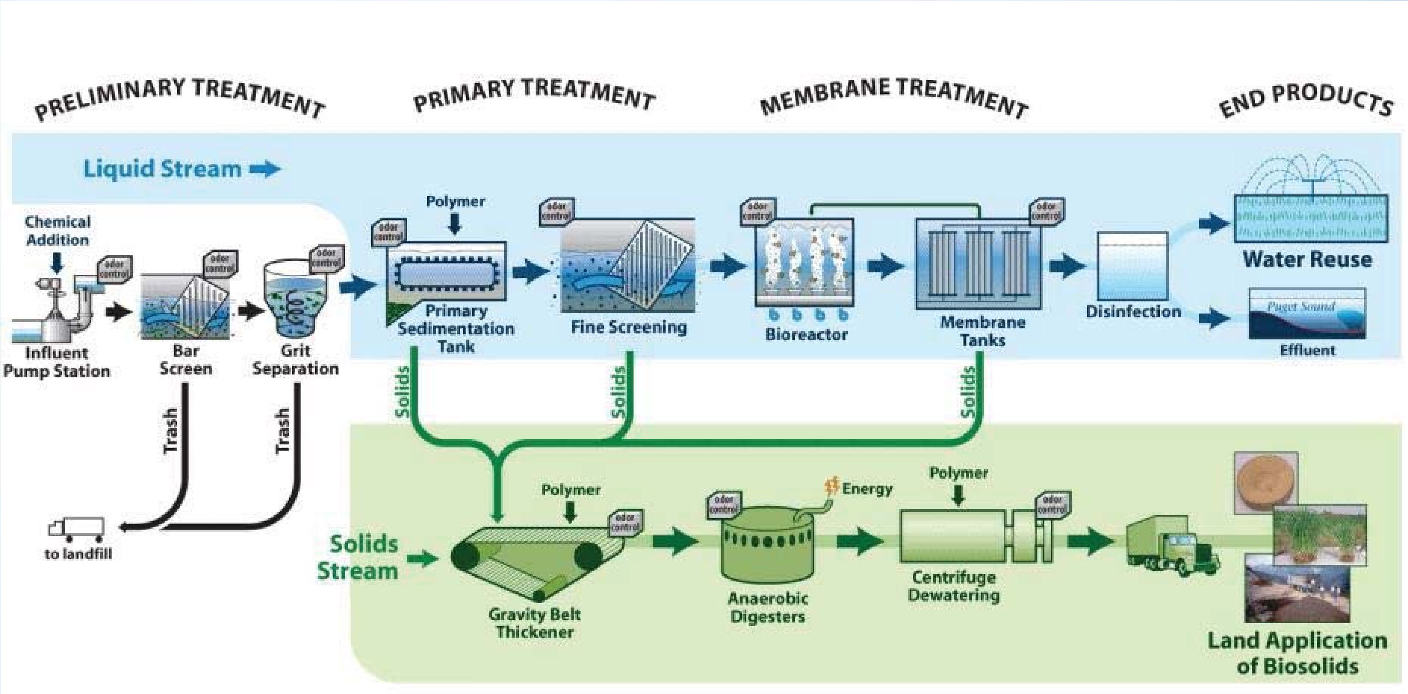

Unit Operations & Unit Processes

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Unit Operations & Unit Processes

Introduction:

- Various industrial waste treatment methods: identical to domestic sewage treatment methods.
- Differences B/W 2 methods arise because of:

a) A very high degree of variability in quality of industrial wastes compared to domestic sewage.

b) Large variations in flow rates of industrial wastes.

c) Presence of hazardous &/or toxic pollutants in some industrial wastes.

- In terms of population equivalent: IWW- few times stronger than an equal volume of domestic sewage.
- Possible presence of hazardous &/or toxic pollutants: necessary to provide adequate preliminary treatment to IWW before subjecting it to further treatment.

Unit Operations & Unit Processes

- Achieved by: Unit operations & unit processes.
- Unit Operations: Physical forces are employed to purify waste water.
- Ex: screening, sedimentation, flotation, filtration, mixing, equalization, flow proportioning, drying, incineration, freezing, foaming, dialysis, osmosis, adsorption, gas transfer, elutriation.
- Unit Processes: Chemical &/or biological forces are used to purify waste water.
- Ex: pH correction, coagulation, oxidation, reduction, disinfection, aerobic & anaerobic biological treatment.

Unit Operations & Unit Processes

- Its rarely adequate to apply only UO or only UP to an IWW to get an effluent fit for discharge to environment.
- Based on lab scale-studies &/or pilot plant studies, proper choice of UO & UP is made: arranged in a logical sequence : adequate treatment scheme.

UNIT OPEARTIONS:

1. Screening:

- Done to remove large suspended & floating solids from waste water to protect pumps, pipes & valves from clogging & damage, example;

- Rags & pieces of cloth from cotton textile wastes
- Fine fibres from woolen mills
- Spent tan bark from vegetable tanning process
- Leather trimmings from leather processing houses.

Unit Operations & Unit Processes

- Bark from debarking machines in pulp & paper mills.
- Fruit peelings & fruit rinds from fruit canning & packing industry.
- In industries where good housekeeping practices: not followed.

• Screens: coarse, medium or fine -- clear space B/W bars.

• Fine screens: rotary drum type

- tangential type
- vibratory type

• Cleaning of screens: Manual or mechanical

- Adequate arrangement necessary to treat & dispose off the screened material.

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2. Sedimentation & Flotation:

• Plain sedimentation: removal of finely suspended & settleable solids.

• Chemically aided sedimentation: removal of colloidal solids.

• Flotation (-Ve sedimentation): removal of impurities lighter than water & do not settle in a reasonable time length.

• Like coagulants in sedimentation, flotation may be done with or without aid of flotation agents.

• Sedimentation: Used in industries producing high suspended organic & inorganic solids

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- Flotation: particularly useful in woolen mills, slaughter houses, pulp & paper mills, oil refineries & dairies.
- Both sedimentation & flotation: reduce solids load on the following treatment units.
- Flotation: also useful for recovery of useful materials from waste water streams.

3. Filtration:

- More often practiced D/S of other treatment processes than as a stand-alone pretreatment method.
- Used during neutralization/precipitation of heavy metals & biological treatment to reduce BOD loads.
- Used to remove lime precipitates of phosphates.

Unit Operations & Unit Processes

- Used as a pretreatment for WW before it is discharged in to an activated Carbon column or to a dialysis or reverse osmosis unit.
- In reuse applications, filtration used if treated WW is to be spread on land for irrigation, groundwater injection, lawn sprinkling, etc.

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- 4. Mixing:
- Vital Unit Operation in waste water treatment.
- Used for - mixing one substance with another, e.g. chlorine or sodium hypochlorite with treated waste water , liquid suspensions: in aeration tank of activated sludge process or sludge undergoing aerobic or anaerobic digestion.

- For flocculation of finely divided suspended solids with coagulants.
- For heat transfer as in heated digesters.
- For mixing neutralizing chemicals with acidic or alkaline waste water streams.

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Unit Operations & Unit Processes

- Continuous, rapid mixing is achieved by:

- Providing baffles or hydraulic jumps in open channels.
- Fixing static mixers or venturi flumes in pipelines.

- Continuous mixing is achieved by:

- Pumping the tank contents &
- recycling a part of the pumped liquid, by using mechanical mixers, or with the help of compressed air bubbles into liquid.

- Compressed air & mechanical mixers: also serve purpose of maintaining tank contents in a fresh condition.

Unit Operations & Unit Processes

- If WW contains: oily & greasy matter- compressed air helps float a part of this matter , which can be skimmed off.
- Mixing: helps in giving partial treatment to WW streams of opposite nature, e.g.:

- Mutual neutralization of acidic & alkaline effluents, or
- Partial cooling of hot streams when mixed with cold streams.

- WW streams: highly fluctuating in quality & flow rates: best handled by mixing them in equalization tanks.

Unit Operations & Unit Processes

5. Equalization:

- Used to

- overcome operational problems caused by variations in quality & flow rates.
- Improve the performance of D/S units of processes.
- Reduce the size & cost of D/S units of treatment.

- Helps dilute toxic pollutants.
- Attractive proposition for upgrading performance of an overloaded treatment plant
- Equalization: done 'in-line' or 'off-line'
- In-line: done when equalization of plant loading: desired.

Unit Operations & Unit Processes

- Off-line: used when D/S treatment units (specially, biological units): to be protected against shock loads due to slugs of toxic &/or organic pollutants.
- An essential requirement of an equalization basin: adequate mixing of the basin contents. This:

- Ensures a more or less uniform quality of outflow
- Minimizes chances of deposition of solids in the basin &
- Helps keep the waste water fresh.

6. Flow Proportioning:

- Strictly speaking, its not UO, but can be used in conjunction with equalization.

Unit Operations & Unit Processes

- It consists of:

- Storing a WW stream in a tank of suitable size &
- discharging it into other streams (DS OR IW).

- This is done in proportion to flow in receiving WW stream: so that mixture does not exert an unduly high organic, hydraulic, toxic load on receiving water body or WWT plant.
- Method: useful in dealing with toxic wastes, or wastes having a high oxygen demand.

7. Drying & Incineration:

- Exclusively used for handling WW sludges generated during various treatment processes.

Unit Operations & Unit Processes

- Drying is done:

- To get rid of a large moisture fraction entrained with sludge solids &

- To reduce its volume.

- Drying is done:

- By spreading sludge in a layer ranging in thickness from 20 cm to 30 cm on sand drying beds.

- A part of moisture evaporates

- The rest percolates through sand & gravel layers of drying beds.

- This filtrate: recycled to plant inlet.

- sludge so dried: removed from beds when its moisture contents are reduced b/w 50% & 55%.

Unit Operations & Unit Processes

- Space for bed construction: inadequate- mechanical means- vacuum filtration, centrifugation, plate & frame presses, belt filters employed.

- Dried sludge incineration: practiced when sludge contains toxic matter in concentrations (having adverse effect on receiving medium such as soil)

- Reduces biological sludge in to harmless end products such as water vapor & CO_2.

- Incineration: preceded by heat drying: sludge can be burnt effectively & economically.

- Heat drying: needed to convert sludge in to soil conditioner.

Unit Operations & Unit Processes

- Drying permits:
- Grinding of the sludge
- reduction in its weight
- prevention of continued biological activity
- Moisture is reduced to 10% or less.

Heat drying: achieved by using-

- Flash dryers
- Rotary dryers
- Multiple hearth dryers
- Multiple effect evaporators.
- Incineration: should not give rise to air pollution.

8. Freezing:

- Impure water (an industrial effluent): frozen- ice crystals formed (pure water).
- 3 steps are involved in freezing process:

1. Heat is removed from water to cool it to its freezing point.
2. Additional heat is then removed by vaporization of refrigerant (butane) in direct contact with cooled water, causing fine crystals of ice to freeze out of solution.
3. When roughly ½ the water: frozen to ice, ice-water slurry: transferred to another tank (where unfrozen liquid is drained off & crystals are washed with pure water). Washed ice: transferred to another tank: melted to form a pure end-product.

9. Foaming:

- Foam separation: useful for WW containing foaming agents (detergents & other surface-active pollutants).
- Process: takes advantage of tendency of surface-active pollutants to collect at a gas-liquid interface.
- A large interface is created by passing air (or gas) bubbles through the liquid.
- Foam: becomes enriched in pollutant & liquid is depleted of the pollutant.
- Foam is subsequently collected & collapsed to produce a solute-rich liquid product.

10. Dialysis & Osmosis:

- Electric potential: impressed across a cell containing mineralized water: cations migrate to **–Ve electrode**, anions migrate **to +Ve electrode**.
- If cation & anion-permeable membranes are placed alternately between electrodes- ions will concentrate in alternate compartments: become dilute in intervening compartments.
- If apparatus is so arranged that concentrated & dilute streams: flow continuously: large-scale demineralization of water can be done.
- Phenomenon: specific to ions- application of process: limited to removal of soluble ionized contaminants.

- When solutions of 2 different concentrations: separated by a semi-permeable membrane: water tends to pass through membrane from more dilute side to more concentrated side.
- This produces concentration equilibrium on both sides of the membrane.
- Driving force impelling this flow: related to osmotic pressure of system.
- If pressure on more concentrated side: deliberately increased: water flow through membrane reverses (water moves from more conctd compartment to less conctd compartment).
- It is reverse osmosis.

- Process: useful for caustic soda recovery from spent caustic resulting from mercerizing of cloth in cotton textile industry.

11. Adsorption:

- WW: organic contaminants (resistant to biodegradation & present in dissolved state) : suitably removed by adsorption.
- It's a surface phenomenon.
- It involves: collection of contaminants on a suitable interface (liquid & a gas, a solid or another liquid).
- Process: used as a polishing step for improving effluent quality (which has already received treatment for removal of a bulk of the contaminants).

- Adsorption: occurs in activated sludge process: dissolved & colloidal organic matter, acting as a substrate for microorganisms , concentrates @ biomass-water interface.

12. Gas Transfer:

- Gas: transferred from one phase to another (usually form gaseous to liquid phase).
- Functioning of aerobic processes (activated sludge process, trickling filtration, aerobic sludge digestion): depends on sufficient O_2 availability.
- Chlorine (used as a disinfectant): must be transferred from gaseous phase to liquid phase.

- Post-aeration of treated effluents: depends on gas transfer.
- One process of Nitrogen removal: consists of converting nitrogen to ammonia , transferring ammonia gas from water to air.
- Industrial wastes (**containing volatile solvents**): can be conveniently treated by aeration: to strip off a large fraction of solvents.
- These solvents may be recovered thereby helping to reduce COD of WW to some extent.

13. Elutriation:

- Here, a solid or a solid-liquid mixture: intimately mixed with a liquid: to transfer certain components to liquid.
- Example: chemical conditioning of anaerobically digested sludge before mechanical dewatering: can be done by washing digested sludge with water containing low alkalinity.
- Such a sludge: contains a high alkalinity concentration: consumes a lot of conditioning chemicals.
- Elutriation: transfers alkalinity from digested sludge to wash water.
- Wash water: returned to waste treatment plant.
- Done as : single stage, multi-stage or countercurrent process.

Unit Processes:

1. pH Correction:

- Almost universally used UP.
- Renders a WW stream fit for further treatment in which pH value plays a vital role.
- Example: ammonia removal, biological treatment, nitrification & de-nitrification, disinfection with chlorine, phosphorous removal & coagulation.
- Chemicals used: sulphuric acid, hydrochloric acid, nitric acid, phosphoric acid, lime, sodium hydroxide, sodium carbonate, sodium bicarbonate, ammonium hydroxide, etc.

- adequate mixing B/W waste stream & neutralizing chemical.
- An equalization tank: provided with mixing arrangement: pH correction: can be conveniently combined with equalization.
- Care to be taken: check whether pH correction results in increasing suspended solids in WW.
- Better to conduct lab-scale studies : choosing right type of neutralizing chemical & optimum dose.
- It has a direct bearing on operating cost of treatment.

2. <u>Coagulation</u>:

- Used to aid suspended solids removal from WW by sedimentation.
- Chemicals commonly used: alum, ferric chloride, ferrous sulphate, ferric sulphate, lime, etc.
- Coagulation followed by sedimentation: results in an increase in sludge volume to be handled.
- Organic polymers: Sometimes used as coagulant aids.
- Sludge resulting from chemical coagulation: may be difficult to dewater or difficult to biodegrade.
- So, lab-scale trials to be made: to select appropriate coagulant.

- 3. **Oxidation & Reduction**:
- Occasionally used: to remove pollutants from industrial wastes.
- Example: -reduction of hexavalent chromium to its trivalent form before its removal by precipitation

- Ozone oxidation to remove dissolved organics & cyanide during pretreatment.

- Alkaline chlorination: preferred to ozone treatment for cyanide destruction

- Oxidation with chlorine is used for:

- BOD reduction
- Odor control
- As an aid to grease removal
- Reduction of sludge bulking in activated sludge process.
- Eliminating ponding & fly nuisance in trickling filtration
- Wet scrubbing of gas from anaerobic digestion.

- Chlorine: also useful: minimize biological aftergrowths in pipelines & conduits conveying treated effluents over long distances.
- A biologically treated sewage or industrial waste: to be subjected to tertiary treatment with a view to recycle: chlorine plays an important role in keeping down biological growths

- Chlorine: successfully used in treatment of:
- Cyanide-bearing wastes
- textile wastes
- phenol-bearing wastes
- oil refinery wastes
- paper mill wastes
- food processing wastes
- tannery wastes
- Chlorine acts in one or more of following ways:
- As an oxidizing agent
- As a bleaching agent
- As a disinfectant (depending on nature of pollutants in WW)

- IW: highly variable in their quality: necessary to find proper dose of oxidizing agents by conducting lab-scale studies.

Aerobic & Anaerobic Processes:

- These aim at converting non-settleable organic matter in to settleable organic matter & to stabilize it.
- Purification of WW (containing biodegradable organic matter): economically done with help of microorganisms.
- Microorganisms:
- May be inherently present in WW, or
- May be introduced to it in the form of DS, or
- As pure cultures of organisms for destruction of specific pollutants.

- Provision of proper environmental conditions to microorganisms:

- Adequate balanced food
- availability of dissolved O2 (for aerobic systems).
- total absence of molecular oxygen (for anaerobic systems).
- absence of pollutants toxic to microorganisms
- correct pH value
- proper temperature of WW
- sufficient time for microorganisms to grow & complete biochemical reactions (which result in destroying a large part of pollutants).

- Presence of inorganic cations & anions in concentrations below toxic limits for organisms.

- These result in producing a satisfactory effluent.

<u>NOTE</u>:

- All industrial wastes need some form of pretreatment before biological treatment. This: may take one or more of UOs &/or Ups.
- These are aimed at creating environmental conditions fit for microorganisms to work in.

- Microorganisms: require carbon, nitrogen, phosphorous & other elements in proper amounts.
- Their metabolic activities are not hindered due to this.
- C:N:P ratio should be in the range 100: 5:1 - 100:20:1 for aerobic treatment.
- Anaerobic organisms: slow acting: require much less nitrogen & phosphorous compared with aerobic organisms.

UNIT OPERATIONS & UNIT PROCESSES

Table 3.1 Inorganic Ions Necessary for Most Organisms [2]

Substantial quantities	Trace quantities
Sodium (except for plants)	Iron
Potassium	Copper
Calcium	Manganese
Phosphate	Boron (required by plants and certain protists*)
Chloride	Molybdenum (required by plants, certain protists* and animals)
Bicarbonate	Vanadium (required by certain protists*and animals)
	Cobalt (required by certain plants, animals and protists*)
	Iodine (required by certain animals)
	Selenium (required by certain animals)

*Protists include algae, protozoa and fungi.

- Toxic & inhibitory concentrations of organic & inorganic pollutants: frequently observed in industrial wastes.
- These can either slow down biological treatment process or stop it altogether if present in large concentrations.
- Microorganisms adapt themselves to presence of these pollutants to some extent.

UNIT OPERATIONS & UNIT PROCESSES

Table 3.2 Threshold Values for Aerobic Biological Treatment [7, 8]

Item	Threshold for biological treatment
pH value	6.5–8.5
Sulphides	200 mg/l
Phenols	500 mg/l (after adequate acclimatization)
Chloroform extractables (oil and grease)	50 mg/l
Hexavalent chromium	2 mg/l
Maleic acid	400 mg/l
Oxalic acid	200 mg/l
Acrylonitrile	400 mg/l
Benzoic acid	500 mg/l
Lead as Pb	1 mg/l
Nickel as nickel chloride	15 mg/l
Zinc	10 mg/l
Chlorides	8000–15,000 mg/l
Ammonia	1,600 mg/l
Dissolved salts	16,000 mg/l

UNIT OPERATIONS & UNIT PROCESSES

Table 3.3 Some Common Inhibitors of Anaerobic Digestion [9]

Substance	Toxic threshold
Anionic detergents	900
Methylene chloride (CH_2Cl_2)	100
Chloroform ($CHCl_3$)	0.5–1.0
Carbon tetrachloride (CCl_4)	2.0–10.0
1,1,1,trichloroethane	2.25
1,1,2-trichloro-1,2,2,trifluoroethane	About 10
Monochlorobenzene	900
Orthodichlorobenzene	900
Paradichlorobenzene	1300[a]
Pentachlorophenol	1 to 2.
Cyanide	3–30[b]
Zinc	590[c]
Nickel	530[c]
Lead	1800[c]
Cadmium	1000[c]
Copper	850[c]

Note: Concentrations in mg/l for a digester fed with raw sludge with 4.5% dry solids.
[a]Concentration in sewage entering works.
[b]Initially very toxic, but bacteria acclimatize with time.
[c]Toxicity can be controlled by precipitation as non-toxic sulphide salts.