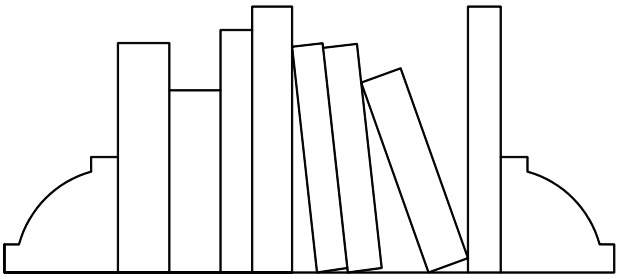
Environmental Science 101 *Fall 2012*

Air Resources

Lecture Outline:

12. ACID RAINFALL
    - A. Principles of Acid Deposition
        1. Acids and Bases
        2. Extent and Potency of Acid Deposition
        3. Source of Acid Deposition
    - B. Effects of Acid Deposition
        1. Aquatic Ecosystems
        2. Forest Ecosystems
        3. Effects on Humans and Artifacts
    - C. Coping with Acid Deposition
        1. Ways to Reduce Emissions
        2. Political Developments
        3. Title IV of the CAA of 1990
        4. EPA's Acid Rain Program



Learning Objectives:

When you are finished with this unit you should be able to:

1. Understand pH, acids, and bases.
2. Discuss the two major acidic pollutants and their sources.
3. Describe the effects of acid deposition on aquatic ecosystems, forests, and human artifacts.
4. List the major strategies for controlling acid emissions and evaluate their effectiveness.
5. Understand the politics of acid deposition and list the provisions of Title IV of the Clean Air Act of 1990.

Terms You Should Know:

- Acids
- Bases
- Acid deposition
- Acid precipitation
- Title IV of the Clean Air Act
- pH
- pH scale
- Dead lakes

Reading Assignment:

Brennan and Withgott:
Chapter 17; pages 482-486.

12. ACID RAINFALL

A. PRINCIPLES OF ACID DEPOSITION

ACID DEPOSITION—any precipitation that is more acid than normal; includes dry particles falling to the Earth.

- Precipitation is often 10 to 1,000 times more acidic than normal in industrialized areas

1. Acids and Bases

   - pH scale—scale from 0 to 14

     – pH 7 is neutral

     – pH values below 7.0 are termed acidic

     – pH values above 7.0 are termed basic or alkaline

pH—negative log of the H^+ ion concentration

- At pH 7.0:

  $H^+ = OH^-$

H^+—acid OH^-—base

Compared to pH 7.0:

pH 6.0—

pH 5.0—

pH 4.0—

pH 3.0—

pH 8.0—

pH 9.0—

2. Extent and Potency of Acid Deposition

   - Normal precipitation has a pH of 5.6

Why?

- So acid precipitation is rainfall with a pH of 5.5 or less
-

- Precipitation + dry particle fallout = acid deposition

Extent of Acid Deposition:

  –

  –

  –

  – pH of precipitation may be as low as 4.0 to 4.5

  – lowest precipitation pH value observed was 2.8 east of Los Angeles

3. Source of Acid Deposition

- In acid precipitation there is:

  – sulfuric acid

  – nitric acid

- Natural sources of acid precipitation:

  – 50,000,000 to 70,000,000 tons S/year:

    ✓

    ✓

    ✓

- 30,000,000 to 40,000,000 tons N/year:
  - ✓
  - ✓
  - ✓

- Human-made sources of acid precipitation:
  - 100,000,000 to 130,000,000 tons SO_2/year
  - 25,000,000 to 35,000,000 tons NO_x/year
  - human additions have increased 5X since 1900
- USA statistics:
  - 21,000,000 tons SO_2/year
    - ✓
  - 20,000,000 tons NO_x/year
    - ✓
    - ✓

B. EFFECTS OF ACID DEPOSITION

1. Aquatic Ecosystems
   - pH values in aquatic ecosystems are critical, as pH affects:
     - –
     - –
     - –
   - Natural pH range:
   - Severe stress when pH becomes more acid
   - Acidification

- dead lakes

  6,750

  1,300

  > 250

- Can remediate dead lakes with lime ($CaCO_3$)

  –

  –

  –

2. Forest Ecosystems

   - ***Serious problems***

     –

     –

     – if forest ecosystems collapse, then animals will follow

3. Effects on Humans and Artifacts

   - Limestone and marble building materials weather rapidly in the presence of acids

   -

C. COPING WITH ACID DEPOSITION

- Impacts cross national boundaries:

  – USA

    acid materials generated in the Ohio River Valley fall in New England and eastern Canada

- Western Europe

  acid materials generated in England, France, Germany, and the Benelux countries impacts forests in Sweden and Finland

1. Ways to Reduce Emissions

   Scientists say:

   - a 50% reduction in emissions would prevent further acidification of water bodies and damage to forests (e.g. stabilize the problem)
   - the main culprit is the burning of coal for electricity (USA and Europe) and in industrial plants (Europe)

   Strategies for reducing SO_2:

   (1)

   (2)

   (3)

   (4)

   (5)

   (6) Reductions in electricity consumption

   Analysis:

   - strategies 1 and 2 are too expensive
   - strategy 3 is difficult to retrofit into existing plants
   - strategy 4
   - strategies 5 & 6 require a major shift in USA energy policy

2. Political Developments

   - The scientific data is collected
   -

  - politicians from affected countries (Canada, Sweden, Finland) wanted action from countries that were responsible for emissions
  - politicians from countries causes emissions (USA, Western Europe) wanted further proof that they actually were causing the problems

3. Title IV of the Clean Air Act (CAA) of 1990
   -
   - Mandates reductions in SO_2 and NO_x levels
4. EPA's Acid Rain Program
   -
   - Goal is to reduce SO_2 and NO_x emissions
     - reduce SO_2 emissions by 10,000,000 tons between 1980 and 2010
     - reduce NO_x emissions by 2,000,000 tons compared to 1980 levels
   - Phase I
     -
     -
     - targets largest and most polluting power plants
     -
   - Phase I Progress:

SO_2 Emissions: (core 263 plants)

Year	SO_2	Allowable
	------- (millions of tons) -------	
1980		
1990		
1995		
1996		
1997		

NO_x Emissions: (core 263 plants)

Year	NO_x emissions (millions of tons)
1990	
1996	
1997	

- Phase II
  - –
  - – set emission restrictions on small coal-, gas-, and oil-fired plants
  - –
- Progress to Date:
  - – concentrations of sulfates in precipitation exhibited a dramatic and unprecedented reduction
  - – compared to trend predictions forecast in 1980 from 1983 through 1994, sulfates are estimated to be 38% lower than if no action had been taken
  - –
  - –