



Overview of Industrial Waste Handling: Reduction, Reuse and Treatment

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Hazardous Waste Management

Hazardous Waste History / Management

Three R's - Reduce / Substitute – Reuse -Recycle / Recovery

Hazardous Waste Treatment

Pretreatment Recovery

Oil / Water Separation

Distillation-extraction

Thermal Methods

Thermal desorption

Pyrolysis-gasification

Combustion-Incineration-Industrial furnaces

Stabilization/ solidification

Land disposal – Landfills- Deep well injection

Wastewater treatment



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



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 - CHCl_3 , CH_2Cl_2 ,
 CH_2ClBr
- 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

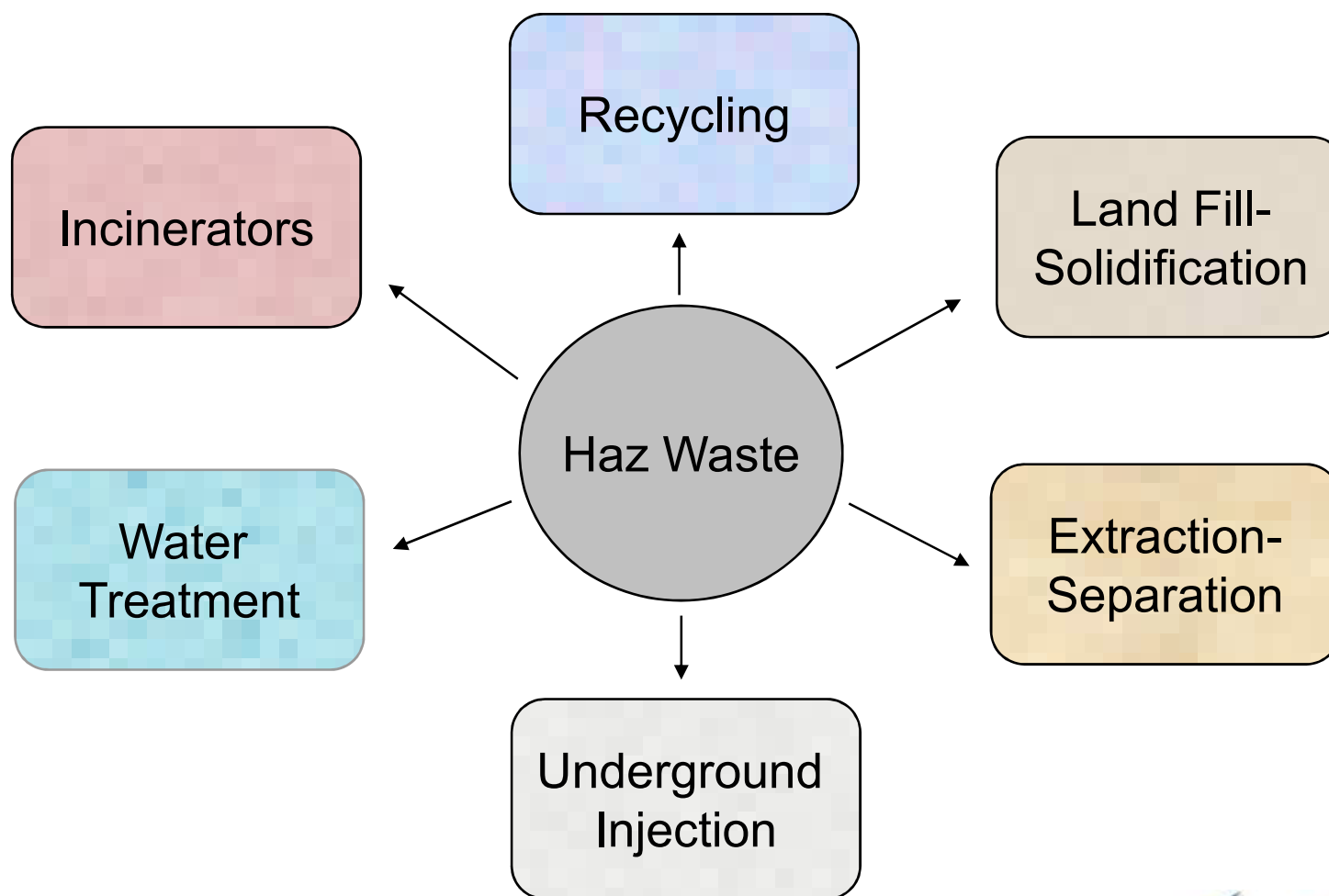
Refuse

Decaying animal and plant
matter



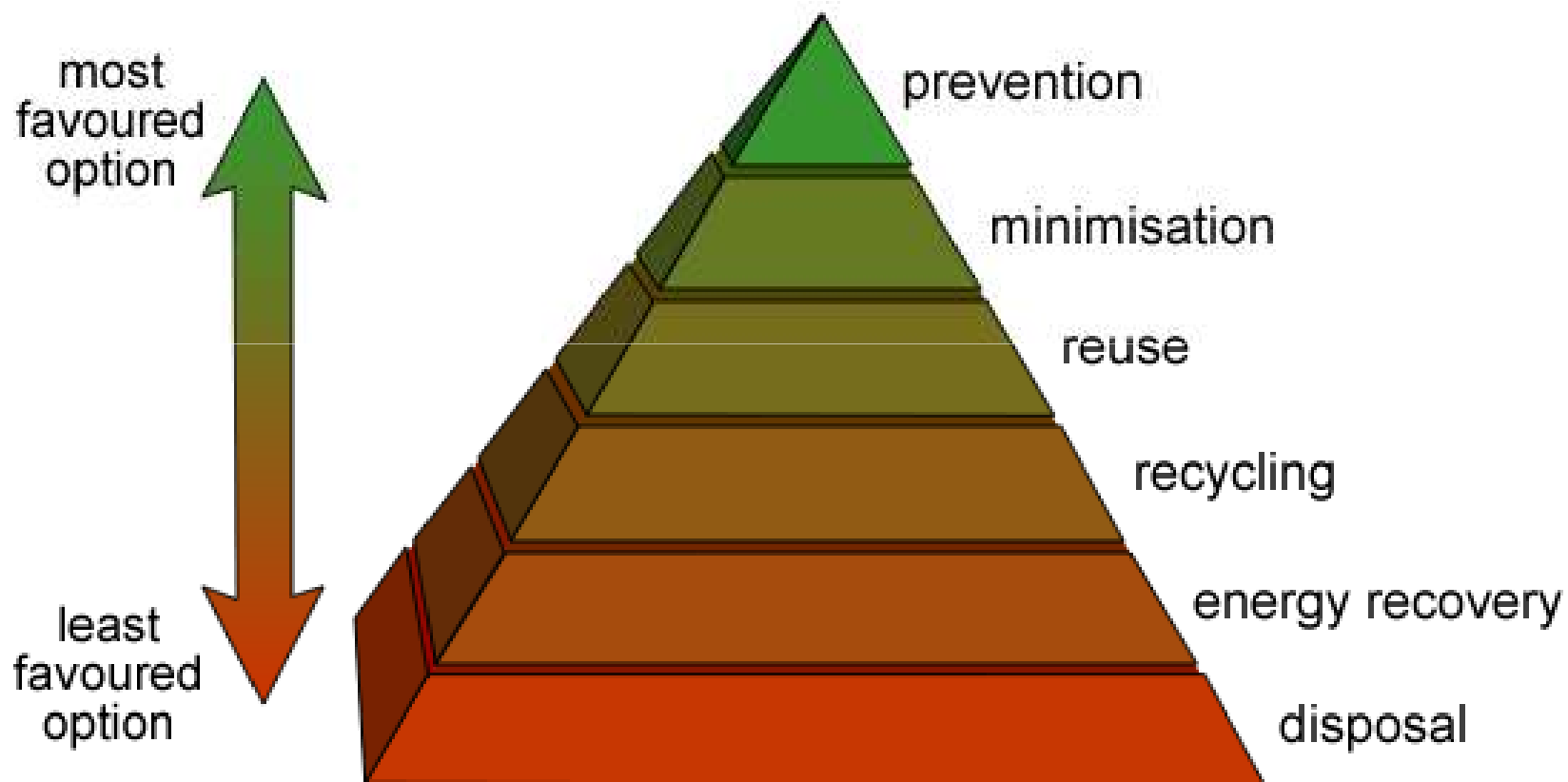


Hazardous Waste Treatment and Disposal is Multifaceted





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



Source: 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



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)
- Naphtha 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



Pretreatment Separation Techniques for 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





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

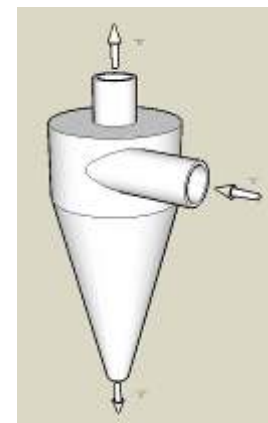
- Similar to distillation – recovery and recycle of organics
- Steam stripping can recover low VP and soluble compounds

Centrifugation

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

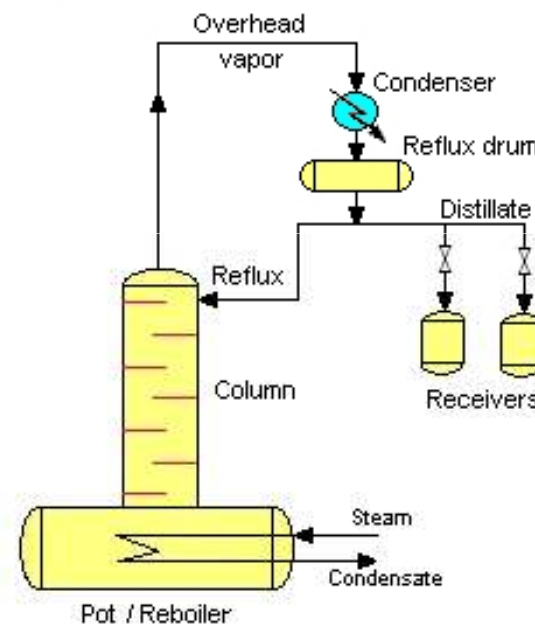
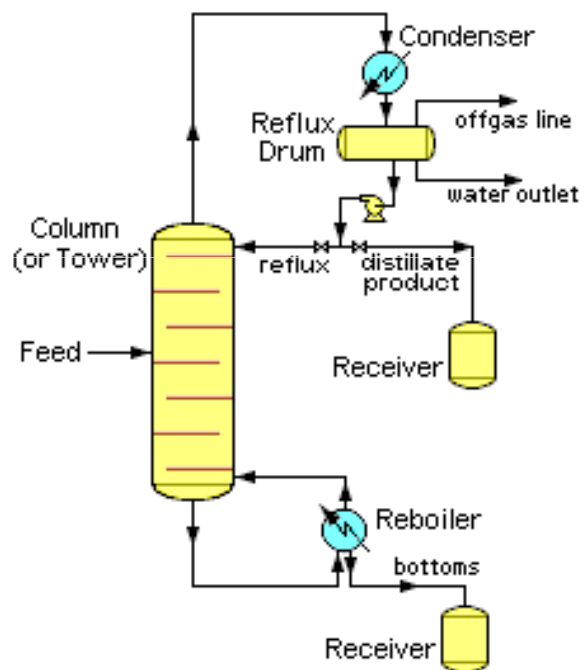
Wet Air Oxidation

- 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.



Thermal Hazardous Waste Treatment Technologies

Thermal Desorption

Incineration

- Dedicated (no power or product)
- High temperature oxidation
- Air pollution control (APC)

Industrial Furnaces

- Boilers – produces steam for power
- Kilns – produces product and reduces fuel
- Furnace – provides process heat
- APC part of industrial process

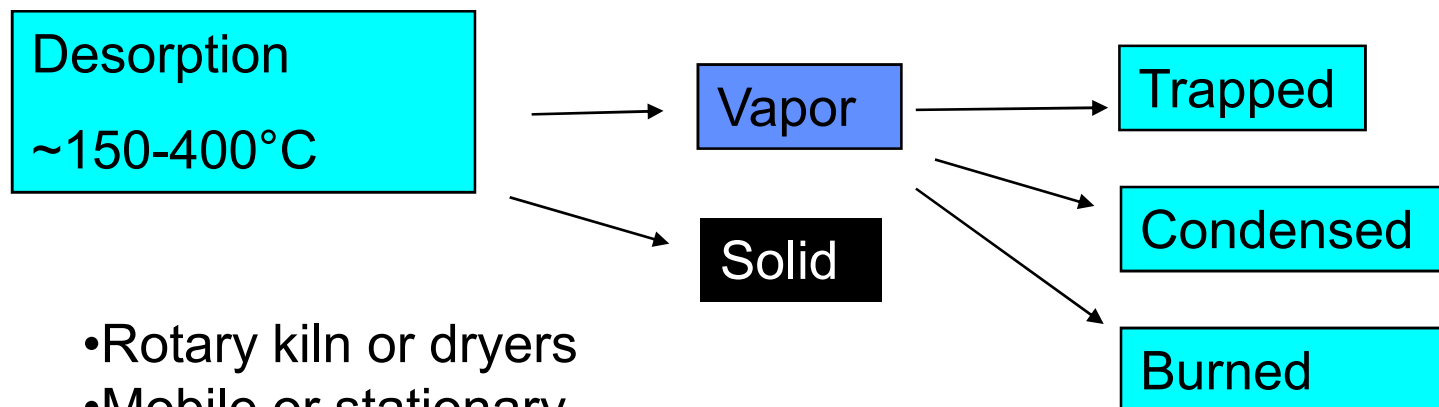
Pyrolysis Gasification

Specialized Methods

- Molten glass
- Plasma arc



Thermal Desorption Very Flexible for Petroleum Waste Solids



- Rotary kiln or dryers
 - Mobile or stationary
 - Co-current or countercurrent
 - Feed and product handling equipment
-
- Desorbed vapor
 - Trapped onto activated carbon
 - Condensed
 - Burned in afterburner or oxidizer
 - Remaining solids cleaned





Thermal Desorption Pros and Cons

• Advantages

- Low capital operating cost compared to other thermal technologies.
- Low regulatory hurdles for permitting.
- Can be applied in the field.
- Allows for both destruction and recovery of organic contaminants.

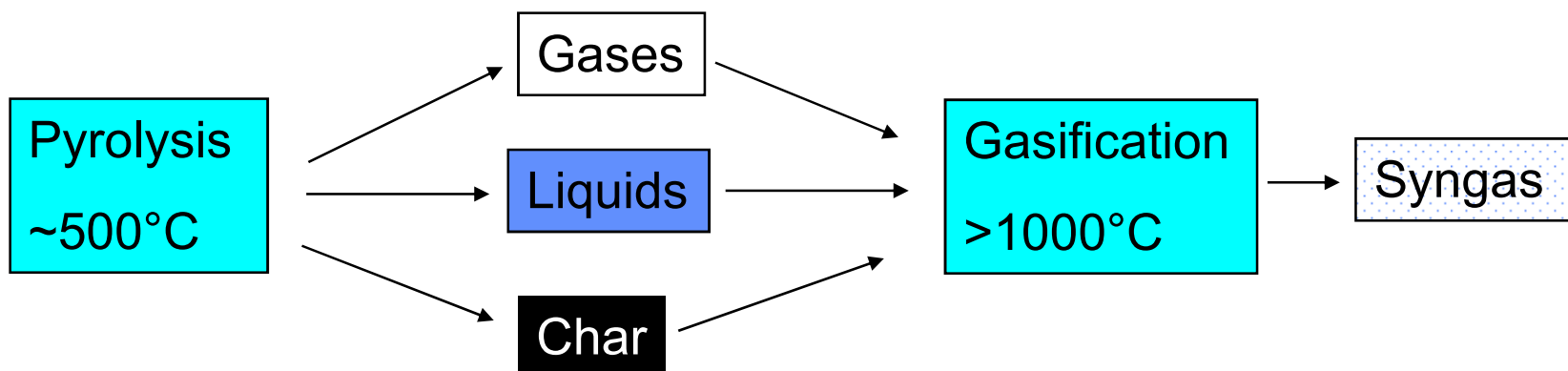
• Disadvantages

- Material larger than 2 inches needs to be crushed or removed.
- Plastic soils tend to stick to equipment and agglomerate.
- Pretreatment- shredding- blending with friable soils/ gypsum.
- Highly contaminated soils will require multiple cycles.
- Not amenable to semi-volatile or non-volatile, chlorinated hazardous constituents. (Example: PCBs, pesticides)
- Fugitive emissions may present exposure risk to workers and environment.





Syngas Formation from Waste Involves Pyrolysis and Gasification



Gas %	Purox (FB-MSW)
H ₂	23.4
CO	39.1
CO ₂	24.4
CH ₄	5.5

Higher Heating Value ~ 19 MJ/kg

Waste Management 24 (2004) 633–639



Pyrolysis Pros and Cons

• Advantages

- Lower temperature process compared to incineration, increasing refractory life and reducing costs.
- High feed rates, up to 5 tons/hour.
- Downstream APC equipment needs reduced since metals and PM tend to be retained in char.
- Degree of pyrolytic reaction can be controlled to yield synfuel or products for recovery. Condensable vapors with economic value can be recovered. Non-condensable vapors can be used for energy.

• Disadvantages

- High capital cost.
- Char still retains hazardous constituents and metals, requiring subsequent treatment and controlled disposal.
- Fume incineration needed to destroy Products of Incomplete Combustion (PICs), and other hazardous organic constituents.



Gasification Pros and Cons

- **Advantages**

- Beneficial use of waste to produce syngas, energy or useable products.
- High temperature process provides for destruction of hazardous constituents.

- **Disadvantages**

- Extremely high capital cost \$30 – 50M. Large scale operation required to make economics work.
- Must be integrated into a chemical or petroleum refining plant. Not a free-standing technology like incineration.
- Off-gas treatment still required, including downstream fume incineration.
- Residues are generated which, like pyrolysis, may contain hazardous metals that require subsequent managed treatment and disposal.





Incineration is not the Same as Open Burning

	Open Burn ($\mu\text{g}/\text{kg}$)	Municipal Waste Incinerator ($\mu\text{g}/\text{kg}$)
PCDDs	38	0.002
PCDFs	6	0.002
Chlorobenzenes	424150	1.2
PAHs	66035	17
VOCs	4277500	1.2



Source: EPA/600/SR-97/134 March 1998

Waste to Energy =WTE

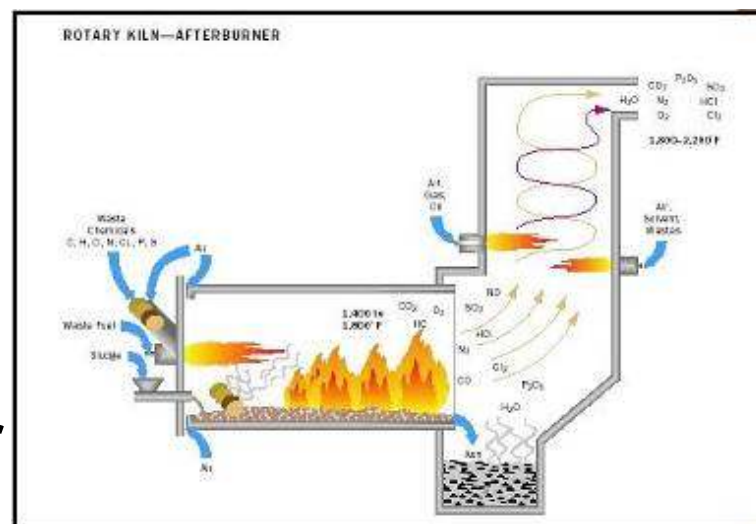


Incineration is the Controlled Combustion of Waste

Requires 3 “T’s”:

- Time: 2 seconds minimum
- Temperatures: 1000°C-1200°C
- Turbulence: Mixing during burn

**Rotary Kiln, Fluidized Bed or
Fixed Grate
Secondary Combustion Chamber
(afterburner)
Rapid cooling of ash to prevent
PCDD and PCDF**



Source :<http://www.pollutionissues.com/>



Incineration Pros and Cons

- **Advantages:**

- Can be applied to a wide variety of hazardous wastes.
- Provides destruction and volume reduction of the waste.

- **Disadvantages**

- Not amenable to waste containing high concentration of heavy metals ($> 1\%$).
- Waste feed mechanisms often complex
- High capital cost due to extensive Air Pollution Control (APC) system and sophisticated controls required to meet emission standards.
- Ash must be treated for leachable metals prior to land disposal.



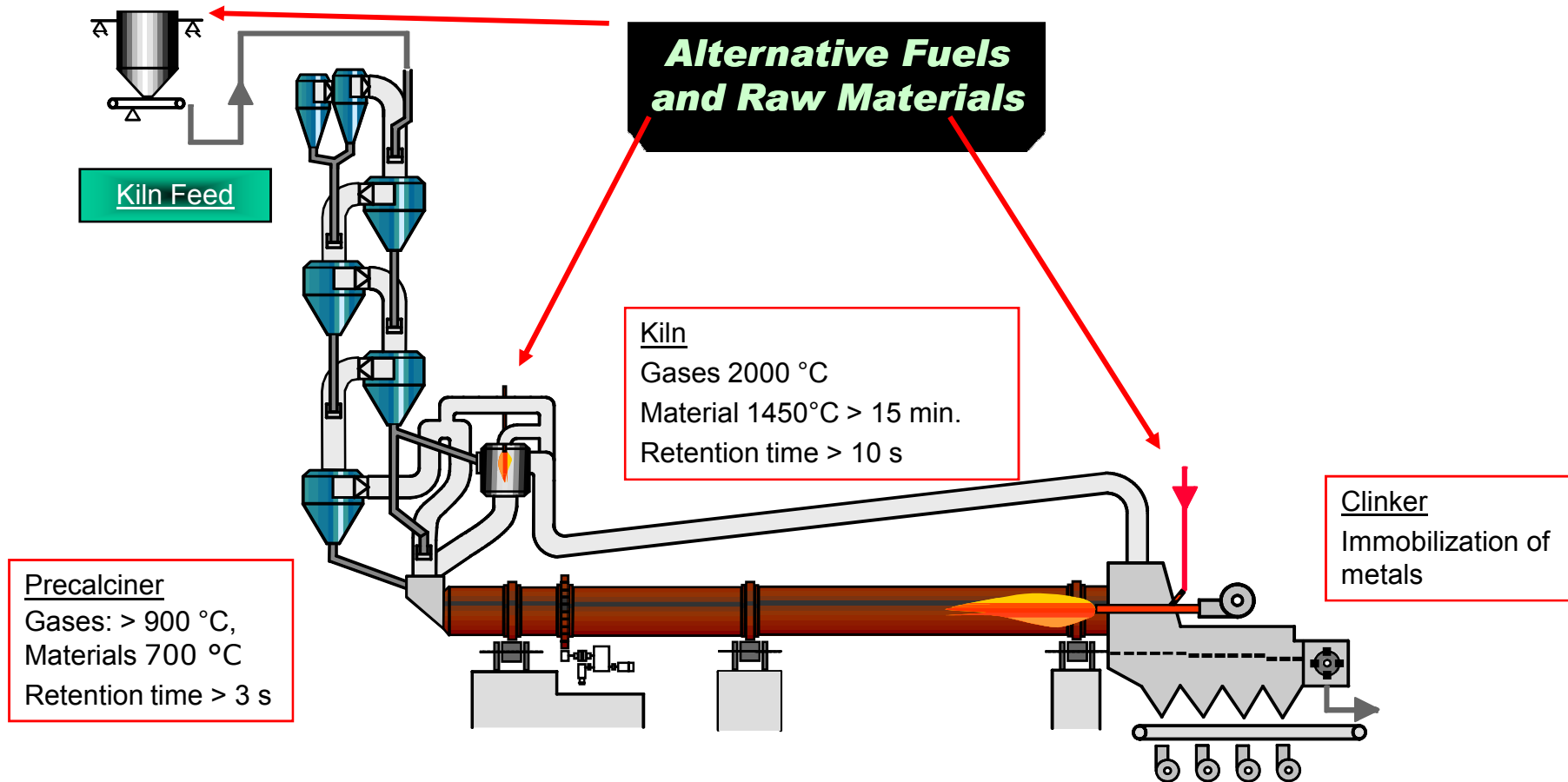
Industrial Furnaces: Kilns and Boilers

(APC part of industrial process)

- **Kilns**
 - **Cement**
 - **Lightweight Aggregate**
 - **Lime**
- **Furnaces**
 - **Halogen Acid**
 - **Sulfuric Acid**
- **Industrial boilers.**
- **Waste types and amount limited**
 - **Protect product and process quality**
 - **Cement and lightweight aggregate kilns only liquid waste**
 - **Minimum heat content > 5000 BTU/lb**
 - **Thermal substitution rate is limited to 50%.**



Typical Dry Process Cement Kiln





Boiler, Furnace and Cement Kiln Pros and Cons

- **Advantages:**
 - Displace other fuels improve economics
 - Waste producers may pay for service
 - Can be applied to a waster oils and other solid waste (tires).
 - APC equipment in place
 - Residence times in kilns are high
 - Steady state is the rule
- **Disadvantages**
 - Industrial process and products may not permit
 - Waste feed mechanisms add complexity
 - Admixture rate may be low
 - Waste destruction may upset industrial process





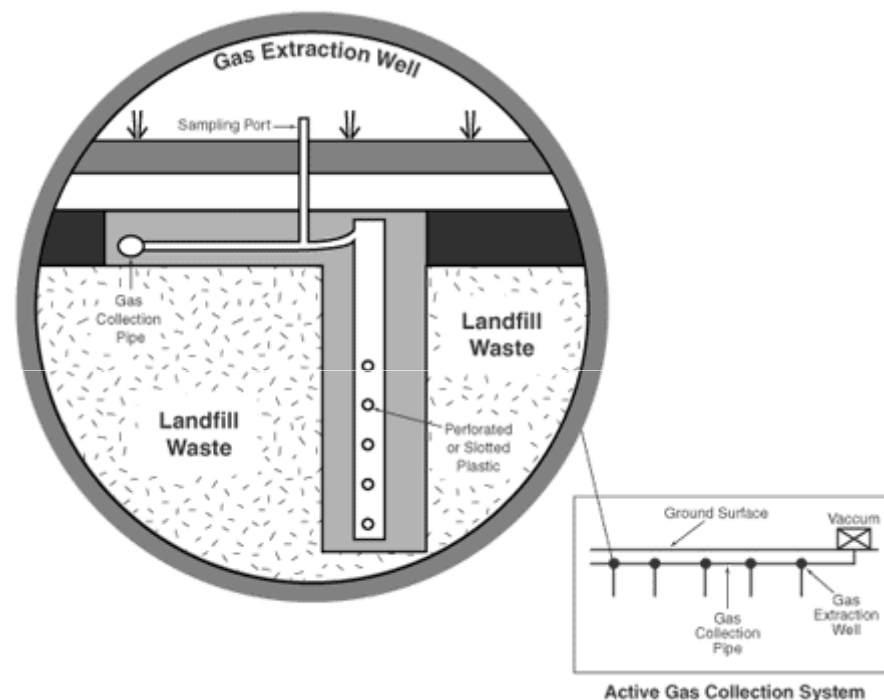
Solidification and Stabilization Processes

- Solidification methods physically encapsulate hazardous waste into a solid material matrix of high structural integrity.
 - Stabilization techniques chemically treat hazardous waste by converting them into a less soluble, mobile or toxic form.
 - Principally used for metal-bearing wastes.
 - Limited applicability to organic wastes.
 - 2 Main types of processes: **cement and pozzolanic.**
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- **Pros:** low cost, low technology, suitable for many types of waste
 - **Cons:** increases volume, may leak



Land Disposal Units (LDUs) Consist of Landfills, Surface Impoundments and Underground Units

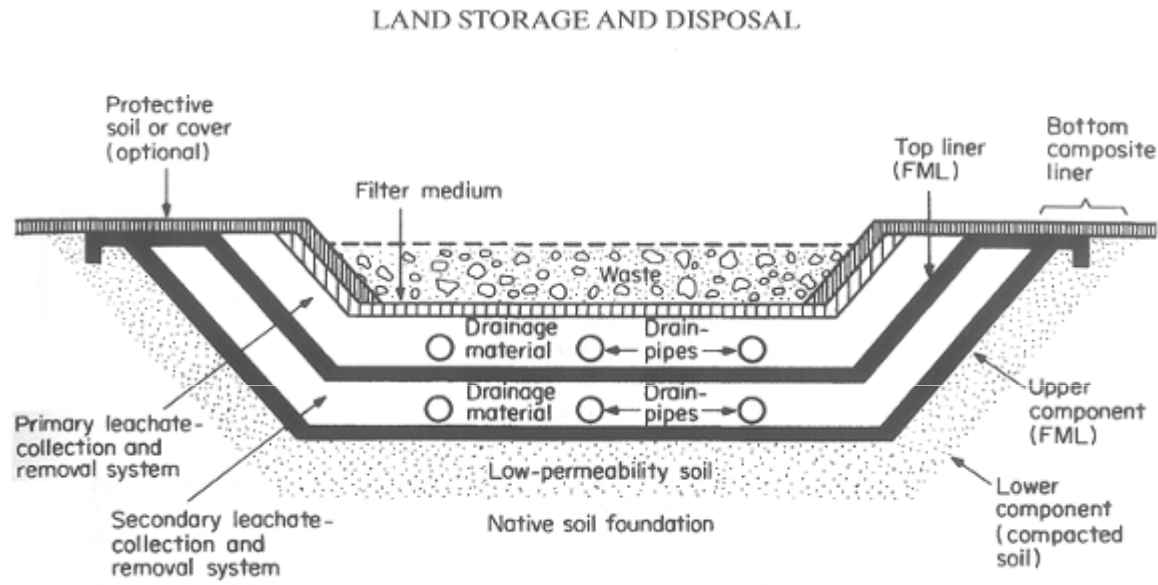
- Landfill
- Surface impoundment
- Waste pile
- Land treatment unit
- Injection well
- Salt dome formation
- Salt bed formation
- Underground mine
- Underground cave



<http://www.epa.gov/lmop/basic-info/lfg.html#01>



Landfill with Flexible Membrane Liner Plus Compacted Soil Double Liner



<http://www.epa.gov/wastes/hazard/tsd/td/disposal.htm>

Groundwater and leachate monitoring important



Landfill Design and Construction

Landfill Liners

Clay

Flexible membrane

Liner/waste compatibility

Landfill Cap

Leachate

Collection-Removal-Recirculation

Primary leachate

Leak detection

Surface water collection

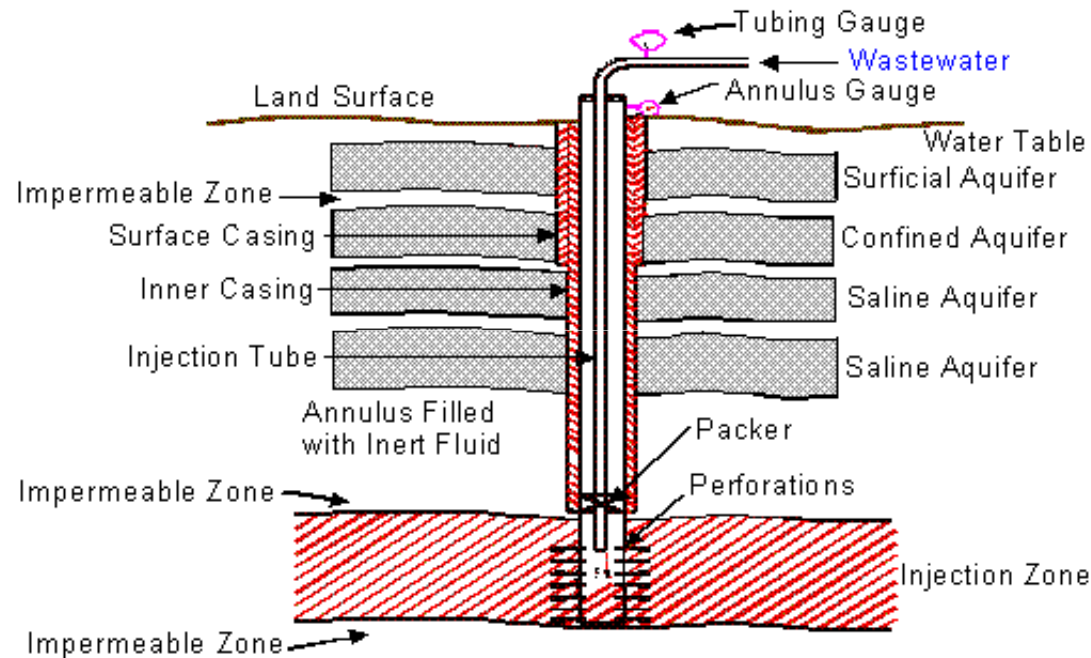
Gas collection and removal

No free or bulk liquids

- Mixed with sorbent
- Small ampoules
- Container is item–battery
- Container is lab pack



Deep Well Injection is an Important Technology



- 550 Class I wells in the United States (22% for HW)
- 43% of all HW in United States !!!



Land Disposal Pros and Cons

- **Advantages:**

- Well known technology
- Landfills often less expensive than incineration
- Landfill liners and leachate collection systems are existing
- Deep well injection can handle large volumes
- Deep well injections are well regulated in the U.S. (EPA)

- **Disadvantages**

- Surface impoundment dam may burst
- All landfills eventually leak
- Some countries have a shortage of suitable sites
- Legislation often prohibits landfill
- Deep well injections are expensive to drill
- Deep well may be incompatible with waste
- Deep well requires detailed geological study



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, electrodialysis, ion exchange



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 • Ground Water •
Surface Water • Air

Building Partnerships

- State Staff
- Facility & Environmental Managers
- Concerned Citizens

Visit our Web site for downloadable program and additional information.

www.epa.gov/industrialwaste

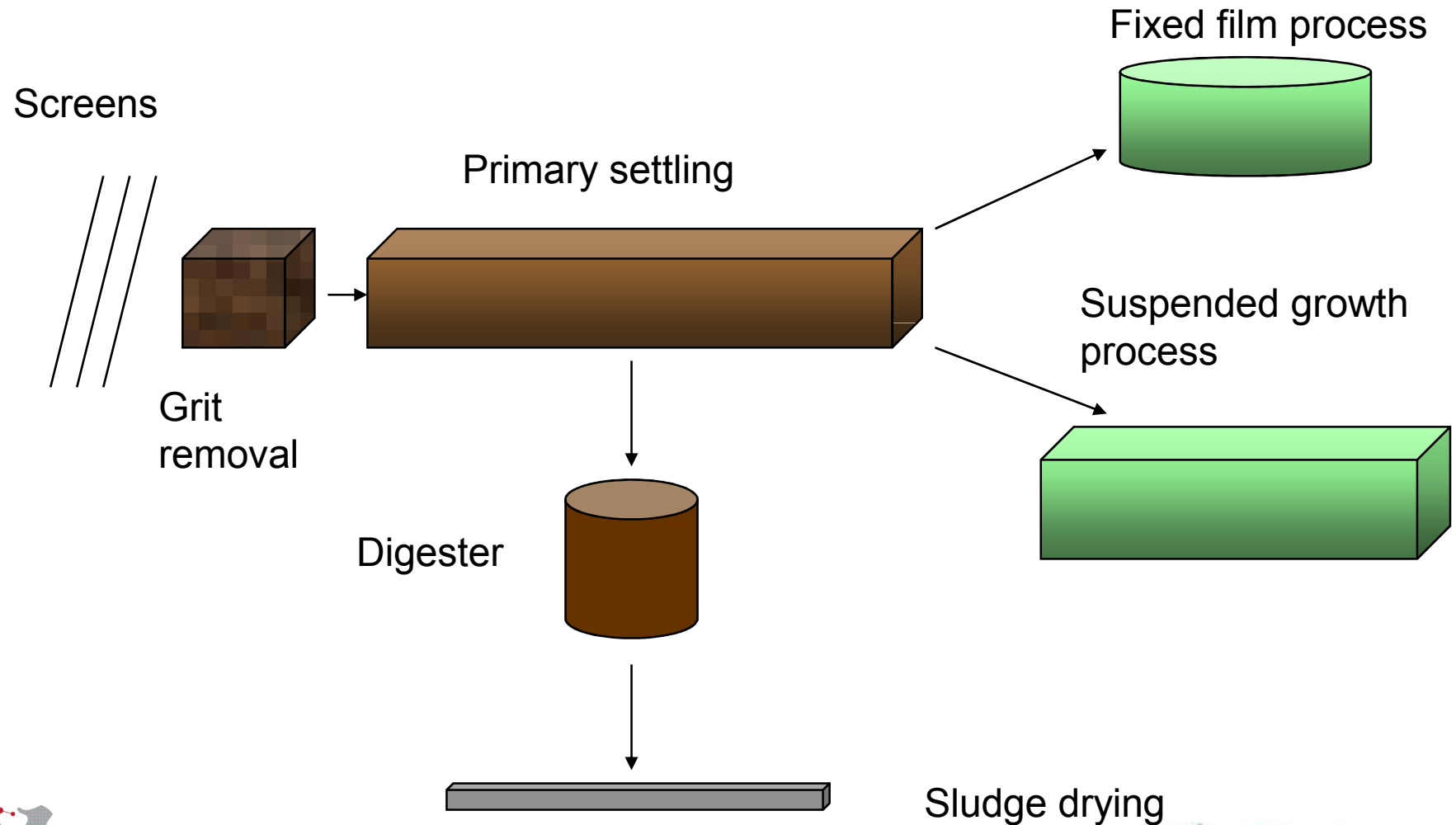




Extra Slides



Wastewater Treatment – Biological Processes





Example: Anaerobic Biosolid Digestion Reduces Solids - Makes Methane



**Anaerobic sludge digestors produce methane
(65% CH₄ - 35% CO₂)**



On-site electricity is produced with the methane 50% of plant power (2.2MW)

Source: Albuquerque NM Waste Water Treatment Plant



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



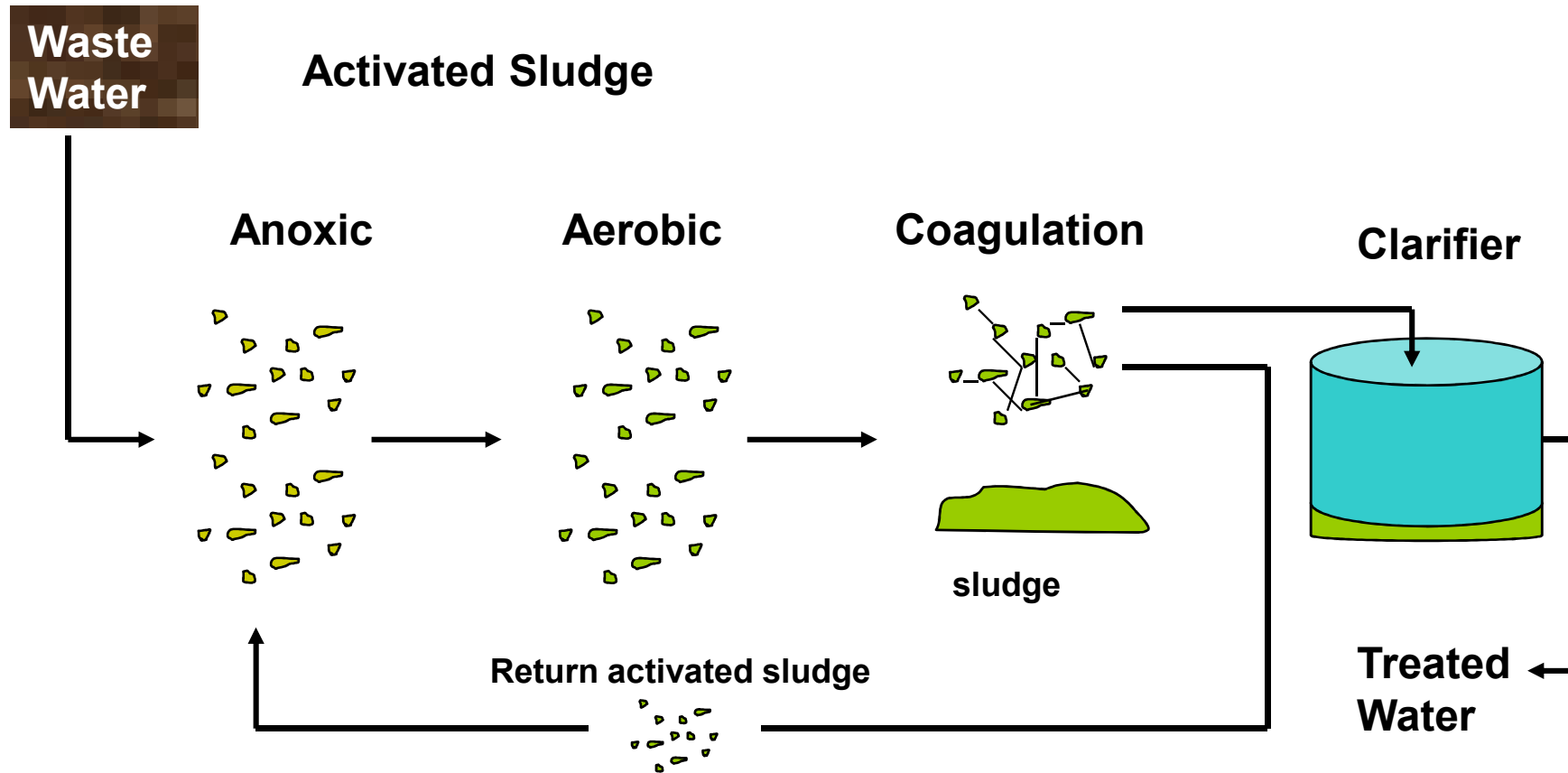
Suspended Growth (activated sludge) Process Requires Energy



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



Wastewater Suspended Growth Biological Process



Anoxic – no dissolved oxygen



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



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)



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**





Wastewater Treatment- Generic ***(continued)***

- **Adsorption** – uses physical adhesion unto 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

