Lecture Topic #2 (Chapter 20)

WASTE MINIMIZATION, UTILIZATION, and TREATMENT

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MAJOR TOPICS

- Means for ***minimizing*** waste
- ***Utilizing*** materials that might go into waste
- ***Treating*** waste
- ***Disposing*** waste

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Policies and Guidance Related to Waste Minimization

Federal requirements: In 1984, amendments to the Resource Conservation and Recovery Act (RCRA) established the following national policy, *making waste minimization the Nation's preferred hazardous waste management practice*:

"...the generation of hazardous waste is to be **reduced** or **eliminated** as expeditiously as possible. Waste that is nevertheless generated should be **treated**, **stored**, or **disposed of** so as to *minimize the present and future threat to human health and the environment*." (RCRA Sec.1003[b], 1984)

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Policies and Guidance, Cont.

In 1990, passage of the Pollution Prevention Act expanded the Nation's waste prevention policy beyond a "RCRA-only" framework, to *minimizing or eliminating toxic releases to all environmental media and natural resources*:

"The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or **reduced at the source** whenever feasible; pollution that cannot be prevented should be **recycled** *in an environmentally safe manner*, whenever feasible; pollution that cannot be prevented or recycled should be **treated** *in an environmentally safe manner* whenever feasible; and **disposal or other release** into the environment should be employed only **as a last resort** and *should be conducted in an environmentally safe manner*." (PPA, Section 6602[b])

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HAZARDOUS WASTE MANAGEMENT

Goals:

- Prevent generation of waste 

- If waste is unavoidable, reduce amount of waste produced
- Recycle it 
- If not recyclable, treat it to become non-hazardous
- If it cannot be made non-hazardous, dispose of it in a safe manner 
- Once disposed, monitor for leaching and other adverse effects

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Waste Treatment Management Options

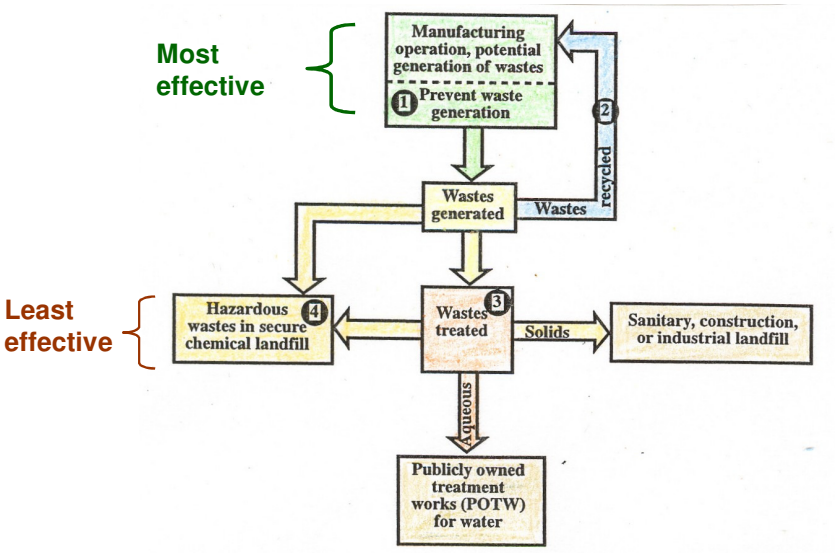

Figure 20.1. Order of effectiveness of waste treatment management options. The darkened circles indicate the degree of effectiveness from the most desirable (1) to the least (4).

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Definitions

Source Reduction: Any practice which reduces the amount of any hazardous substance, pollutant or contaminant from entering any waste stream or otherwise be released to the environment prior to recycling, treatment or disposal.

Recycling: The use, reuse, or reclamation of waste.

Waste Minimization: Includes source reduction and environmentally sound recycling. It is preferable when possible to conduct recycling at on-site locations. Some recycling activities require a permit.

http://www.uos.harvard.edu/ehs/onl_fac_env_min.shtml

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EPA's Waste Minimization Program Goals

http://www.epa.gov/epaoswer/hazwaste/minimize/about.htm

1. Complete **elimination** of, or substitution for, priority chemicals, wherever possible;
2. **Minimizing** the amount of priority chemicals used whenever elimination or substitution is not possible;
3. Maximizing **recycling** whenever elimination, substitution, or minimization is not possible, creating closed loop materials management systems that eliminate or constrict release pathways;
4. Promoting **cradle-to-cradle waste management** instead of cradle-to-grave waste management;
5. Increase cooperative efforts between EPA, States, and the regulated community through **partnership** programs.

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EPA's Waste Minimization Program Goals

What are priority chemicals?

- 31 chemicals found in our nation's products and wastes
  - 28 organics – halogenated, PCBs and PAHs
    - Persistent, bioaccumulative, and toxic (PBT)
    - Industrial waste
    - Found in the environment and plant, animal, and human tissue due to past and present releases.
  - 3 metals – Cd, Hg and Pb

For a complete list go to
http://epa.gov/epawaste/hazard/wastemin/priority.htm

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SOURCE REDUCTION

http://www.epa.gov/epaoswer/hazwaste/minimize/wmindef.htm

Goal:

To reduce or eliminate the amount and/or toxicity of waste at the source before recycling, treatment, or disposal

Examples:

- Modification of equipment or technology — **Engineering change**
- Redesign of products
- Substitution of less toxic raw materials — Change in **chemistry** involved
- Improvement in work practices — **Management** change

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WASTE RECYCLING and REUSE

Perform on-site whenever possible

- Avoids moving waste
- Processes that produce recyclable waste are likely to have use for them

Examples of recycling

- Ferrous metals
- Other metals, such as Al, Cu & Zn
- Glass
- Paper
- Plastic

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RECYCLING PROCESS, Example

Recovery and reuse of hazardous halogenated solvents

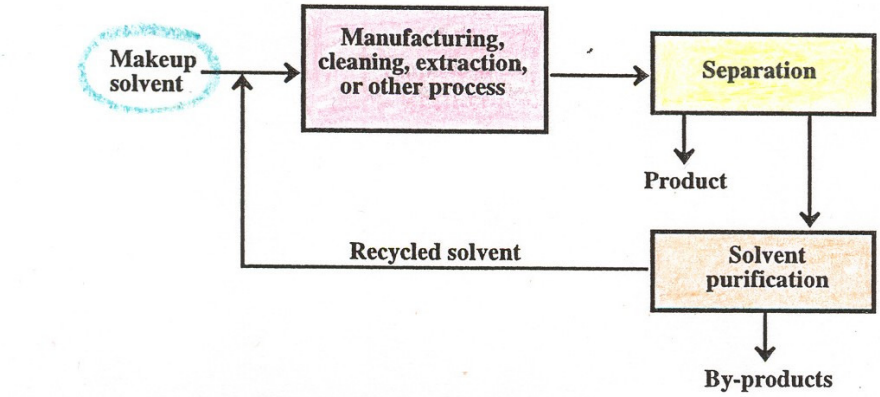

Figure 20.4. Overall process for recycling solvents.

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If waste cannot be recycled, what can be done to prevent potential threat to humans and the environment?

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TREATMENT of WASTE

Three Major Levels Involved

Primary treatment

- Physical processes that prepare waste for further treatment

Secondary treatment

- Physical/chemical processes that destroy and remove hazard

Polishing

- Such as **treatment of water** that is removed from waste
- Also **treatment of other products**

Goal is to discard safely after treatment

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TREATMENT of WASTE (Cont.)

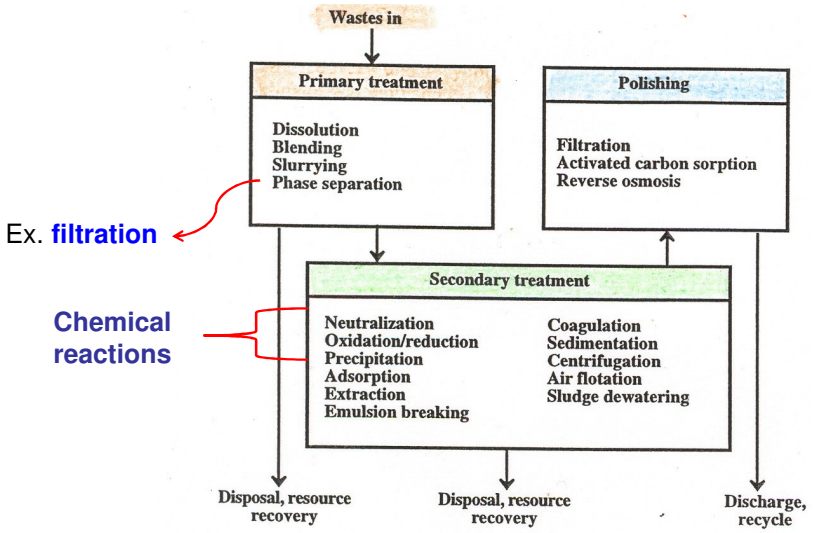

Figure 20.5. Major phases of waste treatment.

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TREATMENT of WASTE (Cont.)

Some Physical Treatment Methods

Molecular separation

- Where dissolved contaminants or solvent pass through a ***size-selective membrane*** under pressure

Molecular Separation Method	Allows passage of:
Hyperfiltration	Species with MW 100-500
Utrafiltration	Organic solutes with MW 500-1,000,000
Reverse osmosis	Water only (Excludes ionic species)

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TREATMENT of WASTE (Cont.)

Chemical Treatment Methods

- Applicability depends on chemical properties of waste components
- Includes one or more of the following methods:

Chemical Method	Example or Application
Acid/Base neutralization	Use of lime [$Ca(OH)_2$] to treat acidic waste; Use of acetic acid to treat alkaline waste
Chemical precipitation	Removal of toxic metal ions by precipitation as metal hydroxide or sulfide. *Ex.* Cd^{2+} => CdS (s) ; Cr^{3+} => $Cr(OH)_3$ (s)
Oxidation-Reduction	Oxidation of organic matter (OM) into CO_2 gas and water; Oxidation or reduction of inorganic species
Electrolysis	Recovery of metals Cd, Cu, Au, Ag, Pb and Zn by direct deposition of ions into the cathode as reduced metal *Ex.* Ag^{+}(aq) => Ag(s)
Ion exchange	Removal of low levels of ions onto a solid resin Cation exchange resin removes (+) ions; Anion exchange resin removes (-) ions

TREATMENT of WASTE (Cont.)

Thermal Treatment Methods

- Most widely used thermal treatment method is incineration

Definition: **Hazardous waste incineration**

- Process that exposes hazardous waste to oxidizing conditions at high temperatures (>900 ^{0}C)

Incineration of waste

- Utilizes the following conditions that destroy waste:
  - High T
  - Oxidizing atmosphere
  - Turbulent combustion conditions

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TREATMENT of WASTE (Cont.)

Hazardous waste incineration (Cont.)

Application:

1) Destruction of OM

- Ex. MeOH, Acetonitrile, Toluene, Xylene

2) Destruction of halogenated compounds

- Will not easily burn; Requires a ***supplemental fuel*** like methane
- Ex. Nonflammable organochlorine waste

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TREATMENT of WASTE (Cont.)

Incinerator System

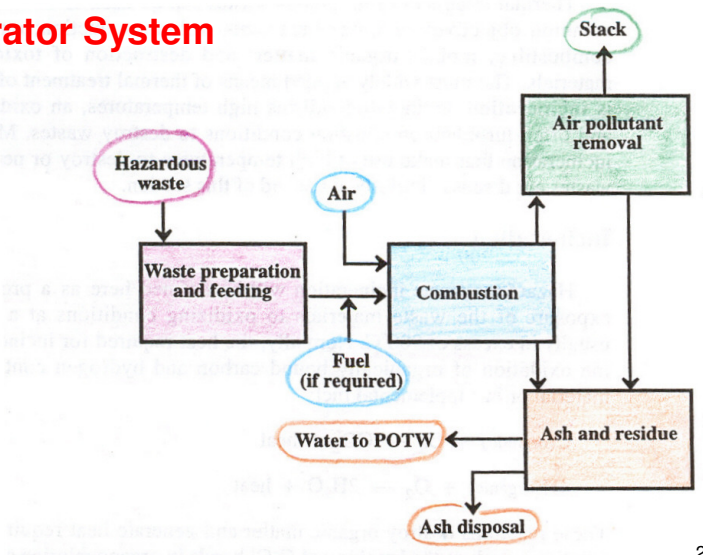

Figure 20.8. Major components of a hazardous waste incinerator system.

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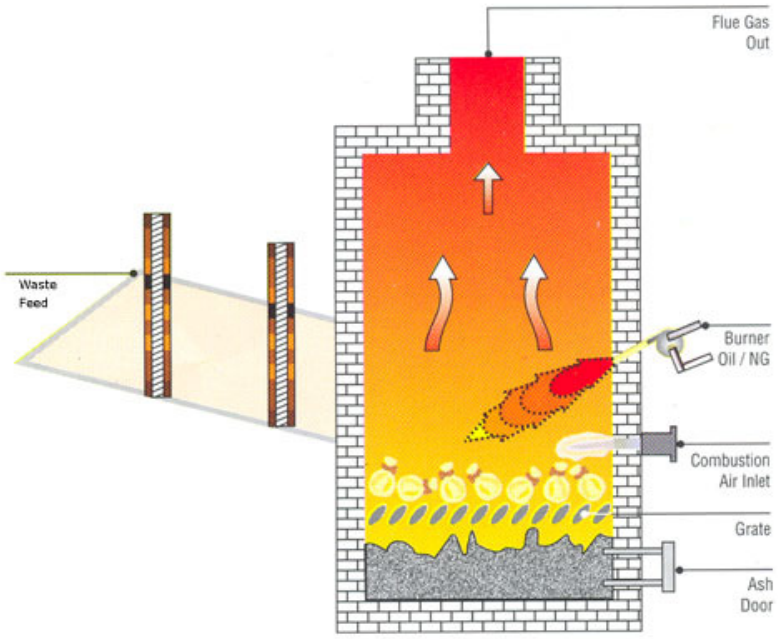

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http://www.pacificincinerators.com/industrial_incinerators.htm

TREATMENT of WASTE (Cont.)

Incineration Systems (Cont.)

Major components and function:

1) Waste preparation system

- Involves processes that prepare waste for combustion

Ex. Shredding of solids; Settling of liquid-solid waste to remove solids and water

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TREATMENT of WASTE (Cont.)

Incineration Systems (Cont.)

2) Combustion chamber

- Burns waste under conditions that favor complete oxidation of components into nonhazardous products, usually CO_2 and water
  - Excess O_2
  - Turbulence => results to thorough mixing of waste, oxidant and, if needed, supplemental fuel
  - High temperatures (>900 ^{0}C)
  - Sufficient residence time => gives enough time for reaction to occur

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Incineration Systems (Cont.)

3) Air pollution control system

- Involves processes that *clean out pollutants from the exhaust gas* coming out of the combustion chamber

  Ex. Particulate matter (PM) removal; Acid gas removal

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TREATMENT of WASTE (Cont.)

Determining Incineration Effectiveness

- Based upon the effectiveness of destruction of the **principal organic hazardous constituents** (POHC)

  Measured before and after incineration

- ***EPA regulations:***
  - 99.99 % of POHCs must be destroyed
  - 99.9999 % of TCDD or dioxin must be destroyed

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TREATMENT of WASTE (Cont.)

Biodegradation of Waste

- Converts waste into simple inorganic molecules (mineralization) using enzymatic biological processes
- Potential for in situ degradation of hazardous waste

Bioremediation

- Destroys hazardous waste using microbial processes

Recalcitrant or **biorefractory** substances

- Resistant to biodegradation
- Accumulate and persist in the environment

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TREATMENT of WASTE (Cont.)

Biodegradation of Waste (Cont.)

Q. How do we deal with recalcitrant/biorefractory waste?

- ***Adaptation*** by some microorganisms to degradation

  Ex. DDT can be degraded by properly acclimated *Pseudomonas*

- Use of ***chemical pretreatment*** (e.g. partial oxidation)
  - Can make some recalcitrant waste much more biodegradable

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TREATMENT of WASTE (Cont.)

Land Treatment of Wastes

- Involves mixing of waste with ***soil***
  - Acts as a natural filter for wastes. HOW?
  - Microorganisms (bacteria and fungi) in the soil can be capable of biodegradation of waste
- Application:
  - Wastes that contain ***biodegradable organic substances***

    Ex. Petroleum refining wastes
  - Fuels and wastes from leaking underground storage tanks
- Limitation:
  - Cannot be used to treat wastes that contain acids, bases, toxic inorganics, salts, heavy metals

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TREATMENT of WASTE (Cont.)

Preparation of Wastes for Disposal

Involves one or more of the following techniques:

Immobilization

- ***Goal***: To minimize leaching of waste
- Most commonly done by ***solidification*** of wastes

  Ex. By reaction with Portland cement
- ***Application***: Treatment of **inorganic wastes** which cannot be treated by other methods

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TREATMENT of WASTE (Cont.)

Preparation of Wastes for Disposal – Cont.

Stabilization

- Conversion of waste to a more stable material using a physical or chemical process

  Ex. Conversion into a less volatile or less reactive substance
- Required for land disposal of wastes

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TREATMENT of WASTE (Cont.)

Preparation of Wastes for Disposal (Cont.)

Solidification

Examples

- Evaporation of water from sludges
- Sorption of waste onto a solid
- Encapsulation

} Physical processes

- Reaction with cement = Chemical process

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PILDYSH TECHNOLOGIES INC.

Concrete and encapsulating cement

The Terra-Bond™ technology can be used to encapsulate hazardous, solid, finely divided waste materials within stable, discrete pellets

http://www.pildyshtech.com/technologies-encapsulation.html

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You've seen what industries are doing to reduce/reuse/recycle waste.

Let's look at what we are doing in the Chemistry Department and beyond to reduce/reuse/recycle waste.

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