Wastewater Treatment Technologies

Introduction:

Wastewater generated from any industrial or domestic activities required proper disposal of the wastewater. Due to stringent norms for disposal wastewater needs to be properly treated before disposing it. Therefore, selection of wastewater treatment technology is the major concern during planning of any wastewater (industrial or domestic) treatment plant.

Process / Technologies available for Wastewater Treatment:

Considering the stages of wastewater treatment, treatment process can be divided into three stages, Primary Treatment, Secondary Treatment and Tertiary treatment, however, in some cases where wastewater is having extreme characteristic, special treatments such as thermal destruction i.e. evaporation, incineration is provided. In some cases, preliminary treatment such as grit removal, oil and grease removal etc are also employed, considering source, transportation and quality of inlet wastewater.

- **Primary Treatment:** Known as physic-chemical treatment, which, as name suggest, provide physical and chemical treatment. In which, flow equalization, pH correction, flocculation, sedimentation stages are involved.
    - **Flow equalization and pH correction:**
        - Wastewater from different section of plant have different characteristic, so first needs to equalize effluents characteristics (quality and quantity) in tanks having large storage capacity. This tanks are known as Equalization tank.
        - Acid or Alkalis are used to neutralize wastewater.
    - **Coagulation & Flocculation:**
        - Coagulation agents such as Lime, $FeCl_3$, $FeSO_4$, Poly aluminum chloride (PAC) are used to enhance coagulation.
        - Afterwards, polyelectrolytes are added to create large flocs of coagulated mass to facilitate better settlement and removal during sedimentation.
    - **Sedimentation :**
        - Generally, it is last stage of primary treatment section, coagulated mass present in wastewater is allowed to settle and remove as sludge from bottom of sedimentation tank, generally called clarifiers.

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- **Secondary Treatment:** Known as biological treatment, in which, primary treated industrial wastewater or raw sewage after removal of suspended particles are fed to microbes, the degrade by taking up organic material in the inlet wastewater and decrease pollution load present in wastewater. Biological treatment is divided in two major categories:

    - **Aerobic biological treatment :**
        - In which, additional oxygen is provided to microbes by means of blowers, surface aerator or any other suitable methods.
    - **Anaerobic biological treatment :**
        - In which, no oxygen is provided and degradation of organic mass is done in absence of oxygen.
- **Tertiary Treatment:** Known as polishing treatment, this treatment is used mostly to remove trace amount or residual pollution load present in wastewater. This method includes Advanced Oxidation Process, adsorption over charcoal etc. when treatmet wastewater needs to be recycled, membrane separation technology (generally followed by thermal evaporation of concentrated part) is also employed during tertiary treatment.

Following table, briefly explains various stages of wastewater treatment:

Treatment section	Brief Description of treatment technology
Preliminary Treatment	
Screening	- It is adopted to remove floating matter and shall be provided at the intake point
Grit Removal	- Used when WWTP has to deal with rainwater which normally entrains a considerable amount of sand
Oil and grease removal	- Oil and grease are skimmed-off by passing the waste water through skimming tank. This process can be rendered more efficient by dissolved air flotation or vacuum flotation
Primary Treatment	

Equalization	- Applicable for wastewaters having different characteristics at different intervals of time and where uniform treatment is required - Each unit volume of waste is mixed thoroughly with other unit volumes of other wastes to produce homogeneous and equalized effluent - Gives better mixing of different unit volumes of effluents
Neutralization	- Applicable for highly acidic and highly alkaline effluents - Acidic effluents may be neutralized by treatment with lime or lime slurry or caustic soda - Alkaline waste may be neutralized by treatment with acids
Sedimentation	- Separation of suspended particles by gravitational settling and floating material - Clarifies collected rainwater from solid content (sand or dust) Clarifies wastewater from inert contents (sand or comparable particles) Clarifies wastewater from reaction material (emulsified metal compounds, polymers and their monomers) Separates heavy metals or other dissolved components after preceding flocculation process - Removes suspended solids in the primary clarifier - Removes biological sludge in secondary clarifier of a biological WWTP
Secondary Treatment	
Aerobic Treatment	
Activated Sludge Process	- Applicable to all biodegradable industrial wastewater streams. - The effluent from primary treatment processes are collected in aeration tank and are aerated with mechanical devices such as fixed/ floating/diffused aeration/ oxygen injection etc.
Aerated Lagoons	- The effluent from primary treatment processes are collected in lagoons and are aerated with mechanical devices such as

	floating/ fixed aerators.
Trickling Filters/Bio filters	- In the trickling or percolating filter process the microorganisms are attached to a highly permeable medium through which the wastewater is trickled – or percolated - Trickling filters are effectively used for the treatment of industrial waste water - Used to treat urban and some industrial wastewater - Used when effluent is highly loaded with COD - Used to upgrade an existing activated sludge plant
Sequential Batch Reactors (SBR)	- The operation is in sequence of "fill , aerate , settle and waste sludge and draw treated waste water but not with secondary clarifier
Sub merged Aerobic Fixed Film reactor	- This technology utilizes an aerobic fixed film process that is a combination of submerged attached growth and activated sludge process. This system is designed to be installed into a two compartment, where the first compartment provides majority of BOD removal, and the second compartment polishes the BOD. Rigid block-type media is submerged within the treatment module, providing surface area for microbial growth.
Membrane Bioreactor	- Treats municipal and industrial waste water - It is particularly suitable for effluents with high COD and /or ammoniacal nitrogen loads ; envisaging recycling of waste water, stringent discharge regulations, sensitive receiving water bodies, sludges which are hard to settle, upgrading existing plants, compact installations
Anaerobic Treatment	
- Used only as Pretreatment for waste water which is characterized by high organic load(>2 g/l) - Applicable mostly for effluents of high BOD loads	
Anaerobic	- Anaerobic contact process (ACP) waste water is mixed with

Contact Reactor (ACR)	recycled sludge and digested in a sealed reactor, the waste water / sludge mixture externally separated (sedimentation, or vacuum fine screening flotation) and the supernatant discharged for further downstream treatment.
Up flow Anaerobic Sludge Blanket (UASB)	- In the UASB process, waste water is introduced at the bottom of the reactor, from where it flows upward through a sludge blanket composed of biologically formed granules or particles.
Fixed-bed Reactor	- In the fixed-bed or anaerobic filter process, waste water flows upward or downward (depending on the solids content of the influent) through a column with various types of solid media on which anaerobic micro-organisms grow and are retained
Biological Removal of Sulphur Compounds / Heavy Metals	
- Much lower solubility of metal sulphides compared to their hydroxides - Applicable to all waste water streams that contain a considerable amount of sulphate	
Tertiary Treatment	
Sand Filters	- Removes undissolved pollutants such as suspended solids, undissolved phosphate and attached organics - Flexible for modifications in basic design structure to accommodate site specific criteria.
Carbon Filters	- Activated carbon adsorbs organics - Flexible for modifications in basic design structure to accommodate site specific criteria.
Micro Filtration	- Applied when a solid free waste water for downstream facilities is desired such as reverse osmosis or complete removal of hazardous contaminants - Used in metal particle recovery - Used in metal plating waste water treatment - Used in sludge separation after activated sludge process in a

	central biological WWTP, replacing secondary clarifier
Ultra Filtration	- Removes pollutants such as proteins and other macromolecular compounds and toxic non-degradable components - Separates heavy metals after complexation or precipitation - Separates components not readily degradable in sewage treatment effluents which are subsequently recycled to the biological stage - It is a pre-treatment step prior to reverse osmosis or ion exchange - Removes SS along with attached COD as a polishing step and avoiding secondary clarification
Retention ponds	- Used to avoid hydraulic overload of downstream facilities - Separates solid pollutants (such as sediment, organic matter, dissolved metal compounds and nutrients) from rainwater - Applied to industrial sites with highly contaminated surfaces
Nano Filtration	- Applied to remove larger organic molecules and multivalent ions in order to recycle and reuse the waste water or reduce its volume - Increase the concentration of contaminants to such an extent that subsequent destruction processes are feasible
Reverse Osmosis (RO)	- Separates water and dissolved constituents down to ionic species - It is applied when a high purity water is required - The segregated water phase is recycled and reused such as desalination, final removal of degradable components if biological treatment is not available, heavy metals, toxic components and segregation of pollutants with the aim of concentrating or further processing - It is often used in combination with post treatment techniques for the permeate.

Ion Exchange	- Applied to remove unwanted ionic and ionizable species from wastewater. - Its greatest value lies in recovery potential - It recovers rinse water and process chemicals - **Examples:** - Heavy metal ions – cationic or anionic, e.g. Cr3+ or cadmium and its compounds, with low feed concentrations Ionizable inorganic compounds, such as H3BO3 Soluble, ionic or ionizable organic compounds, e.g. carboxylic acids, sulphonic acids, some phenols, amines as acid salt, quaternary amines, alkyl sulphates and organic mercury can be removed. - Ion Exchange is the removal of undesired or hazardous ionic constituents of waste water and their replacement by more acceptable ions from an ion exchange resin, where they are temporarily retained and afterwards released into a regeneration or backwashing liquid.
Evaporation	- It is applicable to remove or concentrate inorganics

(Source: Technical EIA Guidance Manual for Common Effluent Treatment Plant, Ministry of Environment Forests and Climate Change, New Delhi.)

Selection of Wastewater Treatment technology:

Generally, analytical parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total dissolved solids (TDS) are considered to select treatment technologies and treatment sequences. Following table illustrates, importance of these parameters during selection of treatment technologies.

Combination	Quality of Effluent	Treatment options
High TDS, and high COD and equivalently high BOD	Waste is not easily biodegradable but toxic	- Thermal decomposition (based on calorific value) - Chemical oxidation by hydrogen peroxide, ozone *etc*. - Evaporation + secured landfill
High TDS, High COD and high difference	May be toxic; not suitable for biological	- Chemical treatment (recovery, precipitation etc.)

between COD and BOD	treatment; mostly inorganic salts	- Evaporation + secured landfill of evaporated residue
High TDS, high BOD and low difference between COD & BOD	Highly organic effluent fully biodegradable	- Anaerobic + Aerobic treatment - If quantity is less, incineration (based on calorific value) + secure landfill of incineration ash
High TDS, low BOD and low BOD & COD difference	Only inorganic salts, no need for biological treatment	- Solar evaporation - Forced evaporation (after separation of volatile organic matter) - Membrane technologies
Low TDS, and high COD and equivalently high BOD	Highly organic effluent, may not be easily biodegradable	- Thermal decomposition - Chemical oxidation by hydrogen peroxide or ozone or sodium hypochlorite etc. - Chemical + biological treatment
Low TDS, High COD and high difference between COD and BOD	Highly inorganic effluent, not suitable for biological treatment	- Chemical recovery - Chemical oxidation + biological treatment
Low TDS, high BOD and low difference between COD & BOD	Organic effluent, fully biodegradable	- Anaerobic + aerobic treatment
Low TDS, low BOD and low BOD & COD difference	Low organic and low inorganic effluent	- Recycle and reuse (after preliminary treatment)

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