Introduction to Environmental Issues
(Chapter 1)

David Shonnard
Department of Chemical Engineering
Michigan Technological University

What are the most important environmental issues for you?
1-minute discussion

**What are the most important environmental issues for you?**

1. Consider this and discuss with your neighbor.

1. Be prepared to discuss why this issue is important.

1. How have your experiences (prior education, COOP, etc.) shaped your attitudes toward environmental issues?

---

**U.S. Energy Flows, 2002**

Values are in quadrillion (10^{15}) BTUs (British Thermal Units)


Michigan Technological University
Values are in quadrillion (10^{15}) BTUs (British Thermal Units).

U.S. industry manufacturing energy use

<table>
<thead>
<tr>
<th>SIC Code</th>
<th>10^15 BTUs/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 Petroleum/Coal Products</td>
<td>7.32</td>
</tr>
<tr>
<td>28 Chemicals / Allied Products</td>
<td>6.06</td>
</tr>
<tr>
<td>26 Paper</td>
<td>2.75</td>
</tr>
<tr>
<td>33 Primary Metals Industries</td>
<td>2.56</td>
</tr>
<tr>
<td>20 Food / Beverages</td>
<td>1.15</td>
</tr>
<tr>
<td>32 Nonmetallic Mineral Products</td>
<td>0.94</td>
</tr>
<tr>
<td>24 Wood Products</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Numbers represent roughly the % of US annual energy consumption.


Global carbon flows and fuels use

CO₂ and temperature in the northern hemisphere

Temperature rising

- Temperature and CO₂ records

- Warming trends: The concentration of carbon dioxide in the atmosphere helps determine Earth's surface temperature. Both CO₂ and temperature have risen sharply since 1950.

National Geographic, September 2004, pg 20, National Geographic Society, Washington, D.C.

Global Energy Balance


Michigan Technological University
Greenhouse Effect


What’s ahead for the planet?

National Geographic, September 2004, pg 20, National Geographic Society, Washington, D.C.

Michigan Technological University
Global warming and related impacts

Possible adverse effects of global warming

1. Increased average temperatures and temperature extremes
2. Melting of glaciers / polar ice and sea level rise
3. Increased incidence of diseases such as malaria due to warmer temperatures
4. Changing climate and altered weather patterns
5. Disruption of land use due to droughts
6. Migration of human populations
7. Decreased life expectancy in some regions of the world
Stratospheric ozone depletion

Chemical Processing

Cause and Effect Chain

Ozone depleting substances: CFCs, HCFCs

Ozone layer loss increases in UV

Human mortality or life adjustments

Ecosystem damage

From Ozone FAQ - see http://www.unep.org/ozone/faq.shtml

Catalytic ozone destruction

Principal ingredients for ozone loss:
UV radiation & a free radical (e.g., X = OH, NO, Cl, Br)

Net: \(2\text{O}_3 + \text{hv} \rightarrow 3\text{O}_2\)
Production trends of ozone depleting substances (Fig. 1.4-3)

Stratospheric ozone depletion (cont.) Figure 1.4-4
Stratospheric ozone depletion (cont.)
Figure 1.4-4

CFC mole balance: Atmosphere response to CFC phase-out

1. Troposphere (0 - 10 km) is well-mixed
2. Annual CFC production is emitted to atmosphere (assumed)

\[
\frac{dy_{\text{CFC}}}{dt} = \frac{E_{\text{CFC}}(t)}{M_{\text{CFC}} m_{\text{ATM}}} - \frac{1}{\tau} y_{\text{CFC}}
\]

I.C. \( t=0, \ y_{\text{CFC}} = y_{\text{CFC},o} \)

\( y_{\text{CFC}} \) = mole fraction of CFC in the troposphere
\( E_{\text{CFC}}(t) \) = emission rate of CFC (g/yr) = \( E_{\text{CFC},o} e^{-at} \) (AFEAS web site)
\( M_{\text{CFC}} \) = molecular weight of CFC (g/mole)
\( m_{\text{ATM}} \) = atmosphere content (1.5x10^{20} moles) (Wallace/Hobbs, 1977, pg6)
\( \tau \) = CFC residence time in the troposphere (yr)
\( y_{\text{CFC},o} \) = mole fraction of CFC in 1988 (Figure 1.4-3)
CFC mole balance model prediction

\[ \text{ppt} = y_{\text{CFC}} \times 10^{12} \]

\[ y_{\text{CFC}} = y_{\text{CFC}0} e^{-\frac{t}{\tau}} + \frac{E_{\text{CFC}}}{M_{\text{CFC}} n_{\text{ATM}}} (\frac{1}{\tau} - a) (e^{-at} - e^{-\frac{t}{\tau}}) \]

CFC-11. \( E_{\text{CFC}} = 3.14 \times 10^{11} \text{ g/yr}, a = 0.1796 \text{ yr}^{-1}, M_{\text{CFC}} = 137.4 \text{ g/mole} \)
CFC-12. \( E_{\text{CFC}} = 3.93 \times 10^{11} \text{ g/yr}, a = 0.1250 \text{ yr}^{-1}, M_{\text{CFC}} = 120.9 \text{ g/mole} \)

Smog formation and related impacts

Chemical Processing. NOx and volatile organic substances, photochemical oxidation reactions, human/ecological damage from O3 and other oxidants

Cause and Effect Chain

1. Chemical & Allied Processing
2. Petroleum & Related Industries
3. Metals Processing
4. Other Industrial Processes
5. Solvent Utilization
6. Storage & Transportation
7. Waste Disposal & Recycling

Fuel Combustion, Industrial Processes, Transportation, Miscellaneous

VOCs and NOx emissions in 1997.
Acid rain / Acid deposition

Materials  Energy  Products  Cause and Effect Chain
Chemical Processing  SO₂ and NOx emission to air  Acidification rxns. & acid deposition  human/ecological damage from H⁺ and heavy metals

Cause and Effect Chain:
1997
1. Chemical & Allied Processing
2. Petroleum & Related Industries
3. Metals Processing
4. Other Industrial Processes
5. Solvent Utilization
6. Storage & Transportation
7. Waste Disposal & Recycling

Human health toxicity

Materials  Energy  Products  Transport, fate, exposure pathways & routes  Human health damage; carcinogenic & non...
Chemical Processing  Toxic releases to air, water, and soil  EPCRA Hazardous Waste  RCRA Hazardous Waste

EPCRA Toxic Waste:
- Chemical and Allied Products 27%
- Primary Metals 22%
- Electronic Equipment 6%

RCRA Hazardous Waste:
- Chemical and Allied Products 51%
- Electronic Equipment 9%
- Petroleum Refining 9%
- Primary Metals 8%
- All Other Industries 16%

Transportation Equipment 7%

Michigan Technological University
Hazardous Waste Management Options

Table 1.9-2 Hazardous Waste Managed for Each Management Technology (1986 data).

<table>
<thead>
<tr>
<th>Management Method</th>
<th>Quantity Managed in 1986 (million tons)</th>
<th>Number of Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Recovery</td>
<td>1.4</td>
<td>330</td>
</tr>
<tr>
<td>Solvent Recovery</td>
<td>1.2</td>
<td>1,500</td>
</tr>
<tr>
<td>Other Recycling</td>
<td>0.96</td>
<td>240</td>
</tr>
<tr>
<td>Fuel Blending</td>
<td>0.75</td>
<td>180</td>
</tr>
<tr>
<td>Reuse as Fuel</td>
<td>1.4</td>
<td>300</td>
</tr>
<tr>
<td>Incineration</td>
<td>1.1</td>
<td>200</td>
</tr>
<tr>
<td>Solidification</td>
<td>0.77</td>
<td>120</td>
</tr>
<tr>
<td>Land Treatment</td>
<td>0.38</td>
<td>58</td>
</tr>
<tr>
<td>Wastewater Treatment</td>
<td>730</td>
<td>4,400</td>
</tr>
<tr>
<td>Disposal Impoundment</td>
<td>4.6</td>
<td>70</td>
</tr>
<tr>
<td>Surface Impoundment</td>
<td>230</td>
<td>300</td>
</tr>
<tr>
<td>Landfill</td>
<td>3.2</td>
<td>120</td>
</tr>
<tr>
<td>Waste Pile</td>
<td>0.68</td>
<td>71</td>
</tr>
<tr>
<td>Underground Injection</td>
<td>29</td>
<td>63</td>
</tr>
<tr>
<td>Storage (RCRA permitted)</td>
<td>190</td>
<td>1,800</td>
</tr>
<tr>
<td>Other Treatment</td>
<td>2.0</td>
<td>130</td>
</tr>
</tbody>
</table>

Allen and Rosselot, 1997; Pollution Prevention for Chemical Processes
Michigan Technological University

Ecology Concepts

First Trophic Level

Primary Producers

Heat Respiration

Respiration

Mineralization by Bacteria, Fungi, and other Detritus Feeders

SECOND TROPHIC LEVEL

Second Trophic Level

Respiration

Dead Organic Matter

Third Trophic Level

Etc.
Ecological Impacts


ReCap of Chapter 1

Environmental Issues
Global Warming
Ozone Depletion in Stratosphere
Acidification
Smog Formation
Ecology Concepts
Energy Consumption
Water Quality
Life-Cycle Concepts
Product Stewardship

Risk Concepts (Ch 2)
Exposure Assessments
Hazard Assessment
Toxicity
Environmental Fate
Persistence
Dose

What is the contribution from the chemical industry?