Lecture #3

Environmentally Responsible Design and Manufacturing

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Revisiting Concerns

- While environmental challenges are often global in nature, let’s view things from a U.S. perspective...
- What makes a company competitive??
- Taylor & history (Ind. Rev., Wage Incentive Plans, Apollo program, Quality)
- Japan -- no energy resources -- impact on products
- Northern Europe -- diminishing landfills
- Sutherland’s theory: “real or artificial challenges drive technological change”
Global Benchmarking

<table>
<thead>
<tr>
<th>Government Activities—Relative Competitiveness*</th>
<th>Japan</th>
<th>U.S.</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-back legislation</td>
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<tr>
<td>Landfill bans</td>
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<td>Material bans</td>
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<td>LCA tool and database development</td>
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<tr>
<td>Recycling infrastructure</td>
<td>**</td>
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<td>Economic incentives</td>
<td>**</td>
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<tr>
<td>Regulate by medium</td>
<td>*</td>
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<tr>
<td>Cooperative/joint efforts with industry</td>
<td>**</td>
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<td>****</td>
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<tr>
<td>Financial and legal liability</td>
<td>*</td>
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</table>

*Number of asterisks indicate comparative strength, and are intended to be indicative of level of effort and emphasis as much as actual level of success.
## Global Benchmarking

### Industrial Activities—Relative Competitiveness

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<th>Activity</th>
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<tr>
<td>ISO 14000 certification</td>
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<tr>
<td>Water conservation</td>
<td>**</td>
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<tr>
<td>Energy conservation/CO2 emissions</td>
<td>****</td>
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<tr>
<td>Decreased releases to air and water</td>
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<tr>
<td>Post Industrial solid waste reduction/recycling</td>
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<tr>
<td>Post-consumer recycling</td>
<td>**</td>
<td>*</td>
<td>****</td>
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<tr>
<td>Material and energy inventories</td>
<td>***</td>
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<td>**</td>
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<tr>
<td>Alternative material development</td>
<td>**</td>
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<tr>
<td>Supply chain involvement</td>
<td>**</td>
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<tr>
<td>EBM as a business strategy</td>
<td>****</td>
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<tr>
<td>Life-cycle activities</td>
<td>**</td>
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## Global Benchmarking

### Research and Development Activities—Relative Competitiveness

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<tr>
<td>Relevant Basic Research (&gt; 5 years out)</td>
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<tr>
<td>Polymers</td>
<td>**</td>
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<td>Electronics</td>
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<td>Systems</td>
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<tr>
<td>Applied R&amp;D (&lt; 5 years out)</td>
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<td>Polymers</td>
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Course Philosophy

- Abandoning industrial activity -- not an option!
- We must improve the products and processes we develop -- less environmental impact.
- Our challenge: identify environmental improvement opportunities that are “win-win” -- benefit the environment AND reduce cost, improve performance, etc.
Emissions and Impacts

- Organic Chemicals
- Metals and Inorganic Materials
- Contaminant Transport / Transformation
- Air Pollution
Organic Chemicals

- **Aliphatic Compounds**
  Straight or branched chains of carbon atoms or rings with single bonds between the carbons

- **Alkanes**: all bonds between carbon atoms are single bonds (paraffins)

  - Methane, Ethane, Propane, Butane

  ![Aliphatic Compounds Diagram](image-url)
replace one or more hydrogen atoms with other atoms: Halides (Cl\(^{-}\), F\(^{-}\), Br\(^{-}\), I\(^{-}\)), Amines (NH\(_2\)), Amides [CO(NH\(_2\))]  

\[
\text{Cl} \\
| \\
\text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3 \\
\text{3-Chlorohexane}
\]

Chlorofluorocarbons (CFCs) an example,
Trichlorofluoromethane or Freon 11  

\[
\text{Cl} \\
| \\
\text{Cl}-\text{C}-\text{Cl} \\
\text{F} \\
\text{Freon 11}
\]
- Alkenes: aliphatic compounds, double bond between two adjacent carbon atoms

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{C} &= \text{C} \\
\text{H}_3\text{C} &\quad \text{CH}_3
\end{align*}
\]

2-Butylene

- Alkynes: Triple bond between two carbon atoms

\[
\text{CH}_3\text{-C\equiv C-CH}_2\text{-CH}_3
\]

2-Pentyne

- Organic acids: Usually have carboxylic acid group on end of molecule (\(-\text{COOH}\)). Molecule’s name ends in -anoic. Methanoic acid.
- Esters: compounds formed by reaction of alcohols and organic acids. Of the form: \( R--\text{COO}--R' \) (where \( R \) and \( R' \) are organic groupings). Ethyl acetate

- Ethers: compounds formed by two alcohols. Form: \( R--\text{O}--R' \)
  - Diethyl ether: \( \text{CH}_3 - \text{CH}_2 - \text{O} - \text{CH}_2 - \text{CH}_3 \)

- Aldehydes & Ketones: Formaldehyde & Acetone

- Cyclic aliphatic compounds, e.g., cyclohexane
• **Aromatic Compounds**
  Ring compounds with alternating single and double bonds between the ring carbons. Benzene is simplest
  Can add aromatics to aliphatics
  Other aromatics: Phenol, Toluene, & Styrene

  *Polycyclic aromatic hydrocarbons - PAH (2 or more benzene rings fused together): e.g., Naphthalene*

  Incomplete combustion produces many PAHs

  *Chlorinated aromatic hydrocarbons - industrial applications*
  *Polychlorinated biphenyls (PCBs)*
Metals & Inorganics

- Arsenic -- not a true metal
- Cadmium
- Chromium
- Lead
- Mercury
- Cyanides
Concentrations

\[ \frac{1 \text{mg contaminant}}{10^6 \text{mg media}} = 1.0 \text{ppm} \]

\[ \frac{1 \text{mg contaminant}}{10^3 \text{mL solvent}} = 1.0 \text{mg/L} \]

For water, 1kg = 1L.

\[ \frac{mg}{L} = \frac{mg}{kg} = ppm \]
Transport Processes

- Loading processes
- Dispersive processes
- Diffusional processes
- Reactive/transformation processes
- Solubility
- Volatilization
Air Pollution

- Carbon Monoxide
- Hydrocarbons (volatile organic compounds)
- Sulfur dioxide (SO$_2$)
- Particulates
- Nitrogen oxides (NO and NO$_2$)
- Carbon dioxide
- HAPs: Hazardous air pollutants
Other Air Pollution Issues

- **Smog:** Smoke + Fog, produced by a photochemical reaction - interaction of nitrogen oxides & hydrocarbons under the influence of sunlight. Automobile exhaust.

- **Acid Rain:** Sulfur dioxide and nitrogen oxide emissions. Reactions for sulfuric and nitric acids. Effect is felt “downwind” from emission source.

- **Global Warming:** Biggest greenhouse gas - CO\(_2\), efficient at absorbing infrared radiation. Other gases with GWP (global warming potential): methane, CFCs,

- **Ozone depletion:** Ozone (O\(_3\)) in stratosphere blocks harmful ultraviolet radiation. Some chemicals (CFCs) react with ozone & destroy it.