



## Industrial Waste Management- I



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## Hazardous Waste Management

- Hazardous Waste Definitions and Laws
- Hazardous Waste Management
- Waste Hierarchy
  - Reduce / Substitute
  - Reuse
  - Recycle / Recovery
- Hazardous Waste Treatment
- Wastewater Treatment
- Case Study



2



## U.S. History of Hazardous Waste Pollution

- In 1962, renowned author and naturalist, Rachel Carson, warned growing contamination "great underground seas" (i.e., groundwater) in "Silent Spring."
- Love Canal – New York, USA. Buried barrels of chemicals underneath new housing development (1950s). Became main cause for the Superfund legislation. Removed from Superfund in 2004.
- Valley of the Drums – Kentucky, USA, 23 acre site with a large number of leaking drums. Fire at site in 1966. Not completely cleaned up until 1990.
- Times Beach – Missouri, USA community where contaminated oil was used for dust control from 1972-1975.



3



## Relevant U.S. Environmental Legislation and UN Convention

### Primary U.S. Legislation

- Clean Air Act- 1970
- Clean Water Act – 1972
- Safe Drinking Water Act – 1972
- Resource Conservation and Recovery Act- 1976
- Comprehensive Environmental Response, Compensation and Liability Act of 1980 ([Superfund](#))
- Hazardous and Solid Waste Amendments - 1984 ([Land Ban](#))
- Pollution Prevention Act -1990



### U.N. Convention

- Basel Convention 1992- Control of Transboundary Movements of Hazardous Wastes and their Disposal



4





## Definition of Waste

### Definition of Wastes- Basel

“substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law”

### Definition of Hazardous Wastes- EPA

“ liquid, solid, contained gas, or sludge wastes that contain properties that are dangerous or potentially harmful to human health or the environment.”

**Characteristic** – Ignitable-Corrosive-Reactive-Toxic  
**Listed** – Industrial source-Type



## Organisation for Economic Co-operation and Development (OECD) Definition of Waste

- Materials that are not prime products (i.e. products produced for the market) for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards, or intends or is required to discard.
- Wastes may be generated during the extraction of raw materials during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity.

### The following are excluded:

- Residuals directly recycled or reused at the place of generation (i.e. establishment);
- Waste materials that are directly discharged into ambient water or air.



6



## Surface and Groundwater Contamination Leads to Health Problems, Water Shortage

### •Mining

- Acid mine drainage
- Heavy metals – Hg, Cr, Pb

### •Industrial / Commercial Pollution

- Dyes and pigments
- Petroleum / gasoline

### •Agricultural runoff

- Pesticides
- Nutrients – nitrates, phosphates
- Salinization – Sodium, chloride

### •Sewage

- Pathogens - Enteric
- Nutrients – Nitrates, phosphates
- Contaminated animal feed



Textile Waste



Petroleum



Mining Waste



## Drinking Water, Wastewater Contaminants Directly Affect Public Health

### Pathogens

- Bacteria – Enteric, fecal
- Protists – Cysts and spores
- Virus - Enteric

### Metals

- Copper
- Lead
- Arsenic

### Disinfection byproducts

- Trihalomethanes -  $\text{CHCl}_3$ ,  $\text{CH}_2\text{Cl}_2$ ,  $\text{CH}_2\text{ClBr}$
- Haloacetic acid –  $\text{CH}_2\text{ClCO}_2\text{H}$
- NDMA

### Pesticides





## Solid Waste can Directly Impact Human Health

### Solvents

Gasoline, diesel, chlorinated

### Leachates

Acid waste, heavy metals

### Hazardous waste

Metals, paints, solvents, pesticides

### Leaking fuel tanks

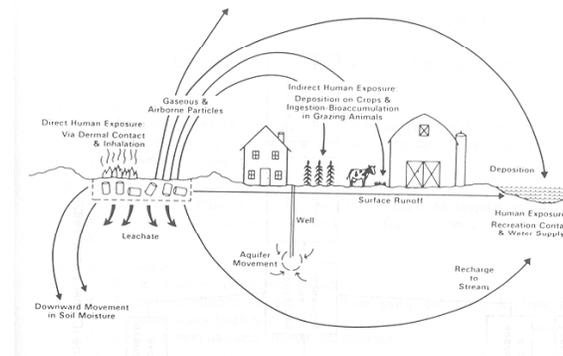
Gasoline, diesel

### Refuse

Decaying animal and plant matter



## Various Pathways Exist for Contamination From Land Disposal

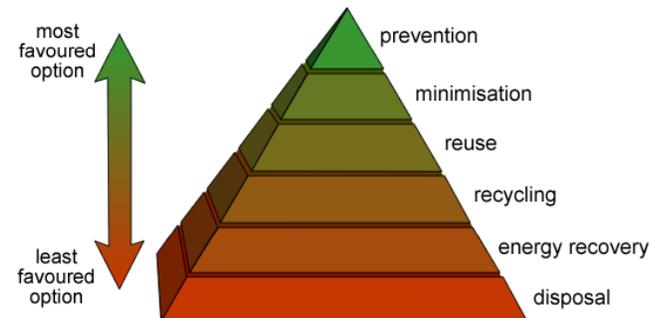


## Effective Waste Management Program Involve Planning

1. Define Current Industrial Waste Management Practices.
2. Identify Industrial Waste Management Improvement Options.
3. Compile Findings / Assessment Report.
4. Evaluate Industrial Waste Program Scenarios.
5. Select Preferred Industrial Waste Program.
6. Start the Selected Program.



## Solid Waste Hierarchy: Reduce, Reuse, Recycle, Treat and Dispose



Source: [http://en.wikipedia.org/wiki/Waste\\_hierarchy](http://en.wikipedia.org/wiki/Waste_hierarchy)





## Industrial Hazardous Waste Reduction

- Reduce the amount of reactants necessary
- Incorporate green chemistry
  - 12 principles-reduce energy, catalysis, reduce derivatives, design to decompose....
- Improve recovery of product
- Reuse/recycle off-specification product
- Separate waste streams (cooling water, storm water, process water)
- Combine streams for neutralization



13



## Industrial Hazardous Waste Reduction

- Improve process control
- Improved equipment design
- Use of different raw material
- Good housekeeping
- Preventive maintenance
- Industrial ecology
  - Colocate plants
  - Waste exchange program
  - Waste heat as a resource
  - Beneficial use
  - Waste to energy



14



## Substitution of Hazardous Materials

Substitution of hazardous substances is an innovation process

- Uncertainty of success
- Inertia
- Economic risk assumed to lower ultimate risk

### Straightforward systems

Cement  
Mineral fibers  
Substitution and maintain technical effectiveness

### Complex systems

Textile auxiliary agents  
Supply chain globally interlinked, more complex products



## Metals Recycling –Resource Recovery and Landfill Protection

Steel  
Aluminum  
Mercury recycling  
Batteries  
Lead  
Battery Acid  
Cadmium  
E-Waste



Off –Specification Materials Returned to Process



16





## Industrial Byproducts can be Recycled

**Construction and Demolition Wastes**  
**Fly Ash, Bottom Ash, Slags**  
**Flue Gas Desulfurization Gypsum**  
**Phosphogypsum**  
**Red Mud**  
**Tires**



Source: Wikipedia - Harvey Hinklemann



## Example: Waste Tires - Technology in Recycling

Simple

- Used to prevent erosion
- Artificial reefs
- Tire derived fuel- cement kiln
- Crushed to crumb rubber for asphalt
- Pyrolyzed to make oil
- Cryogenic grinding- specialty
- High recovery devulcanization



Complex

<http://www.youtube.com/watch?v=Vgk1UZ242kM>  
<http://www.youtube.com/watch?v=xmOkvUlpTL0>



## Example: Spent Catalyst Recovery and Disposal for Petroleum Refineries

- Catalytic cracking- Zeolites regenerated in process
- Hydrotreating – Ni, Mo, W, Co recovery
  - Acid and caustic metals separation and precipitation. (Hydrometallurgical)
  - High temperature fusion (Pyrometallurgical)
- Naptha reforming - Pt or Re on silica or silica alumina support (Recycled for precious metal-chlorinated precipitate)
- Steam reforming - Ni oxide catalyst on alumina support (Nickel recovery Alumina + NaOH)



Source: www.matrostech.com

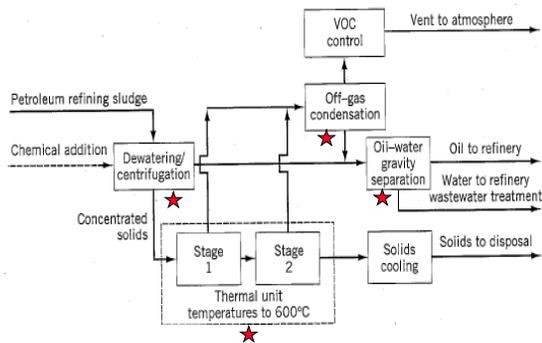


## Thermal Technologies for Oily Waste- Recycling Options

- **Separation - recycle**
  - Solvent Extraction
  - Centrifugation - Hydrocyclones
  - Air and Steam Stripping
  - Distillation
  - Recycle



## Unit Operations for Product Recovery - Refinery Waste (Thermal Desorb)



## Pretreatment of Petroleum Refinery / Oleo Waste

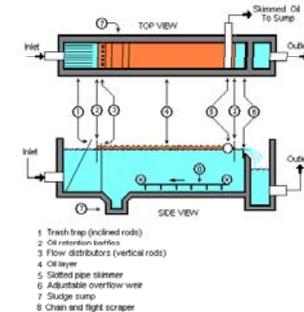
•Heating and decantation with gravity separation

•De-emulsifying  
•Electrostatic coalescers  
•Oil in water  
•Water in oil

•Separation – Centrifugation- Filtration

•Solvent extraction

•Thermal distillation – Product recovery



API Gravity Separator

Source: Milton Beychock Wikipedia



## Oily Water Extraction, Separation and Treatment Processes

### Solvent Extraction

- Preparation (sorting the contaminated material)
  - Extraction
  - Separation of concentrated contaminants from solvent
  - Removal of residual solvent
  - Contaminant recovery, recycling, or further treatment.

### Air or Steam Stripping

- Similar to distillation – recovery and recycle of organics
- Steam stripping can recover low VP and soluble compounds

### Centrifugation

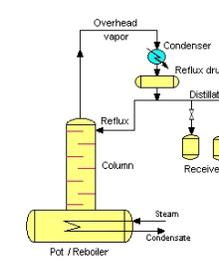
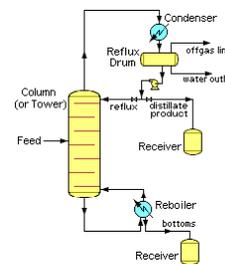
- Hydrocyclone: oil water separator
- Decanter: slop oil, 3 component sludge

### Wet Air Oxidation

- Organic waste oxidation in water
- 150°C-325°C, 300psi-3000 psi



## Distillation: Continuous and Batch



Source: H. Padleckas-Wikipedia



## Distillation Pros and Cons

### •Advantages

- Recovers useable organic solvents from wastes.
- Product purity of a range of levels can be designed into the distillation process, limited mainly by economic considerations.

### •Disadvantages

- Costs of recovery often exceed cost of thermal destruction.
- Complex operation high capital cost, high energy costs.
- Columns can be large if a high degree of purity is required (200 feet).
- Feed must be a free flowing fluid with low solids content.
- Must be custom designed for a given waste stream not for variable feed.



25



## Water Pollution Treatment Processes are Well Established

Water Pollutant	Treatment
Organic chemicals	Air stripping, distillation, oil water separators, adsorption
Biological oxygen demand (BOD)	Aerobic digestion, activated sludge-fixed film and suspended
Chemical oxygen demand (COD)	Aerobic digestion, activated sludge-fixed film and suspended advanced oxidation
Suspended solids (turbidity)	Settling, coagulation, filtration
Color	Coagulation, filtration, adsorption
Metals	Coagulation, filtration, ion exchange, membranes
Microbes	Activated sludge, disinfection
Dissolved solids	Distillation, membranes, electro dialysis, ion exchange



## Wastewater Treatment

### • Primary

- Screening
- Sedimentation /Flotation
- Hydrocycloning

### • Secondary

- Activated sludge/ lagoons

### • Tertiary

- Oxidation / adsorption

### • Dewater sludge

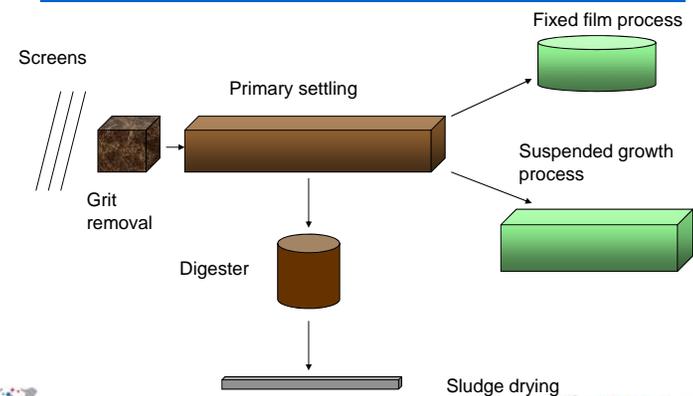
### • Digest or incinerate



27



## Wastewater Treatment – Biological Processes



28



## Wastewater-Fixed Film Biological Process



Trickling filter



Rotating biological contactor  
(40% submerged rotates at 1-1.5 rpm)

Uses biofilm to treat water to remove BOD


29

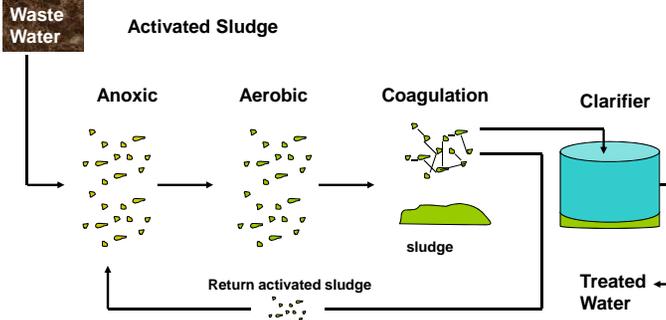

## Suspended Growth (activated sludge) Process Requires Energy




- Use forced air suspension of biological sludge to reduce BOD
- Largest expense for this process is the electrical energy required


30


## Wastewater Suspended Growth Biological Process



Anoxic – no dissolved oxygen


31


## Wastewater Treatment- Generic

- **Coagulation / Flocculation** – removes suspended solids whenever natural subsidence rates are too slow to provide effective clarification
  - Water clarification
  - Lime softening
  - Sludge thickening
  - Dewatering
- **Solids / Liquid Separation**
  - Sedimentation– gravitational settling
  - Air/Gas Flotation
  - Filtration
  - Centrifugation


32




## Wastewater Treatment- Generic (continued)

- **Precipitation (Softening)** – removes hardness by chemical reaction and settling
  - Lime softening
  - Silica removal
  - Heavy metals removal
- **Ion Exchange** – removes unwanted ions by transferring them to solid material
  - Anion exchange (weak base, strong base)
  - Cation exchange (weak acid, strong acid)
  - Regeneration with neutralization
  - Ion specific resins (boron removal)



33



## Wastewater Treatment- Generic (continued)

- **Neutralization** – acid / base addition to adjust pH
  - Neutral pH = 7
  - Neutral pH range = 6 - 9
- **Membrane Separation** – use membranes to remove suspended and dissolved solids
  - Microfiltration (MF) = removes **suspended solids**
  - Ultrafiltration (UF) = removes **suspended solids**
  - Reverse Osmosis (RO) = uses pressure to remove **dissolved solids**
  - Electrodialysis (ED) = uses electricity to remove **dissolved solids**



34



## Wastewater Treatment- Generic (continued)

- **Adsorption** – uses physical adhesion onto porous media to remove unwanted molecules
  - Activated carbon adsorption
  - Resin columns
  - Fluoride removal with alumina
- **Evaporation** – water vaporization / condensation
  - Flow configurations (rising film, falling film, forced circulation)
  - Energy configurations (multiple effect, vapor recompression)
- **Oxidation / Reduction** – uses oxidation / reducing agents to remove unwanted constituents
  - Iron & manganese removal
  - Cyanide removal
  - Sulfide removal



35



## US Environmental Protection Agency Resources

Guide for Industrial Waste Management

- Understand the facility siting process and how you can play a part.
- Promote the best management practices to help facilities in your community protect your health and the environment.
- Use the exhaustive supply of resources and references concerning waste characterization, chemical specifics/impacts, pollution prevention, siting, design, operation, monitoring, corrective action, and facility closure.

Protecting  
Land • Surface Water • Air

Building Partnerships  
• State Staff  
• Facility & Environmental Managers  
• Community Citizens

Visit our Web site for downloadable program and additional information.  
[www.epa.gov/industrialwaste](http://www.epa.gov/industrialwaste)





## Group Exercise

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