



Environment Institute of Malaysia (EiMAS)  
Department of Environment

## TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

### **MODULE 4**

## **Resource Recovery and Reutilization Technologies**

### **SLIDES (PESERTA)**



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# TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

## MODULE 4: Resource Recovery and Reutilization Technologies




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| Module 4: Resource Recovery and Reutilization | TDHW |
|---|------|
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| ◆ Waste-to-Energy Recovery Technology         |      |

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## Introduction

- ◆ Simply disposing of waste materials is unsustainable in the long term, as there is a finite supply of most raw materials
- ◆ Resource recovery technologies provide renewable, reliable and sustainable solutions to meet the waste management and renewable energy needs
- ◆ There are several different methods by which resources may be extracted from waste

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## Purpose

- ◆ To provide participants with:
  - ▼ Options of the various methods that can be selected or used in applying resource recovery and reutilization technologies in the industry
  - ▼ Systematic approach for the reduction of waste materials that are sent to a landfill disposal
  - ▼ Systematic methodologies to capture recyclable materials from the waste stream and convert them into resources
  - ▼ Selection of the most appropriate technologies suitable for their application in the industry

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## WASTE OIL RECOVERY


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## Waste Oil


- Synthetic oil
- Engine oil
- Copper and aluminum wire drawing solution.
- Oils used as buoyant.
- Electrical insulating oil.
- Metalworking fluids and oils
- Industrial process oils

**Examples of waste oil**



- Waste oil that is bottom clean-out waste from virgin fuel storage tanks, virgin fuel oil spill cleanups, or other oil wastes that have not actually been used.
- Products such as antifreeze and kerosene.
- Vegetable and animal oil, even when used as a lubricant.
- Petroleum distillates used as solvents.

**Waste oils are not**



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## Waste Oil

Classifications of waste oil in Malaysia

| Codes  | Description  |
|--------|--|
| SW 305 | Spent lubricating oil  |
| SW 306 | Spent hydraulic oil  |
| SW 307 | Spent mineral oil-water emulsion   |
| SW 308 | Oil tanker sludges   |
| SW 309 | Oil-water mixture such as ballast water  |
| SW 310 | Sludge from mineral oil storage tank   |
| SW 311 | Waste oil or oily sludges  |
| SW 312 | Oily residue from automotive workshop, service station oil or grease interceptor |
| SW 314 | Oil or sludge from oil refinery or petrochemical plant                           |



## Waste Oil Recovery Technology

Reprocessing and re-refining are the two main types of end use technologies

### Reprocessing

Simple physical/chemical treatments to remove the basic contaminants in used oil

### Re-refining

Designed to fully restore the original usefulness of the oil

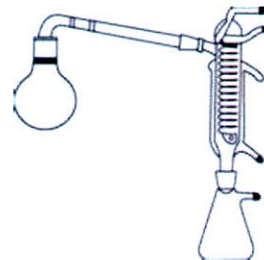


## Waste Oil Recovery Technology

| Technology        | Process  |
|-------------------|--|
| Physical/Chemical | Settling   |
|                   | Filtration   |
|                   | Centrifugation   |
|                   | Coagulation  |
| Thermal           | Acid/Clay Treatment                                      |
|                   | Vacuum Distillation/Clay Polishing                       |
|                   | Vacuum Distillation/Hydrotreating                        |
|                   | Chemical Demetallization/<br>Distillation/ Hydrotreating |

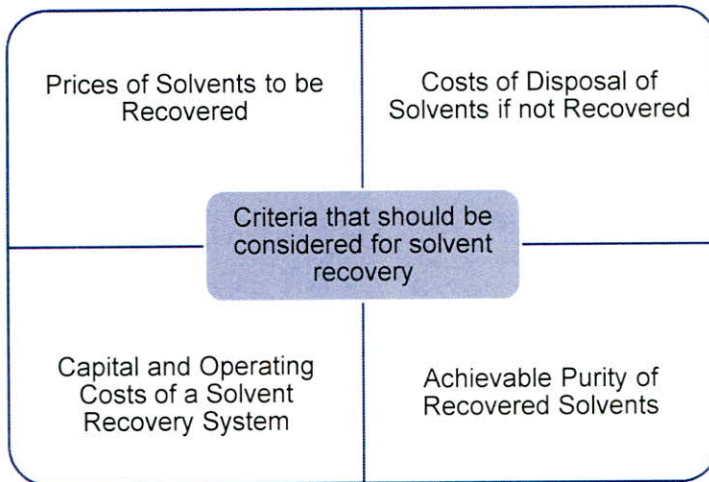


## SOLVENT RECOVERY



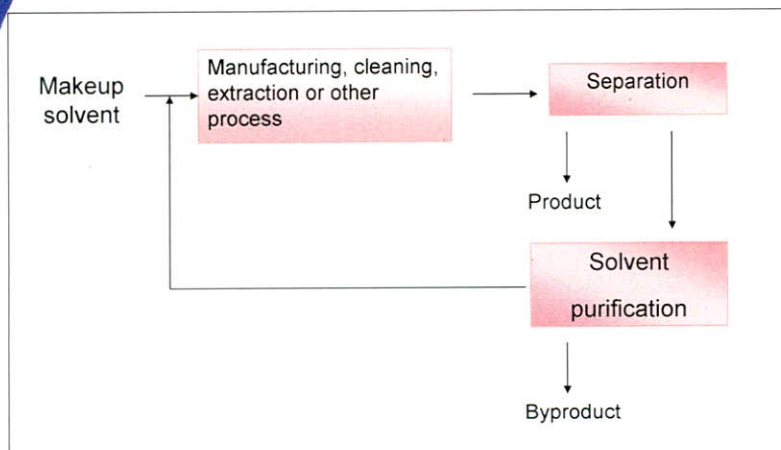


### Solvent Recovery



### Solvent Recovery

#### Example of Recycling Solvents



## Solvent Recovery Technologies

Distillation – Most important technique for solvent recovery

### Continuous Distillation

Used if the separation is fairly simple

Operation is same as described under steam stripping

### Batch Distillation

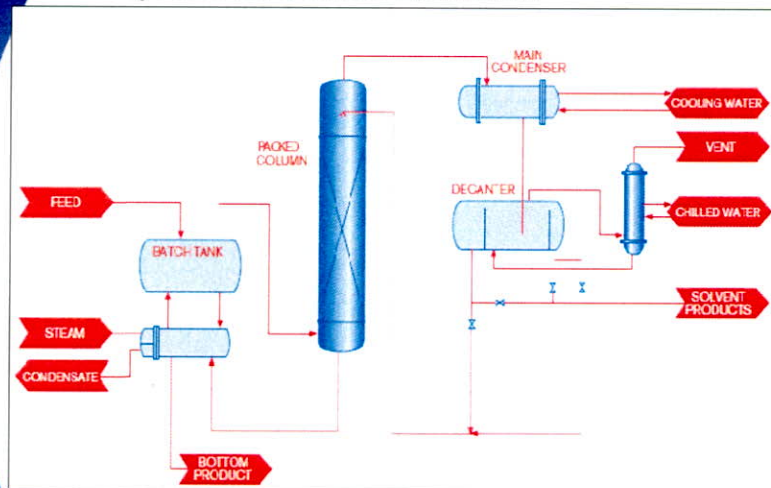
Extremely complicated

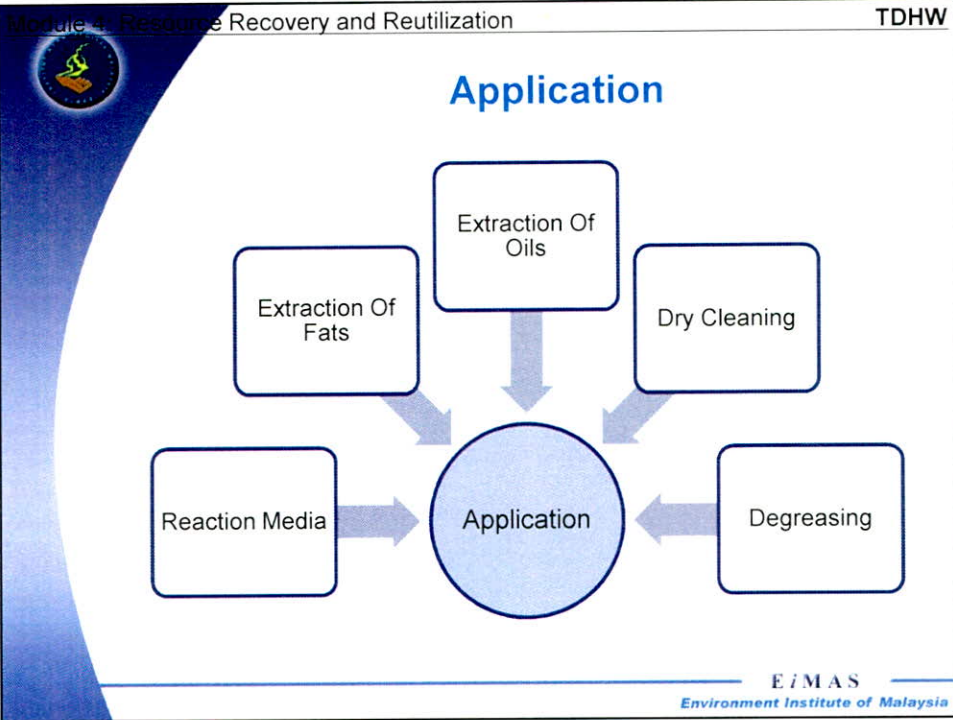
Has only one theoretical stripping stage



## Solvent Recovery Technologies

### Flow Schematic of a Typical Batch Distillation System for Solvent Extraction





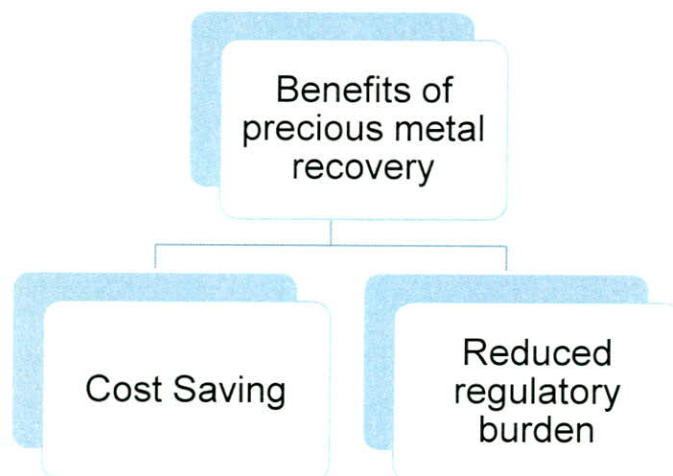


### Introduction

- ◆ Metals can be present in the forms of cationic forms, oxides forms or in combination with other anionic constituents or organic compounds
- ◆ Examples : Arsenic, barium, cadmium
- ◆ Example industry: Metal finishing industry



### Introduction



Water Recovery and Reutilization TDHW

## Metal Recovery Technology

| Technology | Process             | Description   |
|------------|---------------------|---|
| Physical   | Membrane Separation | Microfiltration   |
|            |                     | Ultra filtration  |
|            |                     | Reverse osmosis   |
|            |                     | Electro dialysis  |
|            | Evaporation         | Four basic types of evaporators used in the electroplating industry<br>Rising-film<br>Flash,<br>Submerged-tube<br>Atmospheric |

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## Metal Recovery Technology

| Technology       | Process               | Description  |
|------------------|-----------------------|--|
| Physico-Chemical | Precipitation         | Involves adding chemicals to alter the physical state of suspended metals<br><br>Chemicals used - caustic soda<br>lime; ferrous and sodium sulfide |
|                  | Electrolytic Recovery | Consists of an anode and a cathode immersed in an electrolyte<br><br>Used extensively to recover metals from industrial liquid wastes              |
|                  |                       | Example : Electro Winning<br>Electro Dialysis  |

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## Metal Recovery Technology

| Technology       | Process      | Description  |
|------------------|--------------|--|
| Physico-Chemical | Leaching     | <p>Process in which a solid material is contacted with a liquid solvent for dissolving some solid into the liquid phase</p> <p>Leaching agents : sulfuric acid, ferric sulfate, ammonia or ammonium carbonate,</p> |
|                  | Ion Exchange | <p>Apply to:</p> <ul style="list-style-type: none"> <li>•Metals in liquid wastes</li> <li>•Non-metallic anions</li> <li>•Water- soluble, ionic organic compounds</li> </ul>  |

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## Metal Recovery Technology

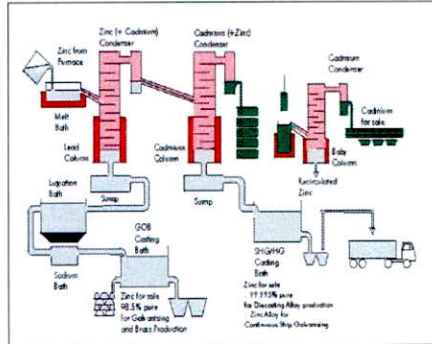
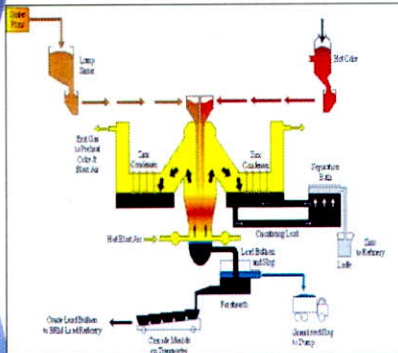
| Technology | Process                          | Description   |
|------------|----------------------------------|---|
| Thermal    | High-Temperature Metals Recovery | <p>Involve plasma-based or high-temperature fluid-wall reactor systems (which use electricity as the energy source) or coal/natural- gas-based technologies</p> <p>Applicable only for the processing of waste containing liquid solution</p> <p>Destroyed at the high temperatures (&gt;1100°C), prevail in the furnaces</p> |
|            | Pyrometallurgy                   | <p>Applicable to most metal bearing wastes</p> <p>Has potential in forming a toxic sludge as its residue</p> <p>These separation techniques form the basis of thermal smelting and refining operations.</p>   |

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## Metal Recovery Technology

Basic Thermal Smelting Operations

Basic Thermal Refining Operations



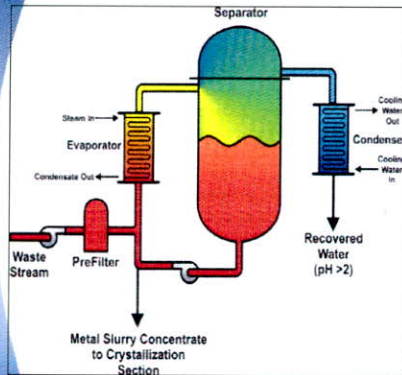
## Metal Recovery Technology

| Technology | Process  | Description   |
|------------|--|---|
| Thermal    | Combination of Evaporation and Crystallization Process | The waste stream enters the evaporation section first, before entering crystallization section<br><br>The solution begins to vaporize at approximately 105°C. |

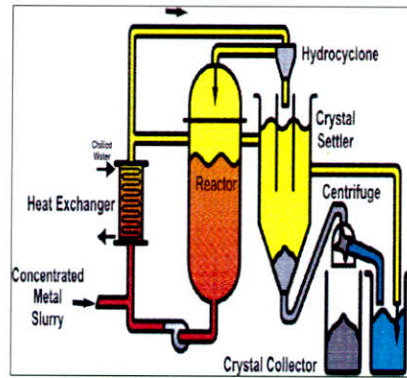


# Metals Recovery Technology

## Evaporation Process



## Crystallization Process



# REUTILIZATION TECHNOLOGY



## REUTILIZATION TECHNOLOGY

- ◆ Conversion of waste into a new valuable product (does not require any treatment process)
- ◆ Being used as:
  - ↳ raw materials
  - ↳ energy
- ◆ Examples:
  - ↳ Calcium sulphate sludge (gypsum) used in production of cement
  - ↳ Sulphuric acid as a latex coagulation agent



## WASTE-TO-ENERGY RECOVERY TECHNOLOGY





## Introduction

- ◆ Waste treatment that creates energy in the form of electricity or heat that has been disposed of in landfill
- ◆ Result in usable fuel commodity (hydrogen/ethanol)
- ◆ Classified as thermal, biochemical or chemical processes



## Waste-to-Energy Recovery Technology

### Thermal Processing

- Combustion or direct incineration
- Gasification
- Pyrolysis
- Plasma arc waste disposal

### Bio-Chemical Processing

- Anaerobic digestion
- Refuse derived fuel
- Fermentation

### Chemical Treatments

- Base catalyzed transesterification of the oil
- Direct acid catalyzed transesterification of the oil
- Conversion of the oil to its fatty acids and then to biodiesel



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## TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

### **MODULE 5**

### **Hazardous Waste Treatment Technologies**

### **SLIDES (PESERTA)**



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# TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

## MODULE 5: Hazardous Waste Treatment Technologies



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### Contents

- ◆ Introduction
- ◆ Purpose
- ◆ Physical Treatment Technologies
- ◆ Physico-chemical Treatment Technologies
- ◆ Biological Treatment Technologies
- ◆ Thermal Treatment Technologies
- ◆ Other Remediation Technologies  
(Hazardous Clean-up Operation)



## Introduction

### ◆ Hazardous waste treatment technologies:

- Physical
- Physico-chemical
- Biological
- Thermal



## Introduction

### ◆ Basic treatment methodologies:

- Phase separation
- Component separation
- Chemical transformation
- Biological transformation



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Possibilities of treatment and disposal of industrial waste

| Contaminant                    | Recovery | Incineration | Treatment (physico-chemical, biological) | Immobilization/solidification | Controlled landfill |
|--------------------------------|----------|--------------|--|-------------------------------|---------------------|
| Effluent / wash waters         |          |              | √  |                               |                     |
| Acids and alkalis              |          |              | √  |                               |                     |
| Heavy metals                   |          |              | √  | √                             | Residues            |
| Toxic inorganic                |          |              | √  | √                             | Residues            |
| Reactive wastes                |          |              | √  |                               |                     |
| Non-toxic inorganic            | √        |              |  |                               | √                   |
| Solvents, oils                 | √        | √            |  |                               |                     |
| Resins, paints, organic sludge | √        | √            |  |                               |                     |
| Organic chemicals              | √        | √            |  |                               |                     |
| Pesticides                     |          | √            |  |                               |                     |
| PCBs, chlorinated hydrocarbons |          | √            |  |                               |                     |
| Biodegradable wastes           |          | √            |  |                               |                     |

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## Purpose

- ◆ Provide participants with:
  - Several treatment technologies that can be used or applied for hazardous waste treatment and recycling, as well as for soil remediation
  - Options for the selection of treatment technologies appropriate for different types of waste
  - Innovative, cost effective and environmentally acceptable hazardous waste treatment technologies for industrial applications

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**PHYSICAL TREATMENT TECHNOLOGIES**

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**PHYSICAL TREATMENT TECHNOLOGIES**

- ◆ Waste is subjected to physical method or process to:
  - Contain the hazards
  - Immobilize the hazardous components or substances
  - Prepare it for further treatment, recycling or landfill
- ◆ Do not destroy wastes
- ◆ Change into forms that are easier to further treat or to dispose of

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Technologies

TDHW

## PHYSICAL TREATMENT TECHNOLOGIES

- ◆ Several physical technologies or methodologies include:
  - ▼ Separation
  - ▼ Filtration
  - ▼ Sedimentation
  - ▼ Centrifugation
  - ▼ Hydrocycloning
  - ▼ Others technologies

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TDHW

## Separation

- ◆ Used for removing contaminated constituents or compounds from soils
- ◆ Principle of separation related to a physical properties such as:
  - ▼ Particle size
  - ▼ Relative density
- ◆ Primary purpose:
  - ▼ Isolating components of waste for recovery
- ◆ In context of final disposal:
  - ▼ Reduce the quantity or hazardousness

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## Separation

- ◆ Two well-developed processes for treating liquid hazardous wastes
  - Gravity separation
  - Sieving/physical separation
- ◆ Target contaminant groups
  - SVOCs
  - Fuels
  - Inorganic
  - Selected VOCs and pesticides

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## Separation

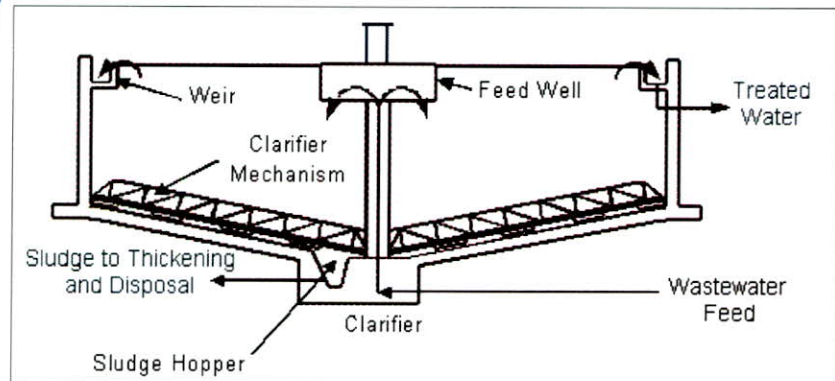
### Gravity separation

- ◆ Solid/liquid separation process
- ◆ Relies on a density difference between the phases
- ◆ Equipment size and effectiveness depends on settling velocity
- ◆ Used for:
  - Removing immiscible oil phases
  - Separation of particles of different sizes

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## Separation



Typical gravity separation system



## Separation

### Sieving/physical separation

- ◆ Use different size sieves and screens
  - To concentrate contaminants into smaller volumes
- ◆ Process principle:
  - Organic and inorganic contaminants bind to the fine (i.e., clay and silt)
  - Clay and silt physically bound to the coarser sand and gravel particles



## Separation

- Separating the fine clay and silt from the coarser sand and gravel soil particles concentrate the contaminants into smaller volume of soil
- ◆ Often preceded by chemical extraction
- ◆ Useful when heavy metal contaminants occur as particulates
- ◆ Advantage:
  - High throughputs can be achieved with relatively small equipment



## Filtration

- ◆ Used for separating solid particles from a fluid through porous medium
- ◆ Driving force in filtration is pressure gradient caused by:
  - Gravity
  - Centrifugal force
  - Vacuum
  - Higher than atmospheric pressure
- ◆ Applications fall into two categories:
  - Clarification
  - Dewatering

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## Filtration

The diagram illustrates two stages of filtration: Clarification and Dewatering. Clarification is shown as a pink box on the left, with a red arrow pointing to a list of three bullet points. Dewatering is shown as another pink box on the left, with a red arrow pointing to a list of three bullet points. The background features a blue circular graphic on the left side.

**Clarification**

- To produce a clear aqueous waste or effluent
- Suspended solid less than 100 p.p.m. are removed from an aqueous waste stream
- Accomplished by depth filtration or cross-flow filtration

**Dewatering**

- To concentrate solids into a paste or solid form
- Dewatering of slurries of typically 1 to 30 percent solids by weight
- Accomplished by cake filtration

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## Filtration

◆ Examples of applications:

- Neutralization of strong acids with lime or limestone
- Precipitation of dissolved heavy metals as hydroxide, carbonate, or sulfide compounds
- Treatment of oil waste contains in the liquid wastes
- Destruction of toxic organic compounds by biological methods

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## Filtration

- ◆ Wastes for which filtration will not work:
  - Hazardous waste substances dissolved in the liquid
  - Waste streams containing soluble toxic organics
  - Chemical components in the same phase (except for membrane filtration)
  - Highly viscous sludges or tars
  - Solid wastes



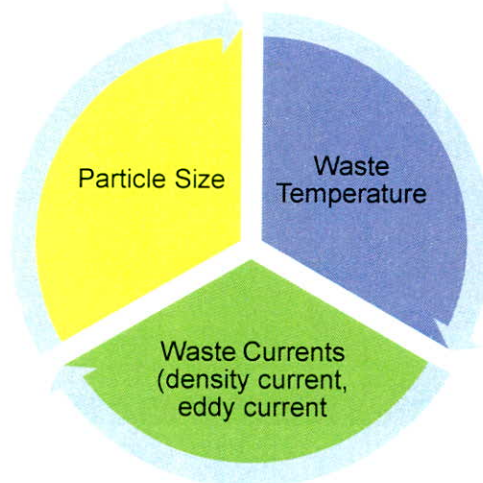
## Sedimentation

- ◆ Process of letting suspended material settles by gravity
- ◆ Suspended material may be particles, e.g., clay or silt
- ◆ Suspended material or floc is created
- ◆ Accomplished by decreasing the velocity of waste
- ◆ When velocity drops, particles are removed by gravity from the flow



## Sedimentation

◆ Factors affect the separation:



## Sedimentation

◆ Types of sedimentation:

- Batch process
- Continuous process

◆ Process principle

- Used gravitational forces
- May be assisted by the heating of the material
- Settlement and the thickening assisted with
  - Coagulants
  - Flocculants



## Sedimentation



Sedimentation tank



## Sedimentation

### ◆ Types of wastes:

- Neutralized acids and alkalies containing suspended metal hydroxides
- Liquid waste streams from which metals and other species have been precipitated
- Certain oil/water mixtures



## Centrifugation

- ◆ The process of solid particles are sedimented and separated from liquid using centrifugal force as driving force
- ◆ Allow very small particles or particles slightly denser than the fluid to settle
- ◆ Common operations:
  - Sludge thickening
  - Sludge dewatering



## Centrifugation

### Centrifuges

- ◆ Sedimentation devices
- ◆ Sedimentation vessels operating under high “gravitational” forces
- ◆ Generated centrifugal forces by spinning the internal bowl of the centrifuge
- ◆ Application:
  - Treat refinery process waste generated from API sludges, heat exchangers, drainage ditches and ballast water

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## Centrifugation

◆ Types of centrifuges:

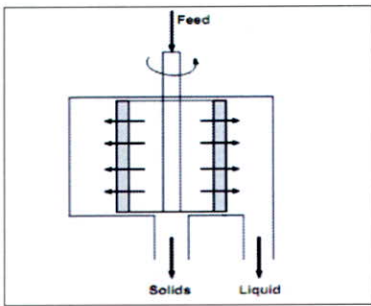
| Batch                              | Continuous                           |
|------------------------------------|--------------------------------------|
| 1. Perforated basket centrifuges   | 1. Solid bowl centrifuges (decanter) |
| 2. Imperforated basket centrifuges | 2. Disk bowl centrifuges             |

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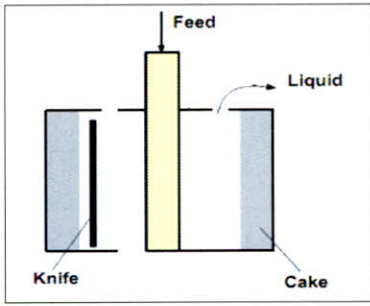
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## Centrifugation

### Batch (basket centrifuge)



Perforated basket centrifuges



Imperforated basket centrifuges

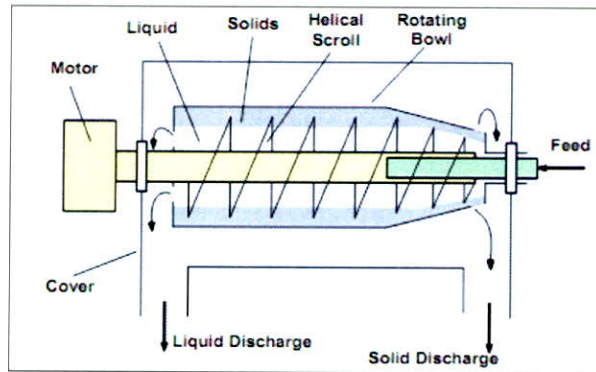
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## Centrifugation

### Continuous



Solid bowl centrifuges (decanter)



## Centrifugation

- ◆ Chemical addition:
  - Conditioners (especially polyelectrolytes)

- ◆ Additive promote:

Suspended particles to flocculate and settle inside the centrifuge

Removal of fine solids

Sludge dewatering

## Centrifugation



Twin decanter centrifuge system for refinery wastewater clarification and dewatering

## Hydrocycloning

- ◆ Use principle of centrifugal separation to remove or classify solid particles from a fluid, based on:
  - Size
  - Shape
  - Density
- ◆ Originally designed for use in the pulp and paper industry
  - Remove high specific gravity debris from paper stock



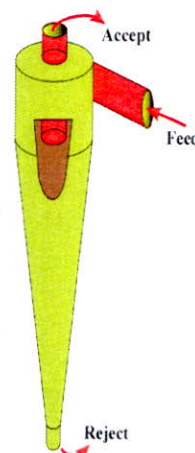
## Hydrocycloning

- ◆ Types of hydrocyclones in the pulp and paper industry:
  - ▼ Forward cleaners
    - Traditional hydrocyclones where high specific gravity rejects are released from the bottom tip of the cyclone
  - ▼ Reverse cleaners
    - Removing lower specific gravity contaminants
  - ▼ Through-flow cleaners
    - Removing lower specific gravity contaminants



## Hydrocycloning

- ◆ Process principle:
  - ▼ Liquid flow is introduced tangentially at a specific pressure, creating a centrifugal motion within the hydrocyclone liner
  - ▼ Causes lighter liquid or oil to separate to the center of the hydrocyclone liner's separation chamber
  - ▼ Denser liquid or water migrates toward the hydrocyclone liner's outer edges and travels in the opposite direction of the oil toward the hydrocyclone's underflow section
  - ▼ Lighter liquid or oil flows in reverse flow in relation to the denser liquid or water and discharges via the hydrocyclone's overflow





## Hydrocycloning



Hydrocyclone



Hydrocyclone liner



## Hydrocycloning

### ◆ Applications:

- Oil/water separation in petroleum refineries
- Oil/produced water separation on platforms
- Treating ship/terminal bilge & ballast water
- Oil separation from industrial wastewaters
- Oil/water separation in chemical plants
- Oil removal from environmental remediation



## Hydrocycloning

### ◆ Advantages and disadvantages

| Advantages  | Disadvantages   |
|---|---|
| <ul style="list-style-type: none"> <li>• No moving parts except for valves and valve actuators</li> <li>• No screens or filters to clean or replace</li> <li>• Progressive removal characteristics should provide adequate protection of pump bearings (better removal for larger particles)</li> </ul> | <ul style="list-style-type: none"> <li>• Higher power cost due to continuous</li> <li>• Pressure drop</li> <li>• Removal efficiency declines quickly below 90 micron particle size</li> <li>• Very flow rate sensitive</li> <li>• Larger system footprint than strainers</li> <li>• Higher capital cost than strainers</li> </ul> |



## Other Technologies

Other physical technologies available used by some industries including:

- ◆ Air classification
- ◆ Ballistic separation
- ◆ Flotation/float and sink
- ◆ Absorption
- ◆ Evaporation
- ◆ Distillation
- ◆ Crystallization

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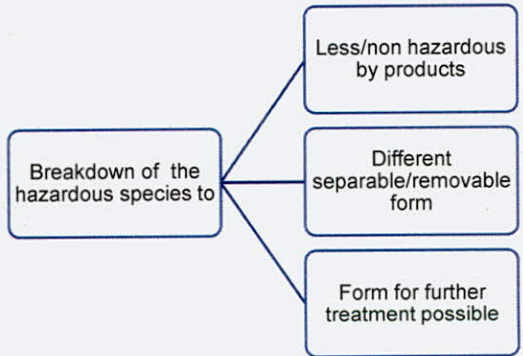
## PHYSICO-CHEMICAL TREATMENT TECHNOLOGY AND PROCESSES

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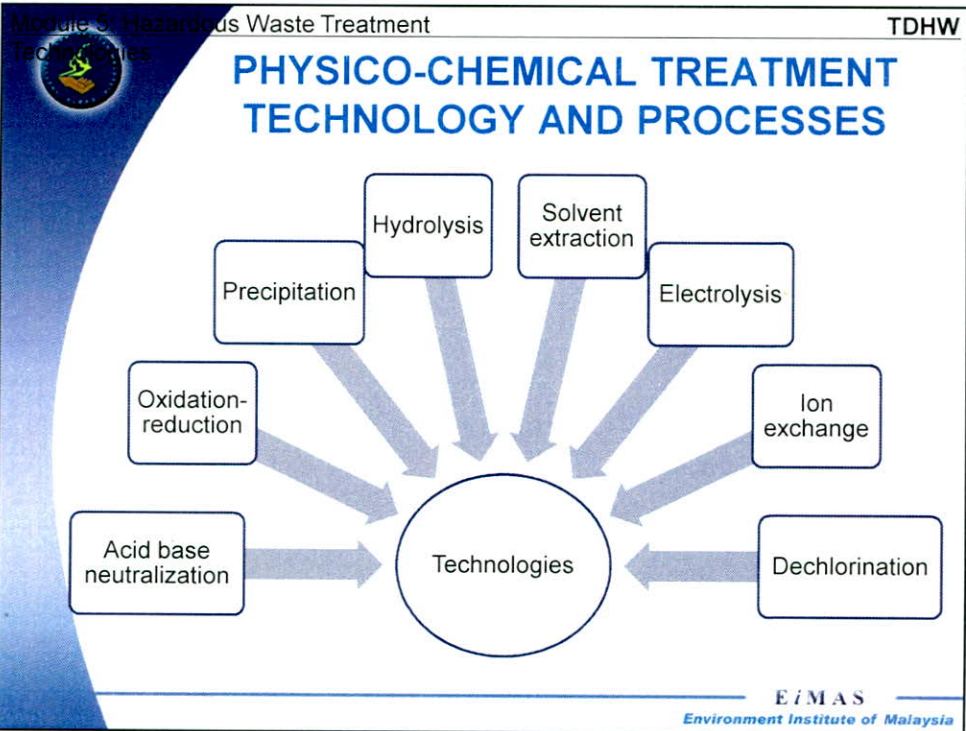
## PHYSICO-CHEMICAL TREATMENT TECHNOLOGY AND PROCESSES

- ◆ Waste is subjected to a chemical reaction, involving the addition of chemicals as reagents



```
graph LR; A[Breakdown of the hazardous species to] --- B[Less/non hazardous by products]; A --- C[Different separable/removable form]; A --- D[Form for further treatment possible];
```

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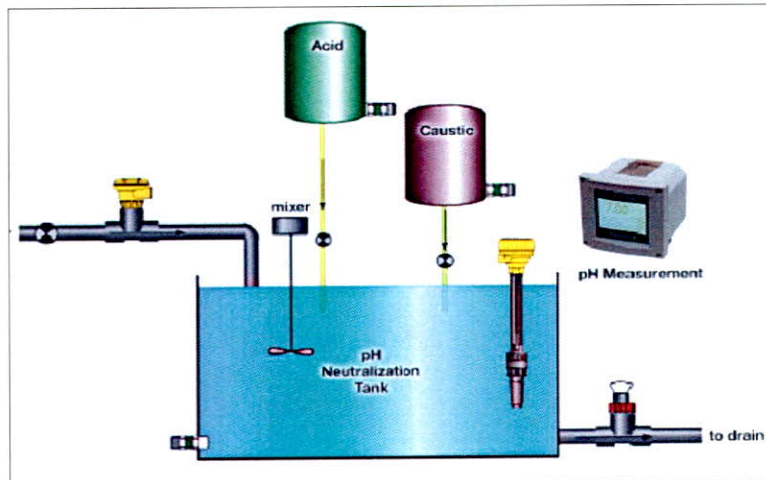
## Acid Base Neutralization

- ◆ Process of pH adjustment of an acidic or caustic waste to a more neutral range
- ◆ Reaction takes place:
 

$$\text{HA} + \text{BOH} \longrightarrow \text{H}_2\text{O} + \text{BA}$$
- ◆ Salts produced are usually non-hazardous and take up less space as solids than the liquid acids and bases

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## Acid Base Neutralization



Acid Base Neutralization

## Acid Base Neutralization

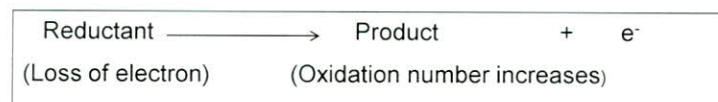
- ◆ Some of the common examples of acids and bases:

| Some Common Acids   | Some Common Bases  |
|---|--|
| <ul style="list-style-type: none"> <li>• Hydrochloric acid, HCl (stomach acid is HCl)</li> </ul>                    | <ul style="list-style-type: none"> <li>• Sodium hydroxide, NaOH (lye or caustic soda)</li> </ul>               |
| <ul style="list-style-type: none"> <li>• Sulphuric Acid, H<sub>2</sub>SO<sub>4</sub></li> </ul>                     | <ul style="list-style-type: none"> <li>• Potassium hydroxide, KOH (lye or caustic soda)</li> </ul>             |
| <ul style="list-style-type: none"> <li>• Nitric Acid, HNO<sub>3</sub></li> </ul>                                    | <ul style="list-style-type: none"> <li>• Magnesium hydroxide, Mg(OH)<sub>2</sub> (milk of magnesia)</li> </ul> |
| <ul style="list-style-type: none"> <li>• Acetic Acid, HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> (vinegar)</li> </ul> | <ul style="list-style-type: none"> <li>• Calcium hydroxide, Ca(OH)<sub>2</sub> (slaked lime)</li> </ul>        |
| <ul style="list-style-type: none"> <li>• Carbonic Acid, H<sub>2</sub>CO<sub>3</sub></li> </ul>                      | <ul style="list-style-type: none"> <li>• Ammonia, NH<sub>3</sub></li> </ul>                                    |

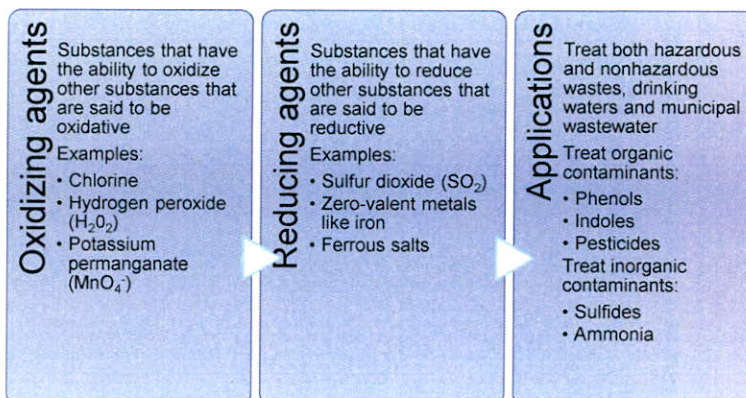


## Oxidation-Reduction

- ◆ Used for partial and complete degradation of many organic and inorganic compounds
- ◆ Common oxidation-reduction process



## Oxidation-Reduction

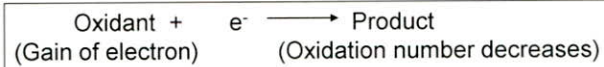




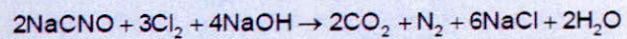
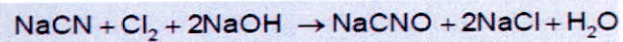
## Oxidation-Reduction

### ◆ Common oxidation-reduction process:

#### → Oxidation

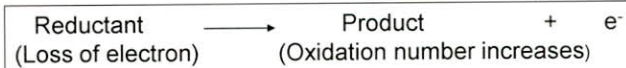


#### → Example: oxidation of cyanide wastes from metal finishing industry

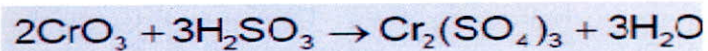


## Oxidation-Reduction

#### → Reduction



#### → Example : Reduction of hexavalent chromium Cr (IV) to trivalent chromium Cr (III) in large electroplating operations



Waste Treatment TDHW

## Precipitation

Process

- Process to remove metals from aqueous waste stream
- Accomplished by pH adjustment and the addition of a chemical reagent

Chemical Reagents Used

- Calcium hydroxide (lime)
- Sodium hydroxide (caustic)
- Magnesium oxide
- Magnesium hydroxide

Affected By

- pH
- Solubility product of the precipitant
- Ionic strength and temperature of the aqueous stream
- Presence of metal complexes

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## Precipitation

◆ Examples of precipitation process:

- ▶ Precipitation of metal as hydroxide with lime

$$M^{2+} + Ca(OH)_2 \rightleftharpoons M(OH)_2 + Ca^{2+}$$

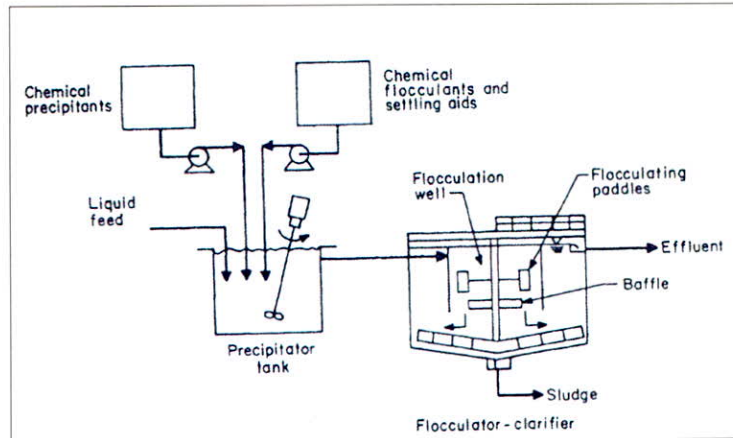
- ▶ Chromium is precipitated as hydroxide

$$Cr^{3+} + 3(OH^-) \longrightarrow Cr(OH)_3$$

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## Precipitation



Chemical Precipitation

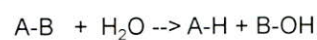
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## Hydrolysis

- ◆ Chemical process where a molecule is cleaved into two parts by the addition of a molecule of water



- ◆ Hydrolysis can remove reactivity from organic and inorganic substances in the gas, liquid or solid phase

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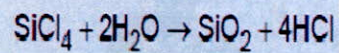
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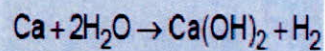
## Hydrolysis

### ◆ Examples of reactions

#### → Reaction of halides



#### → Reaction of active metal



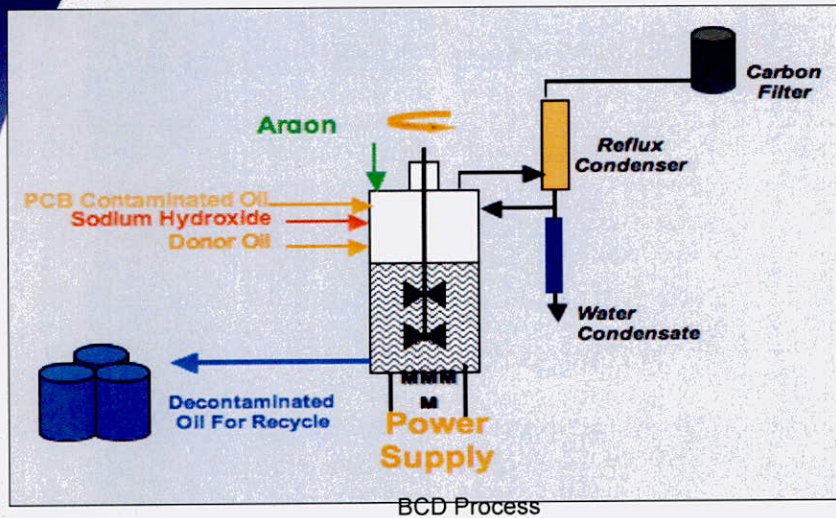
## Dechlorination



### Dechlorination

- Treat halogenated organic compounds
- Suitable for treatment of wastes which contain up to 100,000 mg/kg
- Example waste: halogenated aliphatic or aromatic organic compounds such as PCBs
- Not applies when the waste material is pre-processed by a thermal desorption system

## Dechlorination



## Electrolysis

### The process

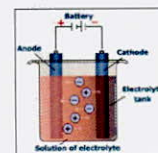
- Process by which electrical energy is used to produce a chemical change

### Example of process

- Recover metal from crystals and sludge and to regenerate process solutions
- Recover copper from sulfuric acid solutions

### Applications

- Preparing elements
- Refining of copper
- Electroplating





## Ion Exchange

- ◆ Chemical reaction where an ion from solution is exchanged for a similarly charged ion attached to an immobile solid particle (i.e., Ion exchange resin)
- ◆ Not for ultimate disposal of hazardous wastes – generates chemical wastes to be further treated



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## Ion Exchange

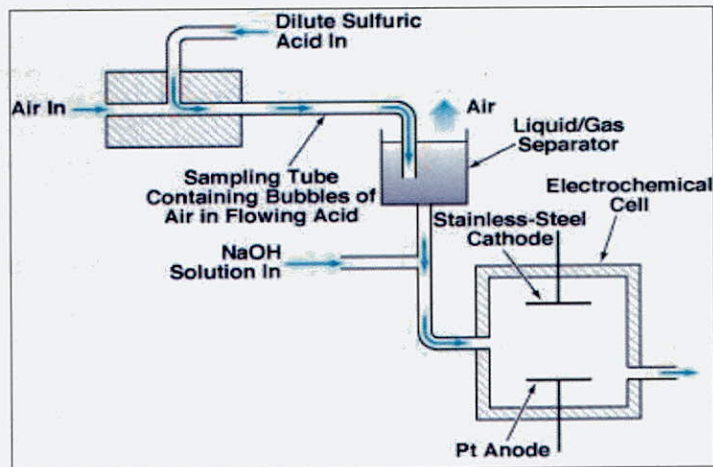
Different resins are used to perform different applications and types of exchanges

|                         |   |
|-------------------------|---|
| Softening               | <ul style="list-style-type: none"> <li>• calcium, magnesium and iron replaced by sodium</li> </ul>  |
| Deionization            | <ul style="list-style-type: none"> <li>• all cations replaced by hydrogen (<math>H^+</math>), all anions replaced by hydroxide (<math>OH^-</math>)</li> </ul> |
| De-alkalization         | <ul style="list-style-type: none"> <li>• bicarbonate and carbonates replaced by chloride</li> </ul>   |
| Precious Metal Recovery | <ul style="list-style-type: none"> <li>• gold, silver replaced by chloride</li> </ul>   |

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## Ion Exchange



Electro-chemical Monitoring of Hydrazine in Air

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## Solvent Extraction

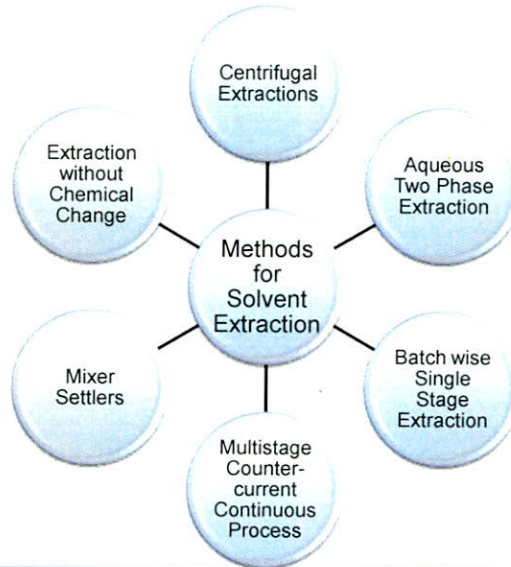
- ◆ Process which involves extracting oil from oil-bearing materials by treating it with a low boiler solvent
- ◆ Recover almost all oils and leaves behind only 0.5% to 0.7% residual oil in the waste material
- ◆ Example: extract pre-pressed oil cakes obtained from high oil content materials

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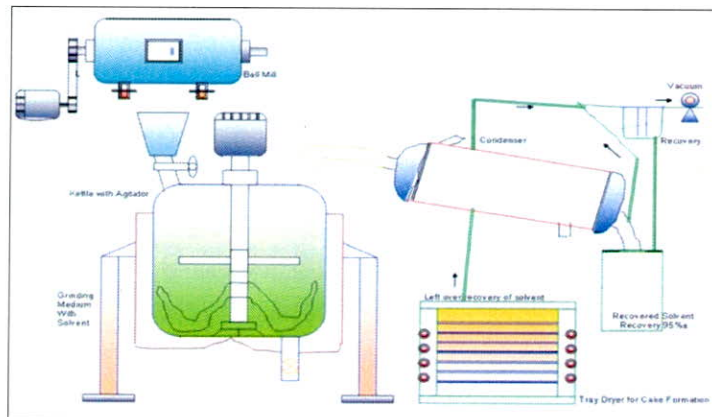
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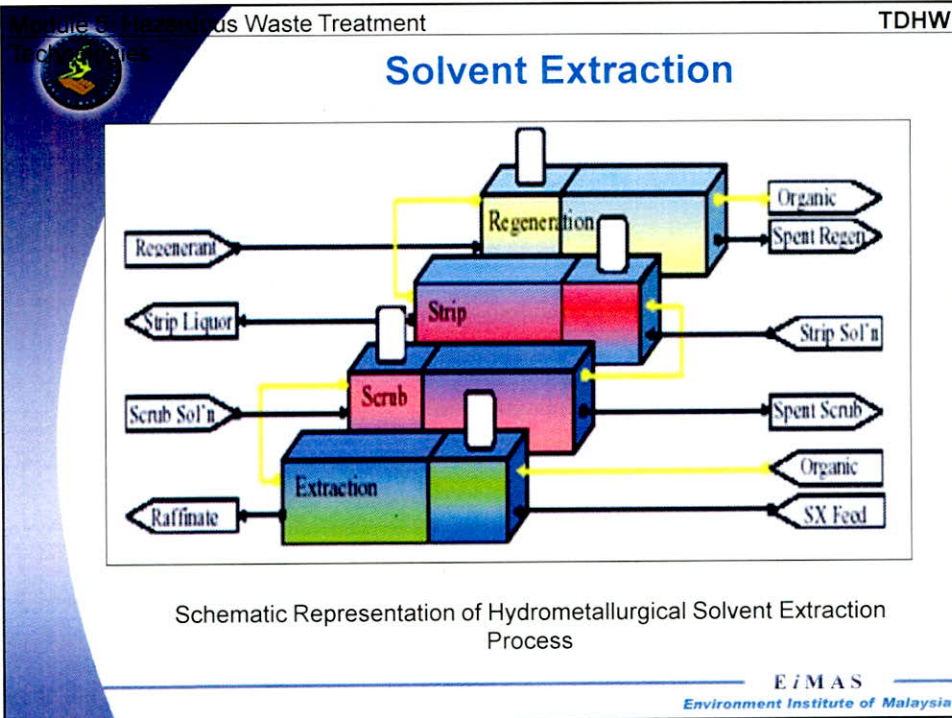
## Solvent Extraction



## Solvent Extraction





Solvent Extraction Plant through Controlled Heating & Evaporation  
Process Involved - Grinding - Mixing with Solvent - Heating -  
Condensation Vacuum Evaporation - Drying & Final Vacuum for Total  
Extraction of Solvent



- Module 5: Hazardous Waste Treatment TDHW
- ## Other Technologies
- Other physico-chemical treatment technologies used by the industries:
- ◆ Pertraction
  - ◆ Stripping/Desorption
  - ◆ Chromatography
  - ◆ Leaching
  - ◆ Scrubbing
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Module 5: Hazardous Waste Treatment TDHW



## BIOLOGICAL TREATMENT TECHNOLOGIES

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Module 5: Hazardous Waste Treatment TDHW

## BIOLOGICAL TREATMENT TECHNOLOGIES

- ◆ Hazardous waste materials are biologically degraded under controlled conditions
- ◆ Micro-organism based activity breaks down certain compounds either through:
  - ▼ Metabolism
  - ▼ Co-metabolism
- ◆ Little effect on inorganic wastes including metals
- ◆ Suitable for treatment of industrial wastes containing biodegradable organic constituents

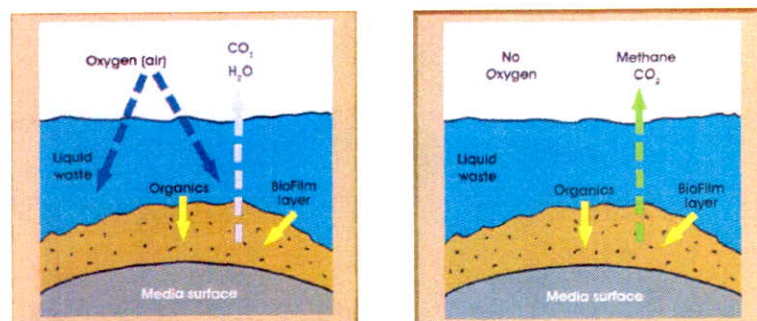
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## BIOLOGICAL TREATMENT TECHNOLOGIES

- ◆ Factors require for design and satisfactory operation:
  - ✓ Solids retention time
  - ✓ Organic loading rate and influent waste characteristics
  - ✓ Effluent and biomass recycle
  - ✓ Media type, specific surface area and placement for fix-film processes
  - ✓ Equalization
  - ✓ Influent waste distribution and waste sludge withdrawal
  - ✓ Operating temperature
  - ✓ Desired final and product ( $\text{CO}_2$ ,  $\text{N}_2$ ,  $\text{CH}_4$ , etc)

## BIOLOGICAL TREATMENT TECHNOLOGIES

- ◆ Two main categories:
  - ✓ Aerobic processes (present of  $\text{O}_2$ )
  - ✓ Anaerobic processes (without  $\text{O}_2$ )



Aerobic process

Anaerobic process



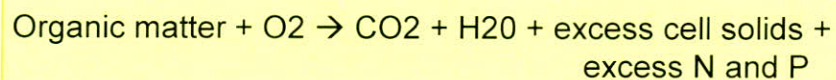
## Aerobic Process

- ◆ Require the present of O<sub>2</sub>
- ◆ Air or oxygen-enriched air is used to provide oxygen to a microorganism culture
- ◆ 2 classes of aerobic processes :
  - ▼ Suspended growth or activated sludge systems
  - ▼ Fixed-film systems
- ◆ 2 basic biological reactions:
  - ▼ Carbon removal
  - ▼ Nutrient removal



## Aerobic Process

- ◆ Composed organic carbon material such as:
  - ▼ Fats
  - ▼ Carbohydrates
  - ▼ Proteins
  - ▼ Organic acids
  - ▼ Alcohols
- ◆ To produce CO<sub>2</sub>, H<sub>2</sub>O and excess cell solids



Waste Treatment TDHW

## Aerobic Process

- Excess nutrients- N and P require further treatment
- N exists in the form of NH<sub>3</sub>
- NH<sub>3</sub> converted to nitrate by nitrification

$$\text{NH}_3 + 2\text{O}_2 + \text{CO}_2 \rightarrow \text{HNO}_3 + \text{H}_2\text{O} + \text{cell solids}$$

- Nitrates further removed by biological denitrification

$$\text{HNO}_3 + \text{organic matter} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{excess cells}$$

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Waste Treatment TDHW

## Aerobic Process

|   |                           |   |
|---|---------------------------|---|
| 1. Conventional activated sludge process configurations | 2. Fluidized-bed reactors | 3. Suspended growth process                                       |
| 4. Combined fixed-film/suspended growth processes       | 5. Pure-film processes    | 6. Nitrification - denitrification processes for nitrogen removal |
| 7. Biological phosphorus removal (BPR)                  |                           |   |

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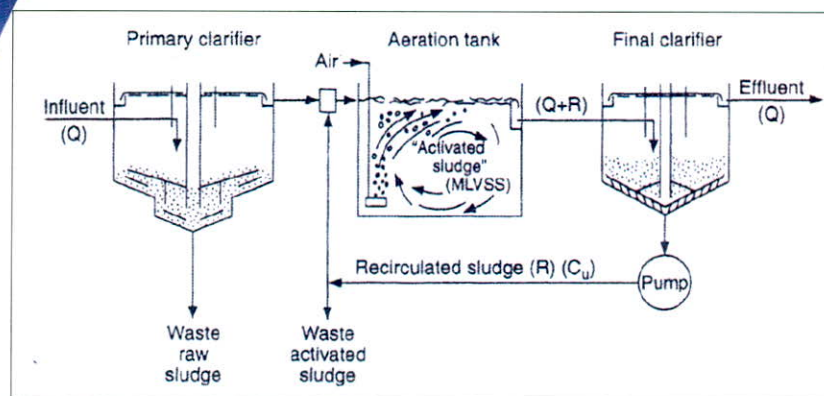
## Aerobic Process

### 1. Conventional activated sludge process configurations

- ▾ Pretreatment followed by an aeration basin and final solids separation unit
- ▾ Aeration basin contains microorganisms needed to biodegrade the organic constituents
- ▾ Final clarifier used to prevent loss of the microorganisms
- ▾ Removed microorganisms may be recycled



## Aerobic Process



Schematic Diagram of Suspended-Growth-Activated Sludge Process with Primary and Secondary Clarification



## Aerobic Process

### 2. Fluidized-bed reactors

- ✦ Biomass grows on the surface of a fine granular medium (0.1 to 0.5 mm diameter)
- ✦ Medium - sand, crushed coal and activated carbon
- ✦ Operate at high organic loading rates
- ✦ Disadvantages:
  - high energy cost
  - high rate of O<sub>2</sub> transfer
  - complexity

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## Aerobic Process

### 3. Suspended growth process

- ✦ Auto-thermal aerobic digestion (ATAD)
  - treat high-strength and difficult-to-treat industrial wastewaters
  - enhancing the biodegradation of organic constituents that are toxic or resistant to biodegradation
- ✦ Membrane biological system
  - use membrane modules to separate the biomass from the flow stream
  - advantage - high biomass concentrations are achievable
  - disadvantage - maintaining a high O<sub>2</sub> transfer rate

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Module 3: Hazardous Waste Treatment TDHW

Fluidized-bed reactors

Auto-thermal aerobic digestion

Membrane biological system

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Module 3: Hazardous Waste Treatment TDHW

## Aerobic Process

### 4. Combined fixed-film/suspended growth processes

- ✦ Addition of fixed media to an activated sludge system
- ✦ Media
  - small plastic particles (diameter 6 -10 mm)
  - fixed sheets of plastic modules
  - fibrous ropes supported within the aeration basin
- ✦ Adds powdered activated carbon to the mixed liquor

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## Aerobic Process

### 7. Biological phosphorus removal (BPR)

- ✦ Removal P element by biological means
- ✦ Accomplished by recycling the biomass through an anaerobic zone
- ✦ P is release in anaerobic zone and consumed in the downstream aerobic zone to for a P-rich biomass
- ✦ P is then removed with the excess solids stream

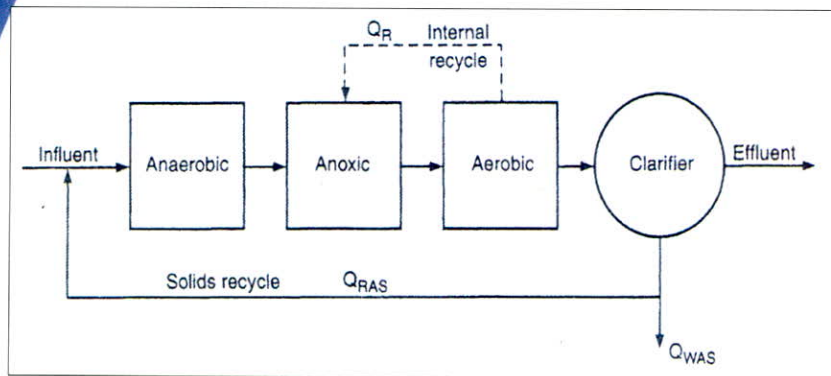


## Aerobic Process

- ✦ Successful operation requires:
  - BOD/P ratios in excess of 20:1
  - precise control of the anaerobic/aerobic sequencing reactions
- ✦ Alum/iron salts added to the final clarifier inlet
- ✦ Benefits in reducing or eliminating the need for chemical addition
  - reduced sludge production
  - improved sludge settleability and dewatering characteristics
  - reduced O<sub>2</sub> requirements
  - reduced process alkalinity requirements



## Aerobic Process



Biological phosphorus removal process



## Anaerobic Process

- ◆ Operating in O<sub>2</sub> free conditions
- ◆ Functions:
  - Reducing mass and volume of sludges from aerobic treatment plants
  - Treating industrial liquid hazardous waste
- ◆ Convert organic matter in liquid hazardous waste to CH<sub>4</sub> and CO<sub>2</sub>

## Anaerobic Process

- ◆ CH<sub>4</sub> gas potential value:
  - Improved treatment efficiency (heating the digester)
  - Production of electrical power
- ◆ Principle advantage:
  - Small amount of excess biomass produced during biodegradation
  - Net yields as low as 2 kg VSS/kg COD removal

## Anaerobic Process

- ◆ Anaerobic fixed-film reactors
  - Treating high-strength industrial liquid hazardous waste (COD conc. > 3000 mg/l)
  - Types:

1. Up flow anaerobic filters

2. Down flow anaerobic filters

3. Anaerobic fluidized reactors

4. Up flow anaerobic sludge blanket reactors



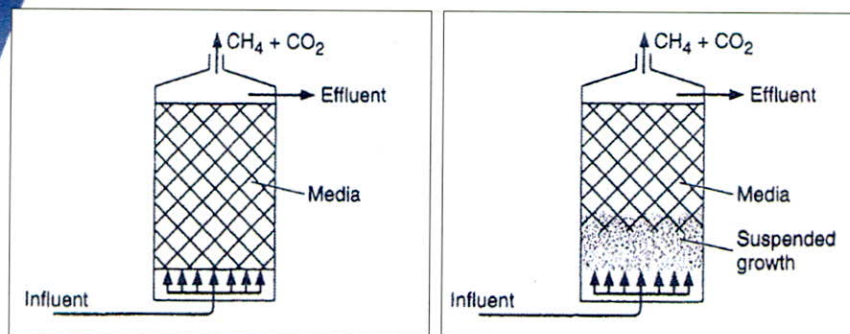
## Anaerobic Process

### 1. Up flow anaerobic filters

- ✦ Consist of cylindrical and rectangular tanks
- ✦ Volumes full-scale reactors ranged 100-2000 m<sup>3</sup>
- ✦ Media heights ranged
  - Full-depth (fully packed anaerobic filter)
  - Only in the upper 50 % to 70 % of the reactor height (hybrid anaerobic filter)
- ✦ Biomass in up flow hybrid anaerobic filters is retained as a granular sludge layer or flocculent sludge blanket



## Anaerobic Process



Fully packed up flow anaerobic filter

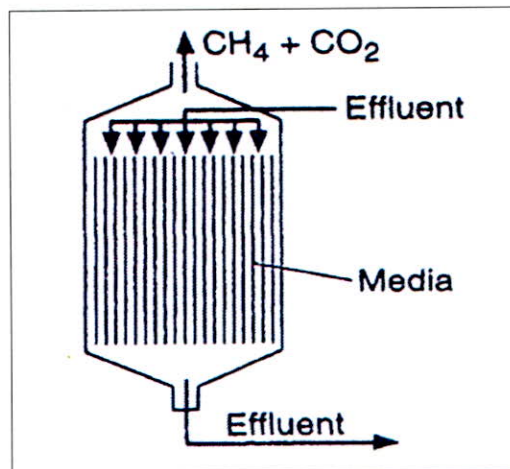
Up flow hybrid anaerobic filter

## Anaerobic Process

### 2. Down flow anaerobic filters

- Treat industrial liquid hazardous waste COD conc. 15,000-85,000 mg/l
- Consist cylindrical tanks volume 600-4000 m<sup>3</sup>
- Media fills the reactor except of shallow distribution and collection zones
- Biomass retained almost exclusively as a biofilm attached to the media
- High recycle ratios are typically used

## Anaerobic Process



Down flow anaerobic filter



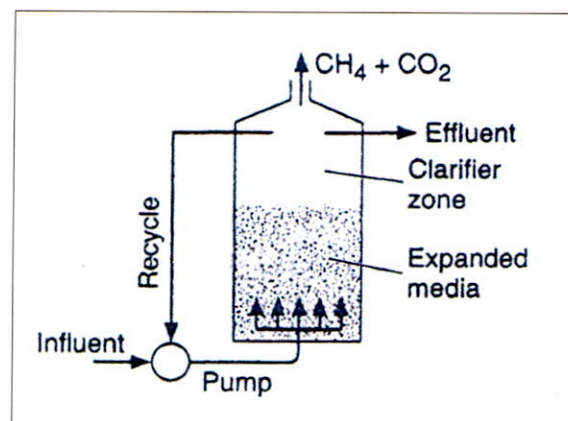
## Anaerobic Process

### 3. Anaerobic fluidized reactors

- ✦ Rely on retention of a large concentration of biomass in suspension against a relatively high up flow velocity by the combined weight of a particulate media and the attached biomass
- ✦ Media's diameter 0.1 - 0.5 mm



## Anaerobic Process



Anaerobic fluidized bed reactor



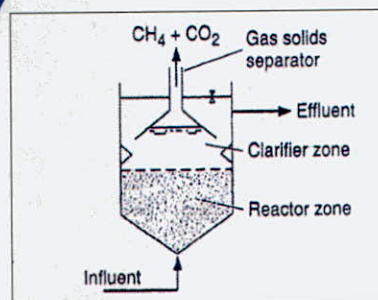
## Anaerobic Process

### 4. Up flow anaerobic sludge blanket reactors

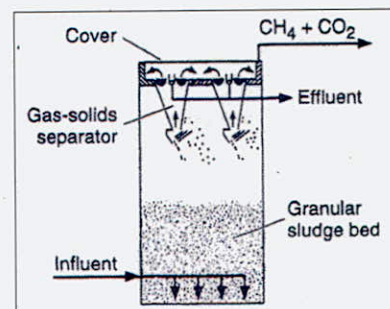
- Retain biological solids in the form of granular pellets or large agglomerates of flocculated cells
- No particulate media is used
- Particulate materials entrapped within biomass aiding flocculation and granulation process
- Recent developments: High-rate anaerobic sludge blanket reactor
  - without a weighing agent



## Anaerobic Process



Up flow anaerobic sludge blanket reactor



High-rate anaerobic sludge blanket reactor

Module 5: Hazardous Waste Treatment Technologies TDHW



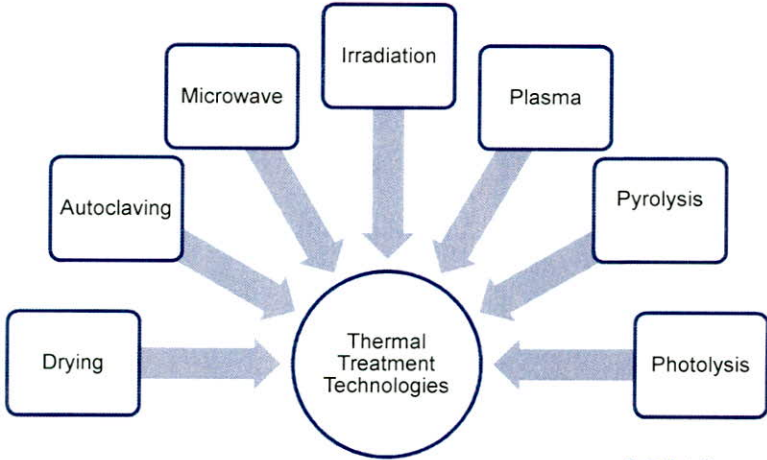
## THERMAL TREATMENT TECHNOLOGIES

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Module 5: Hazardous Waste Treatment Technologies TDHW

## THERMAL TREATMENT TECHNOLOGIES

Heat is applied to remove, break down or treat hazardous waste



```

graph TD
    Microwave --> TTT((Thermal Treatment Technologies))
    Irradiation --> TTT
    Plasma --> TTT
    Pyrolysis --> TTT
    Photolysis --> TTT
    Drying --> TTT
    Autoclaving --> TTT
  
```

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Module 5: Hazardous Waste Treatment TDHW

Topic Series

## Drying

The process

- Removal of solvent or water from solid or semisolid sludge or the removal of solvent from a liquid or suspension, leaving a dried residue

Types of operations

- Gas drying
- Freeze drying

Reaction of drying agents

- Physical adsorption
- Chemical reaction

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Topic Series

## Drying

◆ Example application: Slurry Drying

The diagram illustrates the slurry drying process. It features an engine room where natural gas is used to power an engine. The engine's exhaust gas, at 500 to 550°C, is directed to a heat exchanger. Simultaneously, air from the atmosphere (ranging from -20 to +30°C) is drawn into the heat exchanger, preheated to 70 to 85°C, and then sent to a drying plant. The drying plant also receives radiation heat from the engine. Exhaust gas from the drying plant is captured by a gas burner, which is controlled by a flap. A gas blower maintains a pressure of 130°C throughout the system. The EIMAS logo and name are visible at the bottom right.

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## Autoclaving

### The Process

- Involves the high-pressure sterilization of waste by steam, which 'cooks' the waste and so destroys any bacteria in it

### Materials Cannot Be Autoclaved

- Materials containing: solvents, volatile, chlorinated compounds or corrosive chemicals, etc
- Materials contaminated with chemotherapeutic agents
- Radioactive material (without prior approval)
- Some plastics

### Benefits

- Involves removal of recyclable materials from the waste stream
- Plants are modular
- Plants can be built on a small scale

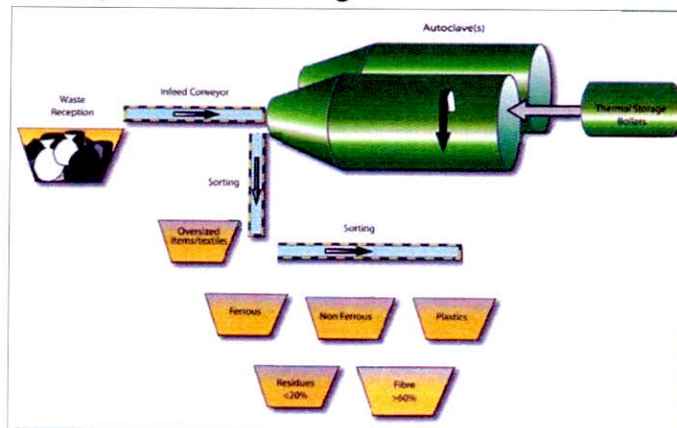
### Applications

- As a stream treatment process to sterilize certain hospital wastes
- As mechanical action to break down portion of waste into fibrous material

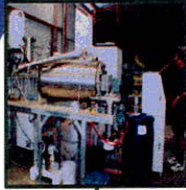


## Autoclaving

### ◆ Example Autoclaving Process



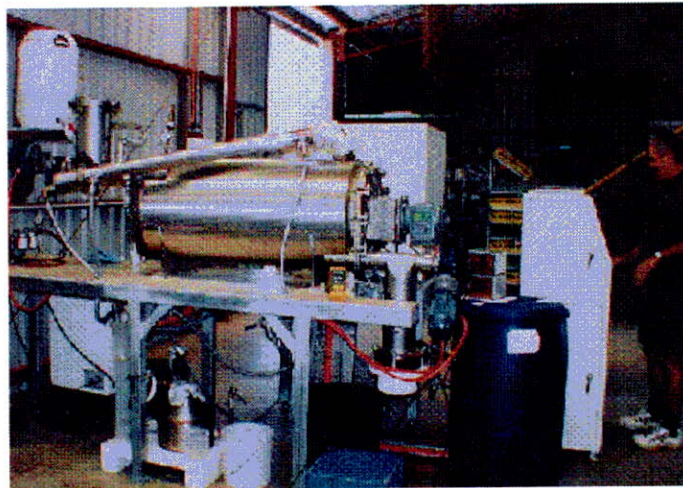
## Microwave



### Microwave

- Applied to treatment of the primary waste streams, and also to treatment of the secondary wastes produced
- Microwave energy interacts with matter in a way different than all other thermal treatment processes
- Use in food processing, analytical chemistry, heating and vulcanization of rubber
- Type of waste: radioactive wastes, sludges, incinerators ashes, industrial wastes and discarded electronic circuitry

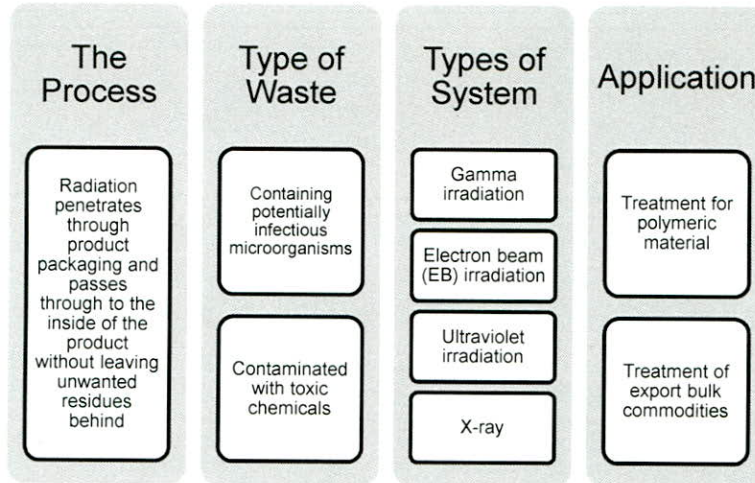
## Microwave



Microwave extraction of essential oil



## Irradiation



## Incineration

### Process description

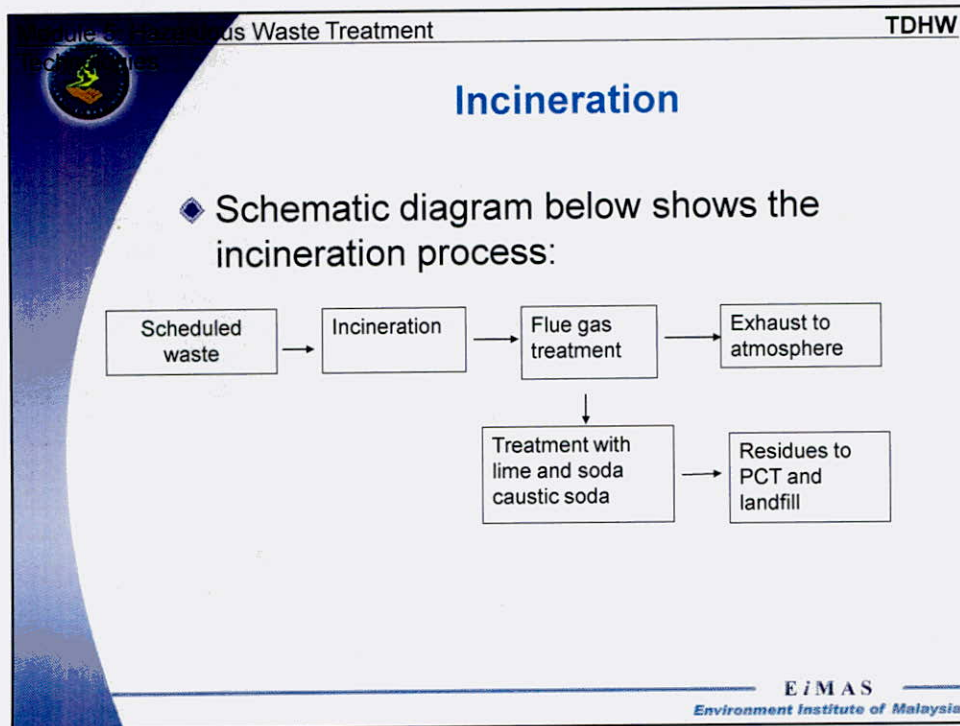
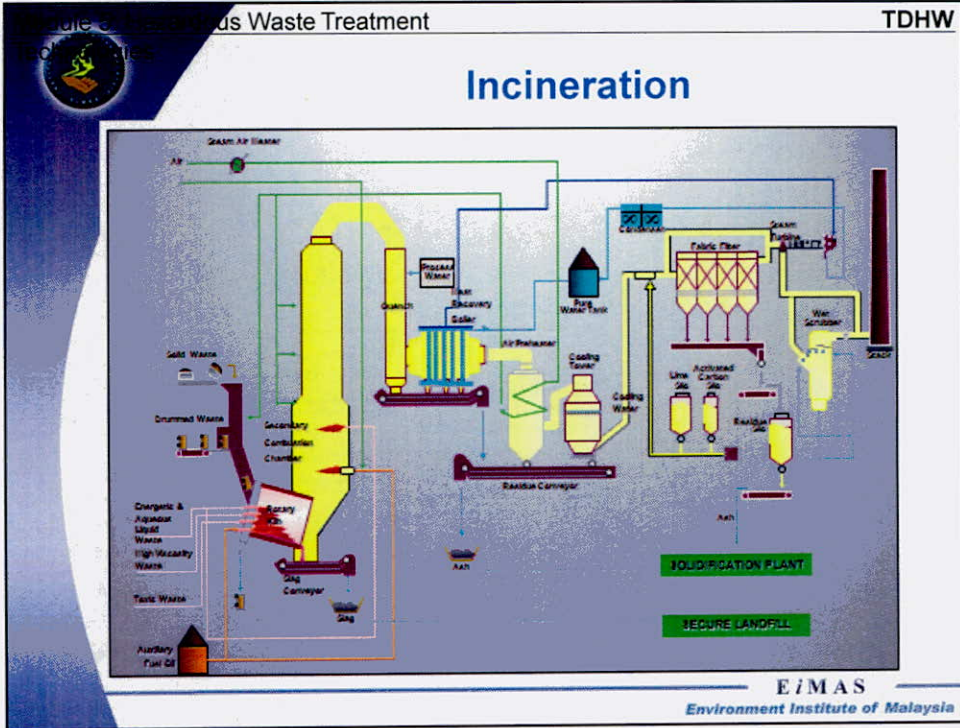
- Process that uses high temperature thermal oxidation to convert waste to less bulky, less toxic or less noxious material

### Waste types

- Biologically hazardous waste
- Waste resistant to biodegradation
- Volatile organic waste
- Other organic wastes

### Waste materials to be excluded from incineration

- Explosive wastes
- Radioactive wastes





## Incineration



Rotary kiln (RK)



Fluidized bed incineration



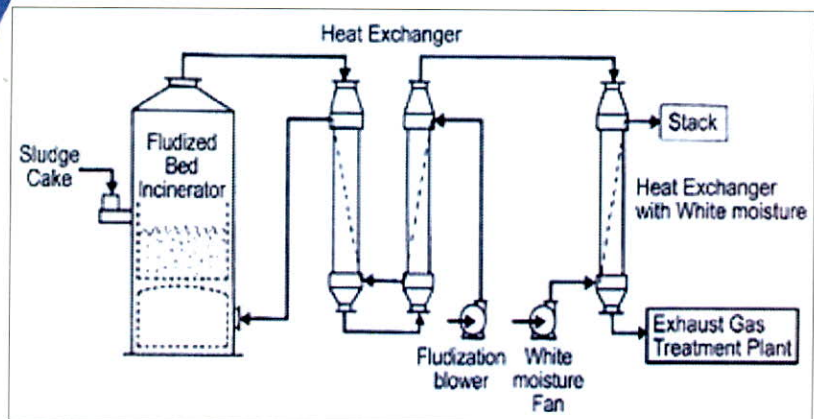
Cement kiln incineration



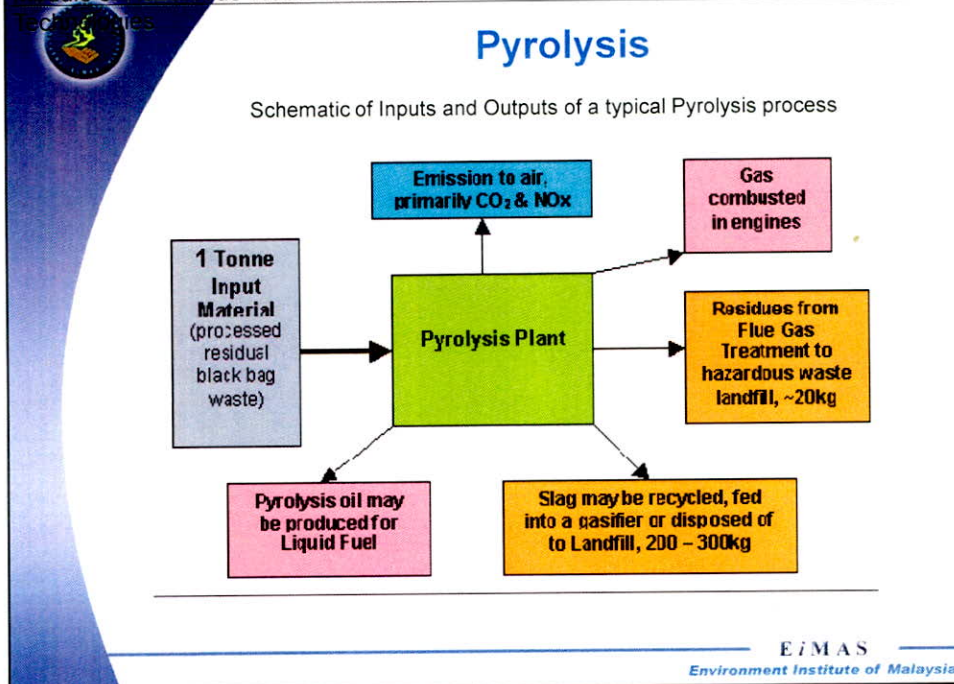
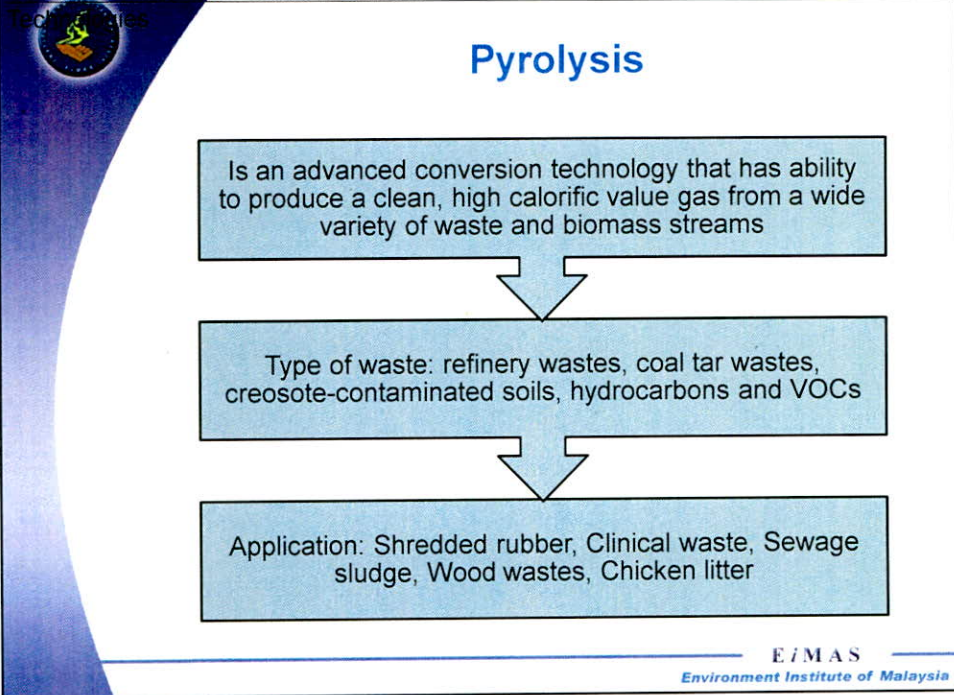
Infectious waste incineration



## Incineration



Fluidized Bed Incinerations

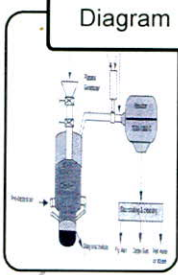


## Plasma

**The process**

- Non-incineration thermal process that uses extremely high temperatures in an oxygen starved environment to completely decompose input waste material into very simple molecules

**Diagram**



**Type of waste**

- Medical waste
- Hazardous industrial waste
- Pesticides
- PCB's
- Cyanide
- Ammunition

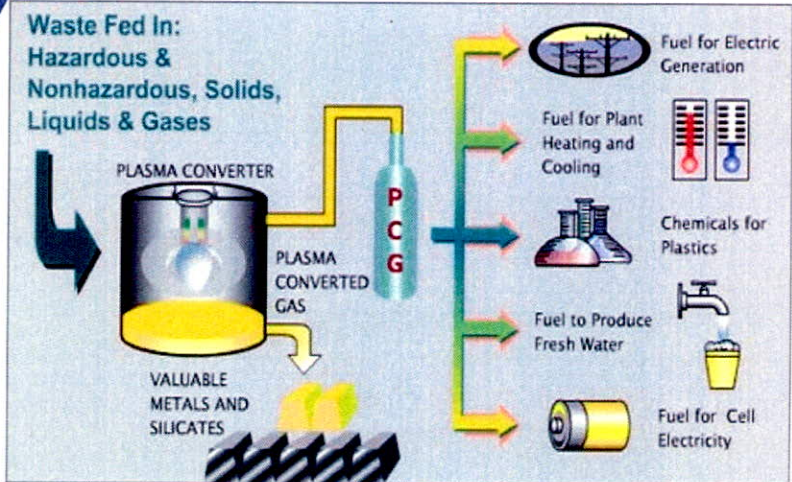
**Applications**

- Organic and Inorganic Wastes
- Mixed Radioactive Waste
- Explosive Compounds
- Asbestos

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## Plasma

**Waste Fed In: Hazardous & Nonhazardous, Solids, Liquids & Gases**



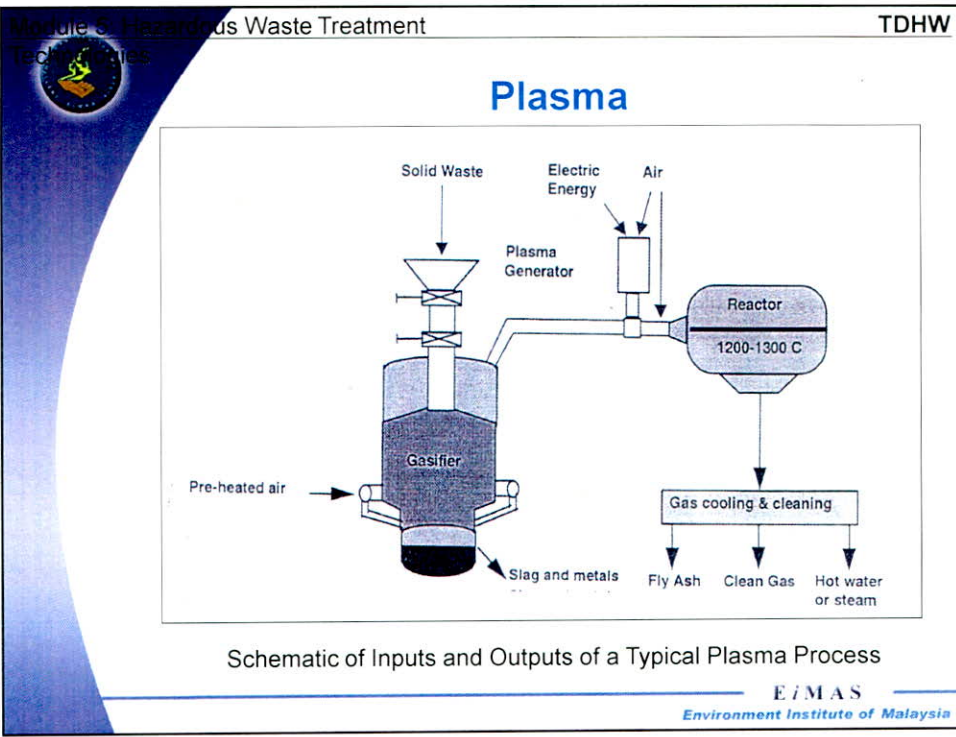
**PLASMA CONVERTER**

**PLASMA CONVERTED GAS (PCG)**

**VALUABLE METALS AND SILICATES**

- Fuel for Electric Generation
- Fuel for Plant Heating and Cooling
- Chemicals for Plastics
- Fuel to Produce Fresh Water
- Fuel for Cell Electricity

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Module 3: Hazardous Waste Treatment TDHW

**Photolysis**

Process Description

- Photons of electromagnetic radiation consisting of short-wavelength visible light or ultraviolet radiation are absorbed by a molecule, causing a chemical reaction to occur

Reaction

- $\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}$

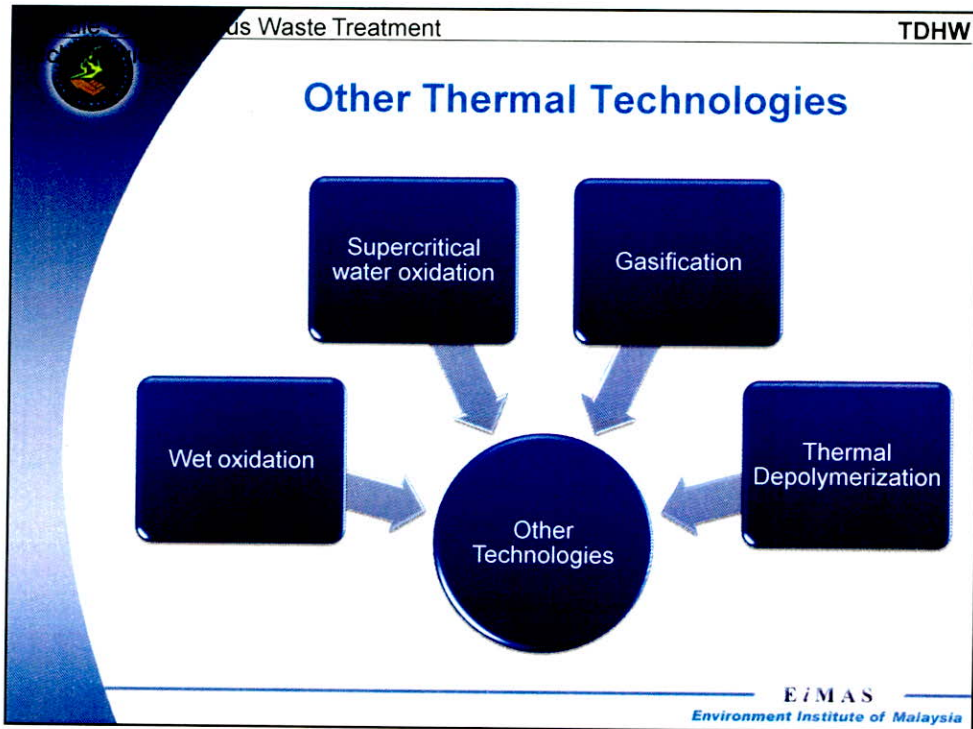
Applications

- Breaking Chemical Bonds In Refractory Organic Compounds

Type of Waste

- PCBs
- Chlorinated dibenzo-p-dioxins (CDDs)

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### OTHER REMEDIATION TECHNOLOGIES (HAZARDOUS CLEAN-UP OPERATIONS)

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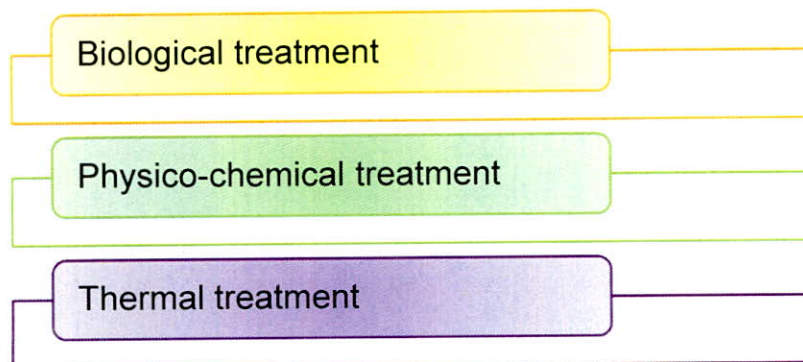
## OTHER REMEDIATION TECHNOLOGIES

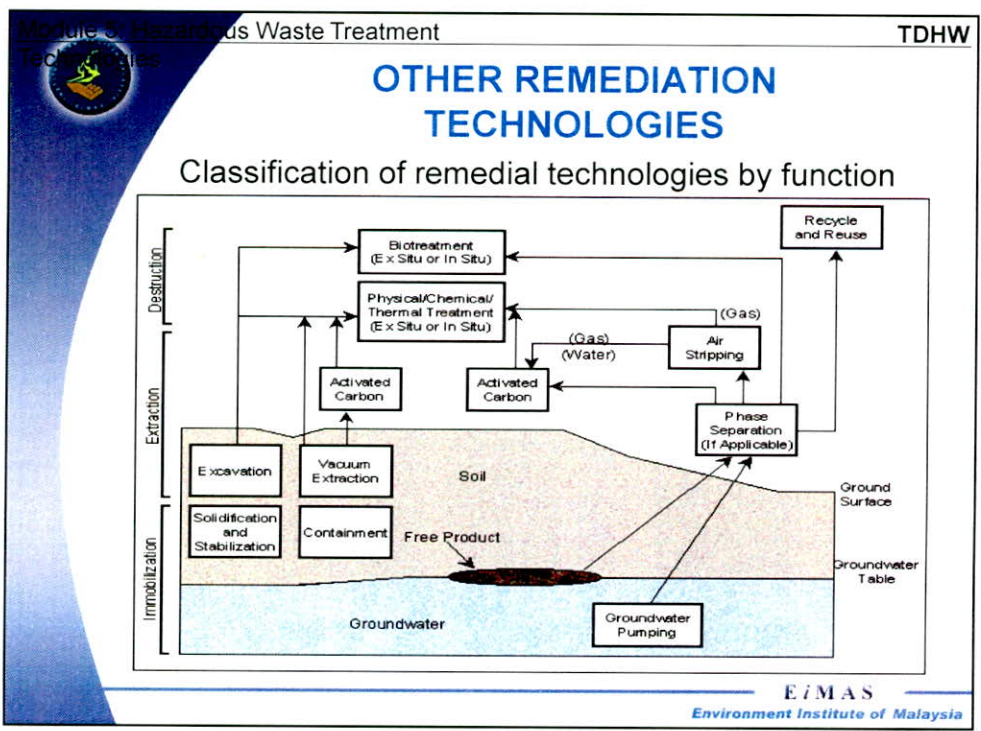
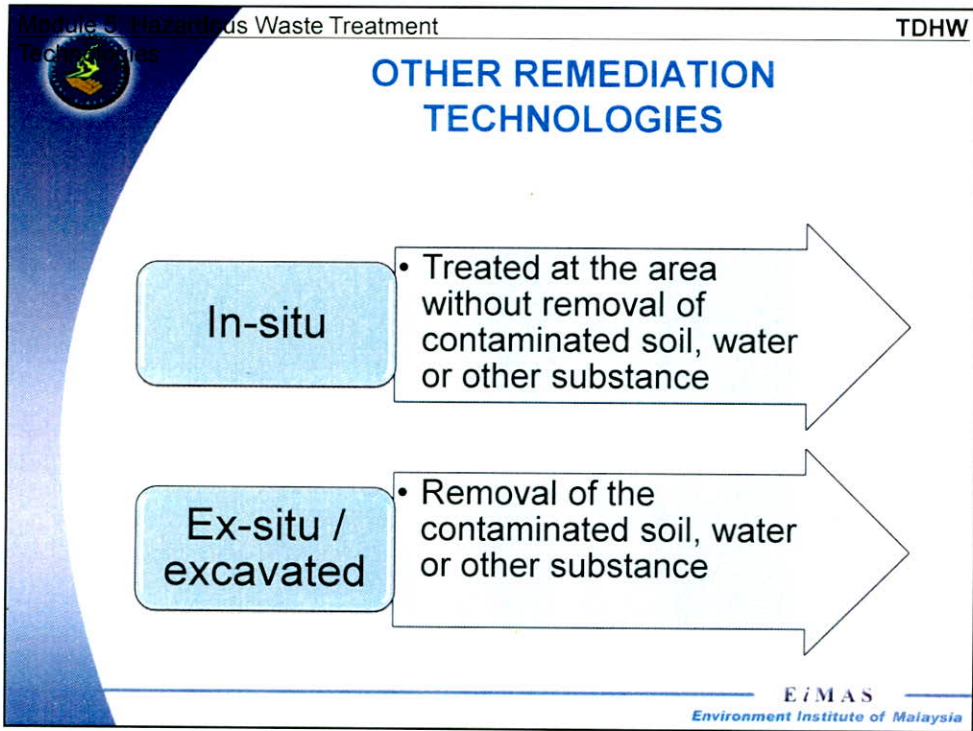
- ◆ Three (3) primary strategies used separately or in conjunction to remediate most sites are:
  - ▼ Destruction or alteration of contaminants
  - ▼ Extraction or separation of contaminants from environmental media
  - ▼ Immobilization of contaminants



## OTHER REMEDIATION TECHNOLOGIES

- ◆ Treatment method:





Module 5: Hazardous Waste Treatment TDHW

**Remediation treatment technologies profile**

| Treatment Method            | Media   |   |   |  |
|-----------------------------|---|---|---|--|
|                             | Soil, sediment, bedrock and sludge  |   | Ground water, surface water and leachate  |  |
|                             | In-situ   | Ex-situ   | In-situ   | Ex-situ  |
| Biological (bioremediation) | <ul style="list-style-type: none"> <li>• Bioventing</li> <li>• Enhanced Bioremediation</li> <li>• Phytoremediation</li> </ul>   | <ul style="list-style-type: none"> <li>• Biopiles</li> <li>• Composting</li> <li>• Landfarming</li> <li>• Slurry Phase Biological Treatment</li> </ul>  | <ul style="list-style-type: none"> <li>• Enhanced Bioremediation</li> <li>• Monitored Natural Attenuation</li> <li>• Phytoremediation</li> </ul>  | <ul style="list-style-type: none"> <li>• Bioreactors</li> <li>• Constructed Wetlands</li> </ul>  |
| Physico-chemical            | <ul style="list-style-type: none"> <li>• Chemical Oxidation</li> <li>• Electrokinetic Separation</li> <li>• Fracturing</li> <li>• Soil Flushing</li> <li>• Soil Vapor Extraction</li> <li>• Solidification/Stabilization</li> </ul> | <ul style="list-style-type: none"> <li>• Chemical Extraction</li> <li>• Chemical Reduction/Oxidation</li> <li>• Dehalogenation</li> <li>• Separation</li> <li>• Soil Washing</li> <li>• Solidification/Stabilization</li> </ul> | <ul style="list-style-type: none"> <li>• Air Sparging</li> <li>• Bioslurping</li> <li>• Chemical Oxidation</li> <li>• Directional Wells</li> <li>• Dual Phase Extraction</li> <li>• Thermal Treatment</li> <li>• Hydrofracturing Enhancements</li> <li>• In-Well Air Stripping</li> <li>• Passive/Reactive Treatment Walls</li> </ul> | <ul style="list-style-type: none"> <li>• Adsorption/Absorption</li> <li>• Advanced Oxidation Processes</li> <li>• Air Stripping</li> <li>• Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption</li> <li>• Ground Water Pumping/Pump and Treat</li> <li>• Ion Exchange</li> <li>• Precipitation/Coagulation/ Flocculation</li> <li>• Separation</li> </ul> |

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Module 5: Hazardous Waste Treatment TDHW

**Remediation treatment technologies profile**

| Treatment Method | Media   |  |  |         |
|------------------|---|--|--|---------|
|                  | Soil, sediment, bedrock and sludge                                    |  | Ground water, surface water and leachate |         |
|                  | In-situ   | Ex-situ  | In-situ                                  | Ex-situ |
| Thermal          | <ul style="list-style-type: none"> <li>• Thermal Treatment</li> </ul> | <ul style="list-style-type: none"> <li>• Hot Gas Decontamination</li> <li>• Incineration</li> <li>• Open Burn/Open Detonation</li> <li>• Pyrolysis</li> <li>• Thermal Desorption</li> <li>• Landfill Cap</li> <li>• Landfill Cap Enhancements</li> </ul> | -  | -       |

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Module 5: Hazardous Waste Treatment Technologies TDHW

## Biological Treatment Method

### In-situ biological treatment

- ◆ Advantages:
  - ✦ No need excavated and transported
  - ✦ Cost savings
- ◆ Disadvantages:
  - ✦ Requires longer time periods
  - ✦ Less certainty about the uniformity of treatment
- ◆ Examples:
  - ✦ 1. Bioventing
  - ✦ 2. Phytoremediation

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Module 5: Hazardous Waste Treatment Technologies TDHW

## Biological Treatment Method

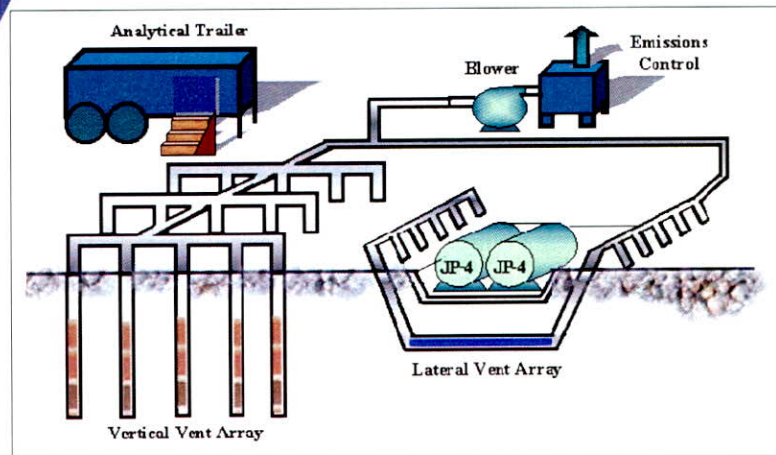
### 1. Bioventing

- ✦ Stimulates natural any aerobically degradable compounds in soil by providing O<sub>2</sub> to existing soil microorganisms
- ✦ Applicability:
  - Remediate soil contaminated with:
    - Petroleum hydrocarbons
    - Non-chlorinated solvents
    - Some pesticides
    - Wood preservative

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## Biological Treatment Method



Typical Bioventing System



## Biological Treatment Method

### 2. Phytoremediation

- ✦ Uses plants to remove, transfer, stabilize and destroy contaminants in soil and sediment
- ✦ Mechanism:
  - Enhanced rhizosphere biodegradation, phyto-extraction, phyto-degradation and phyto-stabilization
- ✦ Applicability:
  - Remediate metals, pesticides, solvents, explosives, crude oil, PAHs and landfill leachates



## Biological Treatment Method

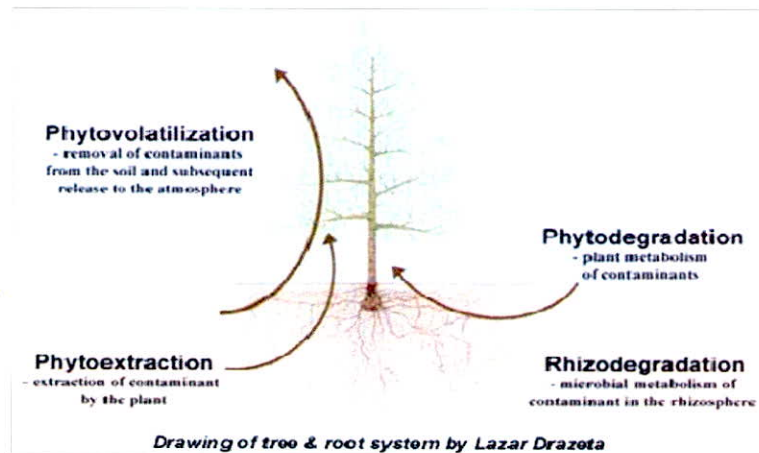


Illustration of a Processes involved in Phytoremediation



## Biological Treatment Method

### Ex-situ biological treatment

#### ◆ Advantages:

- ▼ Requires shorter time periods
- ▼ More certainty about the uniformity of treatment

#### ◆ Disadvantages:

- ▼ Requires excavation of soils (increased costs)

#### ◆ Examples:

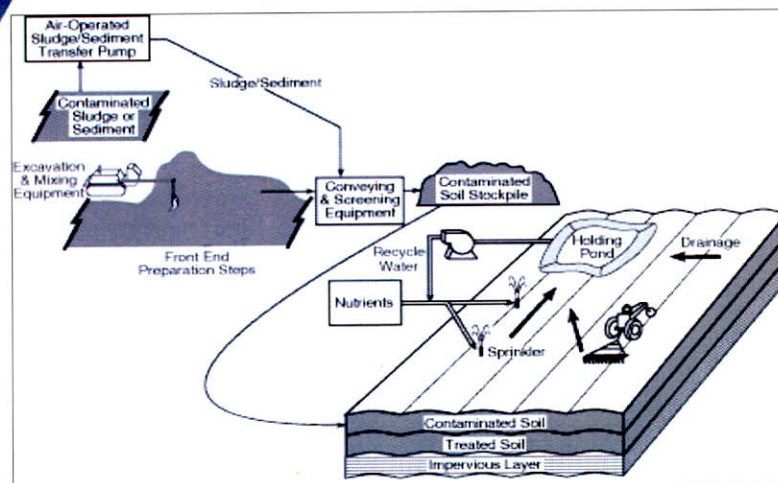
- ▼ 1. Biopile
- ▼ 2. Composting
- ▼ 3. Landfarming

## Biological Treatment Method

### 1. Biopile

- Excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration
- Short-term technology
- Applicability:
  - Treat non-halogenated VOCs and fuel hydrocarbons
  - Halogenated VOCs, SVOCs and pesticides

## Biological Treatment Method



Typical Biopile for Solid Phase Bioremediation



## Biological Treatment Method

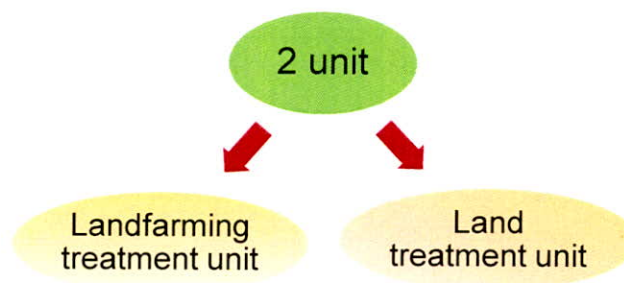
### 2. Composting

- ▼ Organic contaminants (e.g., PAHs) are converted by microorganisms to innocuous, stabilized byproducts
- ▼ Three (3) process designs
  - Aerated static pile composting
  - Mechanically agitated in-vessel composting
  - Windrow composting (most cost effective)
- ▼ Applicability :
  - Soils and lagoon sediments contaminated with biodegradable organic compounds



## Biological Treatment Method

### 3. Landfarming





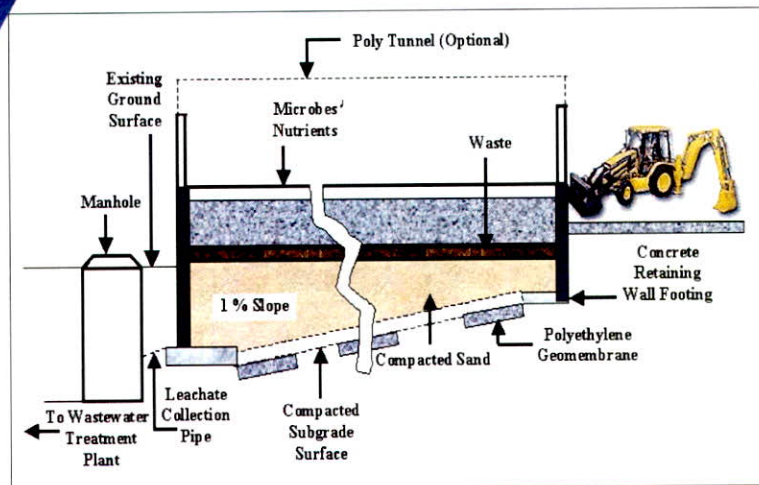
## Biological Treatment Method

- ◆ Landfarming treatment unit
  - Incorporates liners and other methods
  - Contaminated media is applied into lined beds and periodically turned over or tilled to aerate the waste
  - Applicability: treating petroleum hydrocarbons

In Malaysia, the DOE has phased out landfarming as technology for the treatment of scheduled wastes



## Biological Treatment Method

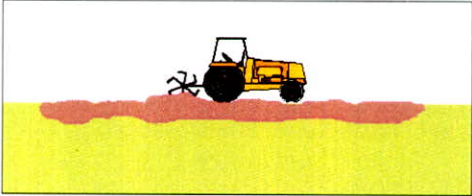


Typical Landfarming Treatment Unit

us Waste Treatment TDHW

## Biological Treatment Method

- ◆ Land treatment unit
  - ▼ Contaminated soils, sediments or sludges are turned over (i.e., tilled) and allowed to interact with the soil and climate at the site
  - ▼ Applicability: treating petroleum hydrocarbons



Typical Land Treatment Unit

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## Physico-Chemical Treatment Method

### In-situ Physico-Chemical Treatment

- ◆ Advantages:
  - ▼ No need excavated and transported
  - ▼ Cost savings
- ◆ Disadvantages:
  - ▼ Certain in-situ physico-chemical treatment technologies sensitive to certain soil parameters
- ◆ Examples:
  - ▼ Fracturing, soil flushing, soil vapour extraction, air sparging

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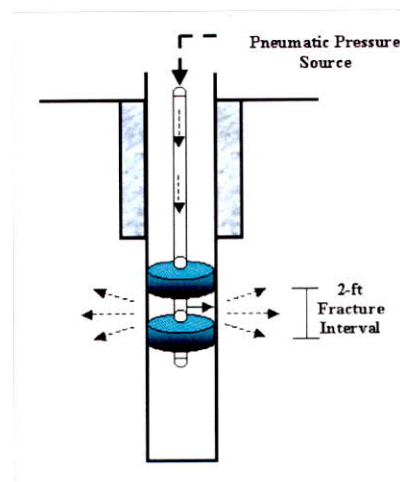
## Physico-Chemical Treatment Method

### Fracturing

- ▼ Increase the efficiency of other in situ technologies
- ▼ Technologies:
  - Pneumatic fracturing (PF)
  - Blast-enhanced fracturing
  - Lasagna™
- ▼ Applicability:
  - No particular target group
  - Primarily to fracture silts, clays, shale and bedrock



## Physico-Chemical Treatment Method



Typical Pneuematic Fracturing Process



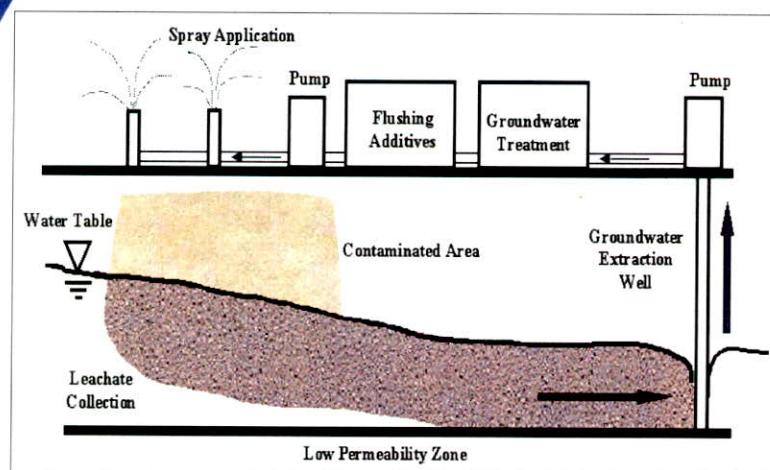
## Physico-Chemical Treatment Method

### Soil Flushing

- Extraction of contaminants from the soil with water
- Accomplished by passing the extraction fluid through in-place soils
- Extraction fluids then are recycled
- Applicability:
  - Inorganics including radioactive contaminants
  - Treat vocs, svocs, fuels, and pesticides



## Physico-Chemical Treatment Method



Typical Soil Flushing System



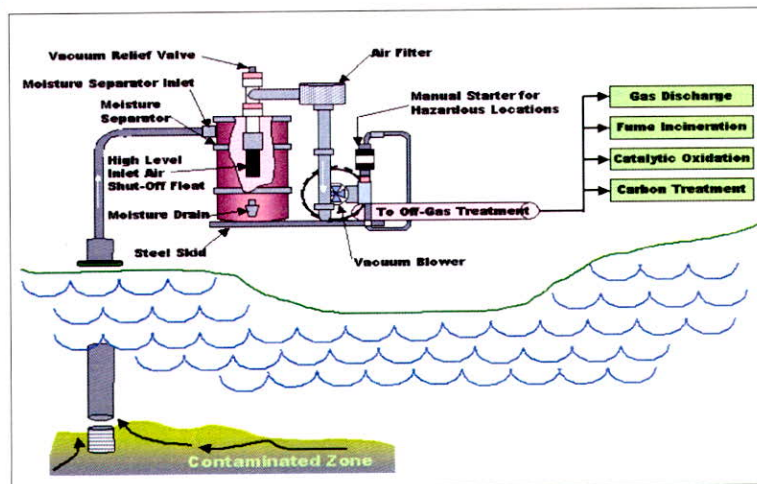
## Physico-Chemical Treatment Method

### Soil Vapour extraction

- ✦ In situ unsaturated (vadose) zone soil remediation technology
- ✦ Vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semi-volatile contaminants from the soil
- ✦ Applicability:
  - VOCs and some fuels
  - Will not remove heavy oils, metals, PCBs, or dioxins



## Physico-Chemical Treatment Method



Typical In-situ Soil Vapor Extraction System



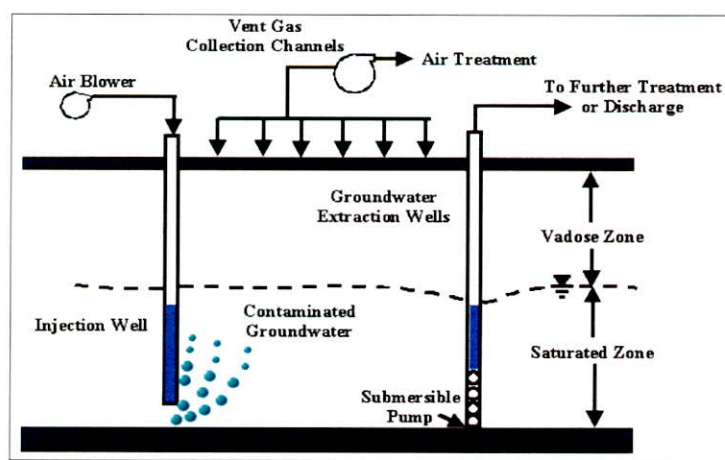
## Physico-Chemical Treatment Method

### Air Sparging

- ✦ Air is injected through a contaminated aquifer
- ✦ Injected air traverses horizontally and vertically in channels through the soil column,
- ✦ Removes contaminants by volatilization
- ✦ Vapor extraction system implemented in conjunction with air sparging
- ✦ Applicability:
  - VOCs and fuels



## Physico-Chemical Treatment Method



Typical Air Sparging System

## Physico-Chemical Treatment Method

### Ex-situ Physico-Chemical Treatment

- ◆ Advantages:
  - ▼ Shorter time periods
- ◆ Disadvantages:
  - ▼ Requires excavation of soils (increased costs)
- ◆ Examples.:
  - ▼ 1. Chemical Extraction
  - ▼ 2. Air Stripping
  - ▼ 3. Ion Exchange

## Physico-Chemical Treatment Method

### 1. Chemical Extraction

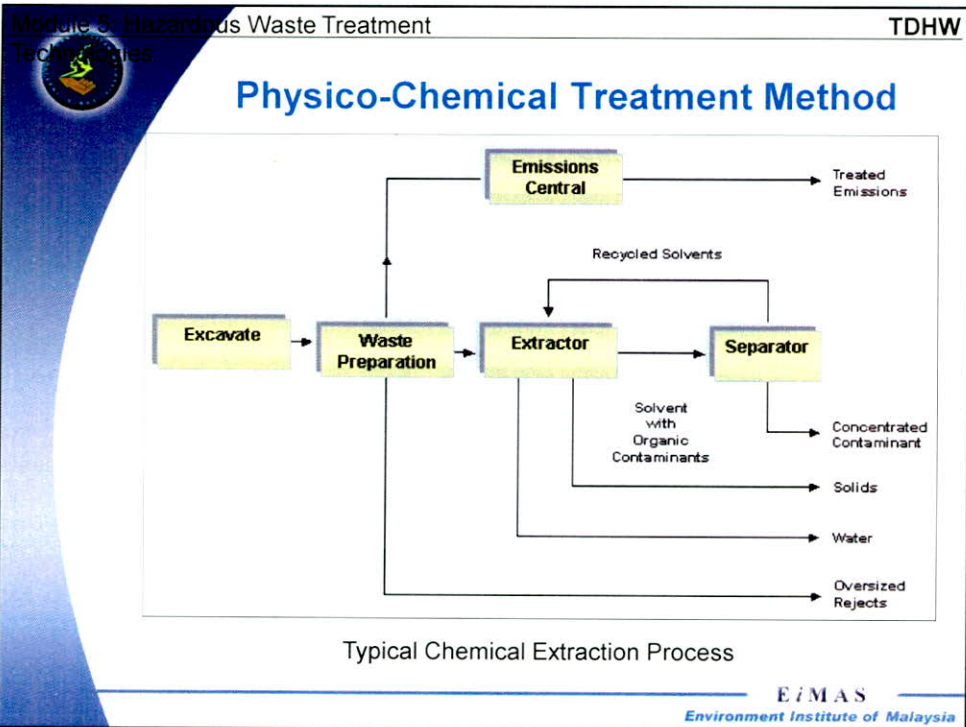
- ▼ Does not destroy wastes
- ▼ Separating hazardous contaminants from soils, sludges and sediments

#### Acid extraction

- Acid as extractant (HCL to extract heavy metal)
- Treat sediments, sludges and soils contaminated by heavy metals

#### Solvent extraction

- Organic solvent as extractant
- Treating sediments, sludges and soils containing organic contaminants (PCBs, VOCs, halogenated solvents, and petroleum wastes)



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## Physico-Chemical Treatment Method

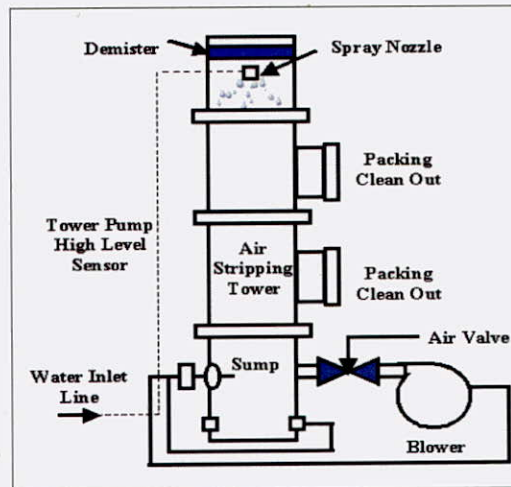
### 2. Air Stripping

- ✦ Volatile organics are partitioned from ground water by greatly increasing the surface area of the contaminated water exposed to air
- ✦ Types of aeration methods:
  - Packed towers
  - Diffused aeration
  - Tray aeration
  - Spray aeration
- ✦ Applicability:
  - Separate VOCs from water (BTEX, chloroethane, TCE, DCE, and PCE)
  - Ineffective for inorganic contaminants

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## Physico-Chemical Treatment Method



Typical Air Stripping System

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## Physico-Chemical Treatment Method

### 3. Ion Exchange

- Removes ions from the aqueous phase by the exchange of cations or anions
- Ion exchange materials consist of resins made from synthetic organic materials
- Resins can be regenerated for re-use
- Applicability:
  - Remove dissolved metals and radionuclides from aqueous solutions
  - Treated nitrate, ammonia nitrogen and silicate

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**Physico-Chemical Treatment Method**

The diagram illustrates the typical ion exchange and adsorption equipment through four stages:

- Service:** Raw Water enters from the top. The tank contains Mixed Resin. Treated water exits from the bottom.
- Backwash:** Raw Water enters from the bottom. The resin bed is inverted, with Anion resin on top and Cation resin on the bottom. Drainage occurs from the top.
- Simultaneous Regeneration:** Acid enters from the bottom and Alkali from the top. The resin bed is inverted, with Anion resin on top and Cation resin on the bottom. Drainage occurs from the bottom.
- Mixing:** Air enters from the bottom. The tank contains Mixed Resin. Air Out exits from the top.

Principle of mixed-bed ion exchange: (a) Service period; (b) Backwash period  
(c) Simultaneous Regeneration

Source: Chemical Engineer's Handbook, Perry and Chilton (5th Edition)

Typical Ion Exchange and Adsorption Equipment Diagram

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**Thermal Treatment Method**

**In-situ Physico-Chemical Treatment**

- ◆ **Advantages:**
  - ▼ No need excavated and transported
  - ▼ Offers quick cleanup times
- ◆ **Disadvantages:**
  - ▼ Requires longer time periods
  - ▼ Less certainty about the uniformity of treatment
  - ▼ Generally the most costly treatment group
- ◆ **Example:**
  - ▼ Thermal treatment

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## Thermal Treatment Method

### Thermal Treatment

- ▼ Thermally enhanced SVE - uses electrical resistance/electromagnetic/fiber optic/radio frequency heating or hot-air/steam injection
  - To increase the volatilization rate of semi-volatiles and facilitate extraction
- ▼ Process similar to standard SVE
- ▼ Applicability:
  - Effective in treating some pesticides and fuels



## Thermal Treatment Method

- ▼ Technology:
  - Electrical Resistance Heating
  - Radio Frequency/Electromagnetic Heating
  - Hot Air/Steam Injection

#### Electrical Resistance Heating

- Uses an electrical current to heat less permeable soils
- Six-phase soil heating (SPSH)

#### Radio Frequency/Electromagnetic Heating

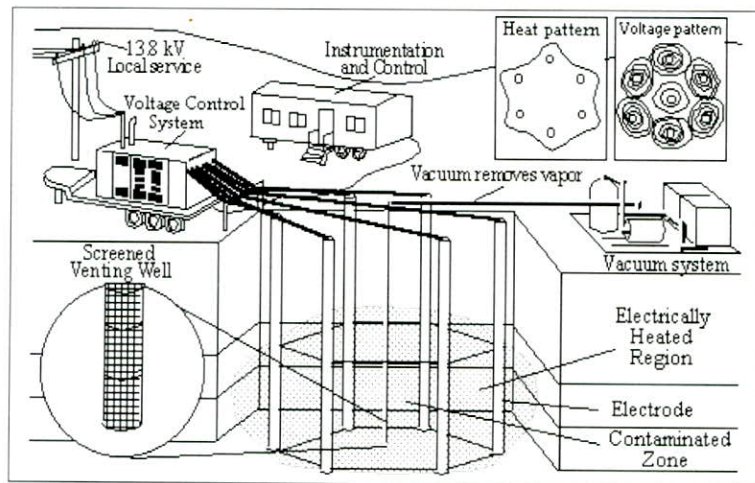
- Uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE)

#### Hot Air/Steam Injection

- Hot air or steam is injected below the contaminated zone to heat up contaminated soil
- The heating enhances the release of contaminants from soil matrix



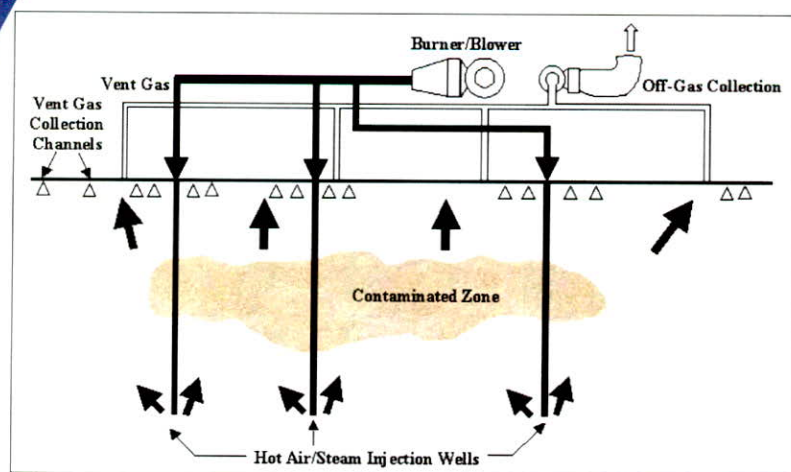
### Thermal Treatment Method



Typical Six-Phase Soil Heating System



### Thermal Treatment Method



Typical Hot Air Injection System



## Thermal Treatment Method

### Ex-situ Physico-Chemical Treatment

#### ◆ Advantages:

- ✦ Shorter time periods
- ✦ More certainty about the uniformity of treatment

#### ◆ Disadvantages:

- ✦ Requires excavation of soils (increased costs)

#### ◆ Examples:

- ✦ Open Burn/Open Detonation



## Thermal Treatment Method

### Open Burn/Open Detonation

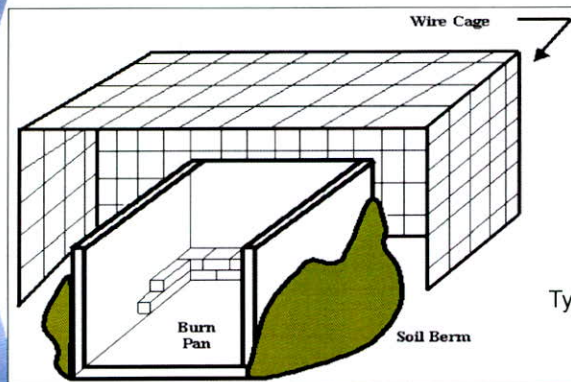
- ✦ OB - energetics or munitions destroyed by self-sustained combustion, ignited by an external source
- ✦ OD - detonatable explosives and munitions destroyed by a detonation, initiated by the detonation of an energetic charge
- ✦ Both can be initiated either by electric, burning, or energetic charge ignition systems



## Thermal Treatment Method

▼ Applicability:

- Destroy excess, obsolete, or unserviceable (EOU) munitions, components, energetic materials, media contaminated with energetic



Typical Open Burning Pan and Cage



# End of Module 5

## Thank You





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## TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

### **MODULE 6**

### **Hazardous Waste Disposal Technologies**

### **SLIDES (PESERTA)**



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# TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

## MODULE 6: Hazardous Waste Disposal Technologies




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### Contents

- ◆ Introduction
- ◆ Purpose
- ◆ Secure Landfill/Specially Engineered Landfill
- ◆ Leachate Management
- ◆ Other Disposal Technologies

us Waste Disposal TDHW




## Introduction

- ◆ There will always remain residues of hazardous wastes for some material that have to be disposed of after they have been treated, destructed and immobilized
- ◆ Land disposal is used for as much as 80% of regulated hazardous waste
- ◆ Other technologies such as surface impoundments, deep wells injection also be applied in some countries

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## Purpose

- ◆ To provide participants with:
  - ▶ Technical guidelines and information of hazardous waste disposal facilities
  - ▶ Guidance and options for the selection of the appropriate waste disposal technology

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Module 6: Hazardous Waste Disposal Technologies TDHW



**SECURE LANDFILL/SPECIALLY ENGINEERED LANDFILL**

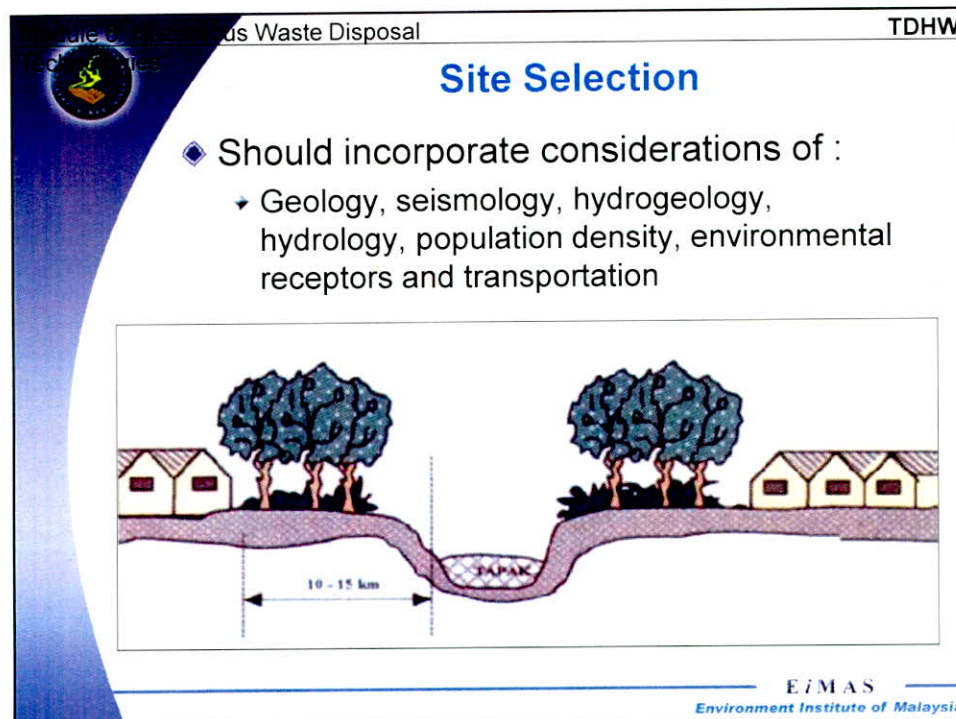
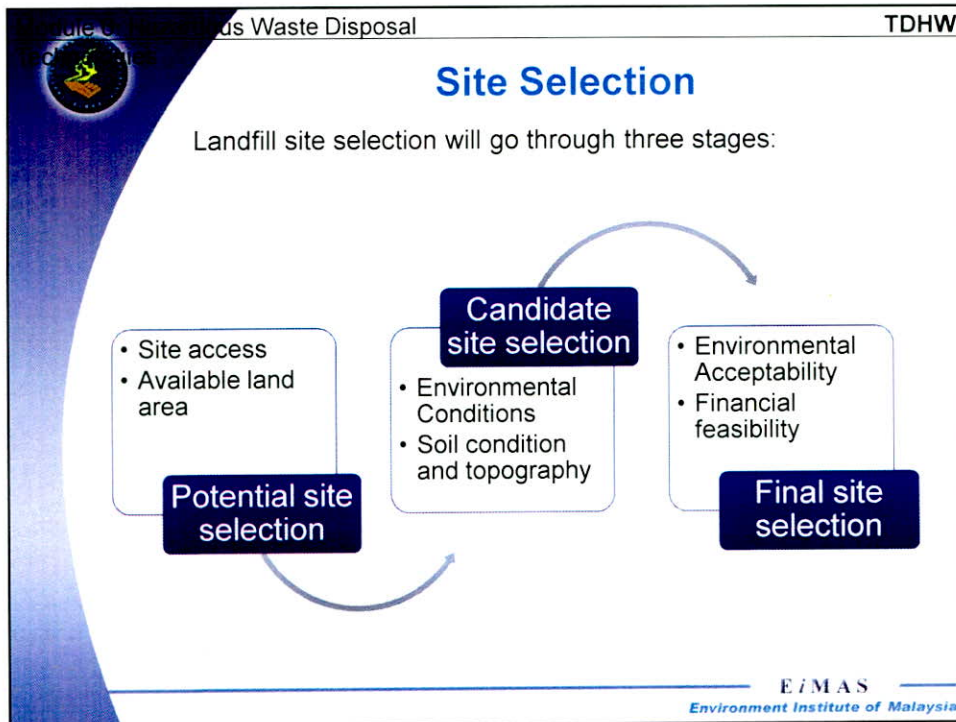
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Module 6: Hazardous Waste Disposal Technologies TDHW

### Introduction

- ◆ Defined as a system designed and constructed to contain discarded waste so as to minimize releases of contaminants to the environment
- ◆ In Malaysia, the operations of secure landfill facility will require the following three-step approvals from the DOE:
  - Environmental Impact Assessment (EIA) study
  - Written Permission to construct the facility
  - Operating License to operate the facility

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Solid Waste Disposal TDHW

## Design Considerations

- ◆ General design consideration for secure landfill

The diagram illustrates a multi-layered landfill design. From top to bottom, the layers are: Final Landfill Surface (with runoff control), Top Cover Soil, a Geomembrane made of Low Density Poly-Ethylene (LDPE), a layer of Vegetation, a Geotextile/Geonet, a 2M Geomembrane made of High Density Poly-Ethylene (HDPE), and a 1M Compact Clay Liner. Treated waste residues are placed in the center. Leachate is collected by pipes leading to a sump. Groundwater monitoring wells are placed on both sides, and runoff drains are located on the surface.

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Solid Waste Disposal TDHW

## Design Considerations

- ◆ Cover liner system

The diagram shows a 'Cover' system and a 'Liner' system. The 'Cover' consists of a vegetative cover, top soil to support the vegetation, a drainage layer, a membrane layer, and a clay layer. The 'Liner' system includes a filter, stone/gravel leachate collection layers, a drainage system, and a clay layer. A height of 5-6 meters is indicated for the cover.

Contaminated soil accepted at secure landfills is stored in a series of "blocks", with each block made up of "cells"

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Waste Disposal TDHW

## Design Consideration

### Leachate Generation

- Is a harmful liquid that collects at the bottom of a landfill
- Can be toxic, acidic, and rich in organic acid groups

### Disposal of Leachate

- Can be disposed of in three ways
  - To sewer
  - To river/water course
  - By road tanker to an alternative treatment site

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Waste Disposal TDHW

## Design Consideration

### Composition of Leachate

- Varies greatly from site to site and can vary within a particular site
- Due to age of landfill, climate/seasonal, type of waste deposited into landfill

### Option for Leachate Management

- Discarded to a wastewater treatment plant
- Built an on-site leachate treatment plant
- Build a pretreatment system and discharge to an off-site wastewater treatment plant
- Develop system for managing leachate on site

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us Waste Disposal TDHW

## Treatment Process Selection

◆ Usually leachate produced contains:

- ▶ Low pH values
- ▶ High BOD<sub>5</sub> and COD values
- ▶ Several other toxic/hazardous compounds

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us Waste Disposal TDHW

## Treatment Process Selection

| Method           | Description   | Example Process  |
|------------------|---|--|
| Biological       | Use of microorganisms to degrade organic and nitrogenous matter from young leachates                          | <ul style="list-style-type: none"> <li>•Activated sludge (most preferred)</li> <li>•The rotating biological contractor (RBC)</li> <li>•Sequencing batch reactor (SBR)</li> <li>•Reed beds</li> </ul> |
| Physico-chemical | Achieve by the oxidation of contaminants with chemicals after which physical separation processes are applied | <ul style="list-style-type: none"> <li>•Coagulation-flocculation</li> <li>•Precipitation</li> <li>•Adsorption</li> <li>•Flotation</li> <li>•Chemical oxidation and advance process (AOP)</li> </ul>  |

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### Treatment Process Selection

| Method                                   | Description  | Example Process  |
|--|--|--|
| Combined Biological and Physico-chemical | Achieve better result due to high content of $\text{NH}_4^+\text{-N}$ and COD          | <ul style="list-style-type: none"> <li>•Using an activated sludge plant after a photochemical oxidation</li> <li>•Combined with adsorption onto powdered activated carbon (PAC) (COD removal)</li> </ul> |
| Membrane Technology                      | Separation of two solutions with different concentrations by a semi permeable membrane | <ul style="list-style-type: none"> <li>•Microfiltration (MF);</li> <li>•Ultra filtration (UF);</li> <li>•Nanofiltration (NF);</li> <li>•Reverse Osmoses (RO)</li> </ul>                                  |

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### Performance Monitoring

- ◆ To check the performance of the engineered system and to determine the nature and interaction of the wastes in the engineered hazardous waste landfill facility
- ◆ To determine the system complies with the operating license conditions issued by the DOE

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## Performance Monitoring

### Leachate Collection System

- To compare the leachate pressure in the system with the design values
- Divided into three general areas:
  - Collection and leak detection specifications
  - Alternative designs
  - Operation of detection and collection systems

### Leak Detection and Recovery System

- Install between each pair of liner systems
- To check the amount of leakage and the ongoing performance of the primary liner

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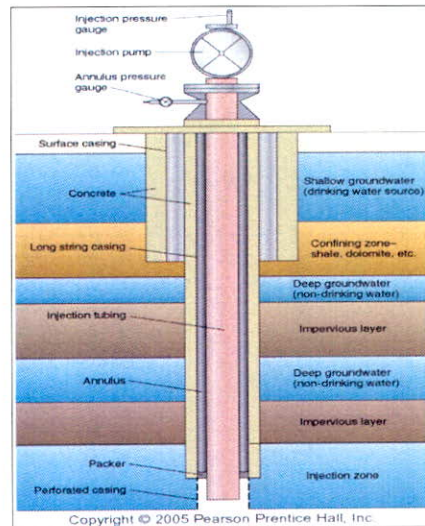
## OTHER DISPOSAL TECHNOLOGIES

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## Deep Well Injection

- ◆ Liquid waste disposal technology
- ◆ Place treated or untreated liquid waste into geologic formations that have no potential use
- ◆ Has been applied mostly in U.S



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## Deep Well Injection

| Elements        | Description  |
|-----------------|--|
| Well Siting     | <ul style="list-style-type: none"> <li>•Thick saline-water bearing injection interval</li> <li>•Thick overlying and underlying strata</li> <li>•Absence of solution-collapse features, faults</li> </ul> |
| Types of Wastes | Chemical manufacturing wastewaters, Leachate, Metal plating and galvanizing solutions, Waste pickle liquor (acids)   |
| Equipment Used  | <ul style="list-style-type: none"> <li>•Sump tank</li> <li>•Oil separator</li> <li>•Clarifier</li> <li>•Filter</li> <li>•Clear-waste tank</li> <li>•Chemical treater</li> <li>•Injection pump</li> </ul> |

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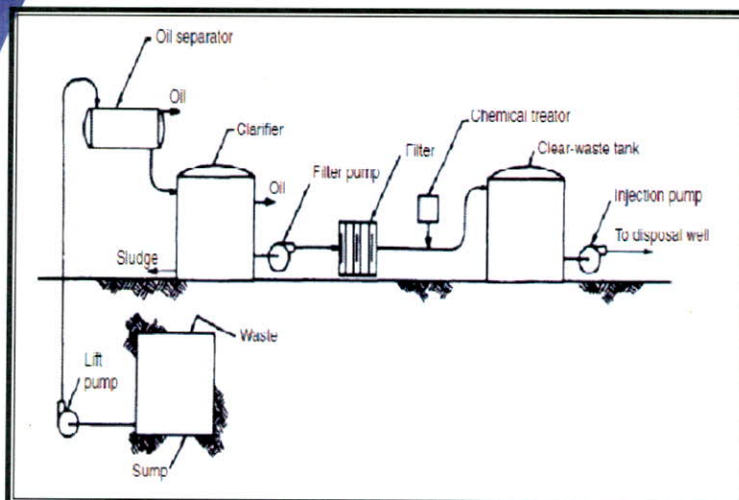
## Deep Well Injection

| Elements | Description  |
|----------|--|
| Process  | Partition processes<br>Transformation processes<br>Transport processes   |
| Impact   | Can occur by:<br><ul style="list-style-type: none"> <li>•Lateral migration of acid wastes to existing unplugged dry holes or producing wells</li> <li>•By vertical migration through the subsurface aquifer due to mechanical failure or geologic fault line shifting</li> </ul> |



## Deep Well Injection

Surface Equipment for Disposal System



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## Special Management

Reduce the quantity of waste by identifying the characteristics of the waste

- Corrosivity.
- Ignitability.
- Toxicity
- Reactivity.
- Infectious

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## Special Management

### Benefits

- Reduce to the maximum extent practicable waste generation using the best practicable means
- Keep an up-to-date inventory of wastes generated, treated and disposed of
- Waste can be stored, recovered and treated on-site or off-site by using other non-hazardous waste facility

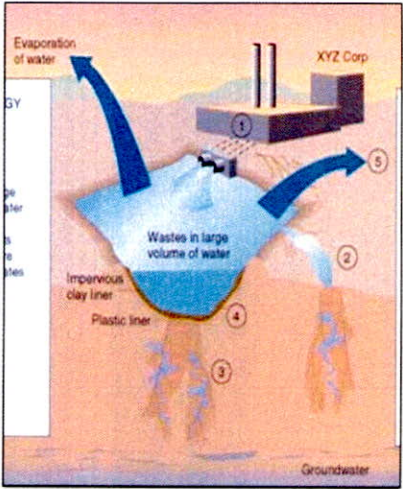
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## Surface Impoundments

Used by many industrial sectors, such as:

- Manufacturing
- Bulk petroleum storage
- Air and truck transportation
- Waste management in order to treat liquid hazardous wastes, slurries and sludges



The diagram illustrates a surface impoundment system. At the top, a building labeled 'XYZ Corp' is shown with a pipe leading to a large blue pool of 'Wastes in large volume of water'. An arrow labeled 'Evaporation of water' points upwards from the surface. Below the waste pool, there are two containment layers: an 'Impervious clay liner' and a 'Plastic liner'. Below these layers, the 'Groundwater' is shown. A blue arrow labeled '2' points from the waste pool towards the right, and another blue arrow labeled '5' points from the right side of the pool towards the right. A blue arrow labeled '4' points from the bottom of the pool towards the bottom right. A blue arrow labeled '3' points from the bottom of the pool towards the bottom left.

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## Surface Impoundments

| Elements             | Descriptions  |
|----------------------|---|
| Types of wastes      | Waste acids and rinse water with traces of propellant   |
| Disposal Constraints | Located in a hydro geologic setting that limits vertical and horizontal hydraulic continuity with ground-water              |
| Procedures           | Decanting; Pumping and settling; Solar drying; Chemical neutralization; Infiltration; Process reuse; Addition of Absorbents |

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## Surface Impoundments


| Elements        | Descriptions   |
|-----------------|--|
| Design Elements | <ul style="list-style-type: none"> <li>•Double liners with a leak detection system and monitoring wells</li> <li>•Prevention of over-topping the sides of the impoundment</li> <li>•Construction specifications</li> </ul>   |
| Closure         | <p>Can be closed in one of two ways:</p> <ul style="list-style-type: none"> <li>•Removing or decontaminating all wastes, waste residues, system components (such as liners), subsoil and structures or equipment</li> <li>•Removing liquid waste or solidifying the remaining waste</li> </ul> |

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# End of Module 6

## Thank You



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## TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

### **MODULE 7**

## **Hazardous Waste Facilities Operations and Maintenance**

### **SLIDES (PESERTA)**



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# TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

## MODULE 7: Hazardous Waste Facilities Operations and Maintenance



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## Contents

- ◆ Introduction
- ◆ Purpose
- ◆ Hazardous Waste Facilities Siting
- ◆ Hazardous Waste Reutilization and Recycling Facilities
- ◆ Waste Recovery and Reclamation Facilities
- ◆ Hazardous Waste Treatment Disposal Facilities



## Introduction

- ◆ Malaysian government through the Department of Environment was aware of the need to set up proper hazardous waste treatment and disposal facilities
- ◆ The government has been promoting the establishment of environmentally sound recovery, treatment and disposal facilities
- ◆ The facilities are required to support the development of industries and the enforcement of legal provisions on scheduled wastes





## Purpose

To provide participants with:

- ◆ Guidance for the establishment, operations and maintenance of the hazardous waste treatment and disposal facilities
- ◆ Guidelines for the licensing requirements of hazardous waste facilities

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## HAZARDOUS WASTE FACILITIES SITING

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## HAZARDOUS WASTE FACILITY SITING

- ◆ Facility:
  - Contiguous land, structures
  - Used for sorting, recovering, recycling, treating or disposing of hazardous waste
- ◆ Hazardous waste facility:
  - Comprise storage, recovery, treatment stages and final disposal
  - Need proper management and supervision
  - Any discharges to be very closely controlled and monitored

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**HAZARDOUS WASTE FACILITY SITING**

**On-site facility** - Generators constructed and operated their own captive facilities

**Off-site facility** - Collected and transported waste to specialized off-site facilities for treatment and disposal

◆ Fundamental consideration in licensing

- ▶ Prevent unacceptable emissions to land, air or water
  - By management and control systems for the site or plant

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**HAZARDOUS WASTE FACILITY SITING**

```

    graph TD
      WG[Waste generation] --> RR[Recovery/Recycling]
      WG --> T[Treatment]
      WG --> LD[Land disposal]
      RR --> P[Products]
      RR --> R1[Residuals]
      R1 --> T
      T --> R2[Residuals]
      R2 --> LD
  
```

**Waste generation**

**Recovery/Recycling**

- Solvent recovery
- Fuel blending
- Metal recovery
- Oil recovery
- Energy recovery

Products

Residuals

**Treatment**

- Thermal destruction
- Aqueous treatment
- Stabilization
- Biological treatment

Residuals

**Land disposal**

- Landfill
- Deep well injection

Hazardous waste recovery, treatment and disposal facilities

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## HAZARDOUS WASTE FACILITY SITING

- ◆ Recovery/recycling facilities:
  - Recover material as a salable product (typically solvents, oils, acids or metals)
- ◆ Treatment facilities:
  - Change the physical or chemical characteristics of a waste, by physical, chemical, thermal or biological methods
- ◆ Land disposal facilities:
  - Permanent emplacement of waste on or below land surfaces



## Relevant Regulatory Requirements


### ◆ Relevant Sections, Regulations and Orders:

|                                       |   |
|---------------------------------------|---|
| • <b>Prescribed Activities No. 18</b> | : Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987 – Waste Treatment and Disposal                     |
| • <b>Section 19</b>                   | : Environmental Quality Act 1974 – Prohibition against causing Vehicle, Ship or Premises to become Prescribed Conveyance or Prescribed Premises |
| • <b>Regulation 4</b>                 | : Environmental Quality (Industrial Effluent) Regulations 2009 – Obligation to Notify the Director General                                      |
| • <b>Order 3</b>                      | : Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Order 1989 Prescribed Premises               |
| • <b>Section 18</b>                   | : Environmental Quality Act 1974 – Prescribed Premises to be Licensed   |
| • <b>Section 13</b>                   | : Environmental Quality Act 1974 – Duration and Renewal of Licenses   |

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## Relevant Regulatory Requirements

- ◆ Licensing of prescribed premises involves a four-stage processing approvals:
  - Planning approval from the relevant local authority under the requirements of Section 20 of EQA 1974
  - EIA Study and Report Approval
  - Written Permission Approval
  - Operating Licence Approval (After Pre-licensing Inspection)



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## Site Selection

- ◆ Principle of Siting
  - Requires a synthesis of two distinct selection procedures
    - A technical screening process
    - Public-approval process
- ◆ Site Suitability
  - Characteristics of the facilities
  - Economic and legal feasibility
  - Characteristics of the site

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## Site Selection

### Facilities Characteristics


- Suitability and the acceptability
- Purpose
- Effectiveness
- Resource requirements and impacts
- Scale

### Economic and Legal Feasibility

- Provide satisfactory benefits
- Satisfy permit and site-approval requirements

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## Site Selection

### Site Characterisation

|                  |                            |
|------------------|----------------------------|
| <b>Level I</b>   | • Exclusion areas          |
| <b>Level II</b>  | • Favourable areas         |
| <b>Level III</b> | • Site-Specific Trade-offs |

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## Site Selection

### Level I: Exclusion Areas

- Flood-hazard areas and wetlands
- Public water supply watersheds
- Groundwater aquifers, wellfields, recharge areas
- Designated state and national parks, forests, natural and historic areas, wildlife refuges
- Seismic-risk zones
- Sites too small for proposed facility

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## Site Selection

### Level II: Favourable Areas

- Sites of existing facilities
- Sites designated for industrial use
- Sites in major generator states/countries
- Sites close to major transportation routes
- Public lands available for this use

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## Site Selection

### Level III: Site-Specific Trade-offs

- Geology (depth to bedrock, solids vs. fractured)
- Soils (permeability, pH, etc.)
- Groundwater (water-table depth, quality)
- Surface water (flow, quality)
- Air (non-attainment areas)
- Ecological habitats
- Transportations access, utilities
- Special site considerations (ownership, archaeology, history)
- Surrounding and downstream land uses
- Population density

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## Site Selection

- ◆ Site acceptability
  - ▶ Two steps:
 

{

Substantive information concerning potential impacts

Willingness to engage in an open process of communication and negotiation with the host community
  - ▶ Information:
 


Environmental impacts

Socioeconomic impacts

Impact prevention, mitigation and compensation

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## Site Selection

### Environmental Impacts

- Potential effects:
  - Ecological processes
  - Human health
  - Esthetics of the natural and cultural landscape
- Impacts depend on:
  - Volumes and types of wastes
  - Design and operation of the facility
  - Location and characteristics of the site, especially the pathways

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## Site Selection

### Examples of Potential Environment Impacts

- Groundwater contamination
- Surface-water contamination
- Air pollution
- Leaks, spills, accidents
- Destruction of wildlife habitat, natural areas, wetlands
- Loss of any unique site features (e.g. archaeological)
- Permanent contamination of site
- Traffic congestion
- Odors
- Noise
- Visual ugliness
- Effects on character of community: magnet for other heavy industry, image as dumping ground

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## Site Selection

### Socioeconomic Impacts

- Cost of proposal review (technical and legal)
- Employment and income (plus secondary services)
- Purchases of goods and services (capital and annual)
- Public-service demands (water, sewer, energy, etc.)
- Payments to local government (property taxes; gross-receipt taxes, tipping fees, etc.)
- Transportation-related values
- Effects on property values
- Monitoring and inspection
- Emergency response
- Closure and postclosure care (monitoring and management loss of taxes from site cleanup)

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## Site Selection

### Impact prevention, Mitigation and Compensation

- ◆ Preventive measures
  - E.g.: monitoring and ongoing local oversight
  - Help to keep an adverse impact from occurring

- Natural barriers (site selection)
- Engineered safeguards (facility design)
- Safeguards in operating procedures
- Financial assistance for community's technical review of proposal
- Monitoring (on-site and off-site)
- Training of inspectors and monitoring professionals
- Ongoing local oversight of plant operations

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## Site Selection

### ◆ Mitigative measures

- E.g.: funds for road maintenance
- Serve to reduce or reverse an adverse impact

- Emergency response capability
- Road construction and maintenance
- Payments to community for water supply, wastewater treatment, energy use, extra security services
- Siting agreements allowing renegotiation of operating practices if adverse impacts occur



## Site Selection

### ◆ Compensatory measures

- E.g.: property-value guarantees
- Provide one type of benefit in exchange for a benefit lost or potentially lost

- Liability insurance
- Payments to finance post-closure perpetual care of site, and in lieu of future taxes foregone
- Property value guarantees, other guaranteed compensation
- Provision of parks and open spaces
- Discounted or free local waste disposal



## Environment Impact Assessment

- ◆ EIA is a mandatory legal requirement for all Prescribed Activities under:

Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987




## Environment Impact Assessment

- ◆ Five Prescribed Activities under EIA Order, 1987

### **Prescribed Activities No. 18 – Waste Treatment and Disposal**

- a) Toxic and Hazardous Waste
  - i. Construction of incineration plant
  - ii. Construction of recovery plant (off-site)
  - iii. Construction of wastewater treatment plant (off-site)
  - iv. Construction of secure landfill facility
  - v. Construction of storage facility (off-site)

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## Written Permission Approval and Conditions

- ◆ **Written Permission Approval**
  - Required before any construction or start-up operation can begin
  - Imposes conditions relating to the design and construction of a facility
- ◆ **After the facility has been constructed, it is inspected for**
  - Conformance with the written permission approval conditions
- ◆ **Pre-licensing visit**
  - To ensure that the treatment and disposal facility had been constructed according to the drawing/plan submitted to DOE

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## Operating License and Conditions

- ◆ **Operating license**
  - Required before a facility/conveyance can be operated
  - Issued with specific set of conditions pertaining to operations and maintenance of the facilities
  - Issued on confirmation that the facility conforms to the conditions of Written Permission
  - Based on the pre-licensing visit and full compliance to all the conditions

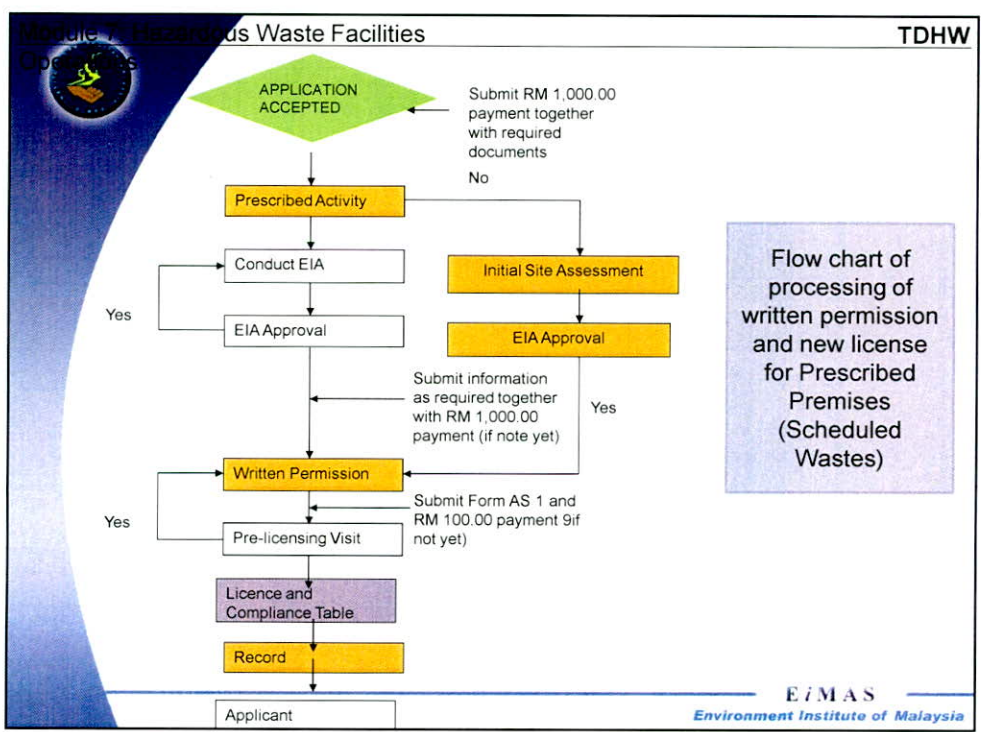
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**Planning Permission Approval and Conditions**

- ◆ Applicant of the prescribed premise must:
  - Obtain planning permission approval from the relevant local planning authority under the requirements of Section 20, EQA 1974 before EIA can be conducted.
  - EIA must be conducted and the report to be approved by the DOE before obtaining the written approval and the facility can be constructed.

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## Licensing Requirements


Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Order, 1989

- ◆ Prescribed premises to have licences to operate:
  - Off-site storage facilities
  - Off-site treatment facilities
  - Off-site recovery facilities
  - Scheduled waste incinerators
  - Land treatment facilities
  - Secure landfill facilities



## COLLECTION, TRANSPORTATION, HANDLING AND STORAGE

Module 7: Hazardous Waste Facilities TDHW




## Collection

- ◆ Waste Generator responsibilities
  - Identify, classify and pack wastes in accordance with EWSQR 2005
  - Store and handle wastes that have potential for reuse or reclamation separately
  - Wastes should be mixed only to the extent that they are suitable to the same types of treatment
  - Segregate wastes if they are incompatible

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## Collection

- ◆ Objectives of waste segregation:
  - To reduce hazard due to mixing, if any (waste-waste compatibility)
  - To achieve dedicated treatment of special wastes
  - To avoid interference and adverse effects on other treatment processes due to presence of any hindering waste type
  - To achieve better control if material recovery is the objective of technology

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## Collection

- ◆ Rules of thumb for waste mixing and segregation

### Within industry

- Hazardous and non-hazardous wastes should not be mixed
- If possible, isolate waste streams on the basis of contaminants (e.g. solvent, metal streams)
- Do not mix two phases of wastes, e.g., if the waste is dry solid do not make it aqueous



## Collection

### Within treatment and disposal facility

- On the basis of waste-waste compatibility
- Liquid streams could be segregated as follows:
  - Those not requiring any pretreatment
  - Acidic wastes (with or without heavy metals)
  - Acidic wastes with phenol
  - Acidic wastes with hexavalent chrome
  - Acidic wastes with emulsified petroleum hydrocarbons
  - Alkaline wastes with organics / oily wastes
  - Alkaline wastes with cyanide
  - Sludges with heavy metals
  - Sludges with toxic organics



## Collection

### ◆ Packaging

- Pack in standard containers for transportation
- Proper packaging is vital for safe transportation and handling of hazardous waste
- Waste generator shall be responsible for the compatibility, correct packaging, labeling and transportation of the wastes as stated in the EQSWR 2005



## Collection

### Selection of Packaging Containers by Waste Type

| Waste type  | Packaging container  |
|---|--|
| <ul style="list-style-type: none"> <li>• Liquid organic/inorganic waste</li> </ul>        | <ul style="list-style-type: none"> <li>• Bung hole drum (steel/plastic) or plastic pallet tank with stopper</li> </ul> |
| <ul style="list-style-type: none"> <li>• Liquid organic/inorganic waste</li> </ul>        | <ul style="list-style-type: none"> <li>• Open top drums (steel/plastic) with covers and clamp</li> </ul>               |
| <ul style="list-style-type: none"> <li>• Dry solid waste and contaminated rags</li> </ul> | <ul style="list-style-type: none"> <li>• One-tonne PP bags</li> </ul>  |
| <ul style="list-style-type: none"> <li>• Pharmaceutical and laboratory waste</li> </ul>   | <ul style="list-style-type: none"> <li>• Open top drums (steel or plastic) with cover and clamp</li> </ul>             |

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## Collection

- ◆ Labeling
  - ▶ Marking of containers such as:
    - Date of waste generation, name of the company, address, telephone number and waste category code
  - ▶ Third Schedule, Regulation 10 of the EQSWR 2005
    - All old markings and labels should be removed
    - Mark the DOE Classification Code and Consignment Note Serial Number with the Trip Number on the top and side of each container
    - The danger/warning label corresponding to the type of waste should be pasted on the container

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## Collection

- ◆ Collection procedure
  - ▶ Consists of the following steps:
    - Ensure the containers are not leaking and the contents are identified
    - Identify the hazard category of the waste
    - Document the type, amount and destination of the waste
    - Ensure the information on Part I and Part II of the consignment note have been filled-up and signed by the waste generator and the contractor
    - Ensure four copies of the consignment note and the waste information are always with the waste packages

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## Transportation

- ◆ Two phases of waste transportation:
  - Waste generator → hazardous waste treatment facility
  - Waste treatment facility → disposal facility
- ◆ To activate waste collection:
  - Waste generator to sign Scheduled Waste Transportation and Treatment Agreement with the treatment facilities
  - To fill-up consignment note document as in Sixth Schedule, Reg. 12, EQSWR 2005 (Use e-consignment note if applicable)

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## Transportation

- Waste generator to provide Waste Information under Seventh Schedule of Reg. 13, EQSWR 2005
- Special training is required for all drivers
- Transportation routes are designated and approved by DOE
- Transporter and generator shall be responsible for any spillage and accidents
- Transporter shall notify the Director General of the DOE immediately in case of accidental discharge or spillage during transportation

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Operations

## Transportation

### Requirements for Off-Site Transportation

|                                      |   |
|--------------------------------------|---|
| 1. Container                         | To be of appropriate leak-proof material with mechanical stability  |
| 2. Labeling of the container         | To identify the waste, describe the possible hazard, and the remedial measures / first aid required in case of accidental spills  |
| 3. Transportation vehicle            | To identify the waste displaying the possible hazard, the remedial measures / first-aid required in case of accidental spills, telephone number of the contact person / controlling agency in case of emergency etc. Through labeling |
| 4. Collector / transporter selection | To have technical competence and relevant skills and other requirements   |
| 5. License / manifest                | To carry application and 'No Objection Certificate' documents   |
| 6. Emergency procedures              | To have knowledge about actions to be taken in case of spills or accidents  |
| 7. Fees and fines                    | To be paid for not having license, or not abiding by the regulations  |





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Operations

## Transportation

### Hazardous Waste Transportation In Malaysia

|  |   |
|--|---|
|  <p>Name: 1 Tonner<br/>Load: Max. 1 – 2 pallets</p> |  <p>Name: 20 Tonner<br/>Load: Min. 18 pallets</p> |
|  <p>Name: 3 Tonner<br/>Load: Min. 3 pallets</p>     |  <p>Name: Skip bin<br/>Load: 7 tones</p>          |

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## Transportation



Name: 8 Tonner  
Load: Min. 10 pallets



Name: Tipper truck  
Load: Min. 7 – 10 tones



Name: 12 Tonner  
Load: Min. 12 pallets



Name: IMO Tank  
Load: Min. 18 tones



## Handling and Storage

### Handling

#### ◆ Reception at Waste Treatment Facility

Weight of the vehicle together with its content



Unloaded at the holding/inspection area



Inspection and sampling by Waste Inspection  
and Sampling Team





## Handling and Storage

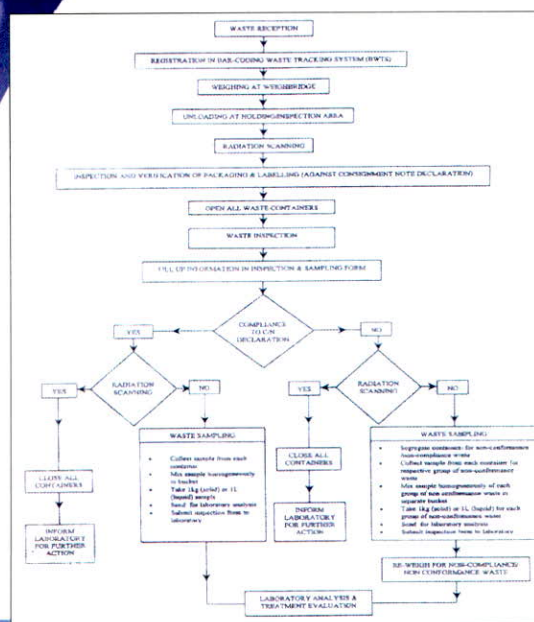
Waste containers will be bar-coded and locked into treatment facility Bar-coded Waste Tracking System



Waste consignment shall be transferred to a temporary storage



Waste then be treated and its residues are finally disposed of at secure landfill facility



Example of the Flow Chart for Reception, Inspection and Sampling of Hazardous Wastes Received at Waste Treatment Facility



## Handling and Storage

### Storage

#### ◆ Waste-waste Compatibility

- Stored separately in accordance with the Fourth Schedule, Reg. 2, EQSWR 2005
- "No Smoking" signs must be placed where ignitable and reactive wastes are stored
- Fenced and always locked when not in use



## Handling and Storage

#### ◆ When storing indoor

- Keep containers closed except when adding or removing wastes
- Ensure all containers are closed at the end of the business day
- Secure all bungs, lid rings, or lever-locks
- Place containers holding liquids on a surface impermeable to that particular waste
- Provide enough aisle space for easy access and visible inspections



## Handling and Storage



- Inspected at least weekly to ensure they are not leaking
- Separate incompatible wastes with at least a 10-foot distance
- Store wastes in an area without floor drains
- Keep waste containers away from equipment routes to prevent incidents
- Ensure hazardous waste storage time limits are not exceeded
- Secure and restrict access to staff responsible for managing the wastes



## Handling and Storage

- ◆ When storing outdoor
  - Follow all requirements for indoor storage
  - Protect wastes from the elements (e.g., temperature extremes, rain, snow, direct sunlight)
  - Minimize risk of inadvertent damage to storage containers


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## STANDARD OPERATING PROCEDURES, HAZARDOUS WASTE PROCESSING, OPERATIONS AND MAINTENANCE PRACTICES

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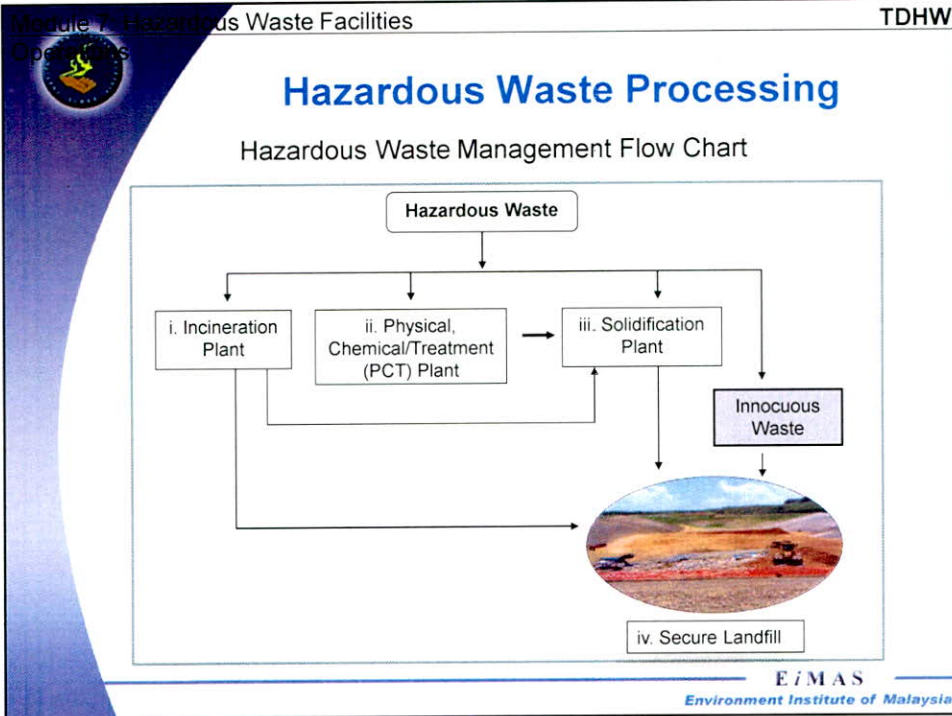
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## Standard Operating Procedures

- ◆ Generators and operators required to follow specific rules in the Standard Operating Procedures (SOP)
- ◆ Primary objective:
  - To provide employees with the specific information necessary
  - To ensure hazardous wastes are handled in accordance with the regulatory requirements

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## Hazardous Waste Processing

### Incineration Plant

- Treat organic waste
  - mineral oil waste, waste solvents pesticide waste and waste containing halogens and sulphur
- Emissions of gases have to comply with the requirements set-up by the DOE
- Slag from the rotary kiln is disposed off at the secure landfill
- Fly ash trapped in the fabric filter is further treated at the solidification plant

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## Hazardous Waste Processing

### Physical/Chemical Treatment Plant

- Treat inorganic wastes mostly in liquid form
- Inorganic acid and alkali wastes – pH-neutralized
- Cyanide wastes – destroyed by oxidation
- Chromate wastes – reduced with ferrous sulfate
- Heavy metals – precipitated out as very insoluble products
- These products will then be stabilized / solidified at solidification plant




## Hazardous Waste Processing

### Solidification Plant

- Treat :
  - Inorganic sludge/slurry waste generated from PCT facility, slag, fly ash and flue gas-cleaning residues from incineration
  - Inorganic solid/sludge wastes received from the waste generators
- Waste are solidified with slag/sand, cement, lime and water into concrete-like form
- Solidified wastes shall comply with the TCLP)Test and the landfill acceptance criteria before disposal

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## Hazardous Waste Processing

### Secure Landfill

- ➔ Final disposal of treated wastes after they have been characterized and treated

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## Hazardous Waste Processing

- ◆ Modern equipment and instrumentation for the laboratory to:
  - Conduct inspection, sampling, waste analysis and characterizations and treatment evaluations on all incoming waste streams
  - Conduct quality control analysis of raw materials and waste products during processing of wastes within the treatment facilities
  - Develop treatment formulations for all the treatment facilities
  - Conduct sampling and analysis of emissions from the facilities for internal environmental monitoring
  - Perform waste characterizations for waste generators

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Waste Facilities TDHW

## Operation and Maintenance Practices

### Control of Gaseous Emissions

| Pollutant  | Controller   |
|--|--|
| PCDDs and PCDFs                                  | Rapid reduction of flue gas temperature immediately following combustion                               |
| Acid gas (sulphur dioxide and hydrochloric acid) | Gas scrubbers using alkaline liquors   |
| Particulate emissions                            | Bag filters (both wet and dry), high energy scrubbers or, less frequently, electrostatic precipitators |

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Waste Facilities TDHW


## Operation and Maintenance Practices

### Other Potential Environmental Impacts

|   |   |
|---|---|
| Ash resulting from incineration of hazardous waste            | Constantly monitored and may require stabilization and encapsulation before disposal to landfills |
| Liquid effluent resulting from used for temperature reduction | Recycling may be incorporated after cooling and chemical treatment                                |

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## Operation and Maintenance Practices

### Used of Cement Kilns

- ▶ Production of cement clinker in the manufacturing of Portland cements
- ▶ Designed and operated in a manner that achieves the required parameters for the destruction of hazardous waste
  - Time at high temperatures
- ▶ Advantage - alkaline particulates involved act to neutralise acidic combustion products

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## Operation and Maintenance Practices

### Equipment Maintenance

- ▶ Implement and maintain an auditable asset management system
- ▶ Undertake planned and reactive maintenance of equipment to ensure:
  - Equipment is safe
  - Accurate
  - Working to optimum performance
  - Maximum availability and continuity of services

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## Operation and Maintenance Practices

- Record information for each device:
  - Name of equipment
  - Manufacturer and/or Supplier
  - Serial No and other unique identifier
  - Warranty and/or guarantee information
  - Acquisition date
  - Cost of equipment
  - Installation date
  - Life of equipment
  - Recommended replacement date
  - Depreciation per year
  - Servicing and/or calibration requirements and timetable
  - Associated hazards and safety bulletins and notices
  - Current location



## Operation and Maintenance Practices

- Current condition
- Repair and maintenance history
- Maintenance shall include:
  - Planned protective maintenance
  - Reactive maintenance
  - Implement and maintain a planned replacement system of time/performance expired asset to maintain quality of performance and service availability
- Repair and service workshop to support the operation
- Repair and maintain all medical equipment

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Operation and Maintenance

## Operation and Maintenance Practices

### Security

- ▶ Adequate security
- ▶ Minimize the possibility of unauthorized entry of people or livestock
- ▶ Provide:
  - 24-hour surveillance system (e.g. guards)
  - Artificial or natural barrier (e.g., fence)

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Operation and Maintenance



## REGULATORY COMPLIANCE AND ENVIRONMENTAL PERFORMANCE

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## Regulatory Compliance and Environmental Performance

- ◆ All facility operators should comply with:
  - The existing environmental quality act and regulations in the EQA 1974 and its subsidiary legislations
  - The licenses and their conditions issued by the DOE
  - Environmental performance as set out by the DOE for the facilities



## End of Module 7

## Thank You





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## TREATMENT AND DISPOSAL OF HAZARDOUS WASTE

### **MODULE 8**

### **Hazardous Waste Emergency Response Plan (ERP)**

### **SLIDES (PESERTA)**



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# TREATMENT DISPOSAL OF HAZARDOUS WASTE

## MODULE 8: Hazardous Waste Emergency Plan (ERP)




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### Contents

- ◆ Introduction
- ◆ Purpose
- ◆ Introduction to Emergency Response Plan
- ◆ Transportation
- ◆ Handling and Storage
- ◆ Treatment and Disposal
- ◆ Effective Emergency Response Plan

... Hazardous Waste Emergency Plan TDHW




## Introduction

- ◆ Disaster at industry can develop very quickly, hitting you full-force with little or no warning
- ◆ When disasters occur, company's emergency response will significantly affect the extent of damages and injuries sustained
- ◆ This program is the responsibility of various departments in the industry

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... Hazardous Waste Emergency Plan TDHW





## Purpose

- ◆ To provide participants:
  - ▶ Knowledge and skills in the preparation and development of an emergency response plan for hazardous waste treatment and disposal facilities
  - ▶ Guidance for implementation of an emergency response plan in case of any accidental discharge or spill during transportation or at scheduled waste management facilities
  - ▶ Selection of safe and appropriate hazardous waste emergency response plan.

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Module 8: Hazardous Waste Emergency Plan TDHW



## INTRODUCTION TO EMERGENCY RESPONSE PLAN (ERP)

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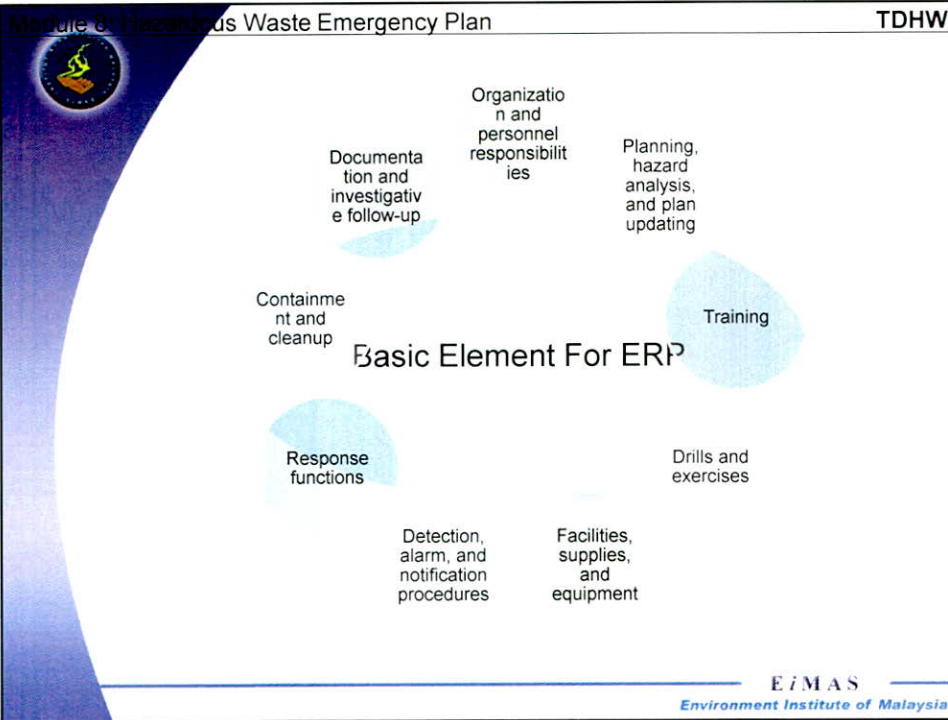
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## Introduction To ERP

- ◆ Encompasses all activities that are necessary to prepare people and organizations to respond to emergencies and disasters

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- Module 8: Hazardous Waste Emergency Plan TDHW
- ### Introduction To ERP
- ◆ Functional responses are determined for each individual location such as during:
    - Transportation
    - Handling and storage
    - Treatment and disposal
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## Introduction To ERP

### General Requirements in Emergency Response Plan

- ◆ Training
  - ▶ Should cover training procedures that address all types of hazards or emergencies covered by the plan
- ◆ Personnel Responsibilities
  - ▶ Organizational responsibilities should be decided



## Introduction To ERP

- ◆ Pre-Planning with Emergency Services
  - ▶ A good working relationship with police and fire departments and outside medical services
- ◆ Drills
  - ▶ Test all elements of the response plan



## TRANSPORTATION



## TRANSPORTATION

- ◆ Required to meet the requirements of the Environmental Quality Act 1974 and Environmental Quality (Scheduled Wastes) Regulations 2005
- ◆ Objectives:
  - To facilitate a rapid and effective emergency response and recovery
  - To provide assistance to emergency and security services



## Planning

- ◆ Should be prepared for the unexpected by identifying response mechanisms to a variety of potential crises arising from the transport of hazardous wastes
  
- ◆ The plan must contain sufficient detail to enable those involved in the response to effectively carry out their duties



## Planning

- ◆ Should have :
  - Stated policy
  - Purpose, and organizational structure,
  - Geographic scope, and contain details of the classes of hazardous wastes and mode of transport

Slide 6 Hazardous Waste Emergency Plan TDHW

## Transportation Emergency Response Plan Elements

### Plan Activation

- ◆ Internal alerting mechanism
  - ▶ Describe about transport emergency calls and response personnel in a position of authority
- ◆ Situation appraisal
  - ▶ A checklist should be developed for decision making
- ◆ Authority and resources mobilization
  - ▶ Identify specific positions within an organization and their scope of authority

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Slide 7 Hazardous Waste Emergency Plan TDHW

## Transportation Emergency Response Plan Elements

### Response Tasks

- ◆ External alerting mechanism
  - ▶ Describe how and when the organization will alert external parties
- ◆ Emergency action/containment/clean-up
  - ▶ Described for each component in order to minimize danger and the impact on the environment

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Site Specific Hazardous Waste Emergency Plan TDHW

## Transportation Emergency Response Plan Elements

**Resources**

- ◆ **Contact list**
  - ▶ Contain an accurate, up-to-date telephone roster for emergencies
- ◆ **Communications**
  - ▶ Describe the communication network to be used
- ◆ **Logistic support**
  - ▶ Describe the movement of people and equipment to and from the emergency site

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Site Specific Hazardous Waste Emergency Plan TDHW

## Transportation Emergency Response Plan Elements

- ◆ **Equipment and materials**
  - ▶ An inventory of emergency response equipment
- ◆ **Personnel**
  - ▶ Designate response personnel, and describe their duties
- ◆ **Media**
  - ▶ The press will often be present at an emergency

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Module 8: Hazardous Waste Emergency Plan TDHW




## Transportation Emergency Response Plan Elements

Preparedness

- ◆ Hazard analysis and risk assessment
  - ▶ Multiple plans based on possible scenarios
- ◆ Training
  - ▶ The capability for rapid and competent response
- ◆ Exercises
  - ▶ Allow the plan to be scrutinized under conditions which approximate an actual incident

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Module 8: Hazardous Waste Emergency Plan TDHW



## Transportation Emergency Response Plan Elements

- ◆ Maintenance of response equipment
  - ▶ Show schedules for preventative maintenance of relevant equipment listed
- ◆ Investigative follow up
  - ▶ To determine the effectiveness of the plan
- ◆ Updating
  - ▶ The plan should be updated at least annually

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## Transportation Emergency Response Plan Elements

- ◆ Plan availability and distribution
  - All staff who have responsibilities within the transportation emergency response plan should have access to the plan



## HANDLING AND STORAGE





## HANDLING AND STORAGE

- ◆ Container Management
  - Must be in good condition, accessible and spacing between containers
- ◆ Good Housekeeping
  - Stored inside buildings, containers should be closed while not in use
- ◆ Marking and Labeling
  - Hazardous wastes are properly marked and labeled in accordance with EQSWR 2005

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## HANDLING AND STORAGE

- ◆ Amenities and personal hygiene
  - Provide changing and washing facilities as well as separate clean room
- ◆ Personal exposure and protection
  - Should ensure the workers exposures to hazardous wastes to health are kept to a minimum and the permissible exposure limits are not exceeded

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## HANDLING AND STORAGE

- ◆ Safety and Health Programs
  - Shall develop and implement a written safety and health program for their employees
- ◆ Site Characterization and Analysis
  - Identify specific site hazards, to determine the appropriate safety and health control procedures needed to protect employees
- ◆ Site control
  - Program for protecting employees



## HANDLING AND STORAGE

- ◆ Training
  - Employees shall receive applicable training prior to being permitted to engage in hazardous waste operations
- ◆ Engineering controls, work practices, and PPE for employee protection
  - Shall be implemented to protect employees from exposure to hazardous substances and safety and health hazards



## HANDLING AND STORAGE

- ◆ **Monitoring**
  - To assure proper selection of engineering controls, work practices and personal protective equipment
  
- ◆ **Handling drums and containers**
  - Shall be handled, transported, labeled, and disposed of in accordance to appropriate regulations



## HANDLING AND STORAGE

- ◆ **Decontamination**
  - Developed to address all aspects of decontamination
  
- ◆ **Spillage and leakage containment**
  - In order to minimize hazards

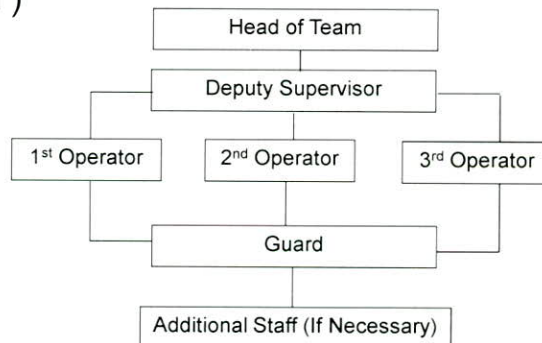


## TREATMENT AND DISPOSAL



## Emergency Response Team (ERT)

- ◆ An effective facility is a facility that has their own Emergency Response Team (ERT)





## Emergency Response Team (ERT)

- ◆ Head of team: carries radio (walkie-talkie) to direct the fire fighting efforts
- ◆ Deputy Supervisor: keep in track on all communication in and out of the facilities/plants.
- ◆ 1<sup>st</sup> Operator: Work together with second operator to start a fire fighting
- ◆ 2<sup>nd</sup> Operator: He will assists 1<sup>st</sup> operator



## Emergency Response Team (ERT)

- ◆ 3<sup>rd</sup> Operator: He will secure the fire water supply and supply additional equipment to the fire fighting group.
- ◆ Security Guards: Remain in the guardhouse and continuing with their duties, among other things admission control
- ◆ Additional staff: They will be under command of the On-Scene Commander (OSC)



## Classification of Accidents

- ◆ Consists of four categories:
  - Operational disturbances
  - Minor operational incidents
  - Catastrophe
  - Larger accidents
- ◆ Each of the categories have their own action plan and are being conducted based on their degree of accidents



## Action Plan

- ◆ Fires
  - The fire alarms will start the fire bells ringing within the actual area and are automatically transferred to the nearest fire station
- ◆ Public Addressing System
  - Support the radio communication system



## Action Plan

### ◆ Alarm Siren System

- ▶ Has three different signals:
  - Fire signal: High tone for 5 seconds, falling tone for 5 seconds, high tone for 5 seconds, etc for 60 seconds
  - Signal for toxic gas release: a different signal pattern is used. For example, 15 seconds increasing tone and 15 seconds falling tone
  - A third signal is used to indicate "Danger over". A tone will last for about 45 seconds.



## Action Plan

### ◆ Evacuation

- ▶ There are two different points:
  - Parking lot outside the facility
  - Road leading to the landfill
- ▶ In order to select the optimal evacuation, point of wind direction should take into consideration



# End of Module 8

## Thank You

