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Atmospheric Science and Air Pollution

Chapter Objectives

This chapter will help students:

Describe the composition, structure, and function of Earth's atmosphere

Outline the scope of outdoor air pollution and assess potential solutions

Explain stratospheric ozone depletion and identify steps taken to address it

Define acidic deposition and illustrate its consequences

Characterize the scope of indoor air pollution and assess potential solutions

Lecture Outline

I. Central Case: Charging towards Cleaner Air in London

A. Since the 13th century, London, England burned coal, and citizens experienced air pollution.

B. Coal use expanded with the industrial revolution in the 18th and 19th centuries and air pollution became worse than ever.

C. In 1952, tragedy struck as weather conditions trapped air pollutants, creating a "killer smog" that killed 4,000 people, and possibly as many as 12,000. This tragedy stimulated England and other countries to address air pollutants so that today, the air is much cleaner.

D. In 2003, after consulting with diverse interest groups, Mayor Ken Livingstone introduced "congestion-charging," a fee paid by drivers entering London at the most congested weekday times.

E. The program was controversial and received complaints, but traffic congestion declined by 20%, traffic-related accidents decreased by 40% to 70%, and air pollutants also decreased.

F. Fees from “congestion charging” go to enhancing bus service and to encourage the use of rail, taxi, bicycle, and foot.

G. In 2006 and 2007, Livingstone’s program expanded to include charging more polluting vehicles more and exempting low-emission vehicles from fees.

H. Air pollution remains a major problem in much of the developing world as poorer nations industrialize.

II. The Atmosphere

1. The **atmosphere** is a thin layer of gases that surrounds Earth.

A. The atmosphere consists of layers.

1. The bottommost layer is the **troposphere**, where temperature decreases with altitude. This layer blankets the Earth’s surface, and air movement in this layer is responsible for weather.

2. The **stratosphere** extends from 11 km to 50 km above sea level, with its temperature rising gradually with altitude. Due to little vertical mixing, substances that rise to this layer tend to stay there for a long time.

3. A portion of the stratosphere between 17–30 km above sea level contains most of the atmosphere’s ozone, and is called the **ozone layer**; this layer greatly reduces the amount of UV radiation that reaches Earth’s surface. The protection of the ozone layer is vital for life on Earth.

B. The sun and the atmosphere drive weather and climate.

1. Enormous amounts of radiation from the sun bombard the Earth. Land and surface water absorb this energy, radiating some heat and evaporating water. The result is that air near the Earth’s surface is warmer and moister than air at higher altitudes.

2. The difference in air temperature and humidity at different altitudes set into motion **convective circulation** as warm air rises, cools and expands, and then descends past other warm air that is rising.

3. **Weather** specifies atmospheric conditions over short time periods, in relatively small geographic areas.

4. **Climate** describes the pattern of atmospheric conditions found across relatively large geographic regions over long periods of time.

5. Convective circulation caused by warm air rising from low to high altitudes is responsible for local and larger area weather conditions. However, if a layer of cool air occurs beneath a layer of warmer air, this is known as a **temperature inversion**, or **thermal inversion**. The band of air in which temperature rises with altitude is called an **inversion layer**. Thermal inversions trap pollutants near the ground as vertical mixing stops.

C. Large-scale circulation systems produce global climate patterns.

1. Sunlight near the equator produces pairs of convection cells called *Hadley cells*.

2. Two pairs of similar but less intense convective cells, *Ferrel cells* and *polar cells*, lift air and create precipitation around 60 degrees latitude north and south, and cause air to descend at around 30 degrees latitude and in the polar regions.

3. These three pairs of cells account for the latitudinal distribution of moisture across Earth's surface.

4. As Earth rotates on its axis, north-south air currents of convective cells appear to be deflected from a straight path; this is called the *Coriolis effect*.

D. Storms may pose hazards

1. Atmospheric conditions can sometimes create storms that threaten life and property.

2. **Hurricanes** form when winds rush into areas of low pressure when warm, moisture-laden air over tropical oceans is rising. Powerful convective currents of these storms draw up water vapor, which condenses and falls heavily as rain.

3. **Tornados** form when a mass of warm air meets a mass of cold air and warm air rises quickly, setting a powerful convective current in motion. The spinning funnel of rising air picks up soil and objects in its path with winds up to 500 km per hour (310 mph). In North America, the Great Plains and the Southeast experience the most frequent tornado activity.

III. Outdoor Air Pollution

1. **Air pollutants** are gases and particulate material added to the atmosphere that can affect climate or harm people or other organisms. **Air pollution** is the release of air pollutants.

A. Natural sources can pollute.

1. Winds sweeping over arid terrain can send huge amounts of dust aloft.

2. Volcanic eruptions release large quantities of particulate matter, as well as sulfur dioxide and other gases, into the troposphere.

3. The burning of vegetation pollutes the atmosphere with smoke and soot.

4. Human activity and land-use policies can exacerbate some of these natural impacts.

B. We create outdoor air pollution.

1. Outdoor air pollution from human activity can originate from *point* or *non-point sources*.

2. **Primary pollutants**, such as soot and carbon monoxide, are pollutants emitted into the troposphere in a form that can be directly harmful or that can react to form harmful substances.

3. **Secondary pollutants** are harmful substances produced when primary pollutants interact or react with constituents of the atmosphere.

C. Clean Air Act legislation addresses pollution in the United States.

1. Congress has passed a series of laws, including the Clean Air Act, first enacted in 1963 and amended multiple times since, particularly in 1970 and 1990.

2. This body of legislation funds research into pollution control, sets standards for air quality, imposes limits on emissions from new stationary and mobile sources, describes and regulates emissions trading, and enables citizens to sue parties that violate the standards.

3. The Environmental Protection Agency (EPA) sets standards; however, it is up to each state to monitor air quality and then develop, implement, and enforce regulations within its boundaries. The EPA approves state implementation plans.

D. The EPA sets standards for “criteria pollutants.”

1. The EPA gives special attention to six **criteria pollutants** judged to pose especially great threats to human health and welfare and has established maximum allowable concentrations in ambient air for these pollutants.

    a. **Carbon monoxide** is a colorless, odorless gas produced primarily by the incomplete combustion of fuel.

b. **Sulfur dioxide** is a colorless gas released when coal is burned that contributes to acid rain.

c. **Nitrogen dioxide** is a highly reactive, foul-smelling reddish gas that contributes to smog and acid rain.

d. **Tropospheric ozone** results from the interaction of sunlight, heat, nitrogen oxides, and volatile organic compounds.

e. **Particulate matter** is any solid or liquid particle small enough to be suspended in the atmosphere and may cause damage to respiratory tissues when inhaled.

f. **Lead** is a metal that enters the atmosphere as a particulate pollutant released by industrial processes and fuel combustion.

E. Agencies monitor pollutants.

F. We have reduced air pollutants.

1. Since the Clean Air Act of 1970, levels of six major pollutants have declined by 57% despite increases in population, energy use, vehicle miles, and gross domestic product.

2. The 1990 Clean Air Act identified 188 toxic air pollutants. While these pollutants are not monitored as extensively as the six criteria pollutants, there are 300 monitoring stations, and coverage is improving.

3. There are reasons for these declines, including: cleaner burning motor vehicle engines, sulfur dioxide permit trading, and technologies that chemically convert or physically remove the pollutants.

G. Recent policy has been contentious.

H. Burning fossil fuels produces **industrial smog**.

I. **Photochemical smog** is produced by a series of reactions.

J. Industrializing nations are experiencing severe air pollution.

K. The Montreal Protocol addressed ozone depletion.

1. Starting in the 1960s, atmospheric scientists began wondering why their measurements of ozone were lower than theoretical models predicted.

2. In 1985, scientists from the British Antarctic Survey announced

that stratospheric ozone levels over Antarctica had declined 40–60% in the previous decade, leaving behind a thinned ozone concentration. This was called the *ozone hole*.

3. The world community came together in 1987 to design the **Montreal Protocol**, which has been signed by 180 nations.

4. The production and use of ozone-depleting compounds has fallen 95% since the late 1980s, and scientists can discern the beginnings of long-term recovery of the ozone layer.

L. Acidic deposition is another transboundary pollution issue.

1. **Atmospheric deposition** is the wet or dry deposition on land of a wide variety of pollutants.

2. **Acidic deposition** is one type of atmospheric deposition, and refers to the deposition of acidic or acid-forming pollutants from the atmosphere onto the Earth's surface.

3. Acidic deposition originates primarily with sulfur dioxide and nitrogen oxides that react with water, oxygen, and oxidants to produce low pH compounds. These compounds are suspended in the troposphere and may travel long distances.

4. Acidic deposition can have wide-ranging detrimental effects on ecosystems and our built environment.

5. Because the pollutants leading to acid rain may travel long distances, their effects can be felt far from their point sources.

6. New technology has helped to reduce acidic deposition, but acid deposition has not been reduced as much as scientists had hoped.

IV. Indoor Air Pollution

1. Indoor air generally contains higher concentrations of pollutants than do outdoor spaces.

2. The average U.S. citizen spends at least 90% of his or her time indoors.

3. Some attempts to be environmentally prudent during the "energy crisis" of 1973–1974 resulted in worsening the environmental problem of indoor air pollution in developed countries by limiting ventilation and constructing windows that do not open.

A. Risks differ in developing and developed nations.

1. Indoor air pollution in the developing world arises from burning organic fuels such as wood, charcoal, animal dung, or crop waste.

2. The top risk in developed nations is cigarette smoke. Radon from the natural decay of uranium in soil, rock, and water is the second leading cause of lung cancer in the United States.

B. Many substances pollute indoor air.

1. Products that emit VOCs surround us—VOCs are emitted in very small amounts.

2. The implications for human health of chronic exposure to VOCs are far from clear—there are so many, at such low levels, that it is difficult to study their effects.

3. Living organisms or their by-products, such as fungi, mold, mildew, and bacteria, can pollute indoor spaces and cause health problems.

4. The use of low-toxicity materials, monitoring air quality, keeping rooms clean, and adequate ventilation are the key to alleviating indoor air pollution in most situations.

V. Conclusion

1. Indoor air pollution poses significant health risks, but by keeping informed of the latest scientific findings, and taking appropriate precautions, we can minimize our risk.

2. Outdoor air pollution has been addressed by government regulation and legislation.

3. Minimizing air pollution in developing countries will continue to pose challenges.