



What is Air Pollution?

• Definition: chemicals in the troposphere in sufficient quantities and duration to cause harm to life and materials.

Sources

Outdoor pollutants

- Natural volcanic eruptions, forest fires, dust storms, etc.
- Human pollutants:
 - Stationary sources (power plants & factories)
 - Mobile sources (vehicles)





Primary Pollutants

- Those emitted directly into the troposphere in a potentially harmful form.
- Examples:
- CO, CO₂, SO₂, NO₂, PM

Secondary Pollutants

- Primary pollutants react with basic components of air to form new pollutants
- Examples:
- SO₃, O₃, HNO₃





Criteria Pollutants – EPA's hit list

- Carbon monoxide CO
- Sulfur dioxide SO₂
- Nitrogen oxides NO_x
- Lead Pb
- Particulate Matter PM
- Ozone O₃

Carbon Monoxide (CO)

- Description: colorless, odorless gas, extremely toxic
- Major Sources: incomplete burning of fossil fuels (81% from car exhaust), cigarette smoke
- Health Effects: headaches, dizziness, slows mental processes, and at high levels can lead to death

Sulfur Dioxide (SO₂)

- Description: colorless
- Major Sources: combustion of sulfur containing fossil fuels (coal & oil)
- Health Effects: irritating to respiratory system
- Environmental Effects: leads to sulfuric acid, corrodes metals, harm textiles, impair visibility, and kill or stunt plant growth



Nitrogen Dioxide (NO₂)

- Description: reddish-brown or yellowish-brown, sweet pungent odor
- Major Sources: auto emissions, power plants
- Health Effects: shortness of breath or coughing, enhanced risk of respiratory disease



Lead (Pb)

- Description: solid toxic metal particulate pollutant
- Major Sources: leaded gas (being phased out of developed countries, still exists in developing countries), paint (old houses), smelters (metal refineries), lead mfg
- Leaded gas phased out entirely in US by 1995.

Lead (Pb)

- Health Effects: toxic to humans, especially intellectual development of children, nervous system dysfunction
- Environmental Effects: enters food chain and bioaccumulates within body tissues

Particulate Matter (PM)

- Description: variety of particles & droplets small & light enough to remain suspended in troposphere for a period of time.
- Solid particles: dust, soot, asbestos, lead, salts
- Liquid droplets: acids, dioxins, pesticides

Particulate Matter (PM)

- Major Sources:
- burning coal in power & industrial plants
- vehicles
- agriculture (burning of fields, plowing)
- unpaved roads
- construction
- smoke particles from fires
- dust particles
- ash from industrial plants & smoke

Particulate Matter (PM)

- Health Effects: Irritate respiratory tract, evades body's natural defense mechanisms
- Environmental Effects: reduces visibility, does property damage (discolors buildings, clothes, fabrics, paints)

Photochemical Oxidants

- Ozone (O₃)
- PeroxyacetyInitrates (PANs)
- Volatile organic compounds (VOC's)
 - Methane, butane, benzene, propane, any other compounds that contain C-H from dry cleaning and industry
- These are secondary pollutants



$0zone(0_3)$

- Major Sources: chemical reaction with VOC's and NOx emitted by cars.
- Health Effects: irritates mucous membranes of respiratory system, causes coughing, choking, and reduced lung capacity; eye irritant

$0zone(0_3)$

• Environmental Effects: damages plants and trees by reducing photosynthesis capability; smog reduces visibility, cracks rubber, deteriorates fabrics, causes paint to fade.



What is Industrial Smog?

- "Gray-Air" Smog
- Consists mostly of SO₂, PM
- Huge problem 50 years ago (London, Chicago, Pittsburgh) – burned large amounts of heavy oil & coal
- Rarely a problem today except in Eastern Europe, China, India

London Killer Smog

- On Friday December 5, 1952 a dense smoke-filled fog shrouded London and it hung over the city for the next four days. London came to a standstill.
- Over 4,000 people died, cattle died, motor vehicles were abandoned, trains were disrupted and airports were forced to close.





How 0₃ is created

- Chemical decomposition of NO₂ due to sunlight
- NO₂ + sunlight → NO + O
- $0 + 0_2 \rightarrow 0_3$
- Note: can only be formed during sunlight hours. O₃ production halted when sun goes down
- $O_3 + NO \rightarrow NO_2 + O_2$



PAN's (Peroxyacetyl Nitrates)

- Major Source: formed by the reaction of NO₂ and VOC's
- Health Effects: causes eye and respiratory irritation
- Environmental Effects: Toxic to plants





Normal Weather Situation

- Daytime temperatures are highest near the ground (earth absorbs sun & heats it)
- Warm air rises carries pollutants upward
- At night, no sun, earth cools below, warm air above – short lived until next day, process is repeated, unless.....

Thermal Inversion

- A layer of warm air overlies cooler air near the ground & prevents the rising and dispersion of air pollutants
- Why? Cool air is denser, does not rise to mix with air above it, thus concentrations of pollutants increase

Donora, PA – October 1948

- Valley town surrounded by mountains
- Pollutants from industries (steel mill, zinc smelter, and sulfuric acid plant) got trapped in fog for 5 days
- 7,000 inhabitants (of the 14,000) became sick, 22 died

Factors that increase Air Pollution

- Urban buildings slow wind speed
- Hills & mountains reduce flow of air in valleys
- High temperatures promotes chemical reactions with pollutants, leading to smog
- Population density
- Amount of industry
- Fuels used in industry & transportation

Air Pollution can be reduced by:

- Rain and Snow cleanse the air
 - Explains why dry climates are more prone to smog than wet climates
- Winds sweep pollutants away, dilute pollutants by mixing with clean air
 - However, pollutants are blown elsewhere & eventually deposited









Acid Deposition Acids are mixed with precipitation and pour down onto earth's surface wet deposition Can also fall down as particulate matter dry deposition



Reaction of NO₂

- 2NO₂ (g) + H₂O(I) → HNO₂ (aq) + HNO₃ (aq)
- HNO₂ (aq) = nitrous acid
- HNO₃ (aq) = nitric acid

Reaction of SO₂

- $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
- SO₃ (g) + H₂O (I) \rightarrow H₂SO₄ (aq)
- H₂SO₄ (aq) = sulfuric acid
- Sulfuric acid reacts with marble (highly water soluble) by slowly dissolving it away

Harmful effects of Acid Rain

- Damages aquatic ecosystems
- Deterioration of buildings and statues
- Decreases crop yields
- Damages forest productivity
- Mobilization of toxic metals



Problems with Clean up Methods

- It is expensive and a temporary remedy that must be repeated annually
- It can kill some types of aquatic flora and fauna
- Difficult to know how much lime to put in or which exact water sources
- Methods still be evaluated



The Clean Air Act Amendments of 1970 The establishment of National Ambient Air Quality Standards (NAAQS) for air pollutants Primary standards – levels intended to safeguard human health, allowing a margin of safety to protect young children and elderly Secondary standards – set more stringent standards to promote human welfare by protecting agricultural crops, livestock, property, and the environment. Many are similar to 1° standards and no deadlines have been set to meet this criteria.

The Clean Air Act Amendments of 1970

- National emission standards for existing and new facilities
- Fines and criminal penalties for intentional violation
- New stricter automobile emission standards
- Additional research funding

1990 Clean Air Act Amendments

- Reduce smog by 15%
- Utilities must reduce release of SO₂ by ½ by 2000
- Utilities must reduce release of NO₂ by 1/3 by 2000

1990 Clean Air Act Amendments

- Utilities can buy and sell "pollution credits"
- Dirty plants can purchase permits to pollute from utilities that are not using their full allotment of pollution credits

1990 Clean Air Act Amendments

- Passenger cars must emit 60% less NO_x by 2003
- · Required cleaner burning fuels
- All CFC production will be banned by 2000



Electrostatic Precipitator

- Small particles are statically charged
- The electrically charged metal plates attract the particles, removing them
- Does not control gaseous emissions

Baghouse Filter

- The baghouse filter is common for removal of particulates
- Its operating principle is similar to a home vacuum cleaner – air carrying particles is forced through a cloth bag where they accumulate

Cyclone Separator

 Centrifugal force cause particles to move outward, collide with outer wall, then slide downward to the bottom of the device to be collected

Wet Scrubber

- Use of water neutralizes the acidity
- This produces a sludge which must be landfilled or otherwise disposed of