Lecture 29  Air Pollution

• Conditions that promote air pollution episodes
• Acid Rain
• Ozone Hole

Air Pollution – Elevated levels of aerosols and harmful gases

Clean Boundary Layer

The atmospheric boundary layer is the lowest layer of the troposphere where friction is important. Most boundary layers are capped by a stable layer above.

We live in and breathe the air of the boundary layer.

Clean Boundary Layer

It is more than a blessing to have clean air. It is essential for good health.

We live in and breathe the air of the boundary layer.

Most pollution enters atmosphere near the surface.
Conditions that Promote Pollution Episodes

Atmospheric conditions that limit horizontal and vertical mixing of the air result in high pollution concentrations. These conditions are found within areas of high surface pressure, especially in winter, when radiational cooling causes cold, stable air to collect near the surface.

Pollution Episodes

Pollution episodes occur in areas of high surface pressure resulting in stable air (temperature inversions) and light winds.

Polluted Boundary Layer

LA and Denver “brown clouds” primarily caused by automobile exhaust plus sunlight.

Pollution in the boundary layer can travel great distances.
Air Pollution: Sources

Intentionally Set Fires are a large source of pollution and CO₂

Historic Pollution Episodes

Many of the worst air pollution episodes occurred during the last two centuries in London, England.
- key ingredients - calm winds, fog, smoke from coal burning
- 1873 - 700 deaths
- 1911- 1150 deaths
- 1952 - over 4000 deaths
- this last event prompted the parliament to pass a Clean Air Act in 1956

US Pollution Episodes

- In the U.S., air quality degraded quickly shortly after the industrial revolution
- Problem was coal burning in the central and midwestern U.S.
- 1948 - Donora, PA in the Monongahela River Valley five-day episode - 1000's became ill, 20 were killed
- 1960s - NYC experience several dangerous episodes
- 1960s-70s - Los Angeles - increase in industry and automobile usage led to many pollution episodes
- The above events led to passing the Clean Air Act of 1970 (updated in 1977 and again in 1990) empowered the federal government to set emission standards that each state would have to meet
Acid Rain

Acid rain is caused by sulfur dioxide (SO₂) and nitrous oxides (NOₓ) being released into the atmosphere and producing sulfuric acid and nitric acid.

Sources of SO₂ and NOₓ include factories, power plants, automobiles, trucks.

Acidic and basic are two extremes that describe chemicals, just like hot and cold are two extremes that describe temperature. Mixing acids and bases can cancel out their extreme effects, much like mixing hot and cold water can even out the water temperature. A substance that is neither acidic nor basic is neutral.
Acid Rain

Sources of SO2 and NOx include factories, power plants, automobiles, trucks and pine forests.

Acid Rain

Acid rain leeches heavy metals into lakes and streams.

Acid Rain

Impacts of Acid Rain
- Lakes and Streams
- Forests
- Human health: asthma, bronchitis, heart failure…
- Materials: Car coatings, roofing,… 

pH of US Rain

Acid rain leeches heavy metals into lakes and streams.
Acid rain leeches heavy metals into lakes and streams.

Acid Rain

Needles collect cloud water, which is extra acid.

Spruce Forest in North Carolina impacted by Acid Rain
Acid Rain

Spruce Forest in Europe impacted by Acid Rain

Buildings: Marble and Limestone is dissolved by acid rain.

Global Ozone Depletion

Atmospheric ozone is measured by satellite instrument in Dobson Units.
The decrease in ozone over the South Pole was first observed in the 1970’s. It is linked to an increase in man made chemicals entering the atmosphere.

Chlorine and Bromine atoms result in global ozone depletion. CFCs release chlorine and halons release bromine. The most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.

Natural ozone production:

Natural ozone destruction:

Ozone Cycle

Ozone Distribution
Ozone Hole

The decrease in ozone also observed at lower latitudes.

Ozone Hole

Decrease in ozone observed in Colorado and Hawaii.

Ozone Depletion

CFCs release chlorine atoms, and halons release bromine atoms.

Clorine and Bromine atoms result in ozone depletion.

Most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.
Clorine and Bromine compounds result in ozone depletion. Most rapid breakdown of ozone occurs on the surface of polar stratospheric clouds.

Ozone Hole

• The polar winter leads to the formation of the polar vortex which isolates the air within it.
• Cold temperatures form inside the vortex; cold enough for the formation of Polar Stratospheric Clouds. As the vortex air is isolated, the cold temperatures and the clouds persist.
• Once the Polar Stratospheric Clouds form, chemical reactions take place and convert the inactive chlorine and bromine to more active forms of chlorine and bromine.
• No ozone loss occurs until sunlight returns to the air inside the polar vortex and allows the production of active chlorine and initiates the catalytic ozone destruction cycles. Ozone loss is rapid.

Ozone Loss

Consequences of ozone loss
• increase in skin cancer cases
• increase in eye cataracts and sun burns
• suppression of the human immune system
• adverse impact on crops and animals due to increased UV radiation reaching the ground
• reduction in the growth of ocean phytoplankton
• cooling of the stratosphere that could alter stratospheric wind patterns, possibly affecting the production (and destruction) of ozone.
Ozone Policy

The Montreal Protocol of 1987 banned CFC’s and Halons

Ozone Hole Animation

Ozone hole approaches but fails to break record in 2003.