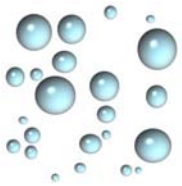
Package Treatment Plant Operation and Management

Treatment Processes: Part 1



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Introduction

In this session we will cover:

Common Treatment Processes

- Physical processes
- Biological processes (aerobic and anaerobic)
- Combined or Coupled processes

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Treatment Processes

Chemical
Phosphorus Removal
Sludge Management

Other
Odour Control
Resonance Frequency
High Temp. Incineration

Physical
Pre-treatment
Screening & grit removal
Grease Arrestors

Gravity Separation
Clarification
Flotation

Filtration
Packed Bed filters
Membranes

Adsorption
Amended materials

Biological
Anaerobic
Digestion
Sludge Blanket

Aerobic
Suspended growth
Attached growth

Combined
BNR

Lagoons
Facultative

Natural Systems
Wetlands and Aquatic systems

Disinfection
Chlorine
Ultraviolet
Ozone

Effluent / Solids Management
Surface discharge
GW recharge
Land Application or Reuse
Solids Handling

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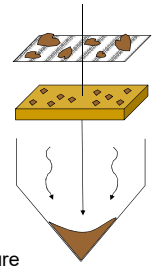
Physical Treatment Processes

Pre-treatment:
- Screening and grit removal

Gravity Separation:
- Settling (may be assisted)
- Flotation

Filtration:
- Packed Bed media
- Membranes

Adsorption:
- Amended media & nutrient capture



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Pre-treatment

- Screening important to remove large material (rags, debris, coarse solids, rodents??)
- Oversize or dense solids can impede treatment processes and harm plant equipment (pumps etc.)
- Finer solids (grit) can be removed using a filter box or grit chamber at the inflow (headworks)
- Grit chambers may use rapid settling, aeration or vortex designs to capture material (~coarse sand size or larger)

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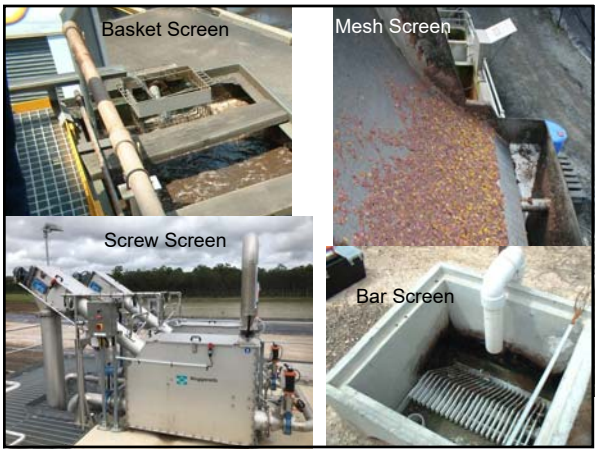


Gravity Separation (Settling and Flotation)

- Used for the removal of grit, TSS, colloids, biological and chemical flocs in primary and secondary treatment units
- Most widely applied unit operation
- Gravity and differential density are the driving forces
- May be 'assisted' using chemical (i.e. flocculation) or physical aids (i.e. DAF)

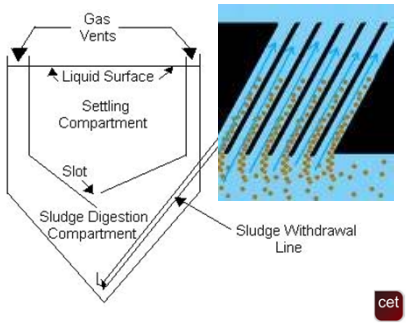
Primary Settling (Sedimentation)

- Primary settling removes bulk coarse solids (sludge) and floatable materials (scum)
- First step in many treatment systems (septic tanks, primary chambers or tanks etc.)
- Typical (well-designed) primary settling chamber will remove:
  - 50% to 70% of suspended solids, and
  - 25% to 40% of BOD_5 from influent wastewater

Secondary Settling (Clarification)

- Removes residual solids, generated flocs, colloids
- Enhanced by structural elements:
  - Lamella or incline plates / tube settlers
  - 'Imhoff' chambers
- Performance a function of design (i.e. Imhoff), detention time (size), and up-flow or surface loading rate
- Secondary clarification can remove:
  - 60% to 70% of residual suspended solids, and
  - 40% to 55% of residual BOD_5

Secondary Settling (Clarification)



Secondary Settling (Assisted Flotation)

- Used to separate solid or liquid particles from a liquid phase
- Involves the introduction of a fine gas (usually air) to the water column
- Bubbles attach to particles causing them to rise
- Commonly referred to as dissolved air (pressure) or diffused air (fine bubble) flotation (DAF)
- Chemicals commonly used to aid flocculation
- Less common – typically used in pollutant specific applications (oils, hydrocarbons)

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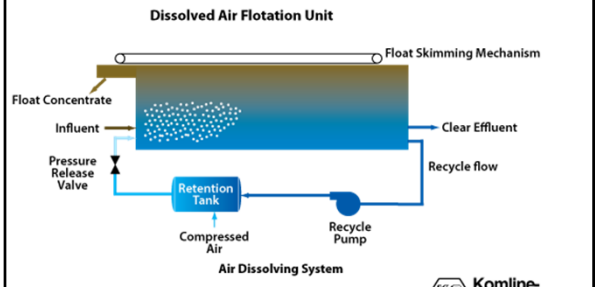
Secondary Settling (Assisted Flotation)



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Filtration

- Residual particulate matter in wastewater removed (mechanically) by passing through a filter medium
- Porosity of the filter medium is the determining factor for particle size removal
- Hydraulic loading rate (HLR) equally important for media filters
- Typically a secondary (or higher) unit process
- Maintenance requirement to remove retained solids from filter medium (backwashing/flushing, chemical cleaning etc.)

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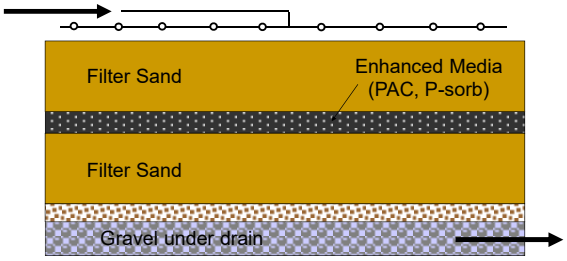
Filtration

- Depth Filtration
  - Packed Bed Reactor
  - Compressible media filters
  - Pressure (high-rate) filters
- Surface Filtration
  - Screen or Drum filters
  - Diatomaceous Earth filters
  - Cartridge filters
- Membrane Filtration
  - Flat Plate, Hollow Fibre / Tubular
  - Submerged or Dry-mounted

Filtration (Packed Bed Filters)

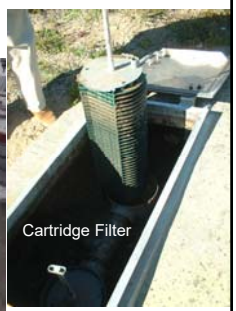
- Single pass, recirculating, up-flow or down-flow
- Filter depth and grain size selection requires balance between capture performance and frictional resistance (head loss)
- Sand or similar (crushed glass, slags, aggregate, carbon) typically used but other materials (plastics, textiles, peat) also available
- Varying layers can be used to target specific particle fractions or pollutants (e.g. PAC for colour/odour)
- Depth filtration of secondary effluent can remove:
  - >90% of residual suspended solids and BOD_5, and
  - 3 log+ (99.9%) of bacterial indicators

Packed Bed Filter



Packed Bed Filter

Surface Filters

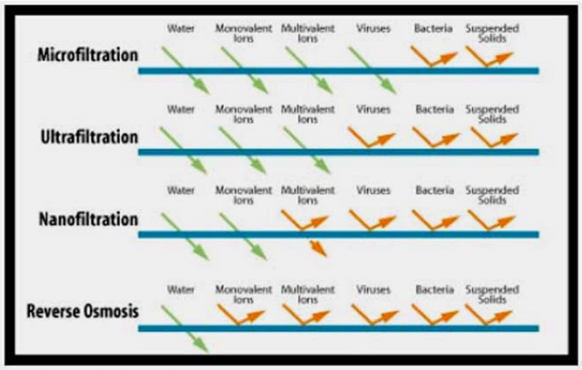


Filtration (Membranes)

- Involves the cross-flow (flux) of secondary or better wastewater through a porous material (membrane)
- Membranes made from organic and inorganic materials and are typically configured as flat plates or hollow fibres
- May be single unit process or incorporated as part of treatment system (MBR's)
- Classes of membrane filtration based on effective pore size:
  - Micro – 0.03 to 10 microns (1/1000th mm)
  - Ultra – 0.002 to 0.1 microns
  - Nano – ~0.001 microns
  - Reverse Osmosis – <0.001 microns (dense)

Filtration (Membranes)

- Require substantial pressure to operate water transfer across membrane (Micro 100-400kPa, Ultra 200-700kPa)
- Transfer may be outside-in (vacuum) or inside-out (pump)
- Fouling can be a substantial inhibitor
- Monitoring and maintenance imperative
- Well designed and maintained membrane systems can consistently remove:
  - Micro – TSS, bacteria, protozoa (Cryptosporidium and Giardia)
  - Ultra – most viruses, colloidal materials and some humic substances



Membrane Process Characteristics

Filtration (Membranes)

Adsorption

- Adsorption is the process of attaching or accumulating substances in solution onto a suitable interface
- Multiple mechanisms (covalent bonding, charge)
- In wastewater, adsorption is typically used for the selective retention of pollutants including organics (colour), odour and nutrients (nitrogen and phosphorus)
- Typical adsorbents include activated carbon, synthetic polymers, and iron or silica-based minerals
- Many natural soils and organics (peats) also have high adsorption co-efficient's

Adsorption (Amended Materials)

- Natural and byproduct minerals are often used to facilitate adsorption in treatment processes
- Alumino-silicates such as zeolites (ammonia), blast furnace slags and bauxite residues (P) are used as filters or amendments to increase nutrient retention
- Activated carbon (PAC) is often used in packed bed filters for organics (hydrocarbons, pesticides etc.)
- Many native soils also display strong adsorption and this process is maximised in effluent irrigation

Adsorption (Amended Materials)

Biological Treatment Processes

Anaerobic Processes:

- Digestion or Fermentation

Aerobic Processes:

- Suspended Growth
- Attached Growth

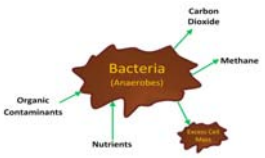
Anaerobic Processes

- Occur in the absence of 'free oxygen' (e.g. septic tank)
- Used for the stabilisation of waste sludge's
- Requires pH and temperature control to aid methanogenesis (methane production)
- New hybrid treatment processes available for soluble organic wastes (food processing)
- 'Contact' or sludge stabilisation utilised for strength moderation

Anaerobic Processes (Digestion/Fermentation)

- Organic material retained at the base of the tank undergoes facultative and anaerobic decomposition (microbiologically facilitated)
- Three steps – hydrolysis, acidogenesis / acetogenesis and methanogenesis
- Converted to stable compounds and gases such as carbon dioxide, methane, minor hydrogen sulphide (gas) and water
- Retained sludge mainly ligneous material that is difficult to decompose and will continue to accumulate

Anaerobic Processes (Digestion/Fermentation)



Aerobic Processes

- Aerobic treatment processes occur in the presence of free (molecular) oxygen
- Primarily facilitated by bacterial metabolism and the conversion of suspended and dissolved organic materials to energy, biomass and wastes
- Efficient process for the removal of:
  - Carbonaceous Organic Matter (BOD and TOC),
  - Nutrients (N & P), and
  - Waste sludge (stabilisation)

Suspended Growth systems

- **Activated Sludge** is the principal aerobic suspended growth process used
- Involves blending raw or primary treated wastewater with a retained population of wastewater-consuming microorganisms within suspension in a reactor
- Wastewater fed into the reactor and the biological populations consume or convert organic material and other constituents as part of their metabolic processes
- Requires a positive dissolved oxygen (DO) concentration

Suspended Growth systems

- Treated mixture requires secondary settlement (clarification) or filtration (membrane) to remove flocculent microorganisms from the waste stream
- Proportion is returned to the aerobic reactor (Return Activated Sludge)
- Large number of adaptations to the basic process to address issues such as:
  - Nutrient Removal
  - Small, intermittent or low-strength flows
  - Operational simplicity

Common Terms

- Mixed Liquor or Mixed Liquor Suspended Solids (MLSS)
- Mixed Liquor Volatile Suspended Solids (MLVSS)
- Non-biodegradable Volatile Suspended Solids (nbVSS)
- Sludge production
- Sludge yield
- Return Activated Sludge (RAS)
- Waste Activated Sludge (WAS)

Aerobic Processes (Activated Sludge)

- Relatively simple, robust process
- However, requires process management of:
  - Food to Microorganism (F/M) ratio – mass of BOD applied relative to mass of retained MLVSS
  - Mean Cell Residence Time (MCRT) – average time biological solids (wastewater) remain in the aeration tank (reactor) – also called Solids Retention Time (SRT)
  - Sludge Production – proportion of generated sludge **must** be wasted periodically to maintain treatment performance and capacity
  - Bacterial Growth Curve

Aerobic Processes (Activated Sludge)

- Process performance limited by environmental factors:
  - Temperature – cold (slow) warm (fast) metabolism
  - pH – 6.0-9.0 prefer limited variation (6.5-7.5)
  - Alkalinity – for nitrification (min 50-100 mg/L as $CaCO_3$)
  - Available oxygen (DO) – 2mg/L to 3mg/L + mixing
  - Essential nutrients – CNP ratio (100:10:1)

Aerobic Processes (Attached Growth)

- Attached or fixed-growth treatment processes are typically used for carbonaceous BOD removal and nitrification
- Facilitated growth of a microbiological film (biofilm) on a fixed or mobile substrate that is either actively or passively aerated
- Common process configurations include:
  - Submerged attached-growth
  - Non (or partially) submerged attached-growth
  - Hybrid suspended and attached-growth

Aerobic Processes (Attached Growth)

- Growth of biomass on a fixed media
- Biofilm consists of aerobic and facultative bacteria, fungi, algae and protozoans
- Biofilm microorganisms consume or convert organic material and other constituents as part of their metabolic processes
- Process requires a positive dissolved or atmospheric oxygen concentration
- Need to provide distribution and contact of the influent flow with the media surface area

Aerobic Processes (Attached Growth)

- Non-submerged systems require careful consideration of media hydraulics (including biofilm) and organic loading rates
- Process typically requires primary sedimentation to remove coarse solids and avoid clogging
- Treated mixture requires secondary settlement (clarification) to remove sloughed biofilms and residual solids from the waste stream
- Sludge may be proportionally returned (RAS) to the treatment reactor in submerged and hybrid systems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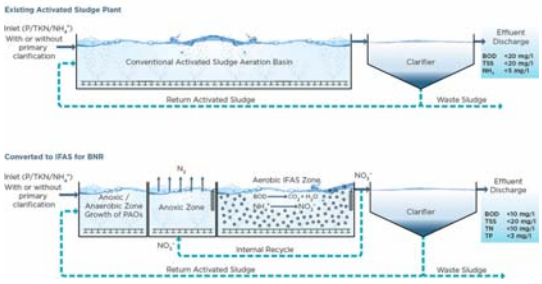
Combined or Coupled Processes (Anaerobic and Aerobic)

- Combined processes dominantly aerobic but may contain zones promoting anaerobic metabolism
- Typically seen in Biological Nutrient Removal (BNR) systems where nitrogen (N) is the typically the primary target
  - Oxic Zone – Aerobic Metabolism – Nitrification
  - Anoxic Zone – Anaerobic Metabolism – Denitrification
- Denitrification requires electron acceptor – carbon source

Combined or Coupled Processes (Anaerobic and Aerobic)

- Numerous proprietary and open source processes available (not commonly incorporated in typical PTP designs)
- Some common processes include:
  - Integrated Fixed-Film Activated Sludge (IFAS)
  - Bardenpho – N (4-stage) and P (5-stage)
  - Oxidation Ditch – N
  - A^2/O – P
  - PhoStrip – P
- Capable of producing high quality, very low nutrient concentration effluent (< 5mg/L N + P)

Combined or Coupled Processes (Anaerobic and Aerobic)



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