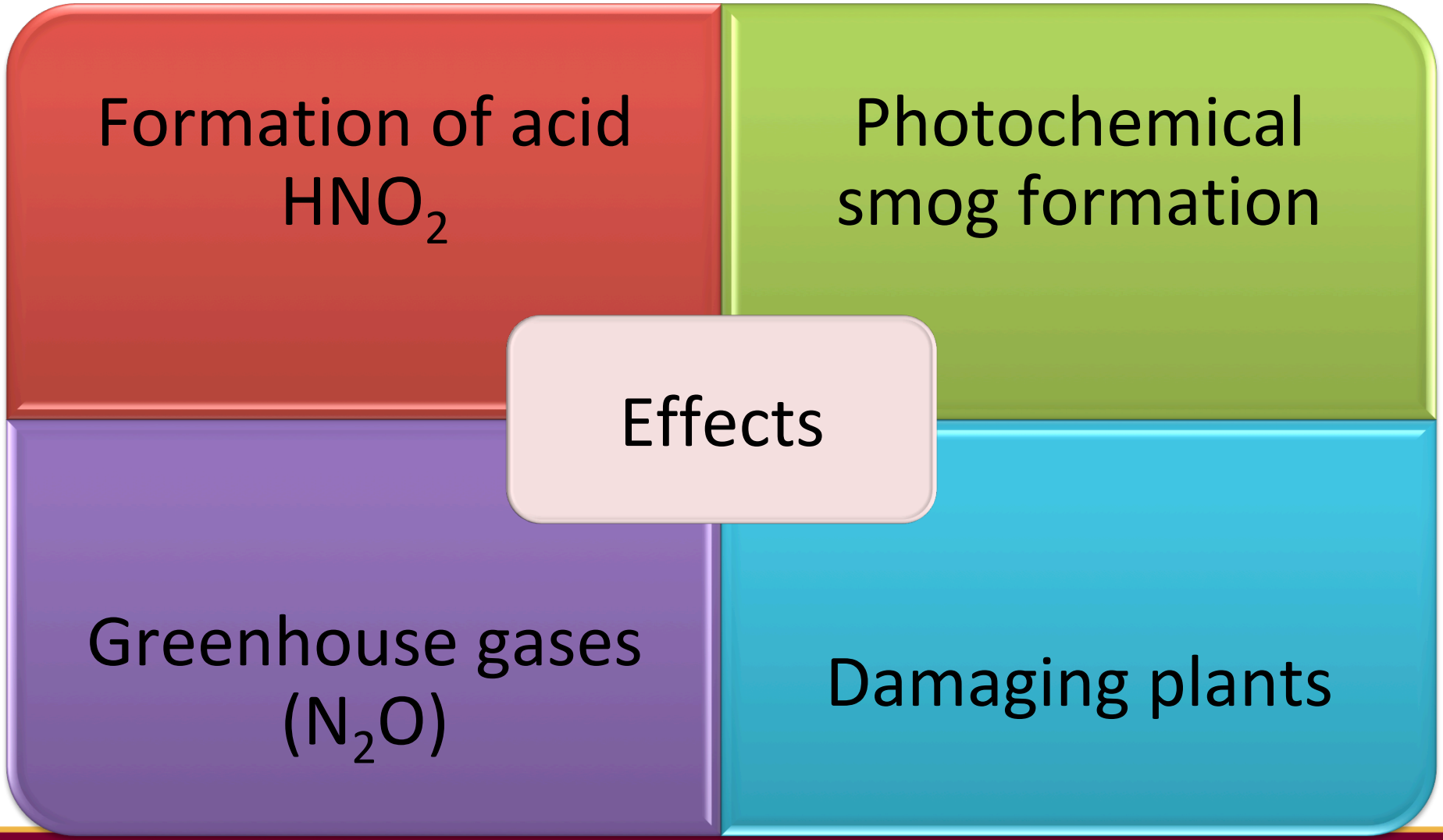
Effects of Particulate Matters

- Respiratory illness, bronchitis, even deaths
- Many of the small particles from wood smoke are too small to be filtered by the nose or upper respiratory system and able to penetrate deep within the lungs
- Due to their ability to evade the defenses of the body, these particles transporting toxic gases, bacteria, and viruses into the lungs, and ultimately the blood stream

Nitrogen Oxides (NO_X)

- NO_X (NO, NO_2, N_2O) is a generic term for the various nitrogen oxides produced during combustion
- Sources include from motor vehicles, power plant industries and open burning

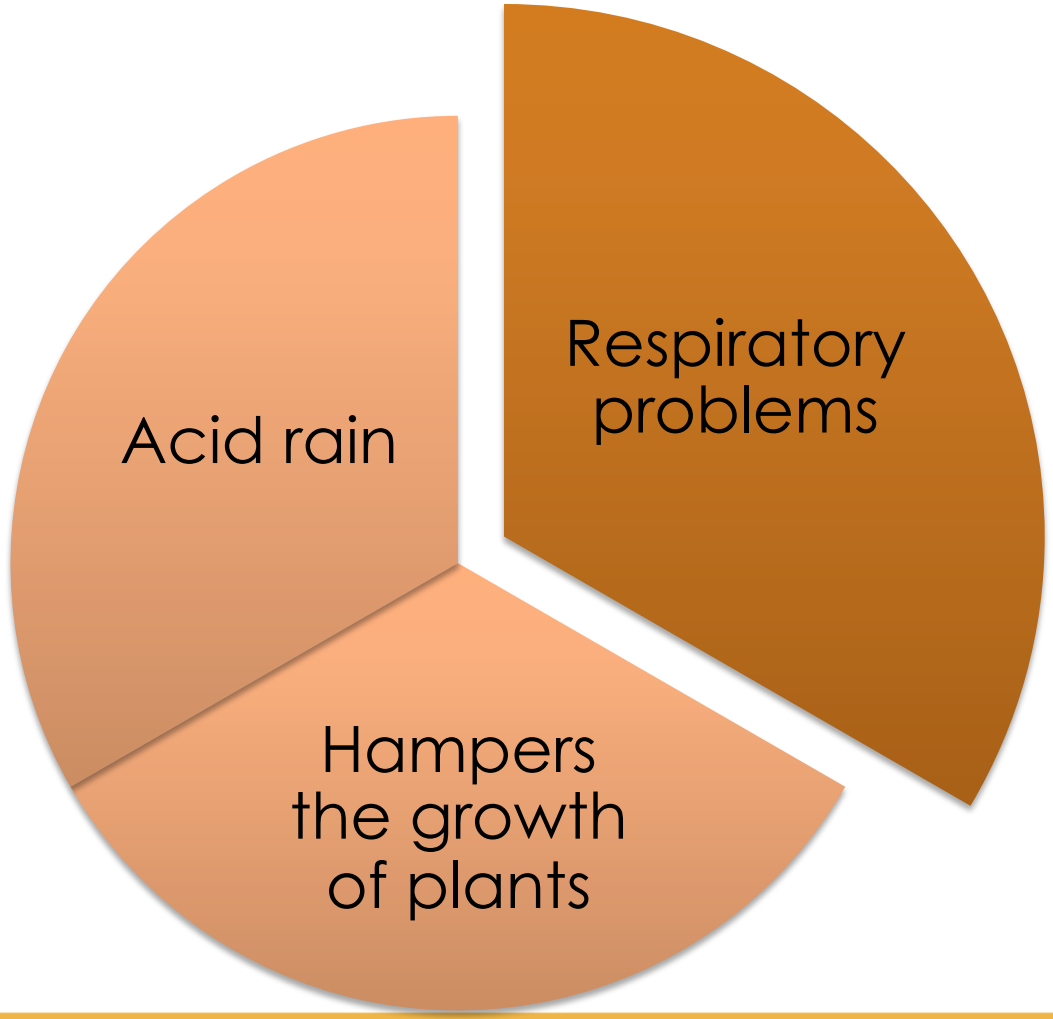
Effects of Nitrogen Oxides (NO_x)



Sulfur Oxides (SO_x)

- SO_x (SO, SO2, SO3) is a colourless, non-flammable and non-explosive gas with suffocating odour
- Sources can be either natural or man-made sources
- Natural sources: Releases from volcanoes, biological decay and forest fires
- Man-made sources: Fossil fuel combustion, smelting, manufacture of sulfuric acid and incineration

Effects of Sulfur Oxides (SO_x)



Oxides of Carbon

- Oxides of carbon comprise of carbon dioxide (CO_2) and carbon monoxide (CO)
- Sources include burning fuels (70% contributed by vehicles), power plants, various types of industries and methane oxidation

Effects of CO_2 and CO

CO_2

- Primary greenhouse gases
- Global warming

CO

- Poisonous, colourless, tasteless and odourless
- Reduce the capacity of the blood to carry oxygen

Hydrocarbons

- Organic compound consisting entirely of hydrogen and carbon

- Sources include vehicles (raw unburned fuel, fuel evaporation), industry, refineries, landfill and solvent evaporation

Effects of Hydrocarbons

Methane (CH_4) is a greenhouse gases

Hydrocarbons react with NOx and UV to form ozone (smog). Ozone irritate eyes, damage lungs and cause respiratory problems

Carcinogenic due to its aromatic characteristics

Phenomenon of Air Pollution

Outdoor Air Pollution

- Acid Deposition
- Photochemical Smog
- Haze
- Ozone
- Greenhouse Effects

Indoor Air Pollution

Acid Deposition

- Emissions of sulphur oxides and nitrogen oxides, when combined with sunlight and water vapor, results in mild sulphuric or nitric acid.

- Acid deposition occurs when pH levels falls below 5. Some references indicate pH level below 5.6 as acid rain.

Acid Deposition (Cont')

Wet acid deposition

- Rain, snow or fog

Dry acid deposition

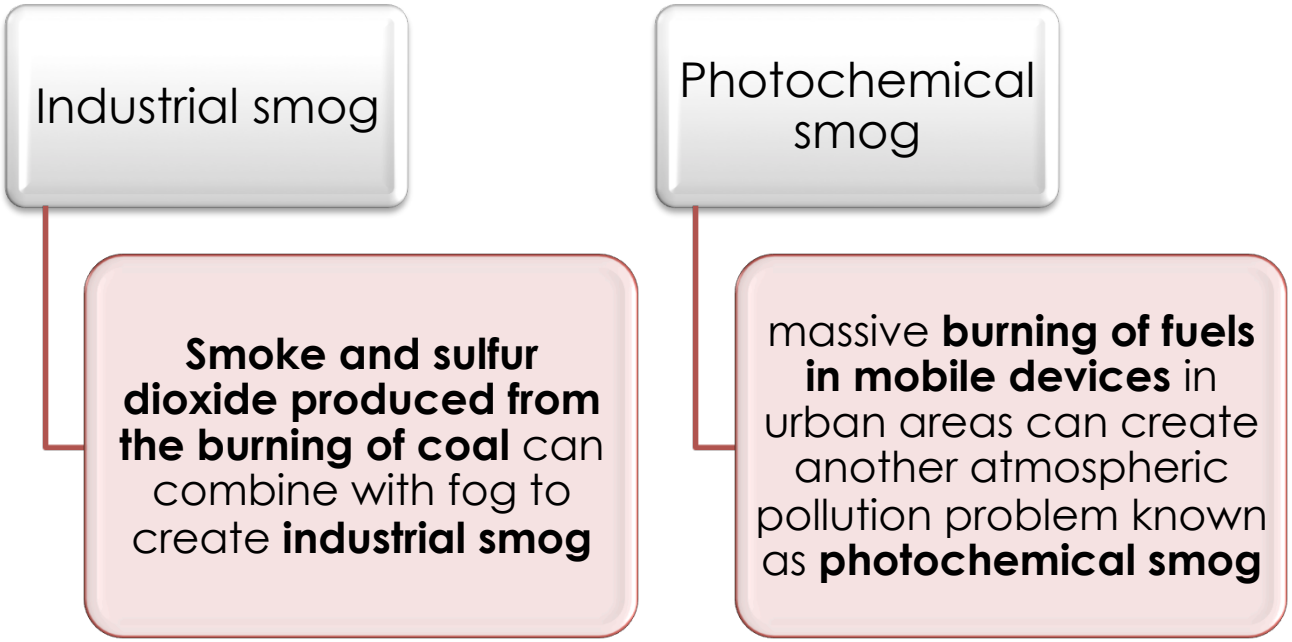
- Dust, smoke, or other aerosols (microscopic particles in the air)
- Can be converted into acids when these deposited chemicals meet water

Acid Deposition: Effects

- Damage materials → buildings, metals, car paints
- Destroys aquatic life
- Damages and kills plants
- Releases ions of aluminium, lead, mercury and cadmium from soil and bottom sediments
- Leaching of soil nutrients
- Leaching of toxic metals such as copper and lead from pipes into drinking water
- Aggravates respiratory illness

Photochemical Smog

- **SMOG = SMOKE + FOG** ; can be of two types – industrial or winter smog and photochemical or summer smog.



Photochemical Smog: Effects

- **Effects on human health -** Low concentrations of ground-level ozone can irritate the eyes, nose and throat. As smog increases, it can trigger more serious health problems, including:
  - Asthma, bronchitis, coughing and chest pain;
  - Increased susceptibility to respiratory infections;
  - Decreased lung function and physical performance.

Photochemical Smog: Effects (Cont')

- **Effects on vegetation and materials**
  - Sensitive crops, trees and other vegetation are harmed at lower ozone concentrations.
  - Ground-level ozone can damage leaves, and reduce growth, productivity and reproduction. It can cause vulnerability to insects and disease, and even plant death.
  - Smog can also accelerate the deterioration of rubber, plastics, paints and dyes.

Haze

- Haze is a form of air which is exacerbated at certain times of the year under specific weather condition.
- It is caused by the presence of a large number of minute particles suspended in the atmosphere. These particles can be natural in origin or from human activities.
- Haze occurs particularly when there are high levels of air pollutants (esp. particulates), combined with dry, stable atmospheric conditions.

Haze: Effects

- Particulate matter less than 10 μm in size, including fine particles less than 2.5 μm, can penetrate deep into the lungs.
- Premature death, difficult breathing, aggravated asthma, and increased respiratory symptoms in children.
- People most at risk from exposure to fine particulate matter are children, the elderly, and people with chronic respiratory problems.

Haze: Effects (Cont')

- Several gaseous compounds in the haze are likely to affect global environment and climate.
- Transport was also severely disrupted by haze. Closures of airports and cancellation of flights were common in the region.
- Economic losses from travel disruptions, were compounded by steep declines in tourist arrivals

Differences Between Haze and Photochemical Smog

Haze

- Forms when fine particles of dust or salt disperse through the atmosphere.
- Color : typically white, gray or even blue…some types of particles such as sulfates, scatter more light, particularly during humid conditions.
- Occurred distance from emission sources→ some particles directly emitted to the air; others are formed when gases carried many miles from the source of pollutants.

Photochemical Smog

- Happens when the gasses mix with water vapor in the atmosphere, then react with sunlight.
- Color: white or brownish haze, usually noticeable during morning hours.
- Typically starts in warm, windless cities with heavy traffic, but because travels with wind, can also appear in rural areas

Ozone

- Ozone (O_3) is a naturally occurring gas in the stratosphere.
- It is created when ultraviolet radiation (sunlight) strikes the stratosphere, dissociating (or "splitting") oxygen molecules (O_2) to atomic oxygen (O). The atomic oxygen quickly combines with further oxygen molecules to form ozone.
- In the stratosphere, it serves to absorb harmful solar UV rays.

Ozone: Effects

- Stratospheric ozone
  - Protects life on earth by absorbing harmful UV-radiation
- Tropospheric ozone
  - Nausea
  - Headaches
  - Coughing
  - Respiratory problems
  - Damages plants
  - Ozone in the troposphere is a greenhouse gas

Ozone Depletion: Effects

- Effects of ultraviolet (UV) radiation
  - Skin cancer
  - Eye cataracts (blurred vision & eventual blindness)
  - Severe sunburn
  - Suppression of human immune system
- Decreased yields in food crops (rice, corn etc.)
- Reduction in growth of marine phytoplankton
- Increase global warming (greenhouse effect)

Preventing Ozone Depletion

- **Montreal Protocol 1990**
  - Banning the use of CFC, halons, carbon tetrachloride and methyl chloroform
  - Substitute coolants in refrigerators and air conditioning with other cooling agents such as HFC (hydroflurocarbon) and HCFC (hydrochlorofluorocarbon) which are decomposed more rapidly in the atmosphere

Greenhouse Effects (Cont')

- Gases:
  1. Carbon dioxide (CO_2)
     - Burning of fossil fuel (automobiles, industries)
     - Deforestation

  2. Chloroflurocarbons (CFC)
     - Leaking of old air conditioners & refrigerators
     - Production of plastic foams
     - Propellants in spray cans

Greenhouse Effects (Cont')

3. Methane (CH_4)
   - Solid waste dumping grounds & landfills
   - Burning of forest & grasslands
   - Agricultural waste

4. Nitrous oxide (N_2O)
   - Nylon production
   - Decomposition of nitrogen fertilizers
   - Burning of fossil fuels

5. Tropospheric ozone
   - Photochemical smog

Global Warming

- Sea level will rise as ice caps melt--inundating many coastal cities
  - sea level rose 9 cm during 1901-2000
  - predicted level of rise for 2001-2100 is 9 to 88 cm
- Weather pattern changes – causing some regions to get drier and some wetter
- Warmer temperatures leads to increase evaporation, more condensation and more energy potential for storms. So storms become more frequent which can lead to an increase in coastal erosion.

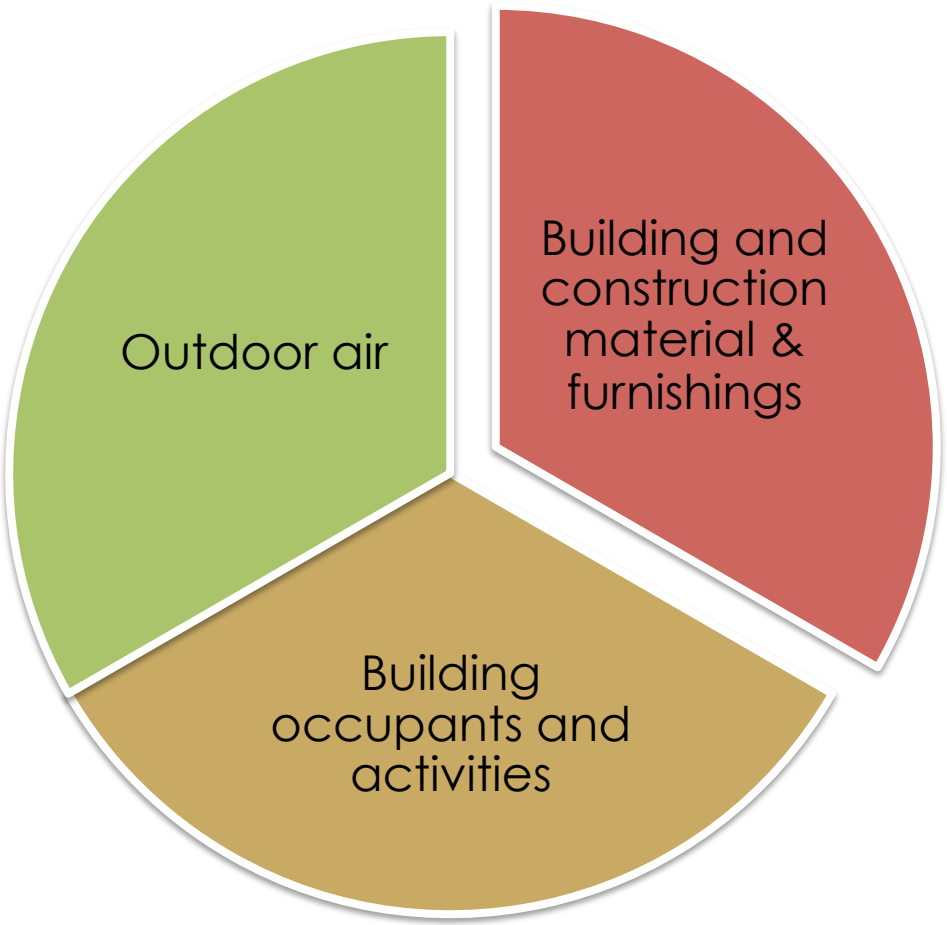
How To Prevent Global Warming?

- Reducing current fossil fuel use.
- Improving energy efficiency.
- Shifting to perpetual and renewable energy resources that do not emit CO_2.
- Stopping deforestation.
- Stopping marine pollution that kills phytoplankton

Indoor Air Pollution

- Most of human will spend 80-90% of their live indoors
- Pollution exposure at home and work place is often greater than outdoors
- Indoor Air Quality (IAQ) refers to the nature of the conditioned (heat/cool) air that circulates throughout space or area where we work and live.

Primary Source of Indoor Air Pollution



Indoor Pollution: Sources

Combustion products

- Tobacco smoke
- Carbon monoxide
- Carbon dioxide
- Nitrogen dioxide
- Sulphur dioxide

VOC

- Pesticide & fungicide
- Alcohols
- Benzene
- Chloroform

Respirable particulates

- Water vapor
- Carbon Dioxide

Biologics & bioaerosols

- Molds & fungi
- Bacteria
- Viruses
- Nonviable microbial

Radionuclides

- Radon
- Radon progeny

Odors

- Odors associated with any of the above

Indoor Pollution: Causes

- The relative importance of any single source depends on:
  - how much of a given pollutant it emits
  - how hazardous those emissions are

- Factor effects indoor air pollution levels:
  - inadequate ventilation can increase indoor pollutant levels
  - high temperature
  - humidity levels and lighting

Indoor Pollution: Effects (Cont')

- Radon
  - Naturally occurring gas that is odorless, colorless, and radioactive comes from soil under basements.
  - Long term exposure can cause lung cancer.
- Environmental tobacco smoke (ETS)
  - Smoke emitted from burning of cigarette, and smoke inhaled by a smoker.
  - It is a complex mix of more than 4,000 chemical compounds, including particles, carbon monoxide and formaldehyde.
  - Deadliest indoor air pollutant.

Indoor Pollution: Effects (Cont')

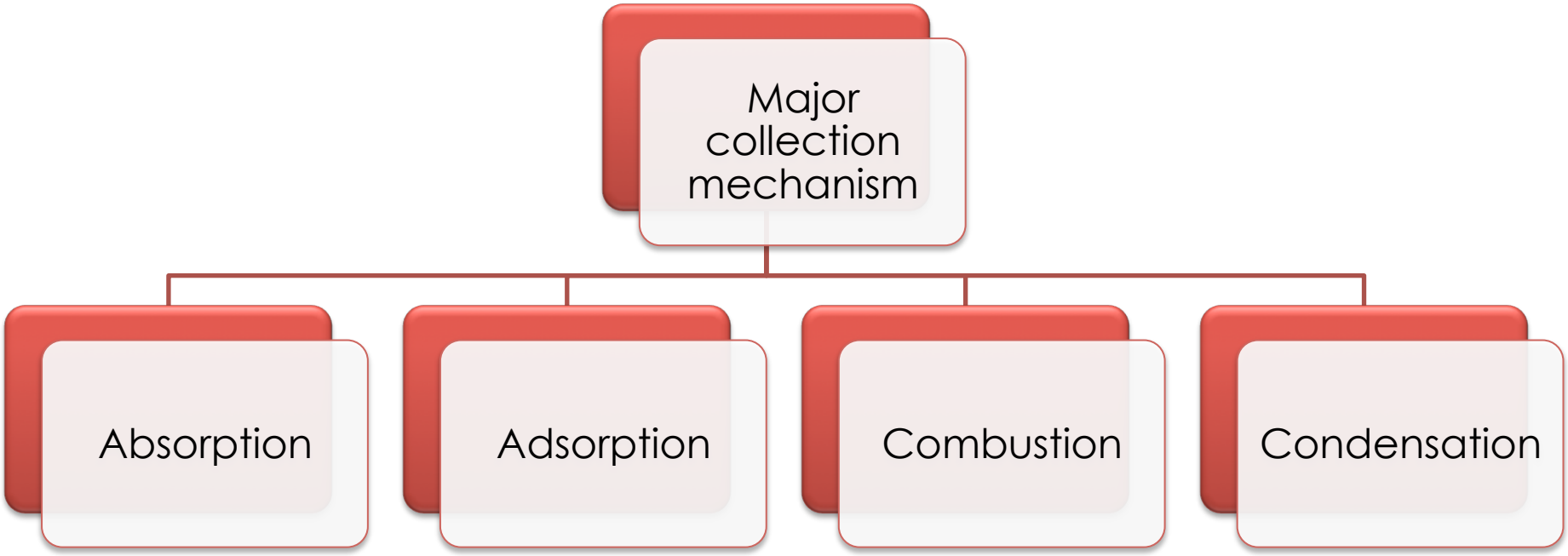
Mold	Carbon monoxide	Asbestos	Lead
• Moisture in vents, carpets • Allergy sympthoms, breathing problems, headache, fatique	• Malfunctioning furnace, gas appliances, cars • Blood cannot carry oxygen • Feel sleepy, nausea, dizzy, cause death	• Roofing, flooring, insulation, brakes • Negative effect if deteriorates • Can cause asbestosis (scarring of lungs) and mesothelioma (type of lung cancer)	• Old homes, toys, lead crystal dishes • Causes behavior & learning problems, slow growth, hearing problems, headaches

Air Pollution Control: Mechanism

- Definition
  - Air pollution control refer to steps taken to maintain a standard of purity of air for good public health, for protection of plant and animal life and property, for visibility and for safe ground and air transportation.

- Air pollution control of removal mechanism can be divided into:
  - Control of gaseous emission
  - Control of particulates emission

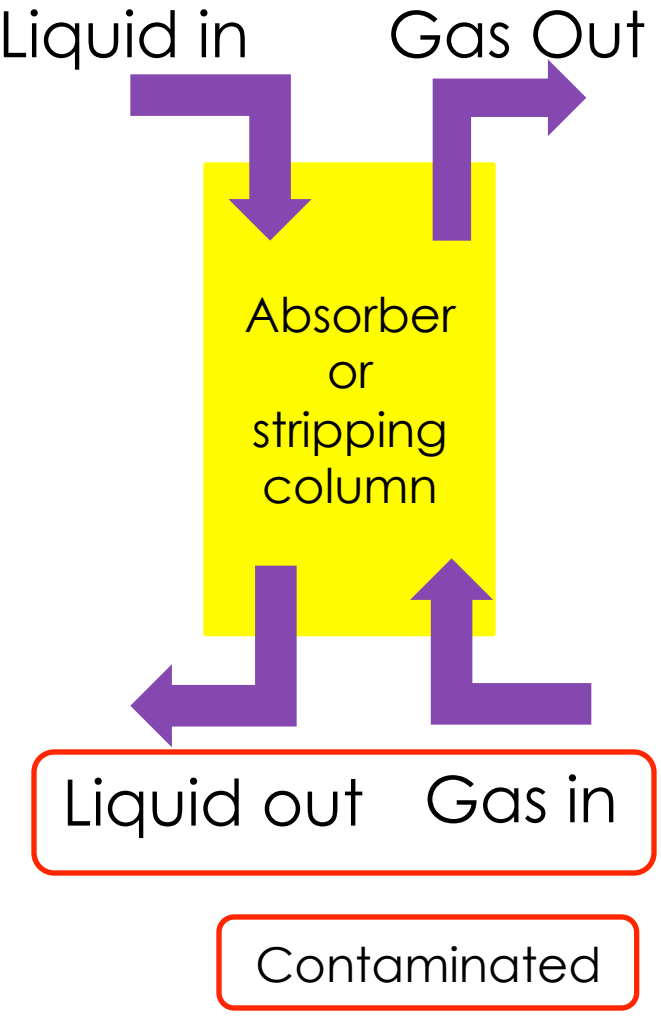
Air Pollution Control: Gaseous Emission



Applicability of each technique depends on the physical and chemical properties of the gaseous pollutant and the gas stream

Gaseous Emission Control: Absorption

- The transfer of gaseous pollutant from the air into a contacting liquid such as water.
- A gas is dissolved in a liquid, where the contaminants diffuses from gas phase into liquid phase.
- Gas absorbers are designed to provide sufficient mixing of gas and liquid phases



Gaseous Emission Control: Adsorption

- In contrast with absorption, adsorption is a surface phenomenon.
- Gas adheres to the surface of a solid with which they are in contact, not destroyed but stored on the adsorbent surface until it is removed by desorption.
- Activated **carbon** is commonly used as an adsorbent materials.

Gaseous Emission Control: Combustion

- Rapid, high temperature, gas phase oxidation where the VOCs and other gaseous hydrocarbon pollutants is oxidized and converted to CO_2 and water vapor.

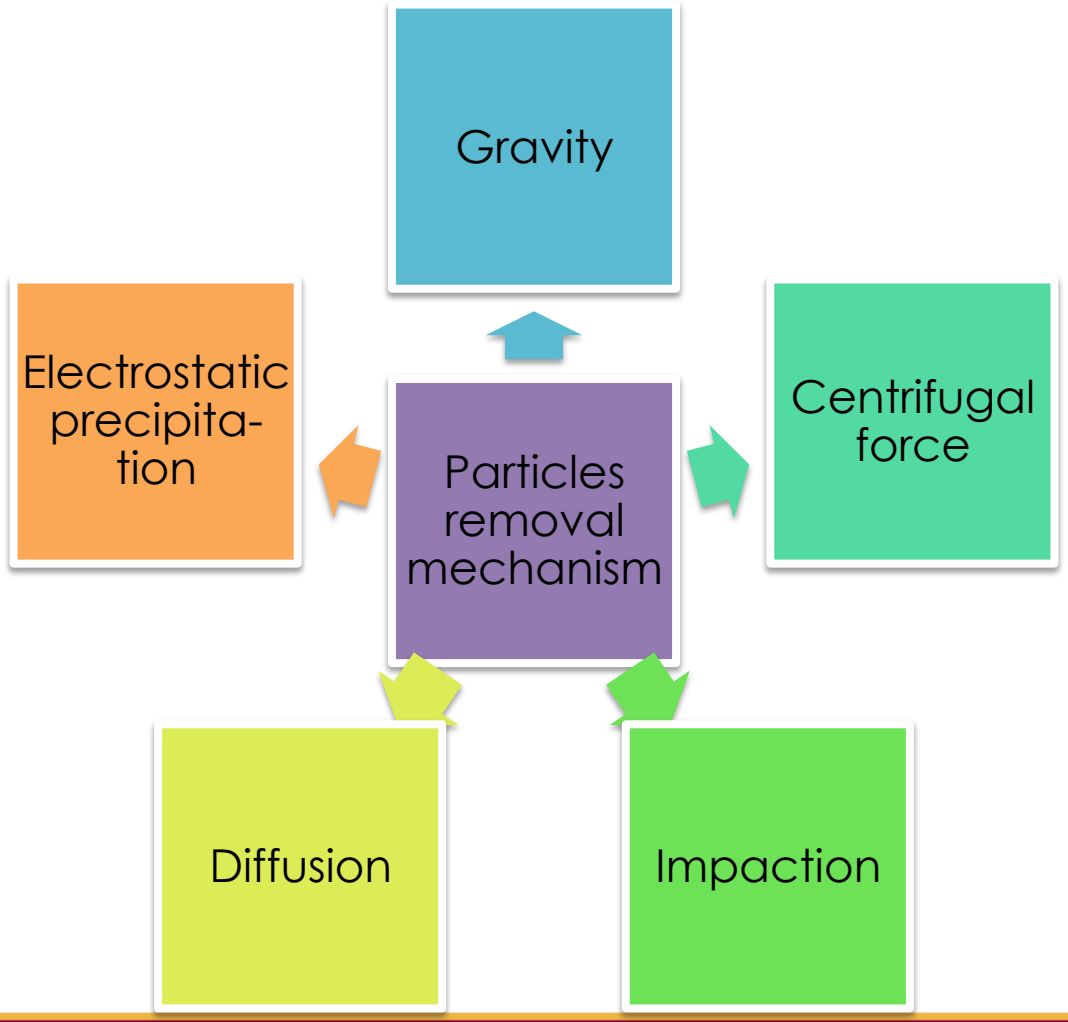
- Incineration usually is accomplished in a special incinerator called an afterburner. Afterburners are used to control odors, destroy toxic compounds, or reduce the amount of photo- chemically reactive substances released into the air.

Gaseous Emission Control: Condensation

- Volatile contaminant gases are removed from a gas stream by adjusting the gas stream temperature until the gas changes into a liquid.

- Condensation devices (condenser) are often used in combination with other control devices , located before absorber, adsorbent or incinerator.

Air Pollution Control: Particulates Emission



Particulates Emission Control: Gravity

- Large particles move slowly through the gas stream are overcome by gravity, and collected at the bottom of control device.

Particulates Emission Control: Centrifugal Force

- The shape or curvature of the collector causes the gas stream to rotate in a spiral motion.

- The particles lose their kinetic energy as they strike the wall of the collector and are separated from the gas stream.

Particulates Emission Control: Impaction

- Involves direct contact between particle and object.

- The particles is too large to follow the gas stream lines around the filter fiber, so its strikes the fiber and left at collection surface.

Particulates Emission Control: Diffusion

- Small pollutant particles are continually and regularly bombarded gas molecules, causes the particles to move in an erratic, zigzag manner.

- The particles move through the gas stream until they strike an object such as a fiber in a fabric filter system.

Particulates Emission Control: Electrostatic Precipitation

- Uses electrostatic forces. Particles can be charged by being subjected to a strong electrical field.

- The charged particle migrate to an oppositely charged collection surface and attached.

Control Device: Cyclone Separator

Advantages

- Low capital cost
- Easy operation and maintenance
- Efficient for particle size greater than 10μm

Disadvantages

- Not very efficient for particles less than 10μm
- Not adequate to meet stringent air pollution regulations

Control Device: Baghouse Filter

Advantages

- High collection efficiencies even for very small particles (< 5μm)
- Can operate on a wide variety of dust types
- Modular design and can be pre-assembled at the factory

Disadvantages

- Require large floor areas
- Fabrics can be harmed by high temperatures or corrosive chemicals
- Cannot operate in moist environments; reduce efficiencies
- Potential for fire & explosion
- High capital cost

Control Device: Electrostatic Precipitator

Advantages

- Very high efficiencies, even for small particles
- Can handle large volume of dusts
- Can be designed for a wide range of gas temperature

Disadvantages

- High capital cost
- Cannot control gaseous emissions
- Once installed the unit is not very flexible to changes in operating conditions
- Requires large floor areas
- May not work on particulates with very high electrical resistivity

Control Device: Wet Scrubbers

Advantages

- Can handle flammable and explosive dust with little risk
- Provide gas absorption and dust collection in a single unit
- Can handle mist or moist type pollutants
- Provide cooling of hot gases
- Acidic gases and dust can be neutralized

Disadvantages

- High potential for corrosive problems
- High capital cost
- Effluent liquid can create water pollution problems

THE END