

Basic Sanitary Wastewater Treatment

Nick Cooper – AECOM USA



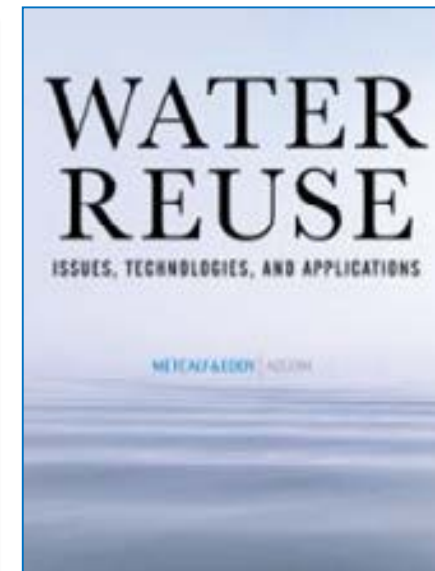
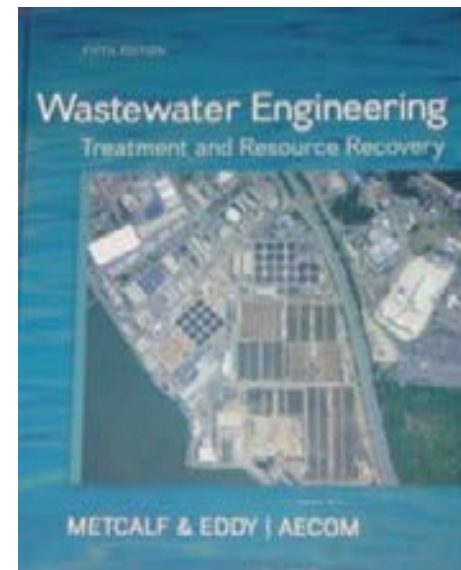
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- Vice President, Wastewater Technical Practice Leader
- Project Manager – Wastewater Treatment, Biosolids, Water Reuse, Industrial Treatment
- Process Design Lead – Jebel Ali (Dubai) STP Phase 2 Expansion; Al Ansab (Oman) STP Expansion
- Experience – USA, Canada, Middle East, UK, Southeast Asia, South America

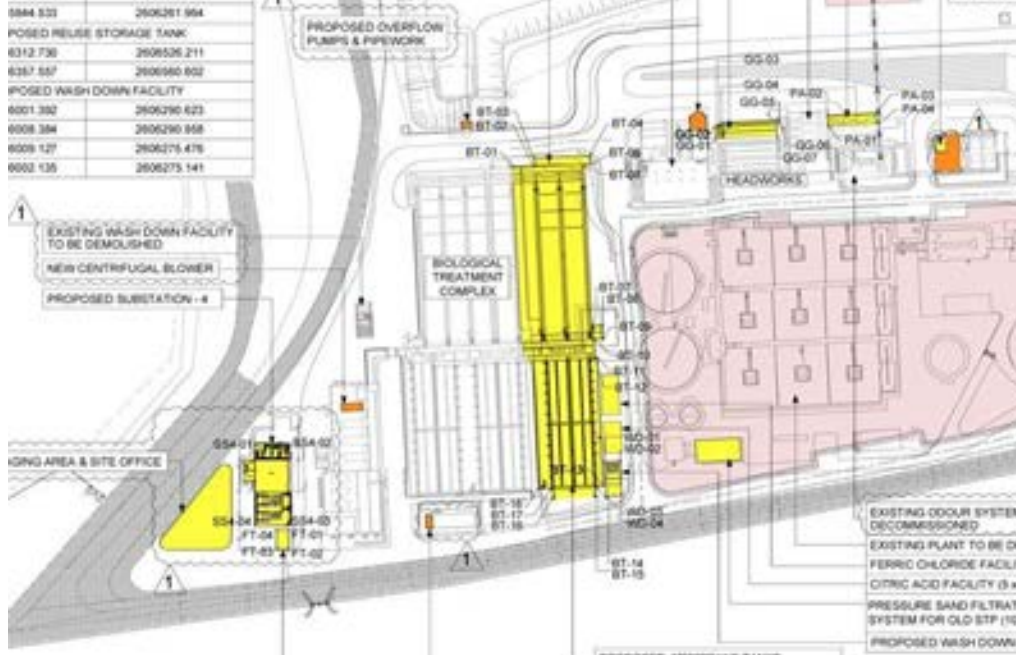
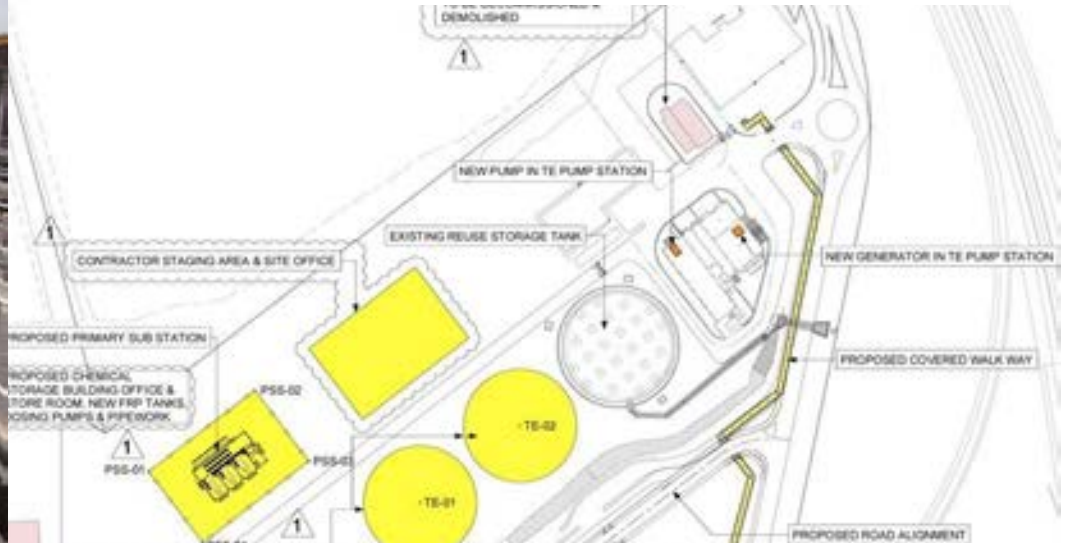


Contributing Author:

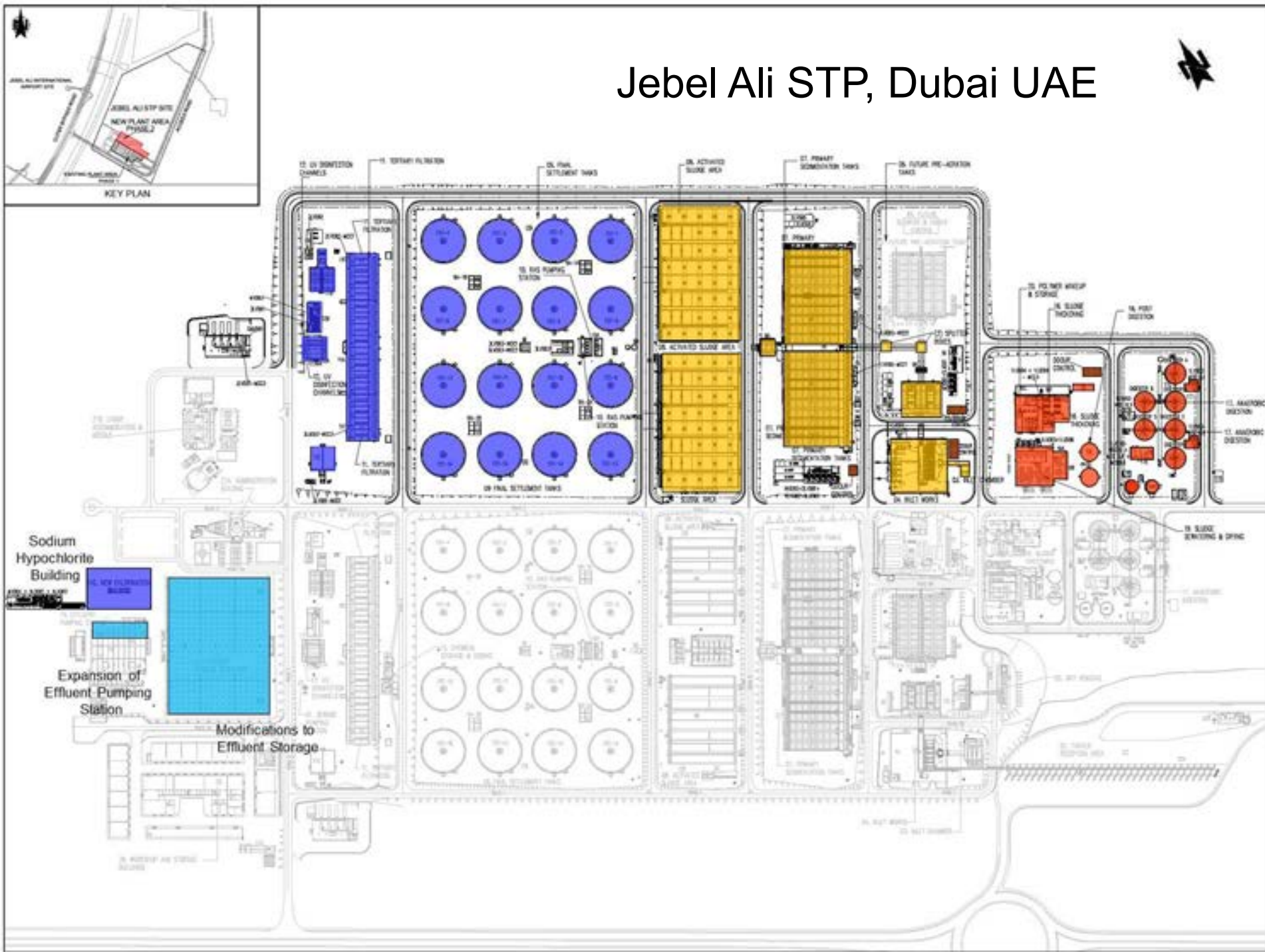
*Metcalf & Eddy – Water Reuse
MOP 32 – Energy Conservation
MOP 34 – Membrane Bioreactors
Metcalf & Eddy – Wastewater
Engineering, 5th Edition*



Al Ansab STP, Muscat, Oman



Jebel Ali STP, Dubai UAE



Agenda

08:30 **Overview of Wastewater Treatment**

09:30 **Preliminary and Primary Treatment**

10:00 – 10:30 Break

10:30 **Biological Treatment Processes**

11:30 – 13:00 Lunch Break

13:00 **Clarification, Filtration and Disinfection**

14:00 **Odor Control and Treatment**

14:30 – 15:00 Break

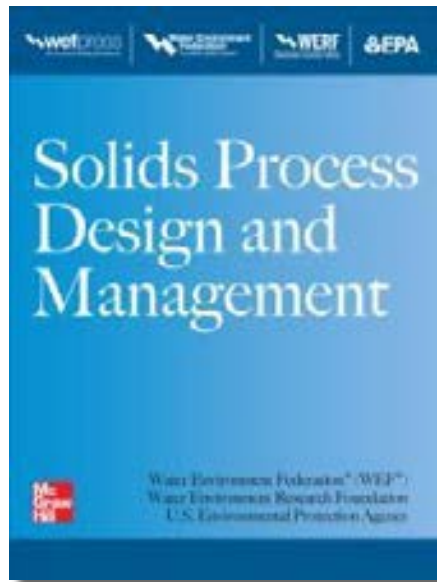
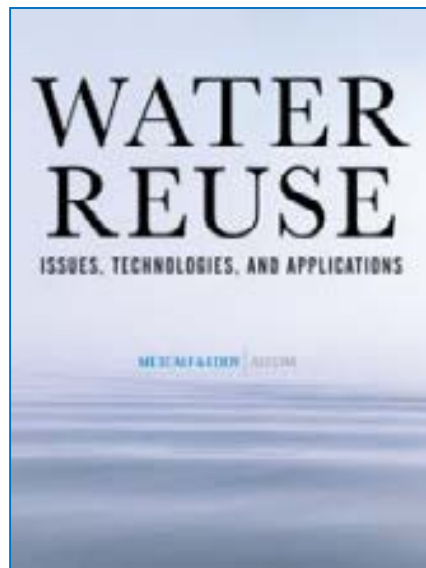
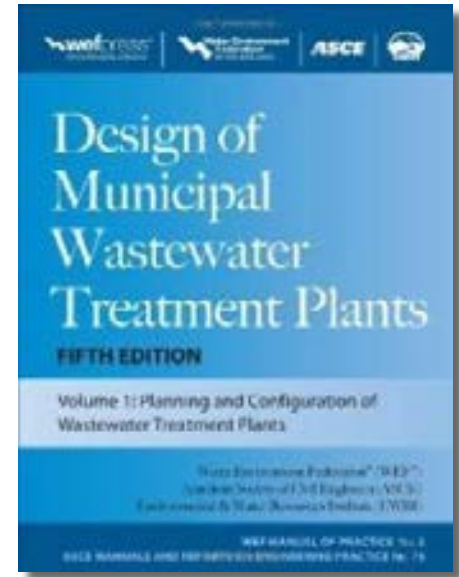
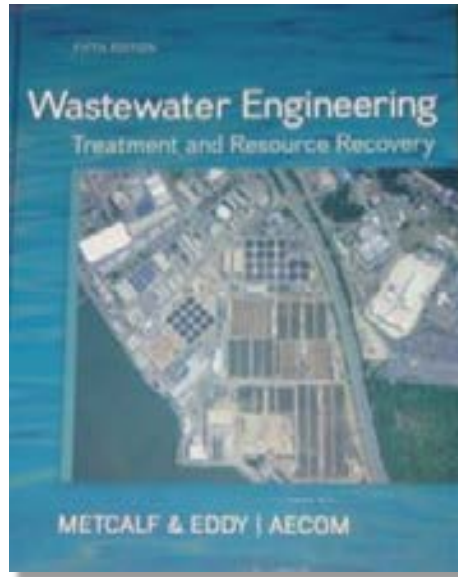
15:00 **Sludge Handling and Treatment**

15:30 – 16:00 Question Period

Session Objectives

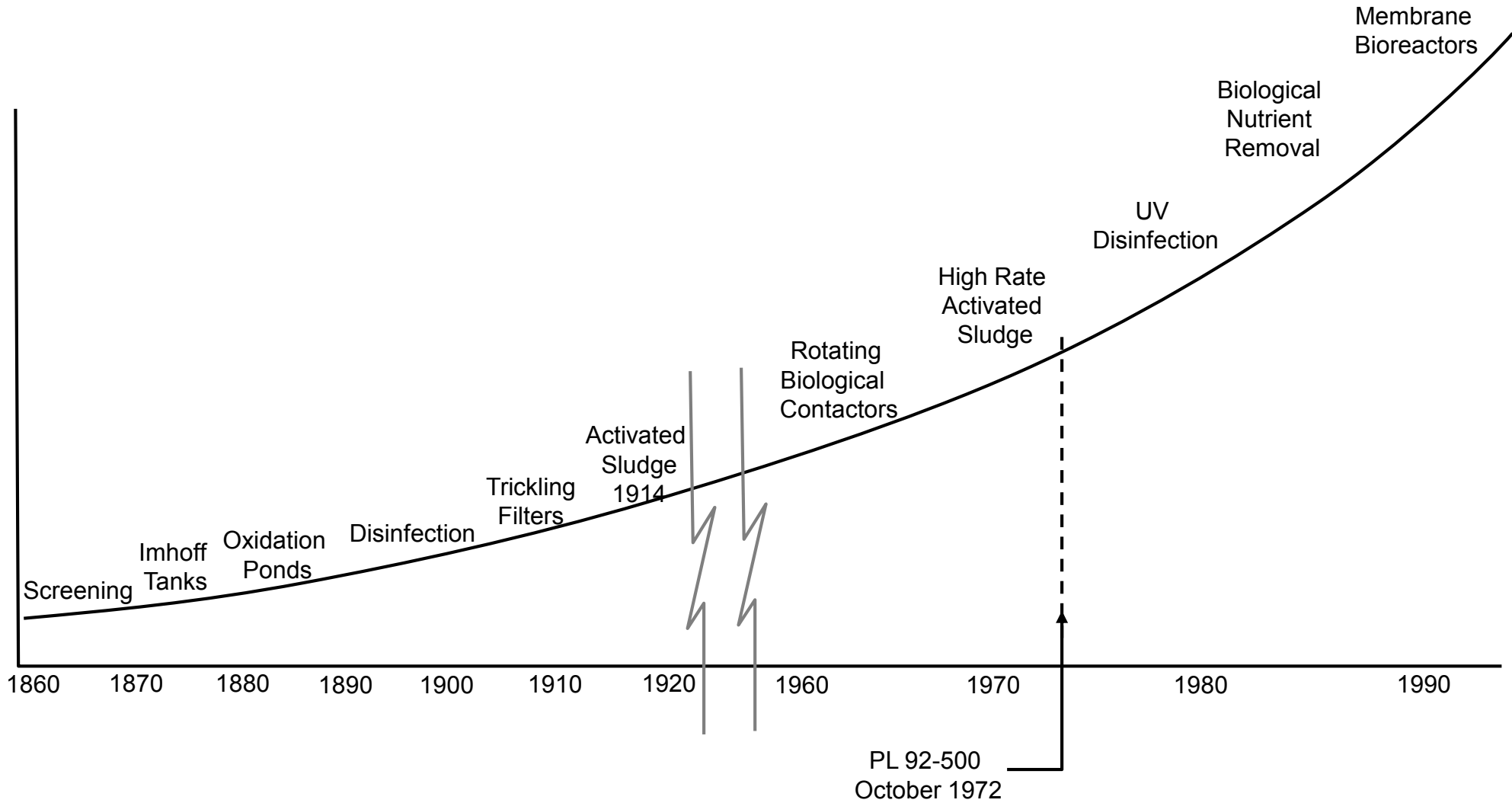
- Overview of Basic Sanitary Wastewater Treatment
- Design considerations
- Types of Treatment – Liquid Stream
- Treatment Systems – Residual Solids Stream
- Process descriptions and design parameters

References



Overview of Wastewater Treatment

History of Wastewater Treatment



1. Many Configurations and Processes in Wastewater Treatment

DC WATER BLUE PLAINS WWTP, USA

1400 MLD Capacity



F WAYNE HILL WRC, GEORGIA USA

227 MLD Capacity



Advanced Wastewater Treatment

Advanced Water Treatment

MALABAR STP, SYDNEY AUS

1000 MLD Capacity



Compact Treatment

60 MLD Membrane Bioreactor STP



20 MLD Membrane Bioreactor STP



10 MLD Membrane Bioreactor STP





Membrane Biological Reactors



Anoxic Tanks



Anoxic Tanks



Equalization Tanks



Cassette Tanks

Where is the Treatment Plant?



Image © 2013 DigitalGlobe

Google earth

135 m

Imagery Date: 3/19/2012



2008

37° 19' 36.86" N 127° 06' 18.63" E elev. 64 m

Eye alt. 659 m

Suji STP (SAMSUNG Engineering)
Yong-in City, Korea
110 MLD



2. Terminology

Terminology

- **BOD** – Biochemical Oxygen Demand
- **COD** – Chemical Oxygen Demand
- **TSS** – Total Suspended Solids
- **Coliform** - Bacteria Colony Forming Units
- **DO** – Dissolved Oxygen
- **Screenings** – Floating debris removed by screening units
- **Grit** – Inert debris (sand, coffee grounds, egg shells)
- **FOG** – Fats, Oils, Grease
- **Sludge/Biosolids** – Residual Waste from Biological Treatment
- **TSE** – Treated Sewage Effluent
- **Mixed Liquor** – Biomass in Activated Sludge Reactors

Terminology, Cont'd

Preliminary Treatment

Primary Treatment

Secondary Treatment

Biological Treatment

Activated Sludge /Suspended Growth Processes

Fixed Film/ Attached Growth Processes

Tertiary Treatment

Nutrient Removal

Return Activated Sludge

Waste Activated Sludge

Overview of Basic Sanitary Wastewater Treatment

- Wastewater is 99.97% Pure Water
- Wastewater Treatment is a series of physical, chemical and biological processes to improve quality before reuse or disposal
- Wastewater Treatment can be to any level, even drinking water quality, with the right selection of processes
- Astronauts recycle wastewater for potable use every day
- Treatment depends on end use of the water and environmental impact

Sewage

- Why treat it?
 - Reduce pollution in rivers
 - Reduce pollution in sea
 - Improve aesthetics
 - Bacteria and viruses are harmful to people
 - Fish need oxygen to live
 - Reuse – valuable resource



Pollutants/Contaminants in Wastewater

- **Floating Debris**
- **Grit**
- **Oil and grease**
- **Biochemical Oxygen Demand**
- **Total Suspended Solids**
- **Ammonia**
- **Bacteria and Viruses**
- **Nitrogen**
- **Phosphorous**
- **Toxic Organics**

Raw Sewage



Screenings



- **Unightly in discharge and residual solids**
- **Can damage equipment in plant**
- **Floating debris - plastics, sticks, paper**

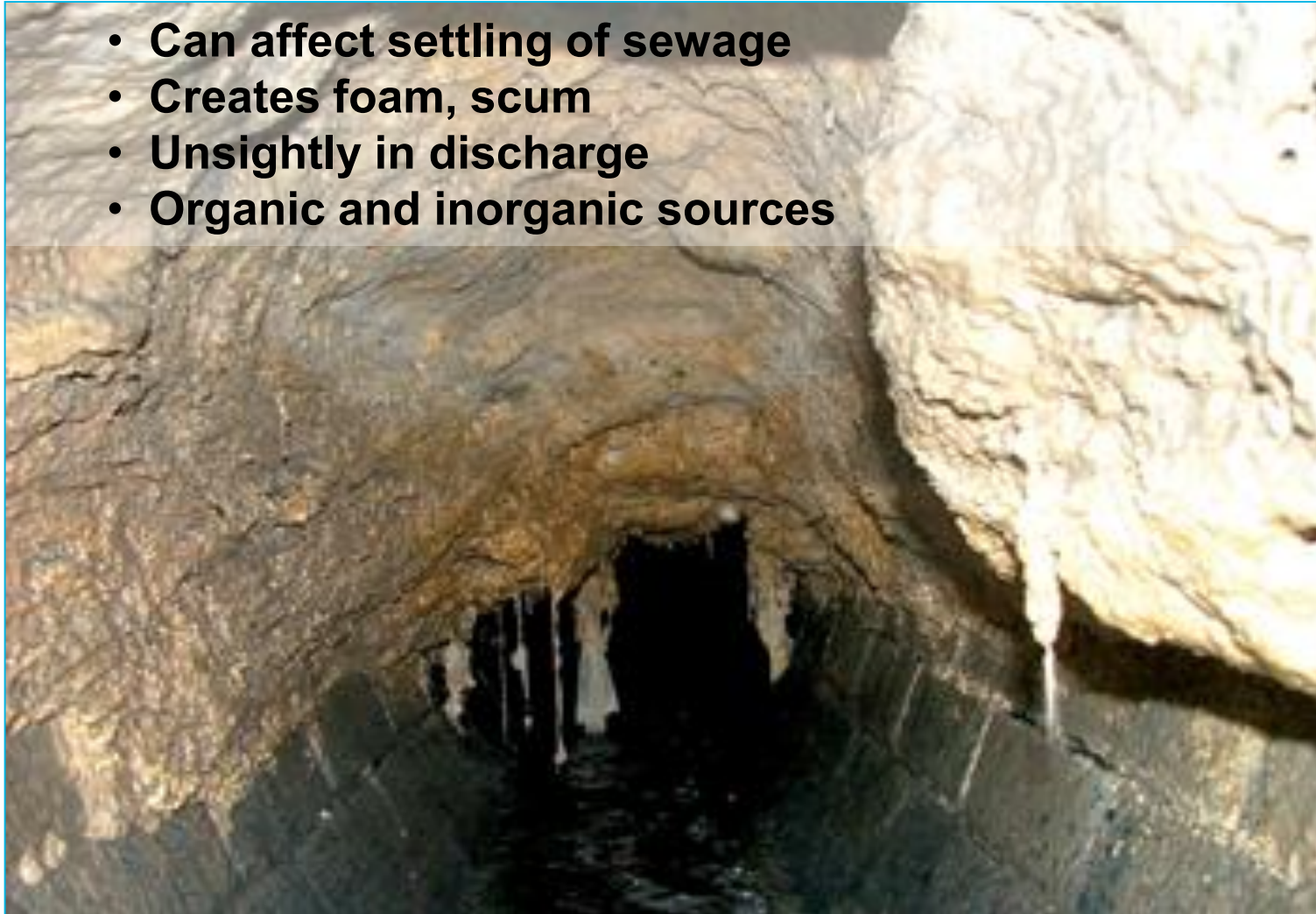
Grit

- **Generally inert, not treatable**
- **Damaging to equipment in plant**
- **Sand, egg shells, plastic particles, coffee grounds**



Fats, Oil & Grease

- **Can affect settling of sewage**
- **Creates foam, scum**
- **Unsightly in discharge**
- **Organic and inorganic sources**



Pollutants/Contaminants in Wastewater

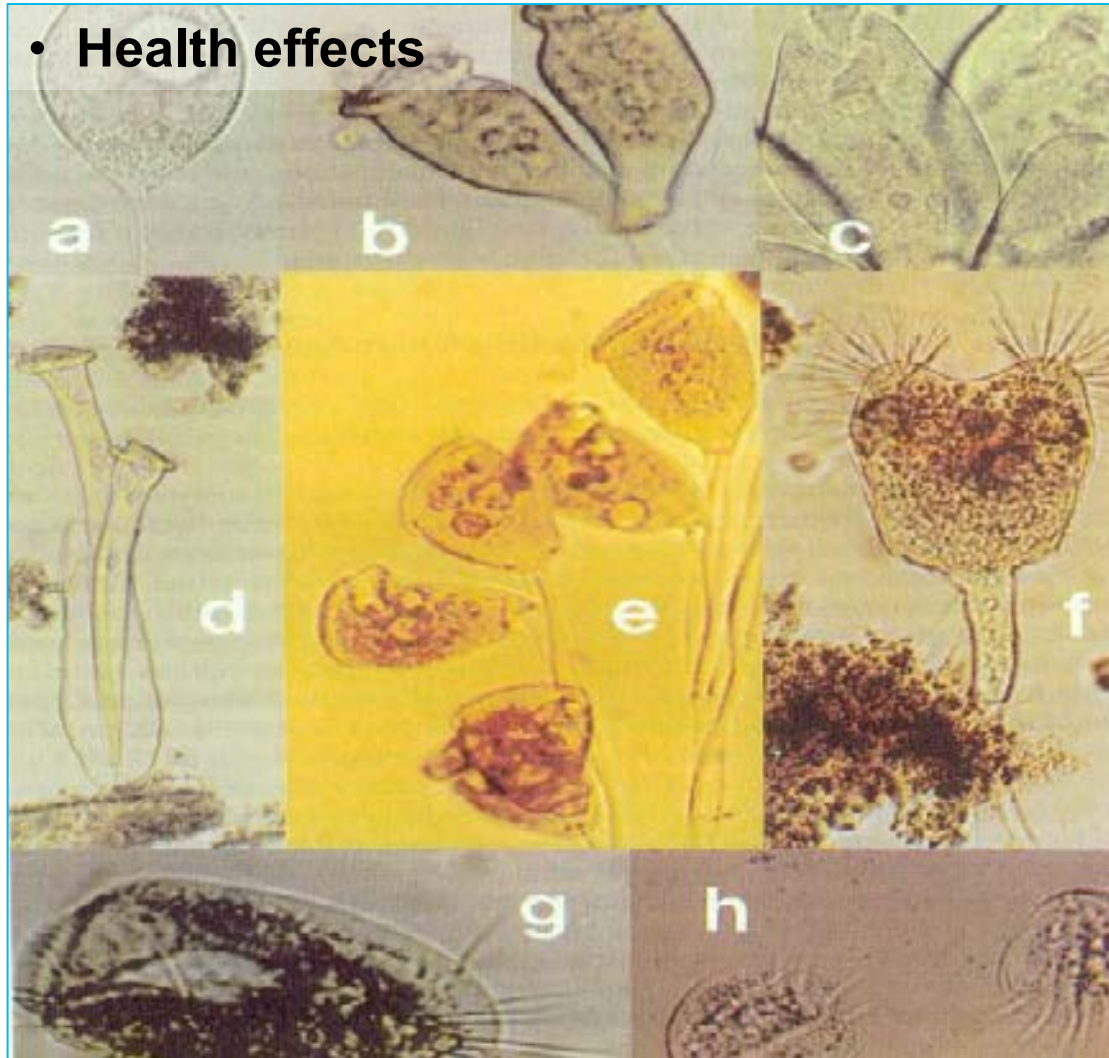
- **BOD – Biochemical Oxygen Demand**
 - Removes oxygen from river water
 - Harmful to fish if depletes oxygen in aquatic environment
 - Organic compounds
- **TSS – Total Suspended Solids**
 - Affects water clarity
 - Can carry BOD
 - Includes floating and colloidal material
 - Organic and inorganic compounds

Pollutants/Contaminants in Wastewater

- **Nitrogen**
 - Ammonia toxic in aquatic environments
 - Promotes algae growth in water bodies
 - Ammonia, organic nitrogen, nitrates, nitrites
- **Phosphorous**
 - Promotes algae growth in aquatic environments
- **Bacteria and viruses**
 - Adverse health effects
- **Toxic Materials**
 - Can affect treatment
 - Toxic to humans and aquatic environments
 - Phenols, organic compounds, medical wastes, metals

Bacteria

- **Health effects**

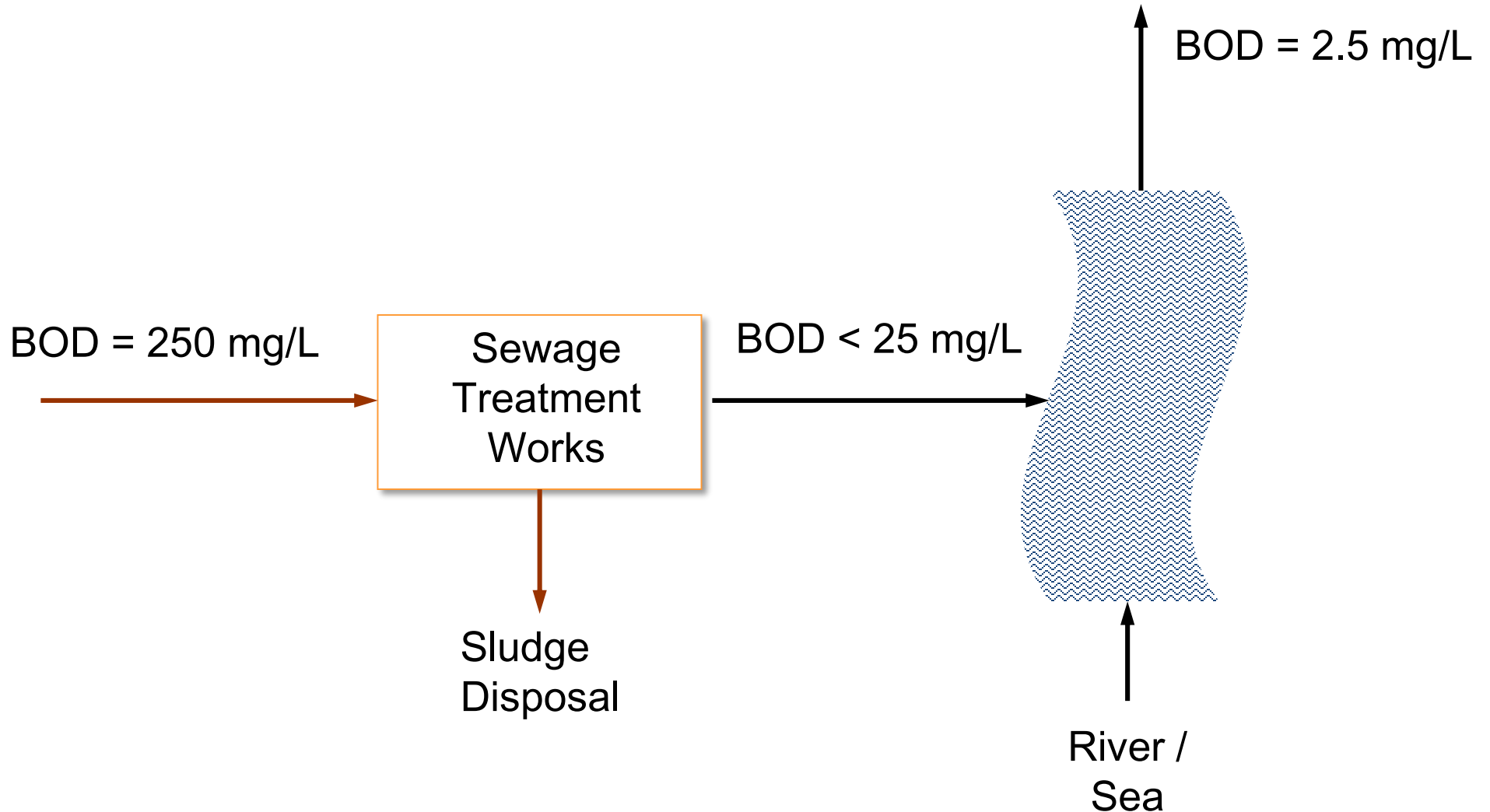


Toxic materials

- Can affect treatment
- Toxic to humans and aquatic environments
- Phenols, organic compounds, medical wastes, metals

3. Effluent Disposal and Reuse

Simplified Principle



Surface Water Discharge



Treated Sewage Effluent (TSE)

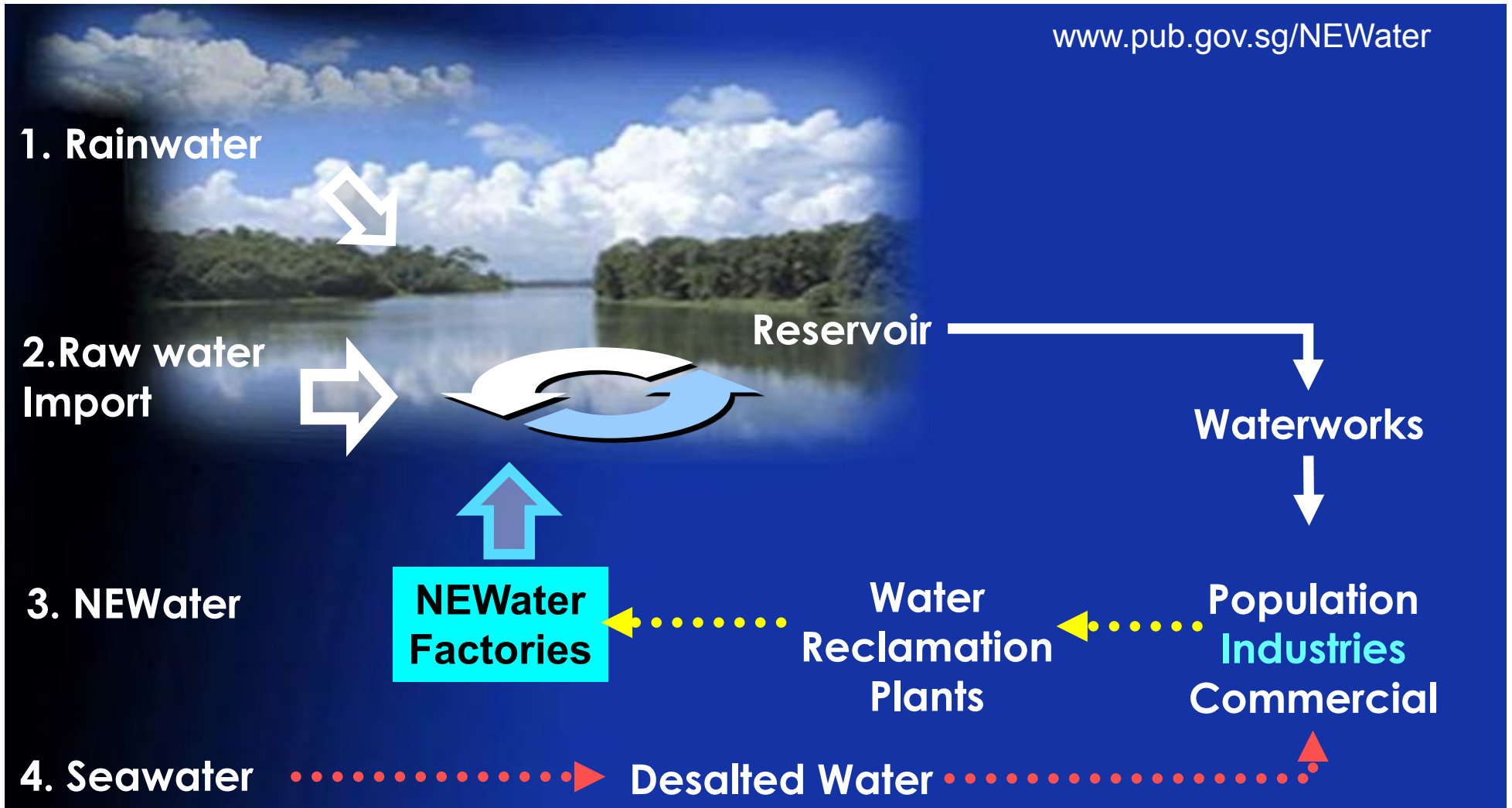
- Irrigation
- Fire protection
- Industrial Water
- District Cooling
- Groundwater Recharge



Kranji – SINGAPORE

Water reclamation for sustainable water supply

www.pub.gov.sg/NEWater





First US Cities to recycle water for potable use.

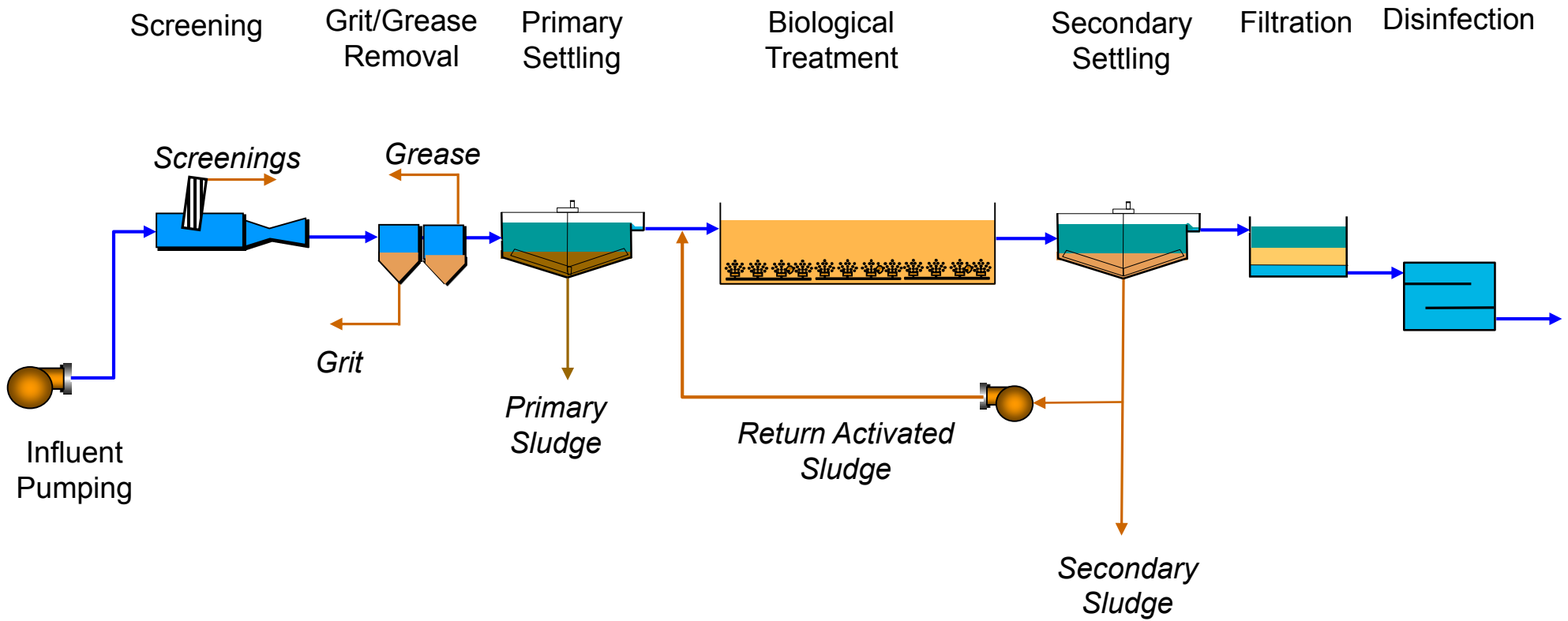


4. Types of Treatment

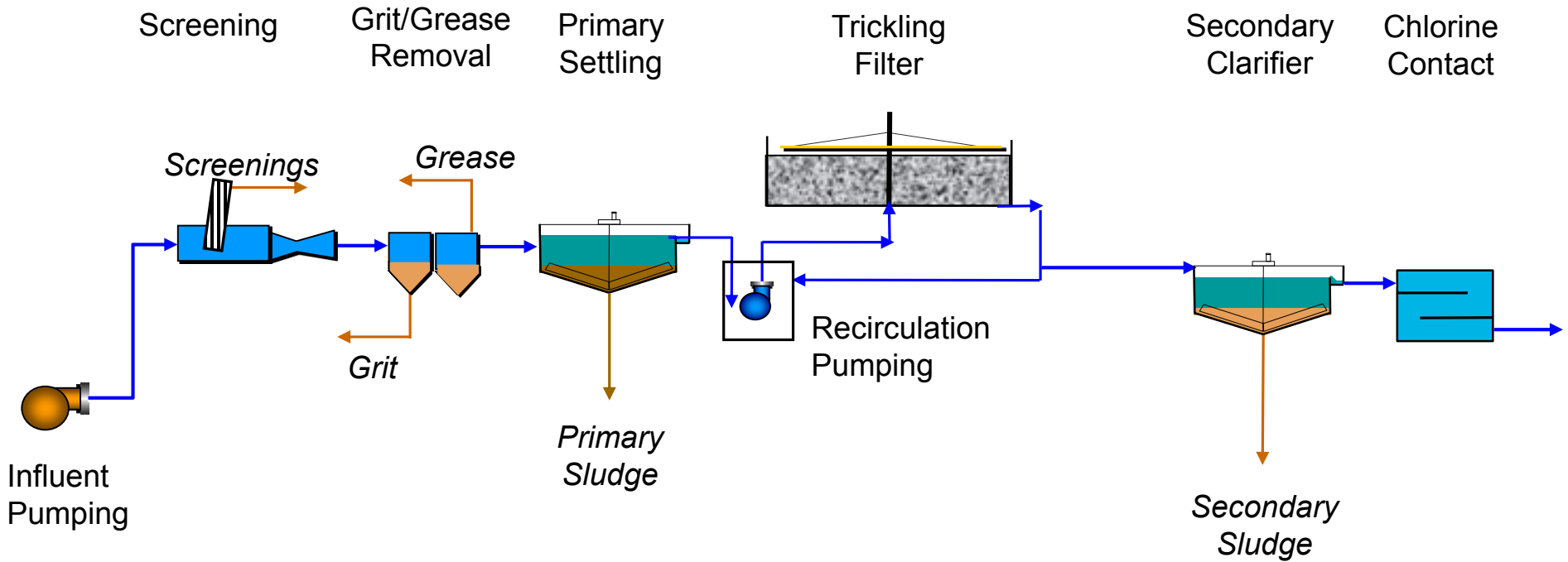
Types of Treatment

- **Physical Treatment (Screening, settling, non-biological filters)**
 - Removes debris, floatable material, coarse solids, fine solids
- **Chemical Treatment (Disinfection, polymer, etc.)**
 - Combines with soluble contaminants
 - Coagulation of solids for separation
 - Disinfection
 - Water quality adjustment – pH, buffering
- **Biological Treatment (Biological Filter, activated sludge, SBR, MBR)**
 - Removes or converts biodegradable organics
 - Converts Ammonia and nitrogen compounds
 - Removes soluble Phosphates

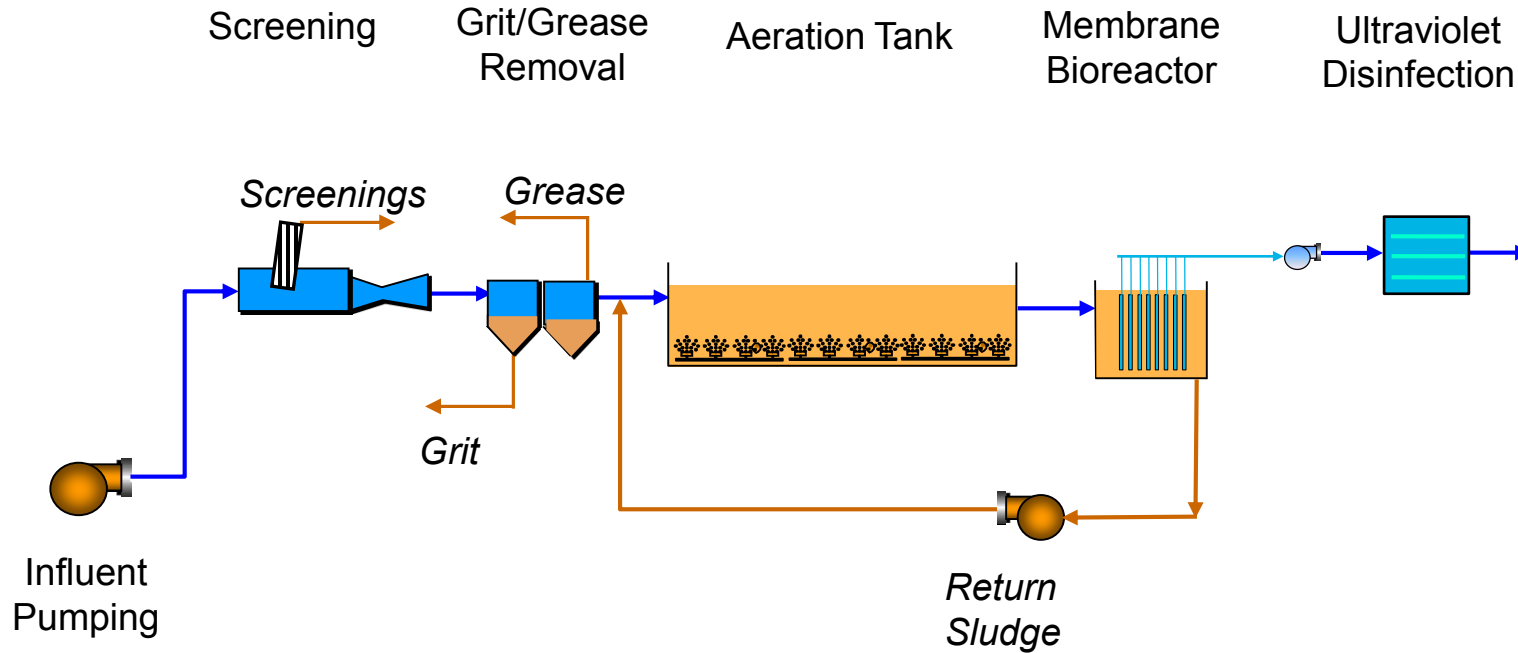
Process Flow Diagram – Activated Sludge with Filtration



Process Flow Diagram – Trickling Filter



Process Flow Diagram – Membrane Bioreactor

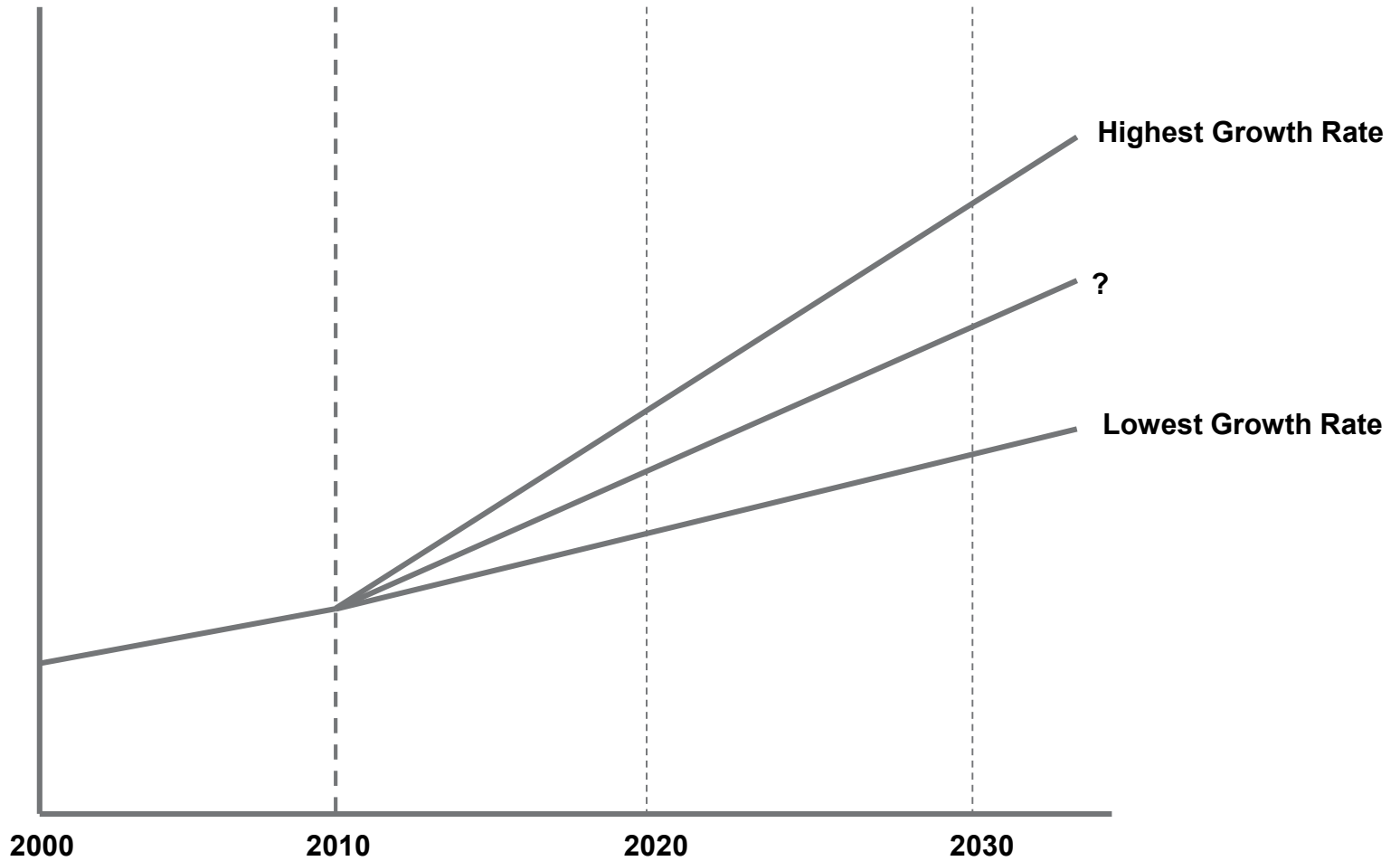


5. Decision-making for Treatment

Wastewater Treatment Planning

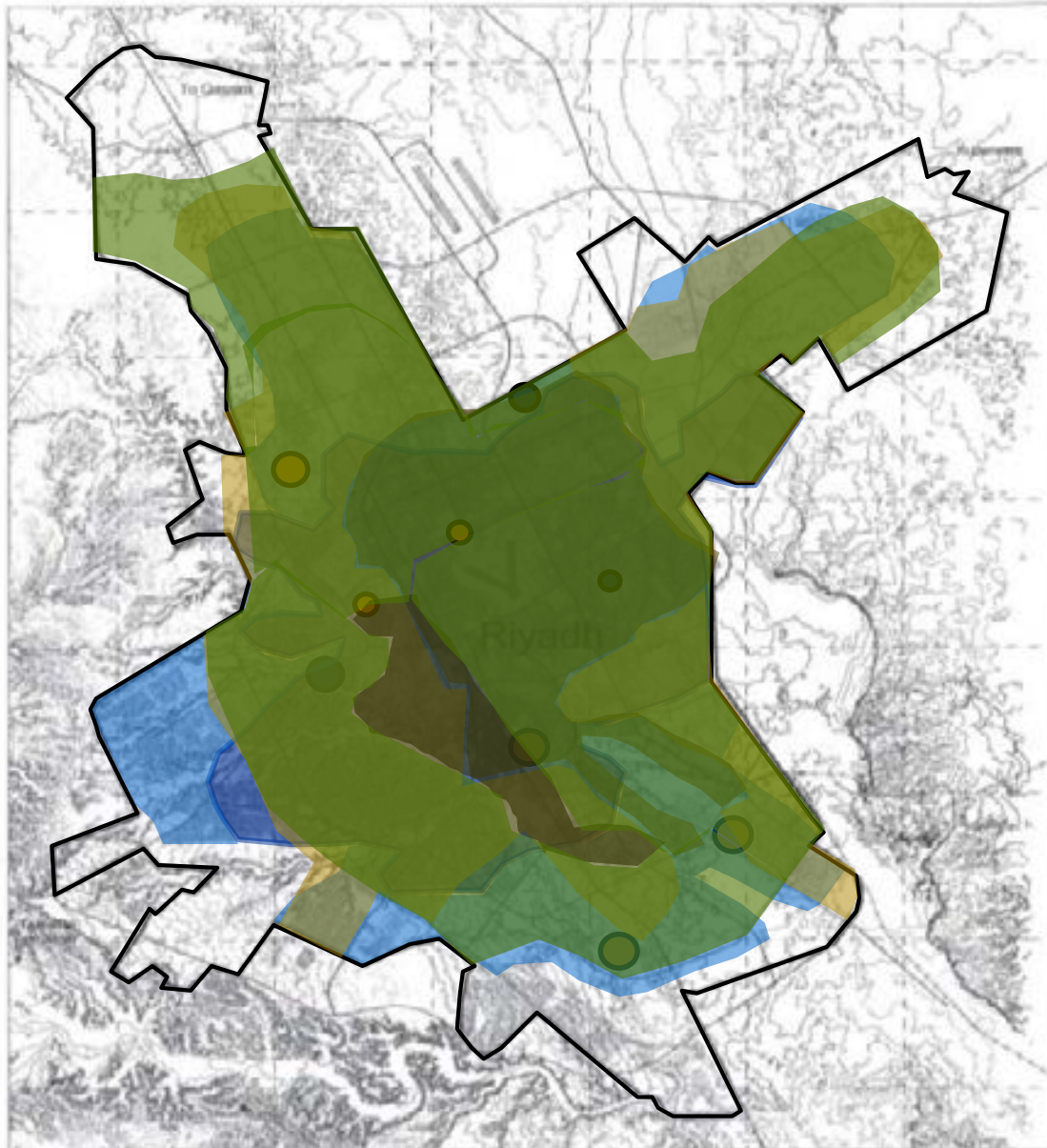
- **Population projections**
- **Location of treatment plants**
- **Disposal/reuse options**
- **Value of land**
- **Siting configurations (topography)**
- **Cost-effectiveness**







Population Projections





Service Area Conditions and Expansion



-  Water Network Existing
-  Water Network Future
-  Sewer Network Existing
-  Sewer Network Future
-  TSE Network Existing
-  TSE Network Future

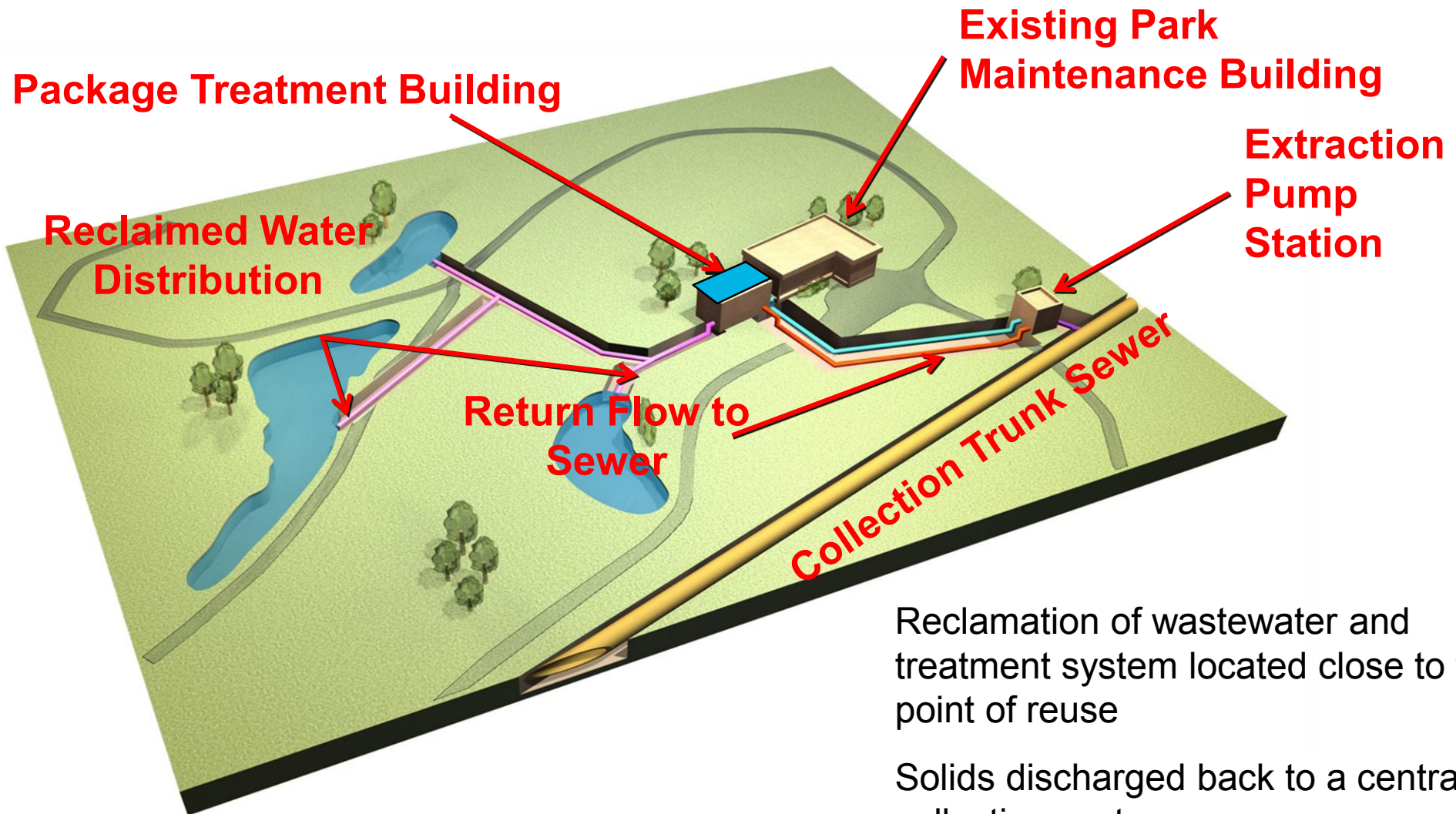
Treatment Process Considerations

There are an infinite number of configurations in wastewater treatment

Treatment Process Decisions can be affected by:

- **Site Configuration and Geology**
- **Initial and Future Capacity**
- **Effluent Standards**
- **Automation Required**
- **Flexibility of Treatment**
- **Proximity to Development**

Decentralized Treatment – Satellite Plant



Reclamation of wastewater and treatment system located close to the point of reuse

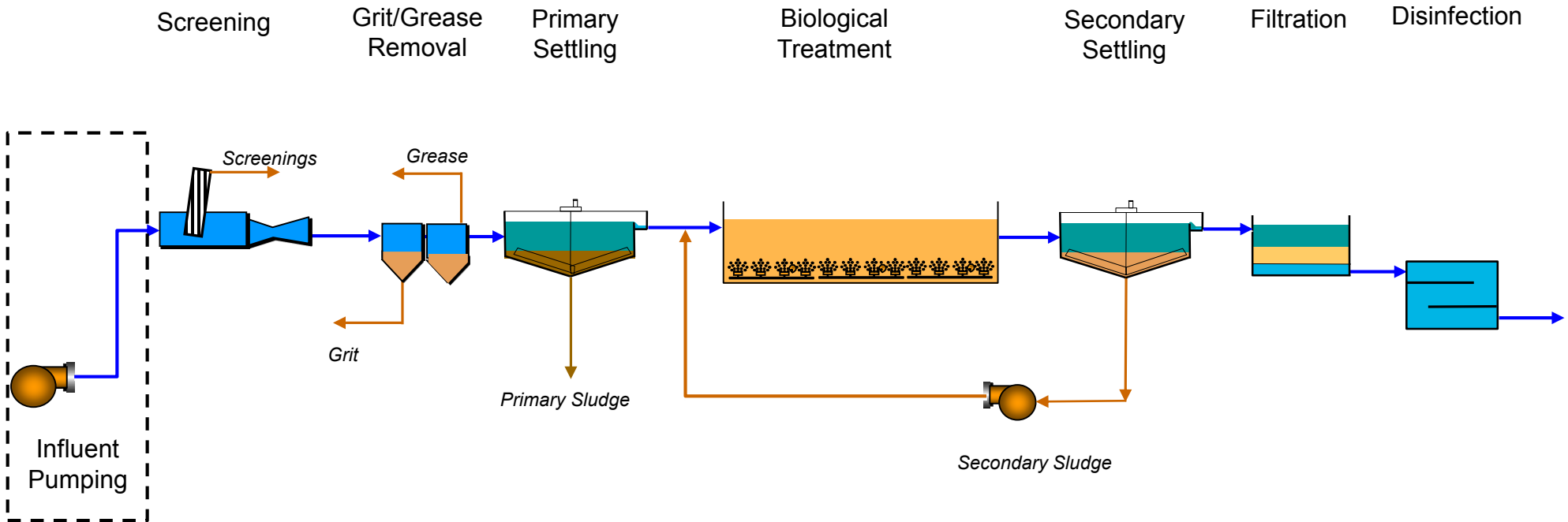
Solids discharged back to a centralized collection system

Break

Preliminary and Primary Treatment

1. Preliminary Treatment

Influent Pumping/Flow Measurement



Influent Pumping sets the hydraulic profile for the treatment plant. It can provide dampened delivery of wastewater with large wetwell design and VFDs. Influent pumping stations often take plant recycles.

Coarse screening ahead of pumps can remove large solids before pumping. Alternatively, grinder systems are designed to allow pumps to deliver solids to the plant headworks. Flow measurement may be provided with flumes upstream of the wetwell, or pump discharge meters.

Influent Pumping

- Required in many plants, where plant hydraulics not available naturally
- Submersible or wet well/dry well
- Coarse screening frequently used
- Constant speed or variable speed pumps
- Odors and odor control
- Health and safety



Pump Station Scale

- Small – Less than 100 l/s
- Medium – 100 to 300 l/s
- Large – Greater than 300 l/s
- Wet Well - Submersible
- Dry Well / Wet Well
- Dry Well

Wet Wells



Dry Well Installations



Large Scale

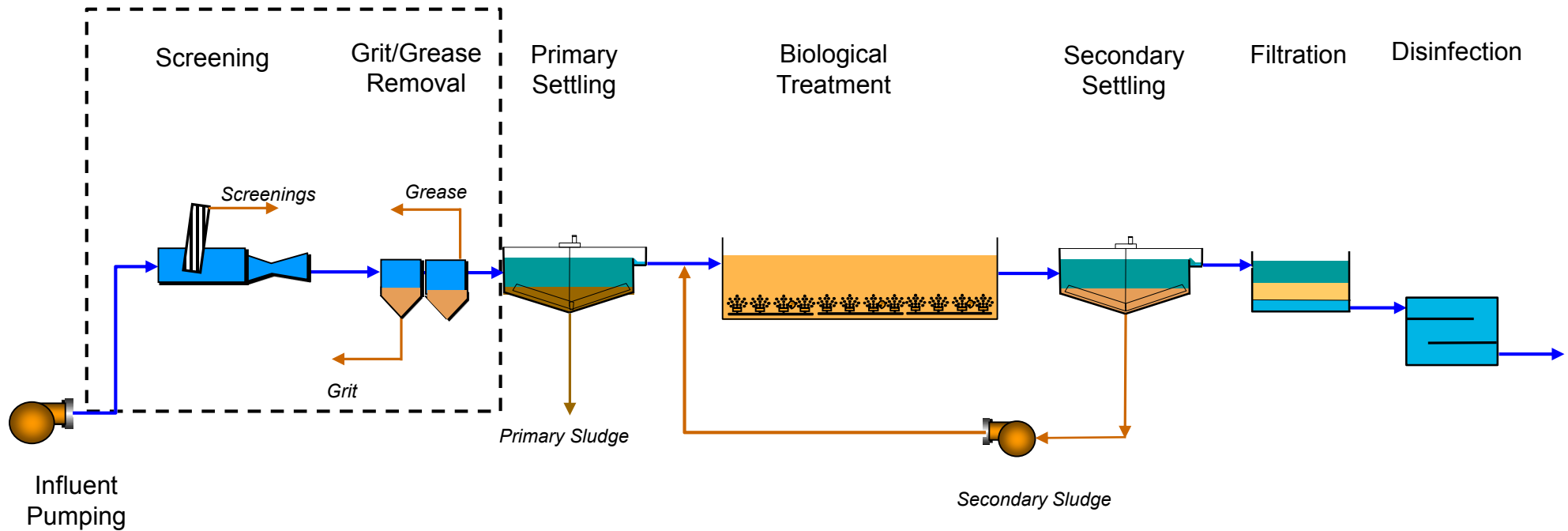


Influent Monitoring

- On pumped flow or in inlet works channel
- Flow monitoring with magnetic flow meter or Parshall flume
- Quality monitoring by influent sampling –
Temperature, pH, TSS,
BOD, Ammonia-N, alkalinity



Preliminary Treatment



Preliminary treatment is required to remove inert materials that can be screened or settled from the raw sewage to prevent damage to equipment, and clogging of pipes and tanks (plastics, paper, inert floatables, etc.).

Preliminary Treatment includes pre-screening ahead of pumps, fine screens, grit removal and floatable grease removal.

Influent Screening

- **Screen or bar rack**
 - A device with openings, generally of uniform size, that is used to retain solids
 - Screening element may consist of parallel bars, wire mesh, or perforated plate
 - Usually mechanically cleaned with automatic screenings removal
- **Classification of screens**
 - **Bar Racks:** Screens with large openings to capture large debris which cannot be pumped
 - **Fine screens:** Common in all treatment plants to remove debris as small as cigarettes
 - **Ultrafine screens:** Used ahead of membrane treatment systems for capture of small solids that can accumulate in a membrane system

Item	Location	Opening Size mm
Coarse Bar Racks/Trash Racks	Ahead of Influent Pumps	24 – 72
Fine Screens	Headworks - Typical	6 - 12
Ultra Fine Screens	Ahead of Membrane Systems	1 - 3

Coarse Screens (Bar Racks)

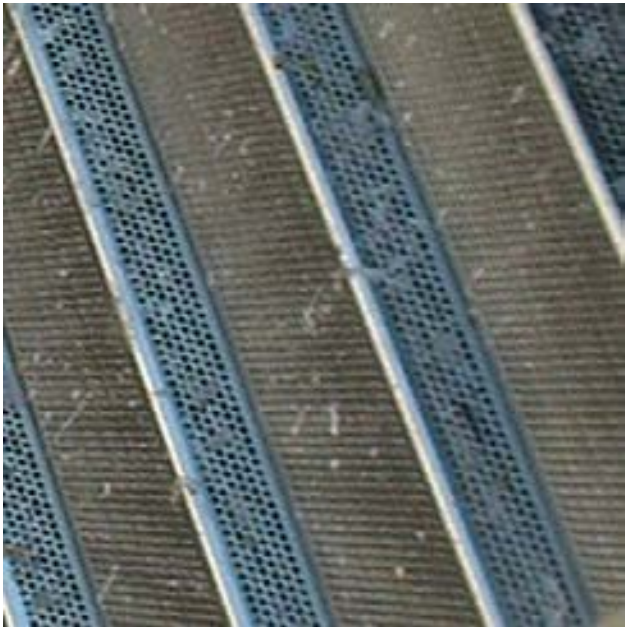
- Clear openings ranging from 6 to 150 mm
- Manually or mechanically, front (upstream) or back (downstream) cleaned
- Manually cleaned screens are usually used for small WWTPs or as standby/overflow in larger WWTPs
- Volume of screenings removed is 6 – 50 l/1,000 m³
- Might not be needed if provided at the pump stations upstream from the WWTP



Design Parameters	
Clear opening	25 to 44 mm
Approach Velocity	0.3 to 0.6 m/sec
Width of the bar	5 to 15 mm

Fine Screens

- Clear openings less than 6 mm
- Openings as small as 1 mm
- Mechanically cleaned
- Usually following coarse screening
- Could remove up to 50% of TSS and BOD
- Washing is critical for the operation



Band Screens: 2 - 4 mm

- Flow goes in thru center and passes thru perforations on side screens
- Screenings are carried by lifting trays and are discharged via gravity/spray into a flume above deck level
- PE links form chains on either side to drive screen
- Screenings are dewatered in a screw compactor before discharging



Drum Screens: 6 - 9 mm

- The screening medium is mounted on a cylinder (drum) that rotates in a flow channel
- Flow goes in thru both sides and passes thru perforations in the screen panels out of the drum
- Screenings are carried by elevating plates and are discharged via gravity/spray water into a flume Inside the drum
- External Bypass channel required (no integral bypass)
- Screenings discharge into a common wet well and are pumped (or flow by gravity) to a liquid-solids separator unit, where they are dewatered before discharging into a screenings skip



Alternative Drum Screen



Screening – Design Considerations

- Size (clear openings)
- Approach velocity
- Straight approach
- Designed based on peak flow
- Headloss
- Head space required
- Screenings handling (raking), processing and disposal
- Duty and standby units
- Odour control
- Washing
- Control (Differential headloss and timer)

Grit Removal

- Grit Removal is done by gravity settling or by centrifugal separation of solids
- Located after bar screens and before primary sedimentation
- Types of Grit Removal
 - Aerated grit chamber
 - Horizontal settling
 - Vortex grit chamber
- Average grit removed is 4 - 40 l/1,000 m³



Aerated Grit Chambers

- Air is introduced along one side of a rectangular tank to create a spiral flow pattern
- Heavier grit particles settle to the bottom
- Lighter particles pass through the tank
- Organics create odors and attract insects
- The velocity of flow governs the size of particles removed
- Normally designed to remove 0.21 mm diameter (65 mesh) or larger with 2-5 minute detention time at the peak hourly flow
- Grit is removed through grab buckets or pumps from grit sumps
 - travelling on monorails, screw conveyor,
 - grit pumps or airlift
- Covers maybe required if release of VOCs is a concern



Aerated Grit Chamber Design Parameters

Parameters	Range
Detention Time (Mins.) at Max. Flow	2 - 5
Depth (m)	2 - 5
Length (m)	7 - 20
Width (m)	2.5 - 7
Width - Depth Ratio	1:1 - 5:1
Length - Width Ratio	3:1 - 5:1
Air Supply (m ³ /hr./m of length)	10 – 25
Grit Quantities (l/1000 m ³)	3.7 - 56

Vortex Grit Removers

- Flow enters/exits chamber tangentially
- Vortex induced naturally thru tangential flow and by mechanical paddle at bottom of chamber, grit migrates to center of chamber and is stored in grit hopper
- Collector drive is on top of unit
- Grit removed from grit hopper by pumping to a cyclone separator and grit classifier
- Internal use water for grit washing
- Grit pumps can be in basement or top-mounted
- Detention time ~ 30 sec range
- Typically 1- 7 m in diameter and 2.5 – 5 m in depth



Civil construction and installation.



The effects of the carbonous aerator can be clearly seen on the tank surface.



The complete after installation.



The small additional blower is designed for quiet operation.



Vortex Design Parameters

Parameters	Range
Detention Time (s)	30
Diameter (ft)	4 - 24
Height (ft)	9 - 16
Removal Rates (%)	50 mesh (0.3 mm) 95+ 70 mesh (0.24 mm) 85+ 100 mesh (0.15 mm) 65+

Grit Removal Design Considerations

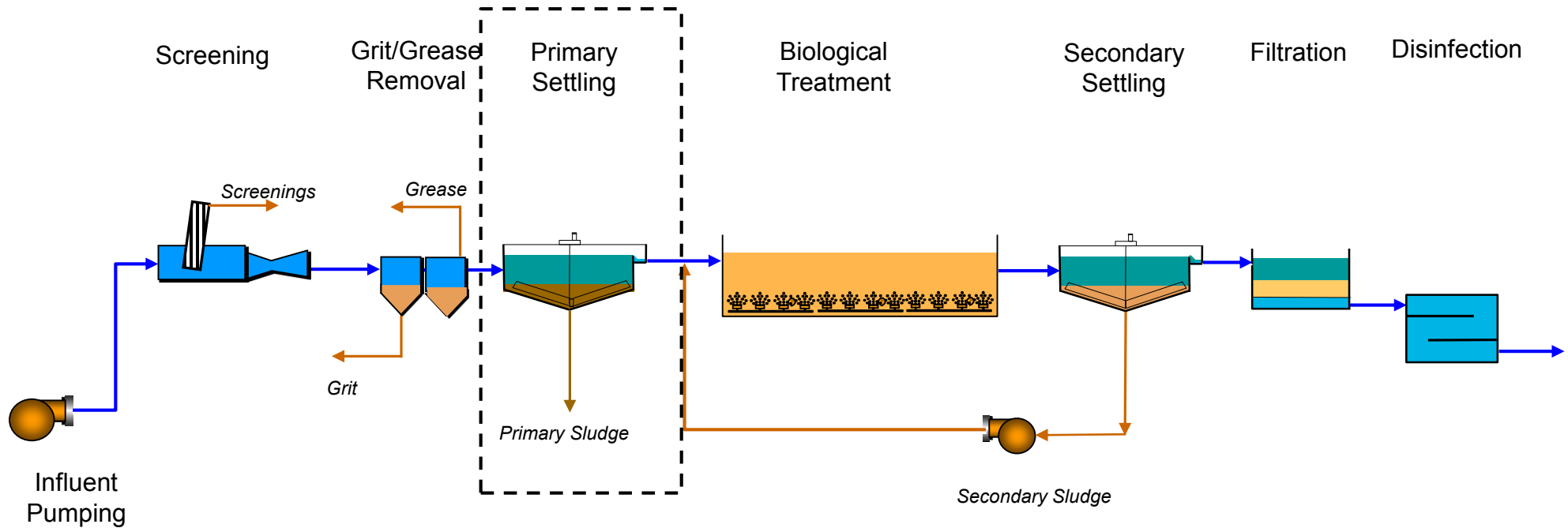
- Detention time - based on peak flow
- Size of particle removed
- Headloss
- Grit handling (collection), dewatering and disposal
- Duty and standby units
- Oil and grease removal
- Odor control

Headworks Designs



2. Primary Treatment

Primary Clarification



Primary Treatment is the physical separation of settleable solids in rectangular settling tanks or circular clarifiers, with detention time of 2 hours or more. Settled solids are removed mechanical sludge collectors, and sludge is further treated. Floating solids are skimmed from the surface.

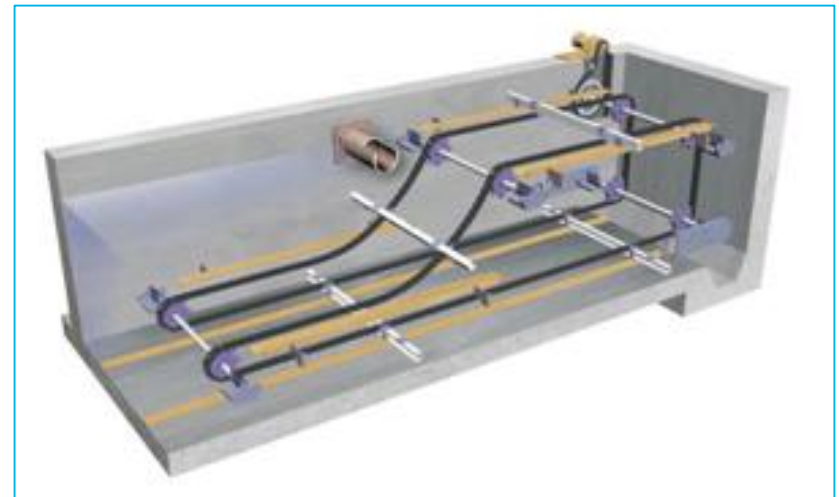
Primary Treatment

- Up to 70% removal of TSS and up to 50% removal of BOD
- Reduce power cost associated with secondary treatment
- Could be supplemented with chemical addition for enhanced sedimentation and/or P removal
- Mechanically cleaned sedimentation tanks of standardized circular or rectangular design.
- Multiple tanks should be provided so that the process may remain in operation while one tank is out of service for maintenance

Item	Hydraulic Retention, Hours	TSS Removal %	BOD removal %
Circular Clarifiers	2 - 3	40 – 60	20 – 30
Rectangular Clarifiers	2 – 3	40 – 60	20 – 30
Lamella Clarifiers	1.5 – 2	40 – 70	25 – 40
Chemically Enhanced Primary Treatment (CEPT)	1.5 - 2	50 - 75	30 – 50

Rectangular Tanks

- Horizontal flow
- Depth: 4 m; Width: 5 – 10 m; Length: 25 – 40 m
- Chain-and-flight solids collectors or traveling-bridge-type collectors



Circular Tanks

- Flow pattern is radial and wastewater is usually introduced in the center of the tank
- Require larger footprint
- Depth: 4 m; Diameter: 12 - 45 m



Lamella Clarifier/Plate Settlers

- Rack of inclined metal plates, which cause flocculated material to precipitate from water that flows across the plates.
- Smaller footprint than conventional clarification equipment for the same solids removal capacity
- Compact design eliminates hydraulic disturbances caused by wind or temperature changes.
- Balanced flow distribution ensures equal flow to each plate and across the plate surface area, preventing short-circuiting.
- Minimal moving parts means low maintenance costs.



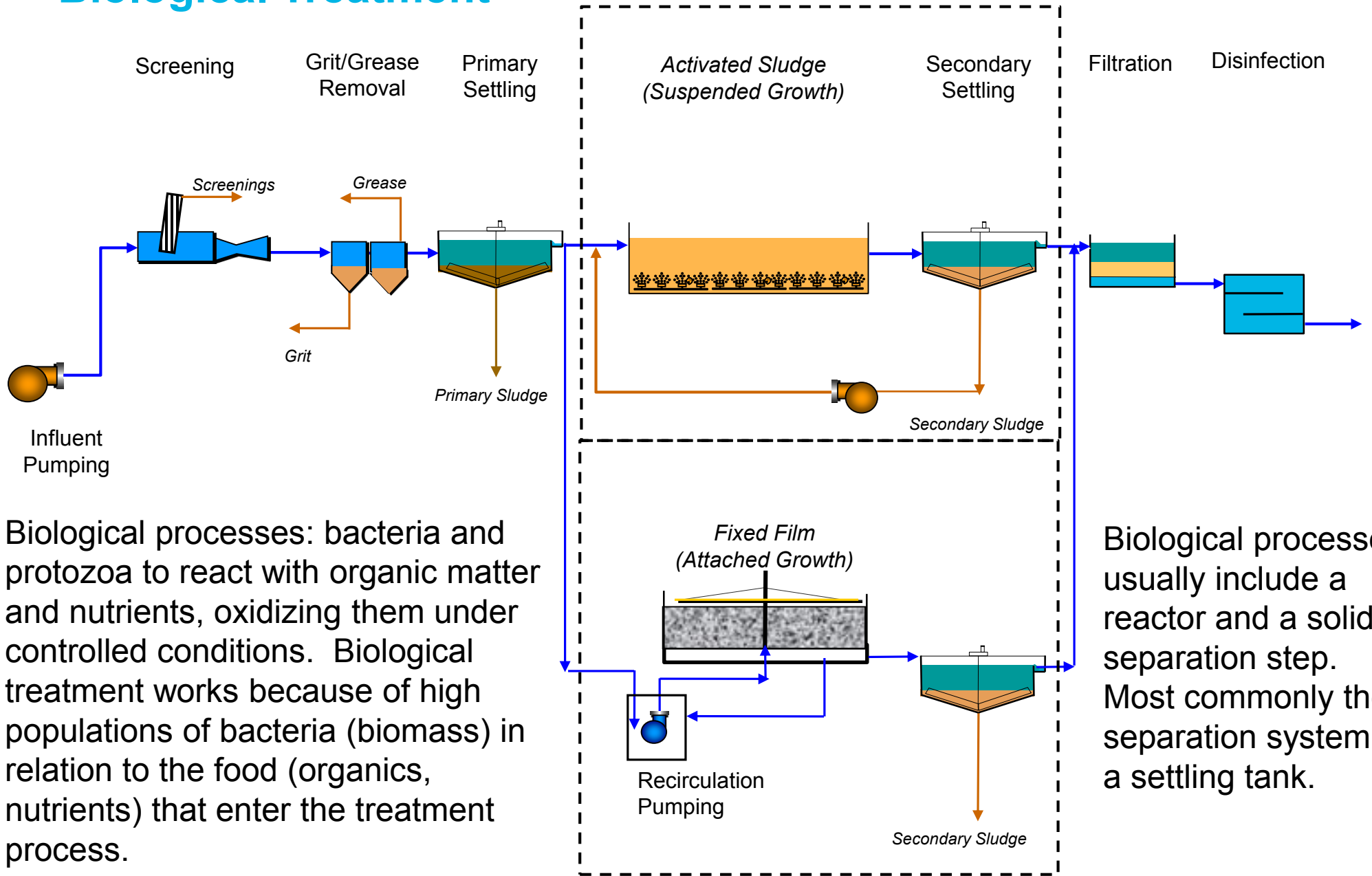
Primary Settling Design Considerations

- Surface overflow rate ($\text{m}^3/\text{m}^2/\text{d}$) - based on peak flow
Typically 80 – 120 $\text{m}^3/\text{m}^2/\text{d}$
- Baffling to reduce short circuiting
- Grit handling (collection), dewatering and disposal
- Duty and standby units
- Odor
- Pumping of primary sludge (3 -5 % solids)
- Scum removal
- Detention times ranging between 2 to 5 hours use a settleometer to check how long solids can be in the clarifier without floating

Break

Biological Treatment Processes

Biological Treatment



Biological processes: bacteria and protozoa to react with organic matter and nutrients, oxidizing them under controlled conditions. Biological treatment works because of high populations of bacteria (biomass) in relation to the food (organics, nutrients) that enter the treatment process.

Biological processes usually include a reactor and a solids separation step. Most commonly the separation system is a settling tank.

Biological Treatment Processes

- Removes or converts biodegradable organics
- Converts Ammonia and Nitrogen compounds
- Removes soluble Phosphates



Activated Sludge Processes

- Extended aeration
- Oxidation ditch
- Step Feed
- SBR's

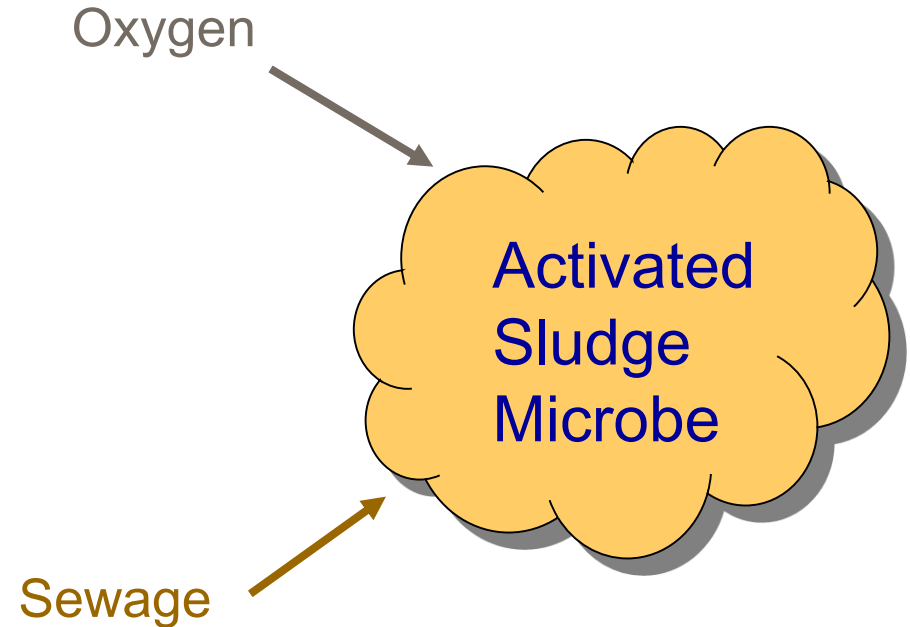
Fixed Film Processes

- Trickling filters
- Biological Aerated Filters (BAF's)
- Submerged Aerated Filters (SAF's)
- Rotating Biological Contactors

1. Activated Sludge Process

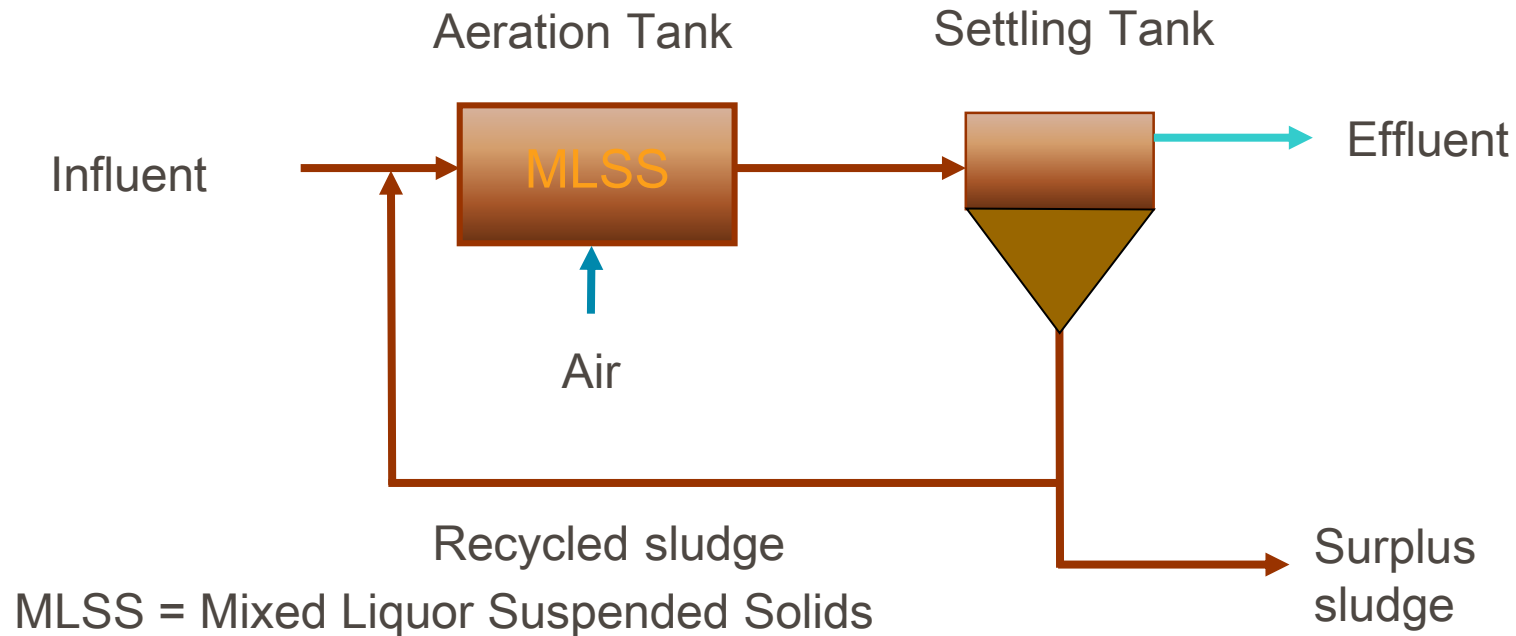
Activated Sludge Processes

- Activated sludge microbes (biomass)
- Oxygen rich environment
- Organic material in wastewater used as food source
- Generating growth of biomass and clean water
- Suspended growth process
- Biomass in free suspension to ensure adequate contact with wastewater
- Correct microbes settle well
- Settlement process allows treated effluent to be drawn off and biomass to settle
- Biomass kept alive by recycling a portion of settled biomass to activated sludge tank as growth medium to generate more biomass
- Excess bacteria removed as sludge



Activated Sludge Processes

- Many variations of activated sludge to treat municipal wastewaters
- Typically follows primary sedimentation in order to reduce the solids and organic (BOD and COD) loading
- Process includes an aeration stage followed by a settlement tank



Activated Sludge Processes

- **Biomass is freely suspended in wastewater and feeds on the organic matter in the presence of oxygen**
- **Important operating and design parameters are HRT, MLSS, SRT, F/M, DO, SVI**
- **Sludge is produced as BOD is removed and needs to be removed to maintain optimum treatment conditions**
- **The dissolved oxygen required for the process can be provided by mechanical agitation or diffused air**
- **Varying degrees of treatment can be achieved:**
 - Carbonaceous : BOD removal
 - Nitrification : Ammonia Removal
 - Denitrification : Nitrogen Removal
- **There are many variants of the AS process which can be designed to achieve the required degree of treatment**
- **The sequencing batch reactor eliminates the requirement for primary and secondary settlement. All processes in one tank.**

Table 7-6 Classification of microorganisms

Type of Bacteria	Common reaction Name	Carbon Source	Electron donor (substrate oxidized)	Electron Acceptor	Products
Aerobic heterotrophic	Aerobic oxidation	Organic compounds	Organic compounds	O ₂	CO ₂ , H ₂ O
Aerobic autotrophic	Nitrification	CO ₂	NH ₃ , NO ₂ ⁻ ;	O ₂	NO ₃ ⁻ , N ₂
	Iron oxidation	CO ₂	Fe(II)	O ₂	Ferric Iron [Fe(III)]
	Sulfuroxidation	CO ₂	H ₂ S, S ⁰ , S ₂ O ₃ ²⁻	O ₂	SO ₄ ²⁻
Facultative heterotrophic	Denitrification anoxic reaction	Organic compounds	Organic compounds	NO ₃ ⁻ , NO ₂ ⁻	N ₂ , CO ₂ , H ₂ O
Anaerobic heterotrophic	Acid fermentation	Organic compounds	Organic compounds	Organic compounds	Volatile fatty acids(VFAs) {acetate, propionate, butyrate}
	Iron reduction	Organic compounds	Organic compounds	Fe(III)}	Fe {II}, CO ₂ , H ₂ O
	Sulfate reduction	Organic compounds	Organic compounds	SO ₄	H ₂ S, CO ₂ , H ₂ O
	Methanogenesis	Organic compounds	Volatile fatty acids {VFAs}	CO ₂	Methane

Activated Sludge Processes

— Step Feed

- **Modification of conventional plug flow process. The feed is introduced at a number of places in the aeration tank. The concept is to even out F/M and reduce oxygen demand**

— Extended Aeration

- **HRT and sludge age much higher than conventional process, encouraging greater degradation of the MLSS. Less sludge for disposal and BOD removals of 98%**

— Oxidation Ditch

- **Best known extended aeration system. Mixed liquor circulates in a continuous channel or 'race track' aerated by a horizontal rotor which maintains velocity to prevent settlement**

Typical Design Parameters

Process	SRT, d	F/M kgBOD/kg MLVSS-d	Volumetric Loading kgBOD/m ³ -d	MLSS mg/L	RAS % of influent
Conventional	3 -15	0.2-0.6	0.3-1.6	1500-4000	25 - 100
Conventional plug flow	3 – 15	0.2 – 0.4	0.3 – 0.7	1000 – 3000	25 - 75
Step feed	3 – 15	0.2 – 0.4	0.7 – 1.0	1500 – 4000	25 - 75
Extended aeration	20 – 40	0.04 – 0.1	0.1 – 0.3	2000 – 5000	50 - 150
Oxidation ditch	15 – 30	0.04 – 0.1	0.1 – 0.3	3000 – 5000	75 - 150

Activated Sludge Processes

— Aeration Techniques

• Surface Aerators

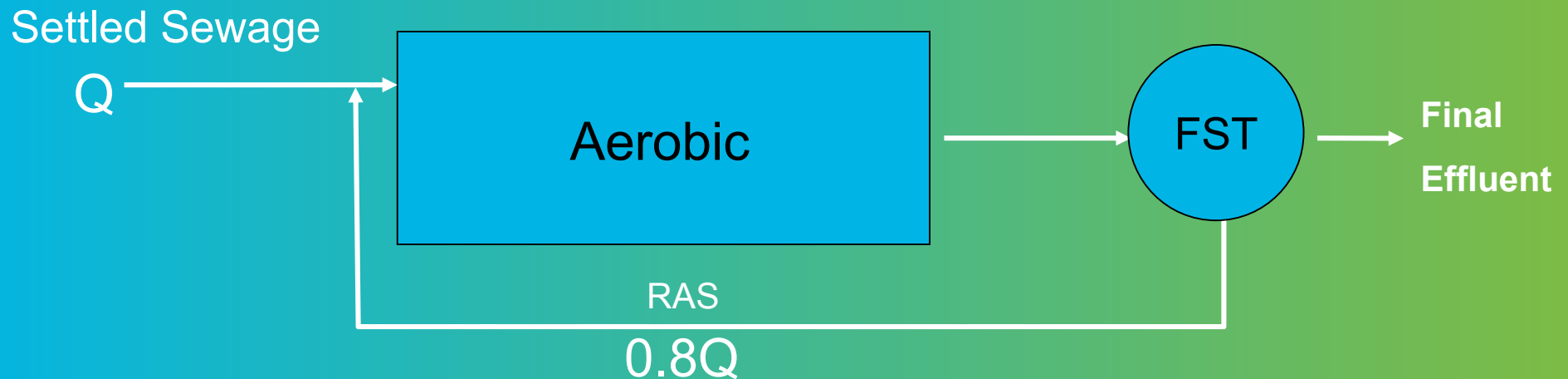
- Vertical shaft or Horizontal shaft
- Throw activated sludge into atmosphere as fine droplets, the contact with the air allows the mass transfer of oxygen into the liquid phase

• Diffused Air

- Compressed air is fed in to the bottom of the tank through fine pore diffusers.
- The mass transfer of oxygen into the liquid phase is via bubbles traveling up through the tank



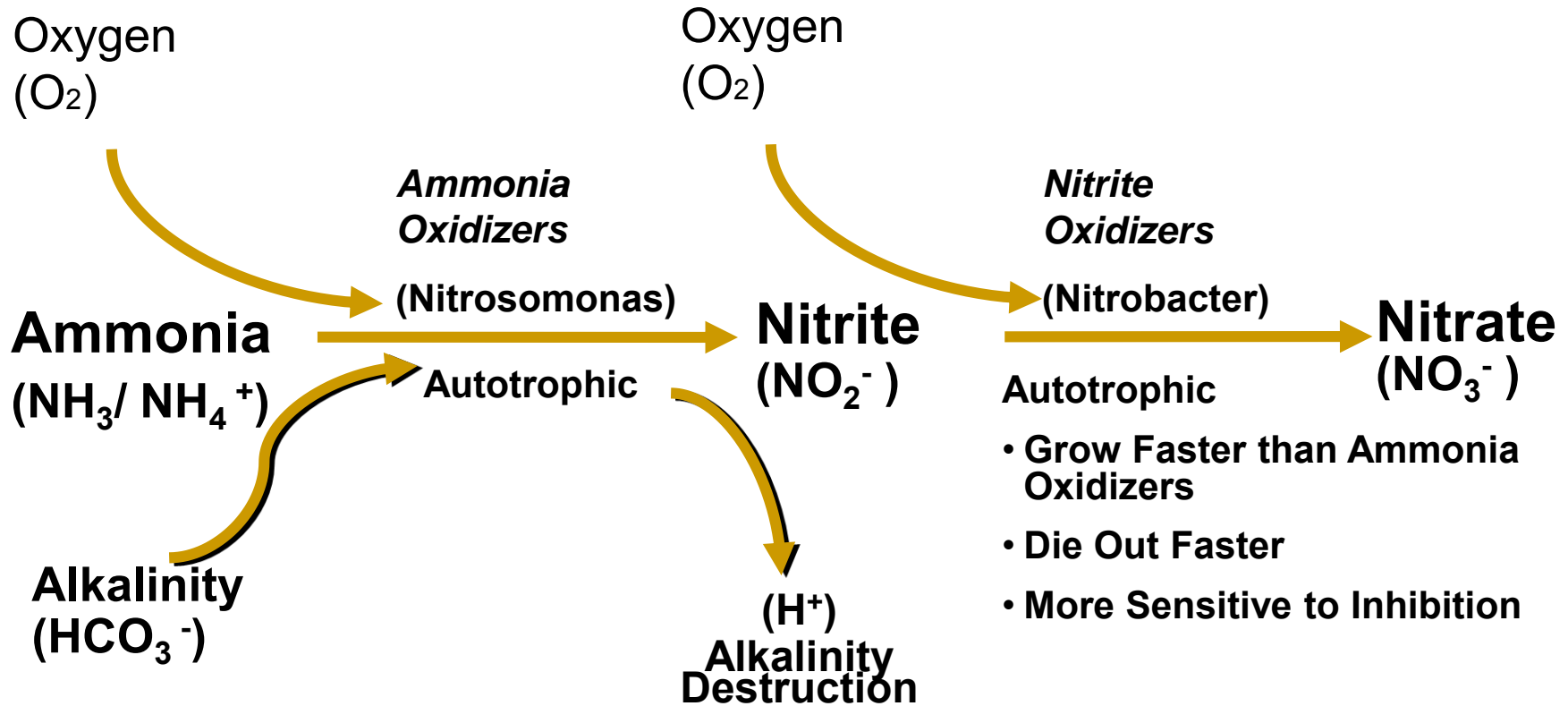
Carbonaceous Organics Treatment



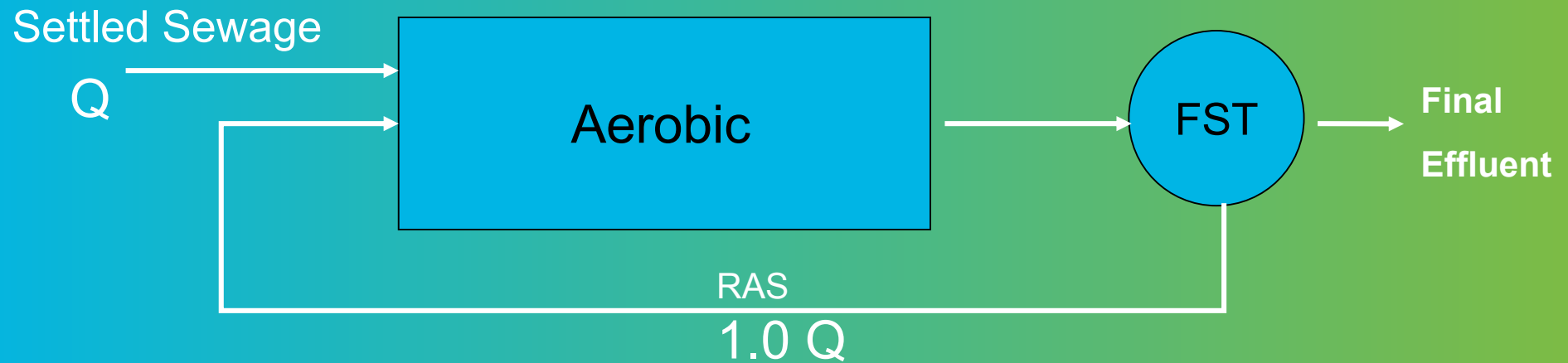
Single Reactor, Relatively Small Volume
BOD 20mg/L, COD 60mg/L, SS 30 mg/L
No reduction of Amm. N, TN, TP

2. Nutrient Removal Processes

Biological Processes - Nitrification



Nitrification

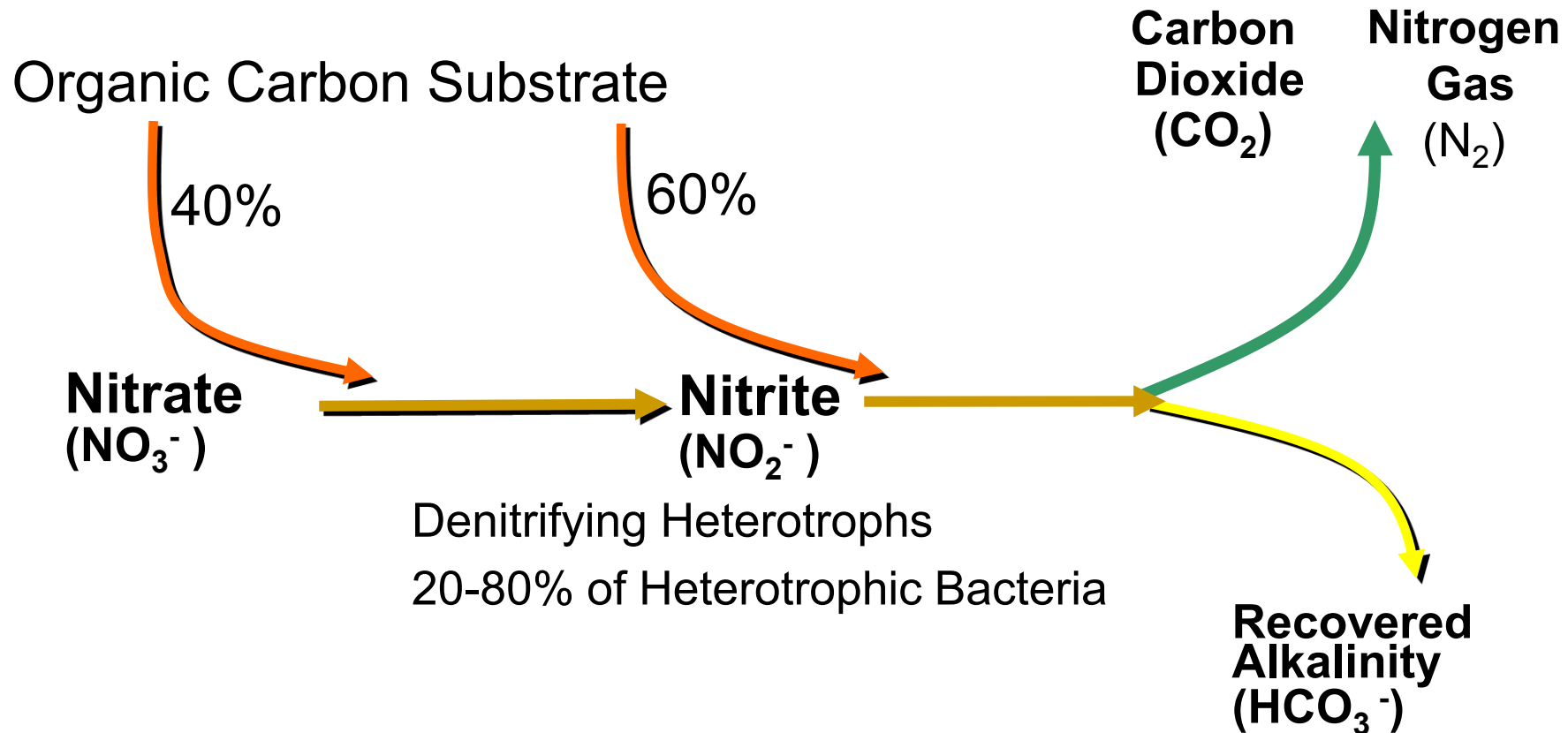


Single Reactor, Larger Volume

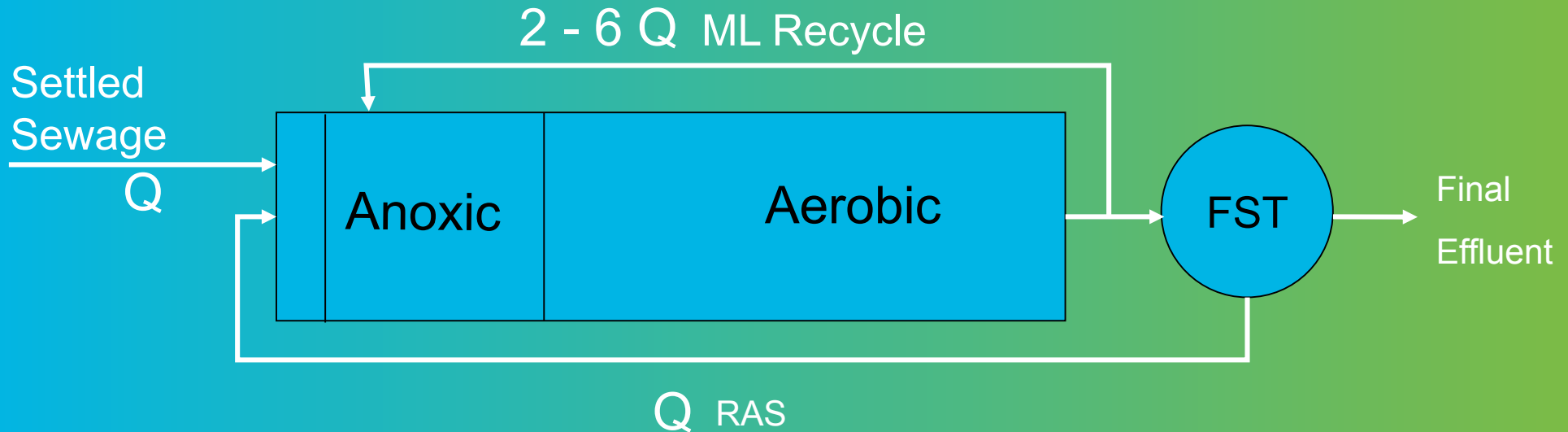
BOD 15mg/L, COD 50mg/L, SS 30mg/L, Amm.N 1mg/L

Some TN, No TP reduction

Biological Processes - Denitrification



Denitrification



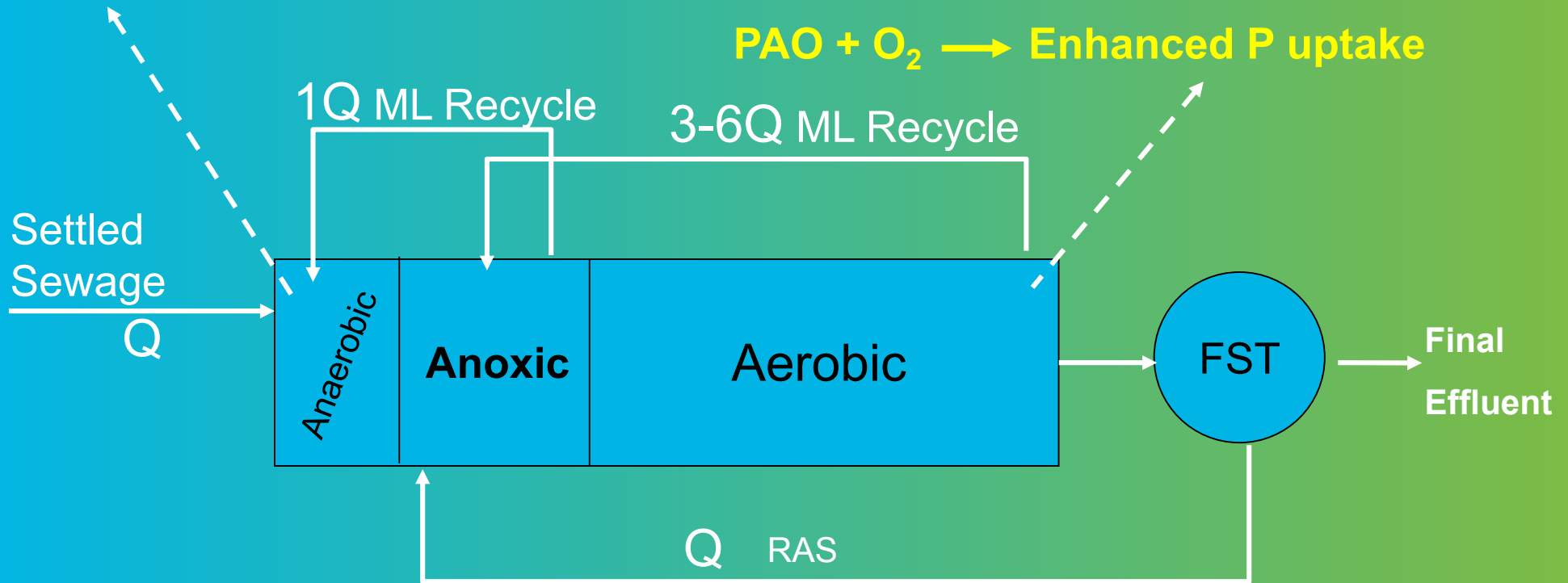
Multiple Reactors, Larger Volume

**BOD 15mg/L, COD 50mg/L, SS 15mg/L, Amm. N <1mg/L,
TN <10mg/L, No TP reduction**

Total Phosphorus Removal

PAO + Carbon \rightarrow P release

PAO + O₂ \rightarrow Enhanced P uptake

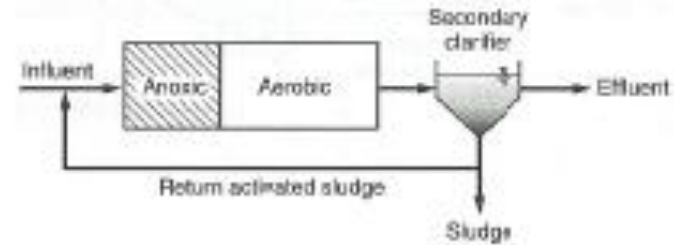


**BOD 10mg/L, COD 30mg/L, SS 10mg/L, Amm. N <1mg/L, TN <10mg/L,
TP 0.5 – 1.5mg/L**

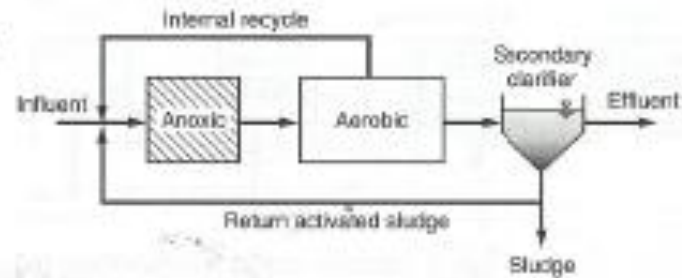
Advanced Activated Sludge Processes

Preanoxic

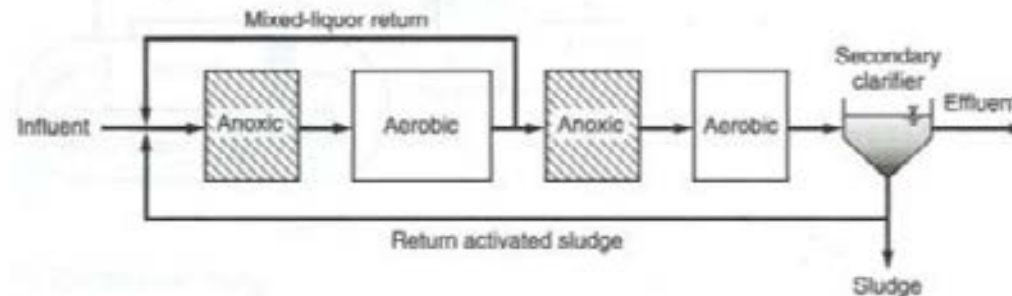
(a) Ludzack-Ettinger



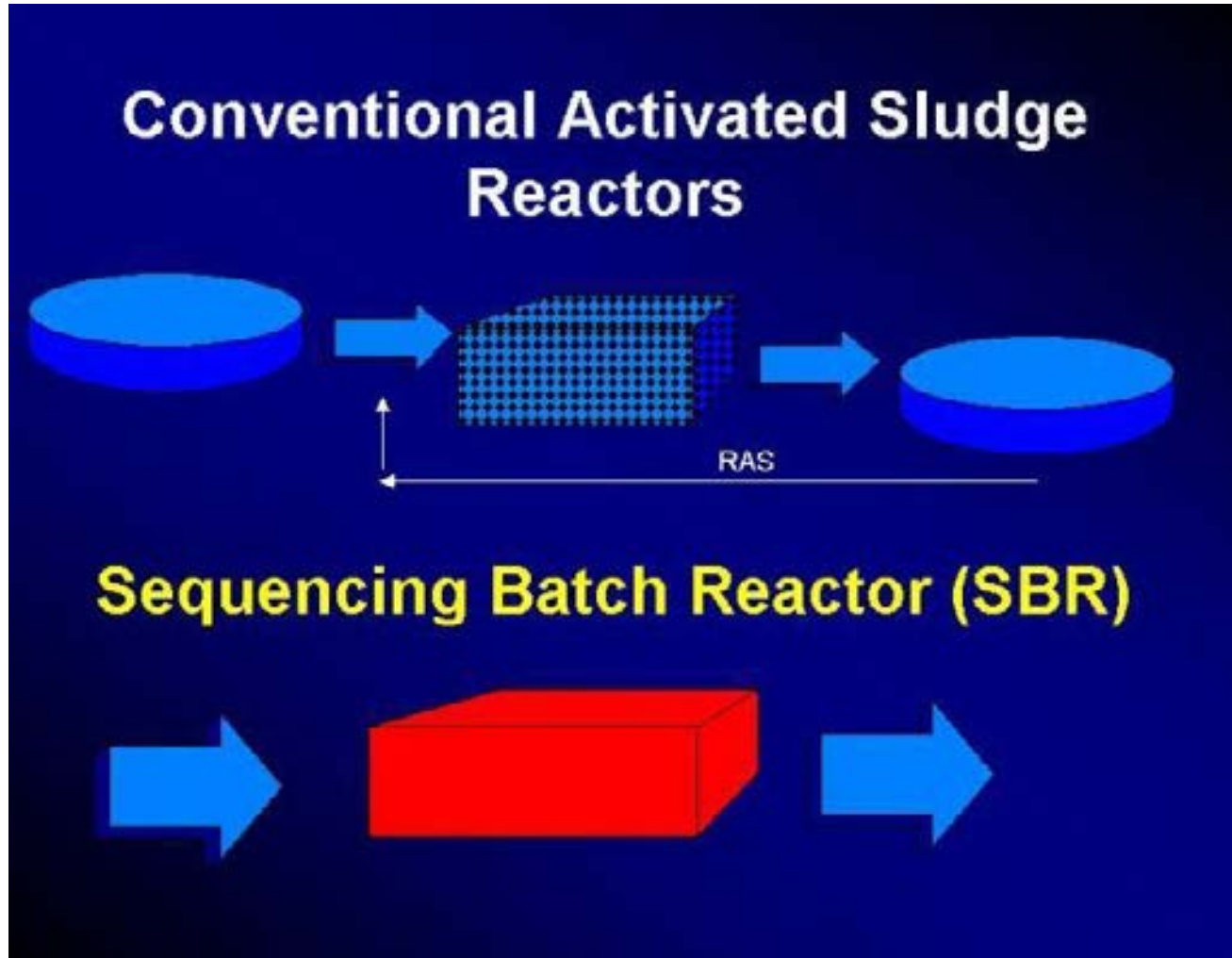
(b) Modified Ludzack-Ettinger (MLE)



(h) Bardenpho (4-stage)

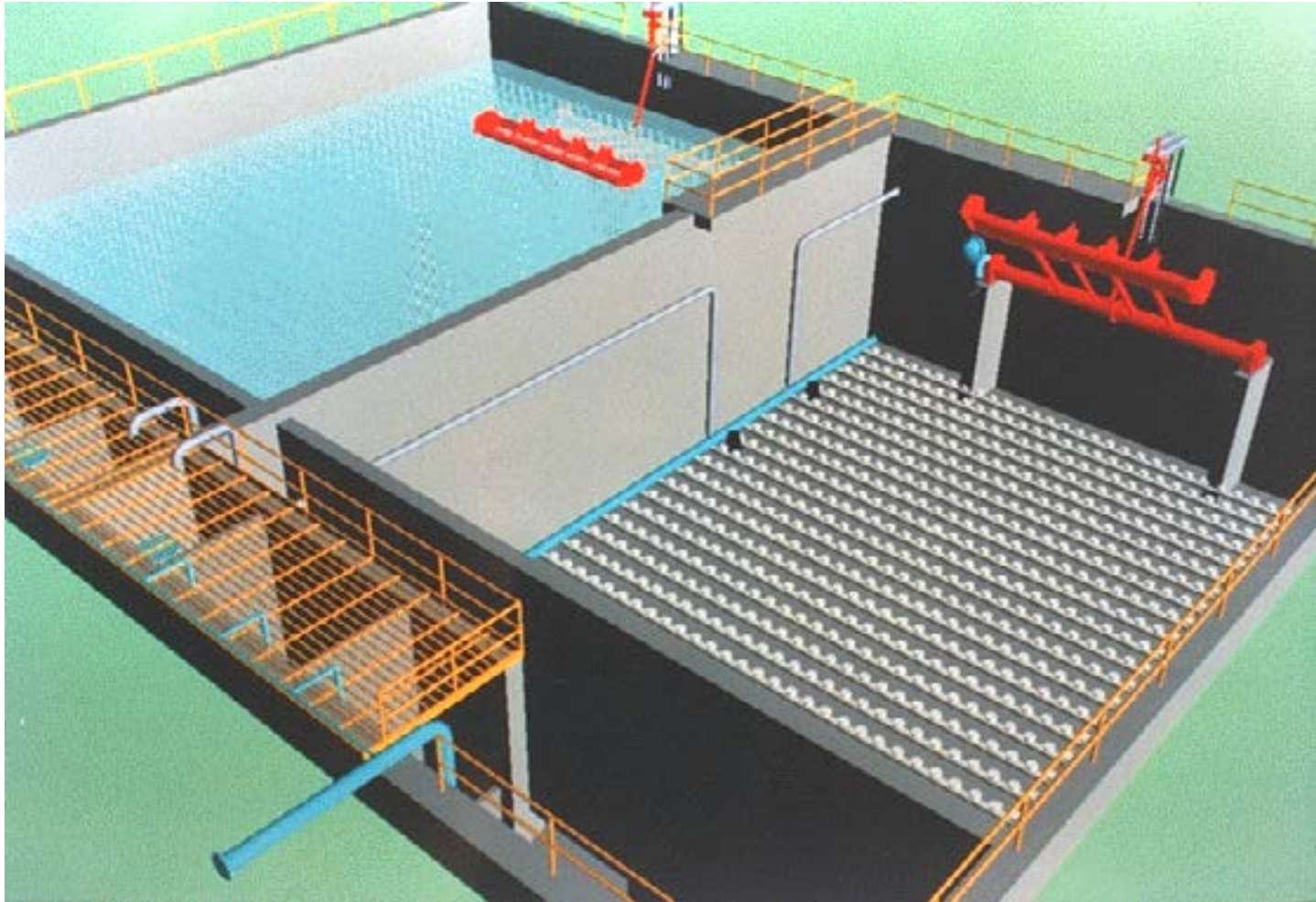


Sequencing Batch Reactor

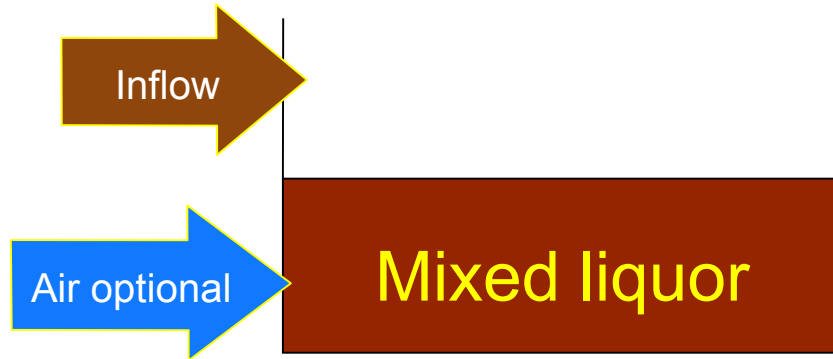


Sequencing Batch Reactor

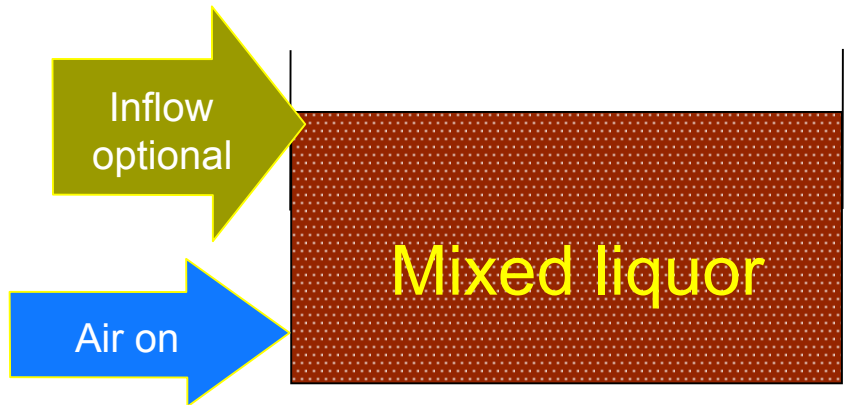
Basin Configuration



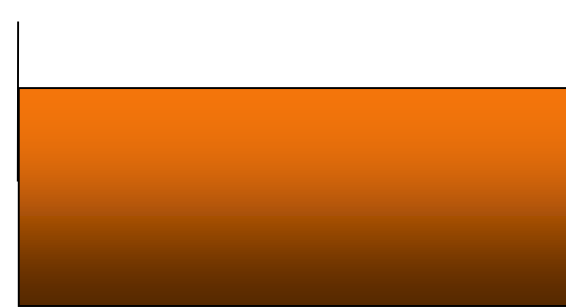
Sequencing Batch Reactor



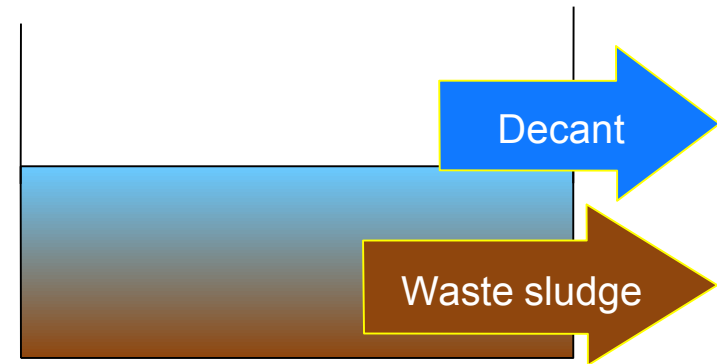
1. Fill (2 hours)



2. React (2 hours)



3. Settle (1 hour)



4. Decant & Idle (1 hour)

Sequencing Batch Reactor

Effluent Decanter

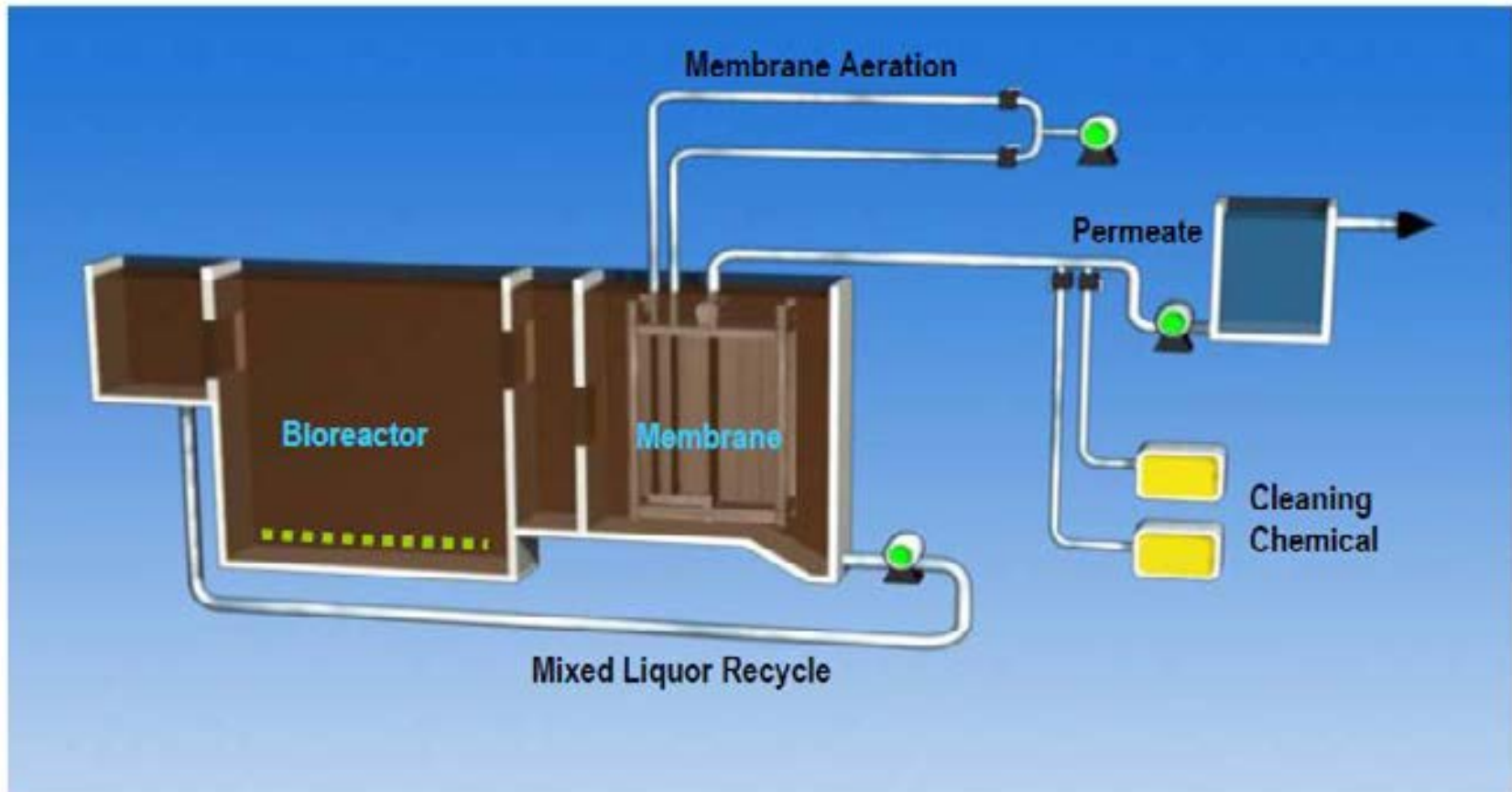
Raised above liquid during aeration

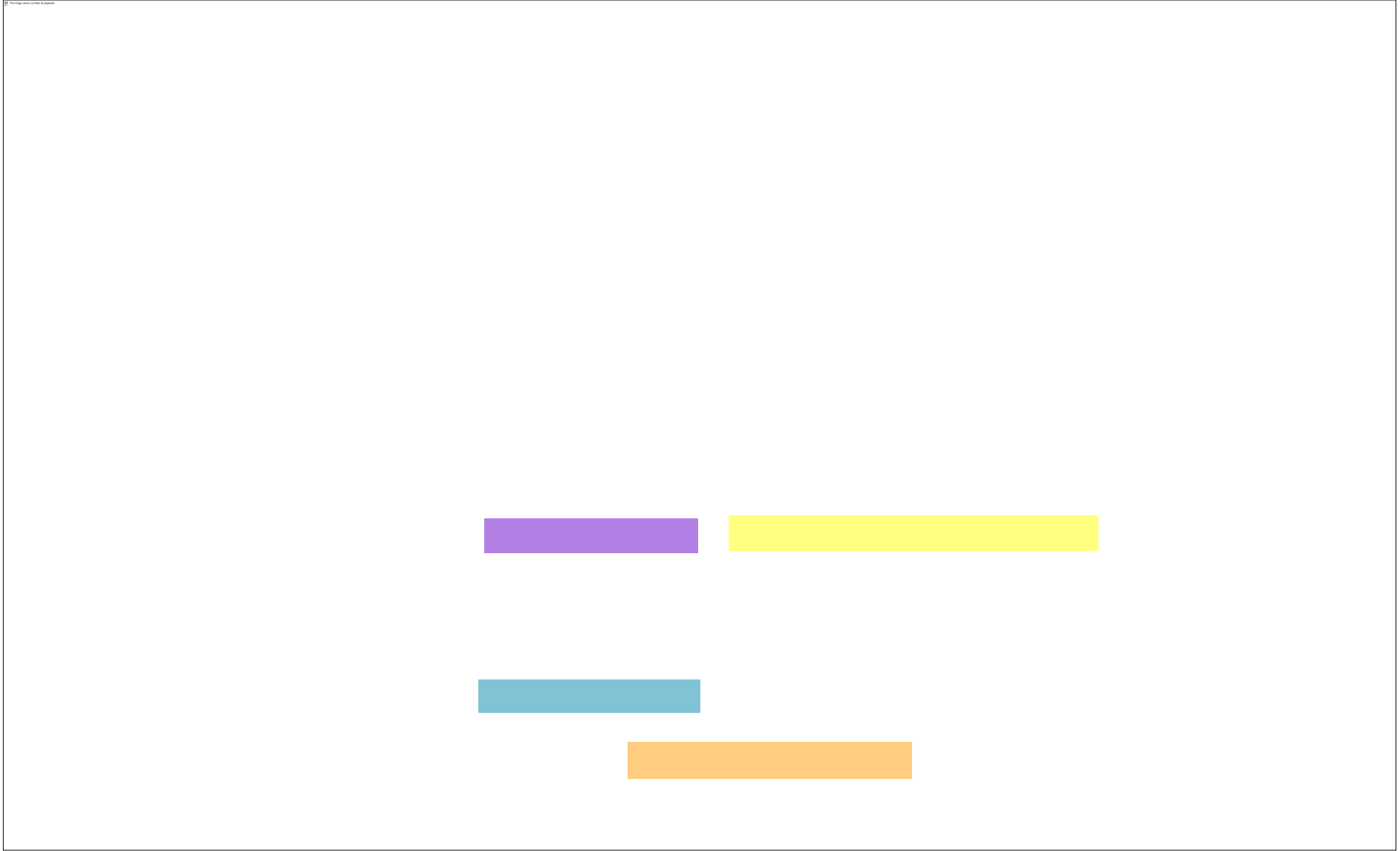


Follows liquid level down during decant



Membrane BioReactor





Membrane Bioreactor

- **Compact System**
- **No Clarifiers or Filters**
- **High Mixed Liquor Concentrations Possible**
- **No TSS or bacteria in effluent**
- **Limits passage of viruses**
- **Small Footprint (0.3 ha/10 MLD)**
- **Highly automated**
- **Requires close monitoring**

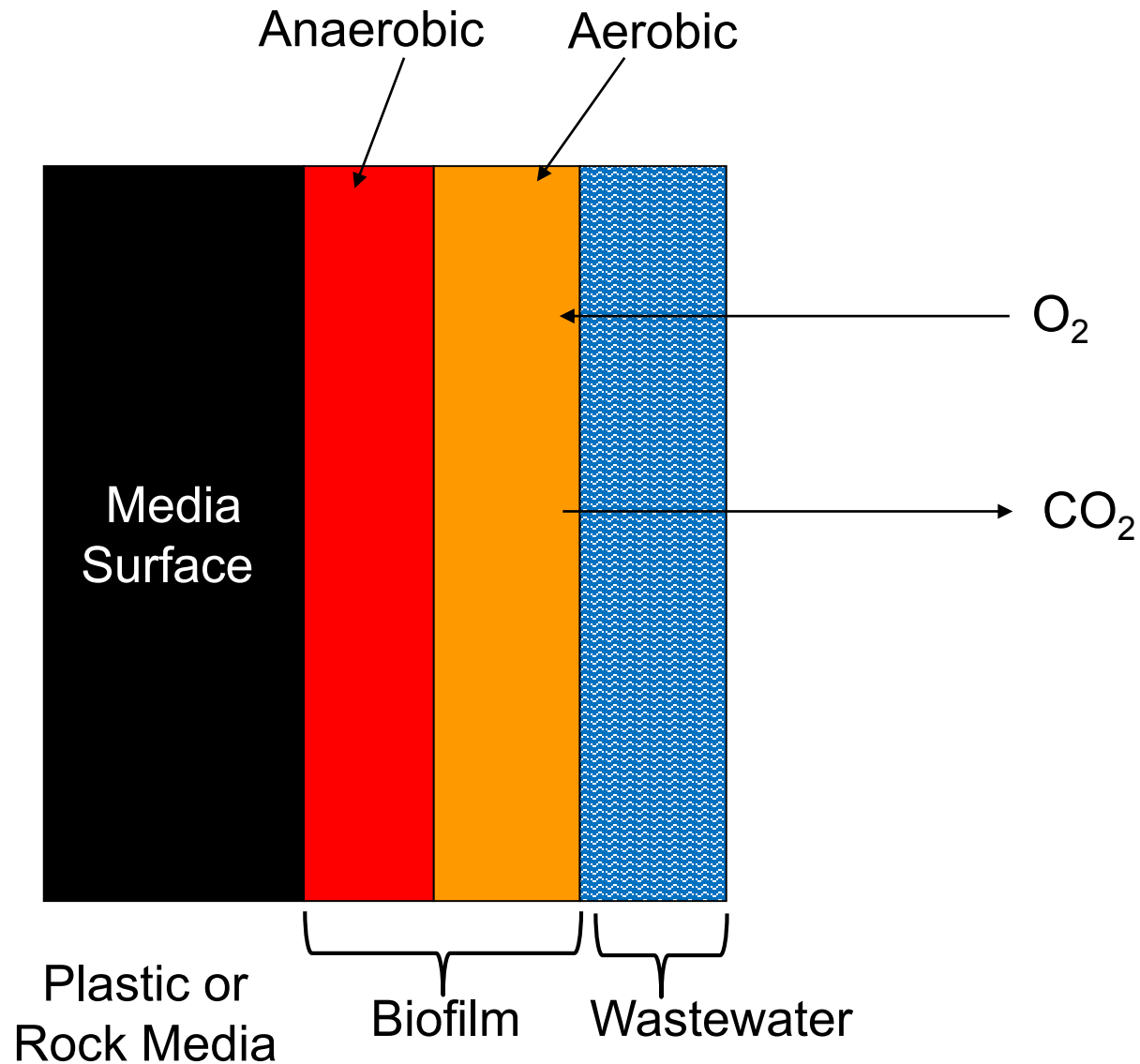


Fixed Film Processes

What are biofilms?

- A cultured biomass attached to a support medium
- The biofilm develops according to the availability of particular wastewater components and will vary according to loading and configuration
- Aerobic biofilms require oxygen to function
- As biofilms grow via the degradation of organic compounds they produce excess biomass which need to be removed from the system

Biofilm Structure



Fixed Film Reactors

- Also known as attached growth reactors to differentiate them from activated sludge or ‘suspended growth’ systems
- Biomass is cultured as a biofilm attached to a biomass support
- Biofilm can be applied across the whole spectrum of wastewater treatment from low rate traditional trickling filters to ultra high rate fluidised bed reactors

Fixed Film Processes

- Non-submerged systems
 - Traditional approach
 - Biofilm wetted regularly but kept in an air environment
 - Developed in 1890's as rock filters
 - Simple, low energy
- Submerged systems
 - Biofilm grows on media whilst completely wetted
 - Air supplied through aeration system
 - High rate, small footprint
 - More complex with greater control required

Fixed Film Processes

Trickling Filters

- Non-submerged fixed film biological reactor using rock or plastic packing over which wastewater is distributed continuously
- Advantages
 - No aeration costs
 - Simple to operate
 - Robust
 - Known process
 - Long-term experience



Fixed Film Processes

- Trickling Filters
 - Media Properties
 - High surface area – maximum biofilm attachment
 - Voids – large pores for aeration
 - Non – toxic – biofilm growth
 - Strength – no crushing
 - Low Cost
 - Distribution
 - Distribute wastewater evenly over filter
 - 2 or 4 arms
 - 30 – 55 mins / revolution
 - Improved BOD removal
 - Insect control
 - Hydraulic, motorized or static



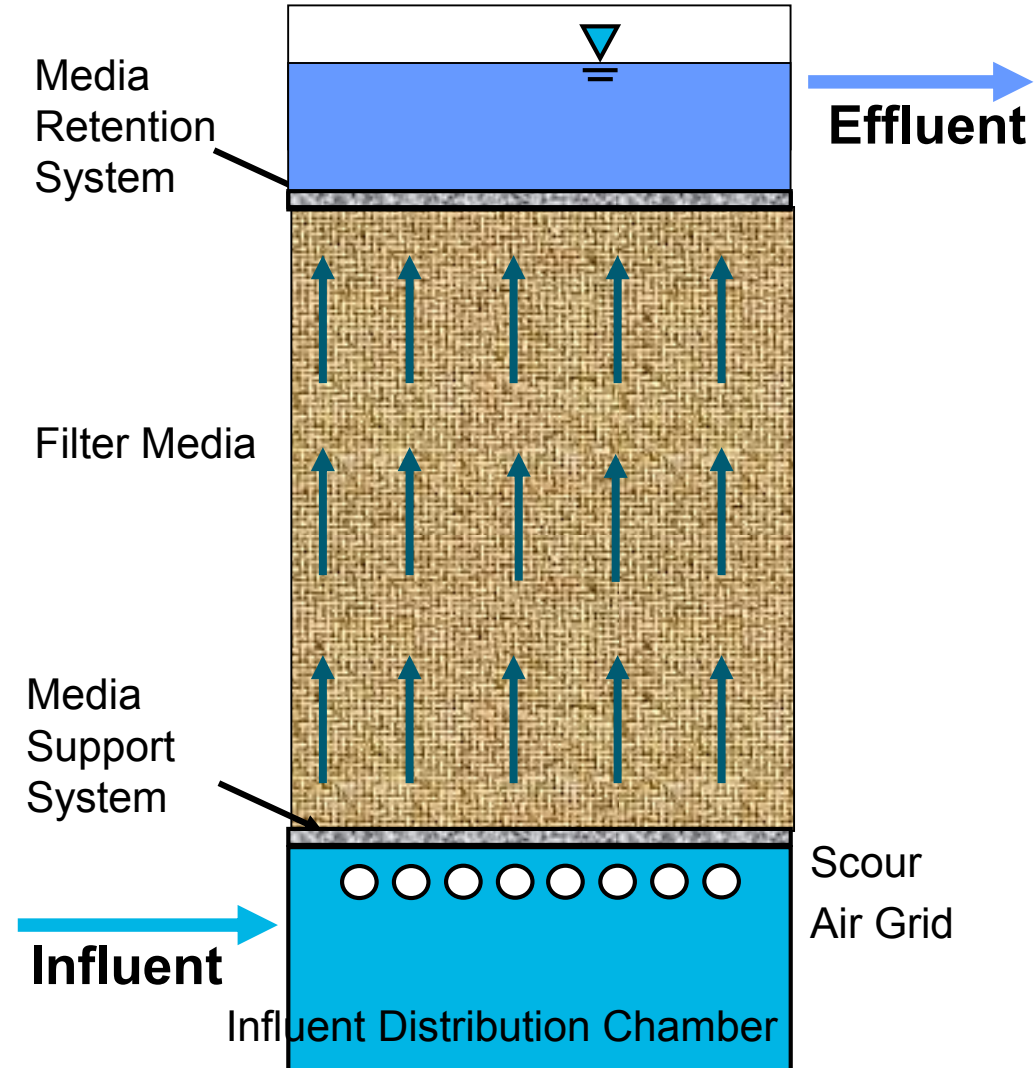
Fixed Film Processes

- Rotating Biological Contactors
 - More suitable for small works
 - Very low power requirement
 - Easily covered
 - Mechanically simple
 - Expensive
 - Tend to have mechanical problems
 - Unreliable

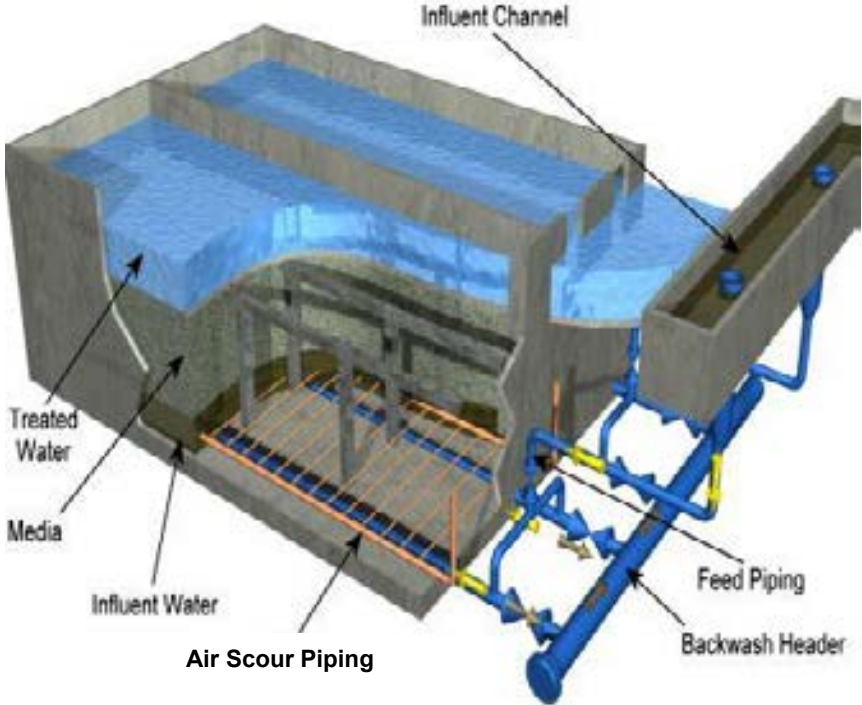


Biological Aerated Filter (BAF)

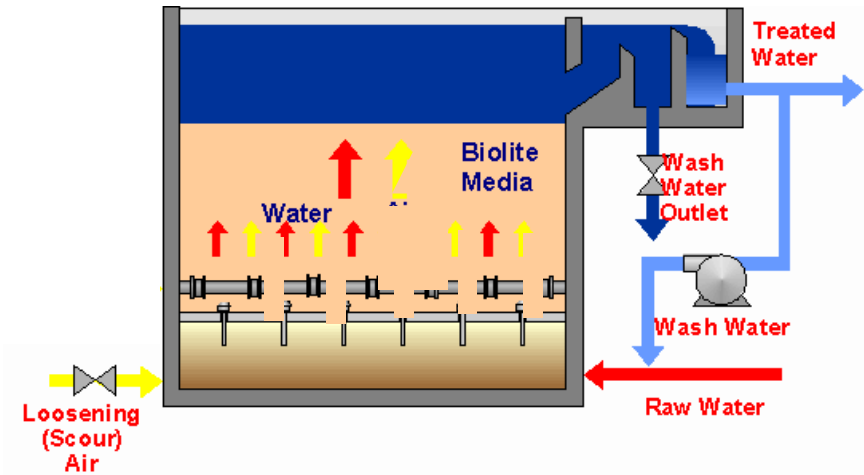
- Attached Growth Biological Process
- Upward Flow Through a Granular Media
 - Media - Surface for denitrifying organisms
 - Media - Solids removal



Biological Aerated Filter (BAF)



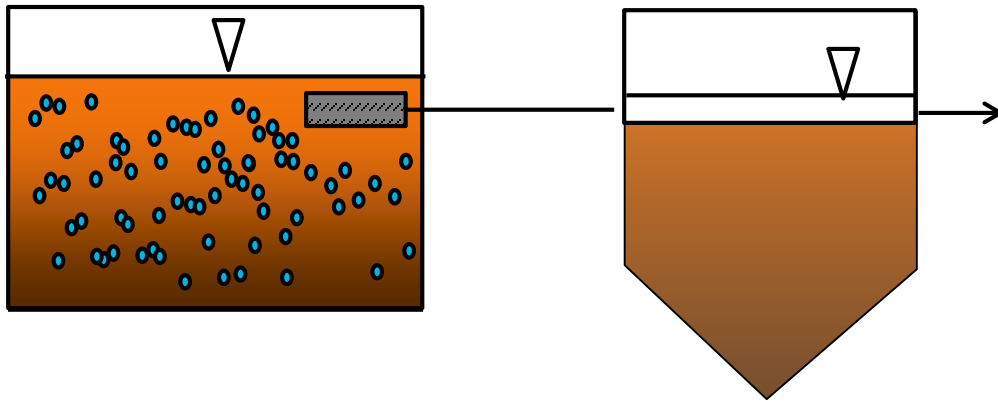
Kruger Biostyr



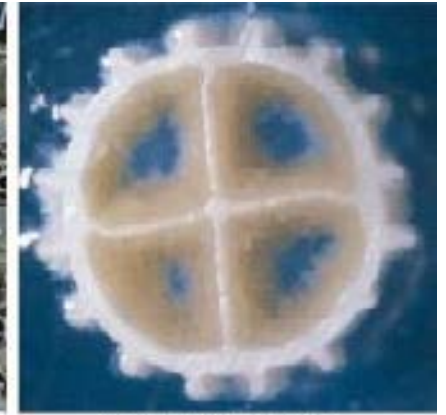
IDI Biofor

Hybrid Biological Processes

Moving Bed Biofilm Reactor (MBBR)



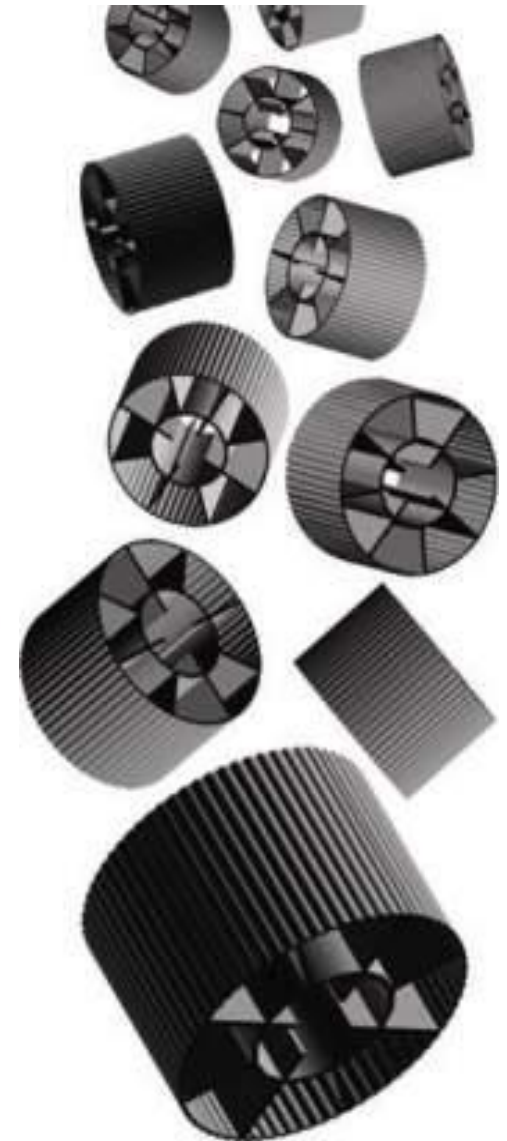
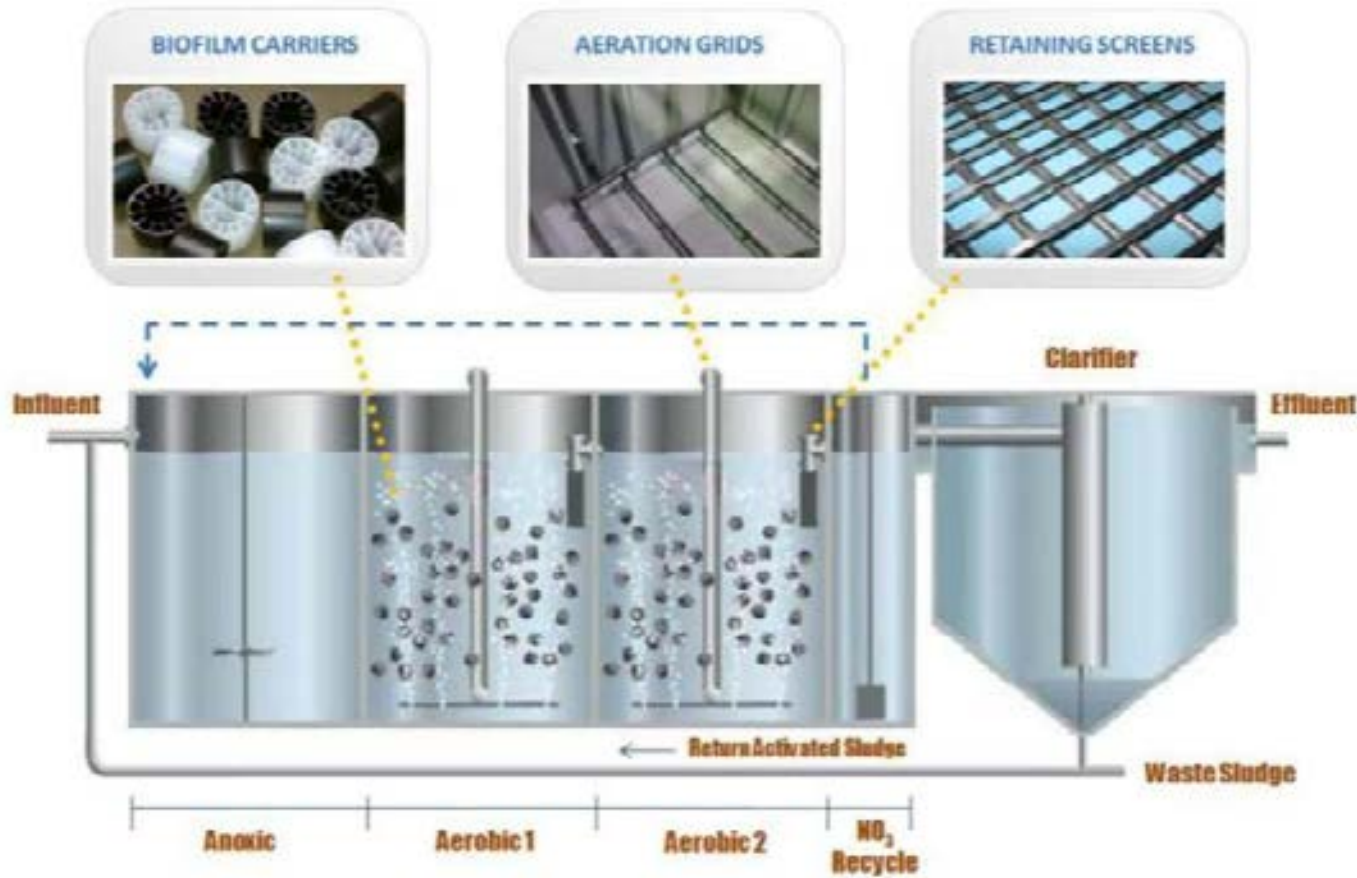
Moving bed plastic media



Bacteria in the plastic media



Integrated Fixed Film Activated Sludge



Break

Secondary Clarification

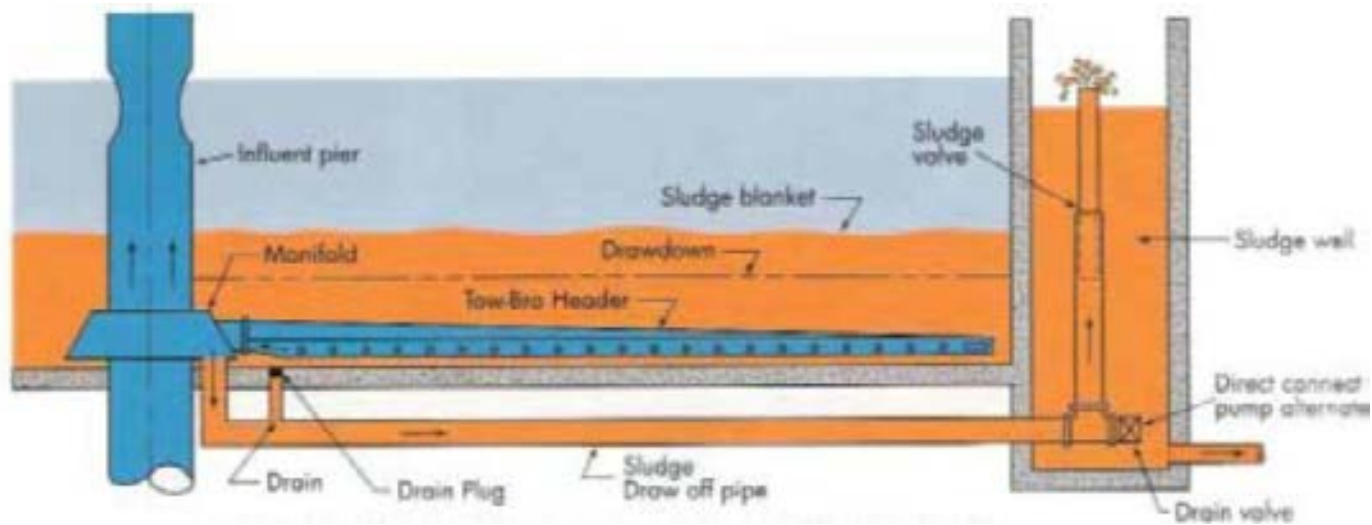
Secondary Clarification

- Tanks in which settleable solids from the biological treatment process are separated from the wastewater
- Design considerations and tanks are similar to those used for Primary Settlement Tanks
- Most common are circular
 - (10 to 50 m)
- Rectangular tanks can also be used



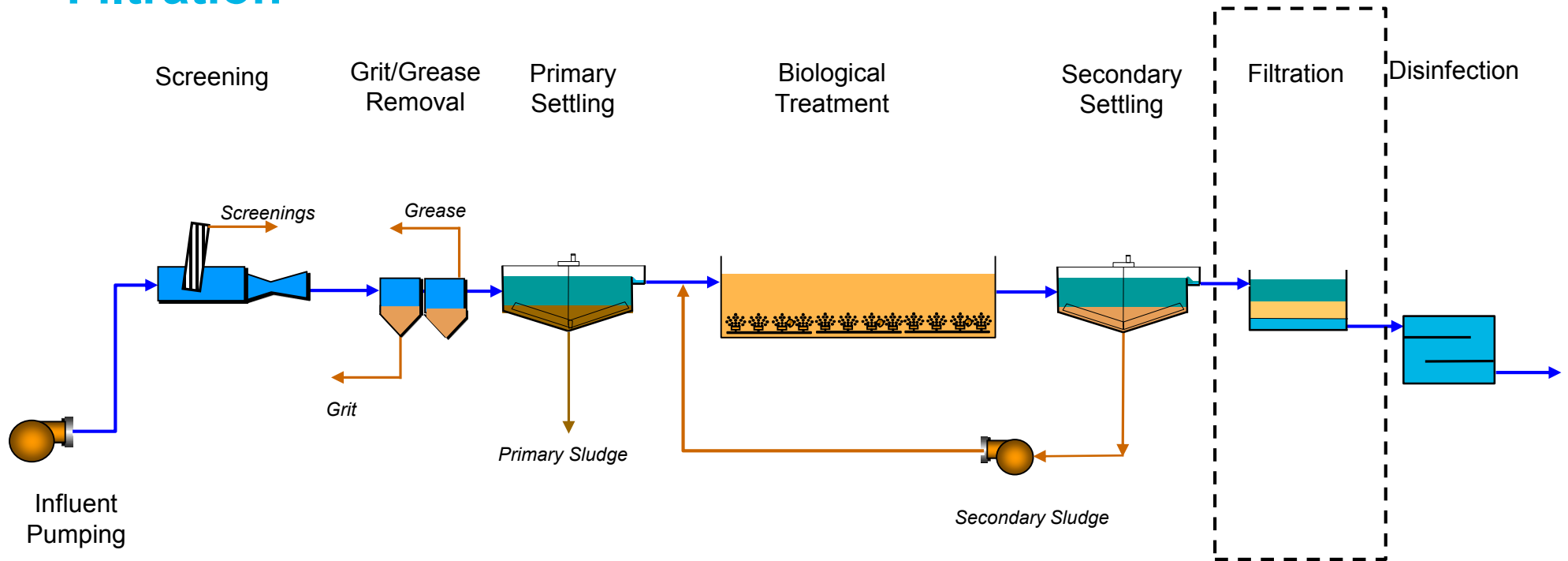
Secondary Clarification

Collectors with suction headers are the preferred type of equipment due to the nature of the sludge



Filtration

Filtration



Filtration is used to remove small solids that may leave the secondary clarifiers. It is used to achieve TSS levels of less than 5 mg/L. Microfilters and ultrafiltration can achieve TSS levels less than 1 mg/L and turbidity less than 1 NTU.

Filtration can be used for tertiary treatment to remove contaminants such as phosphorus and nitrogen with chemicals or through biological activation.

Filtration

– Types of Filtration

- Sand Filters
 - Gravel, sand, other granulated material
 - Dual, multi layer or multi media filters
- Membranes
 - Ultra filters, act as sieves
 - .001- 10 micron
- Biofilm Filtration (Disc or Trickling)
 - Biofilter using microorganism

Disc Filters



Deep Bed Filters



Low Head Filters

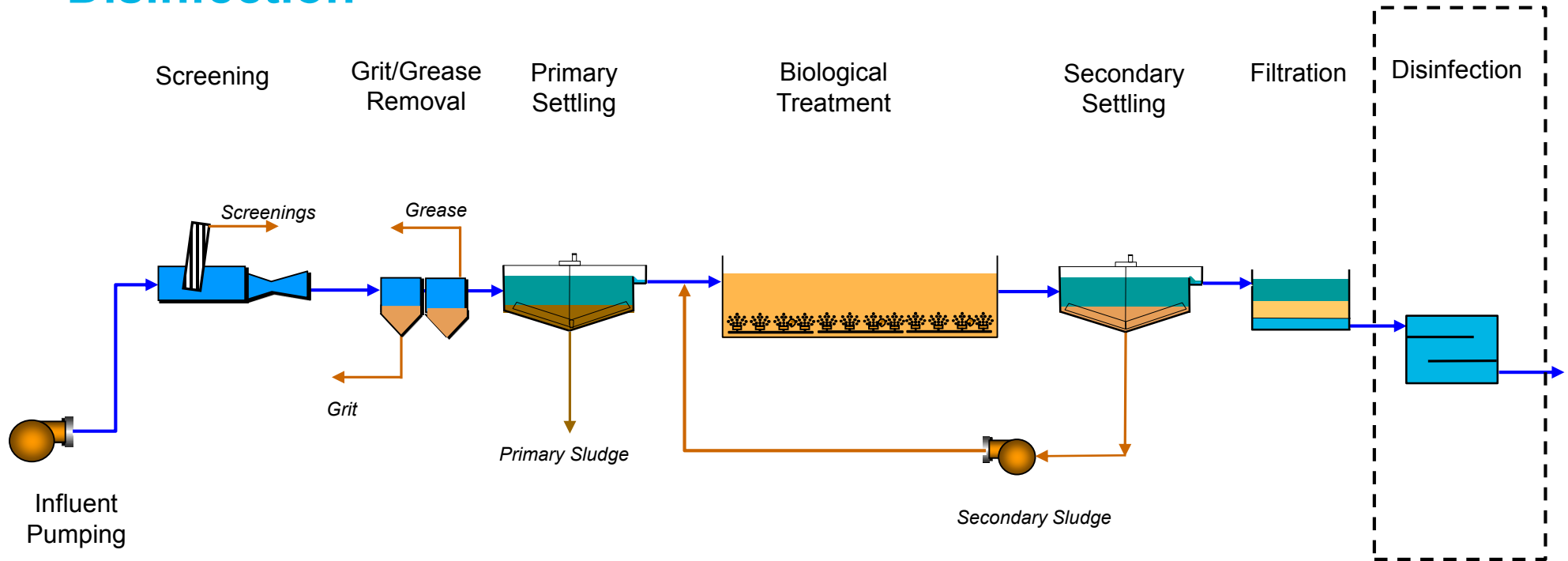


Fluidized Bed Filter



Disinfection

Disinfection



Disinfection removes remaining bacteria and viruses that could be harmful to fish or humans if in great concentration. TSE is disinfected for health reasons and to reduce bacteria growth in reuse mains.

Disinfection is required ahead of disposal or reuse under most conditions. May not be required for dedicated land application, subsurface disposal or disposal to non-critical waterways.

Disinfection

Chlorination

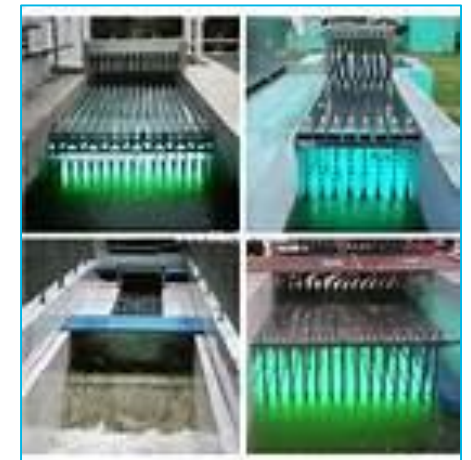
- Most commonly used
- 15 minutes contact time to remove most bacteria
- 30 minutes chlorine contact time to kill giardia cysts

Ultraviolet Radiation

- 20-30 second contact time
- Inactivates viruses
- No chemical addition
- No residual disinfectant

Ozone

- Strong Oxidant



Ozonation



Odour Treatment

Classification of odours

	Odour threshold (ppb)	Long Term OEL (8-Hour) (ppm)	Short term OEL (15 minutes) (ppm)
Hydrogen Sulphide	0.5	5	10
Methyl Mercaptan (methanethiol)	0.0014-18	0.5	-
Ethylmercaptan (ethanethiol)	0.02	0.5	2
Ammonia	130-15300	25	35
Methylamine	0.9-53	10	-
Ethylamine	2400	10	-
Dimethylamine	23-80	10	-

Why Hydrogen Sulphide

WHO guidelines for H₂S.

1000-2000 ppm	Immediate collapse with paralysis of respiration
530-1000 ppm	Strong Central Nervous system stimulation followed by respiratory arrest
320-530 ppm	Risk of Death
150-250 ppm	Loss of olfactory sense
50-100 ppm	Serious eye damage
10-20 ppm	Theshold for eye irritation

Why Hydrogen Sulphide

The importance of Hydrogen Sulphide in odour work

- It is almost always a component of wastewater odour
- It is always a component of septic wastewater odour
- It can be measured at concentrations close to its threshold
- Predictive models can be used
- In 99 cases out of 100, if the generation and release of H₂S is controlled so is the odour problem.

Methods of Treatment

Process	Description	Typical Design Details	Typical H ₂ S Inlet (ppm)	Typical % Removal Results	Approximate size of installation (m ³ /h)
Biofilters	A shallow bed containing a media such as compost or peat mixed with a bulking agent such as heather on which biological growth occurs.	35-100 m ³ /m ³ .h Bed Depth about 1m, Media life 2 - 5 years	Typically < 10 Maximum 50, if irrigated	70-95% H ₂ S Up to 95% TON, Residual odour about 200 OU/m ³	100-15000
Calcified Media Biofilters	A shallow bed containing calcified media such as shells or calcified seaweed sometimes mixed with peat.	35-100 m ³ /m ³ .h Bed Depth about 1m, Media life 2 - 5 years	Typical <100 Maximum 250, Irrigation Required	80-99% H ₂ S	100-15000
Bioscrubbers	Tower packed with plastic media on which bio-film develops. Liquor is re-circulated over the bed against the air flow	Sizing dependent on inlet and required outlet concentrations (as wet scrubber) pH control required	10-1000	60-90% H ₂ S, Residual 1 - 10 ppm	1000-2000
Dry Chemical Scrubbers	Impregnated particles, for example of alumina, held in a bed through which odourous air passes.	Dwell time 1 s	<10 (has been used for much higher concentrations)	95-99.9% H ₂ S with fresh media. Efficiency of passive units likely to be lower than this	Similar to activated carbon 1-52000

Process	Description	Typical Design Details	Typical H2S Inlet (ppm)	Typical % Removal Results	Approximate size of installation (m3/h)
Activated Carbon	Granules of high surface area carbon are held in a bed through which odourous air passes	Bed Depth about 0.25m Velocity 0.2-0.38 m/s, Dwell time 2s, usually 2 or 3 beds	<10	95-99/9% H2S with fresh media. Efficiency of passive units likely to be lower than this	Fan assisted 360-72000 Passive 1-1800
Catalytic Iron Filter	Iron Oxide held in a vertical or horizontal unit over which sulphide containing air passes.		500	50%	100-15000
Wet Chemical Scrubbers	Odourous air is contacted with a flow of recirculating liquid which dissolves and removed the odourous chemicals.	Sizing dependent on inlet and required outlet concentrations, pH control required	<10-1000	95-99% H2S 85-95% Odour	1000-100000

Activated Carbon Filters



Chemical Scrubbers



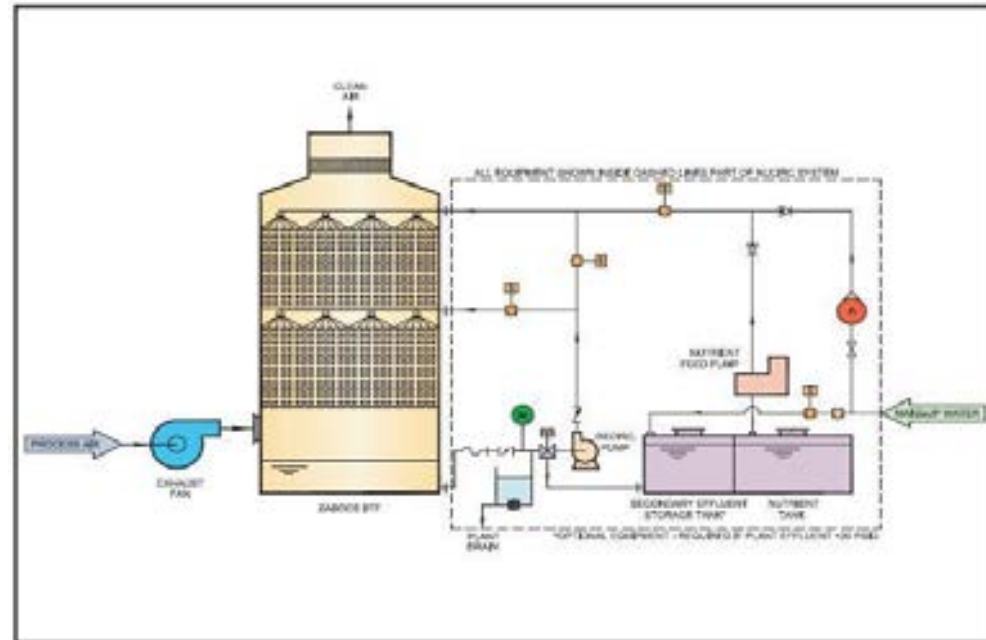
BioScrubber

- Targets H_2S specifically for oxidation.
- Fixed-film biological process which takes advantage of H_2S 's water solubility.
- Designed to reduce H_2S concentrations by 99% (12 to 15 sec.)
- Engineered inorganic media used as fixed bed material
- Microorganisms in Recirculating Water



Biotrickling Filter

- Media can be stacked, high void fraction – low resistance to air flow
- Higher air velocities – allowing smaller footprint than conventional biofilters
- Generally No recirculation
- Higher Capital cost
- Low operational cost
- Low Maintenance
- Media Replacement (10 – 25 years)
- Can remove other odour compounds



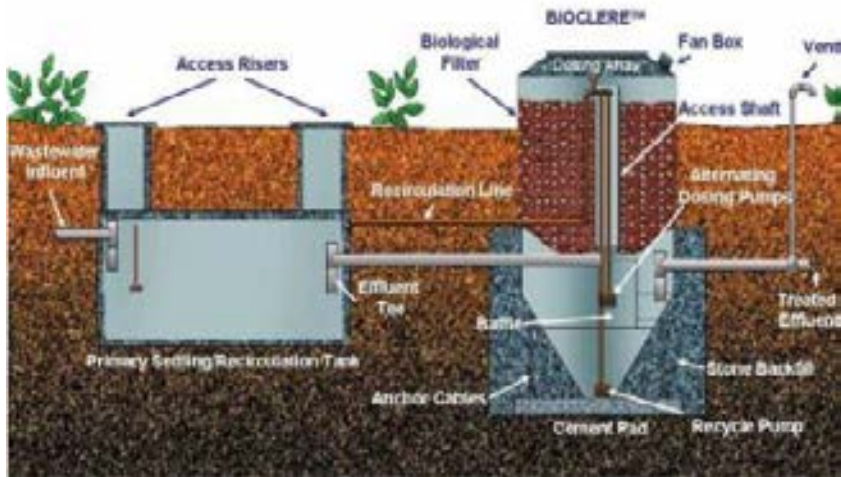
Biofilter

- A biofilter odor control system is based on adsorption and bacterial decomposition of odorous compounds
- Modern media require no added chemicals for treatment
- Various system designs;
 - Custom Built in place
 - Custom Modular
 - Prefabricated units
- Organic Media (5 years)
- Inorganic media (10+ Years)

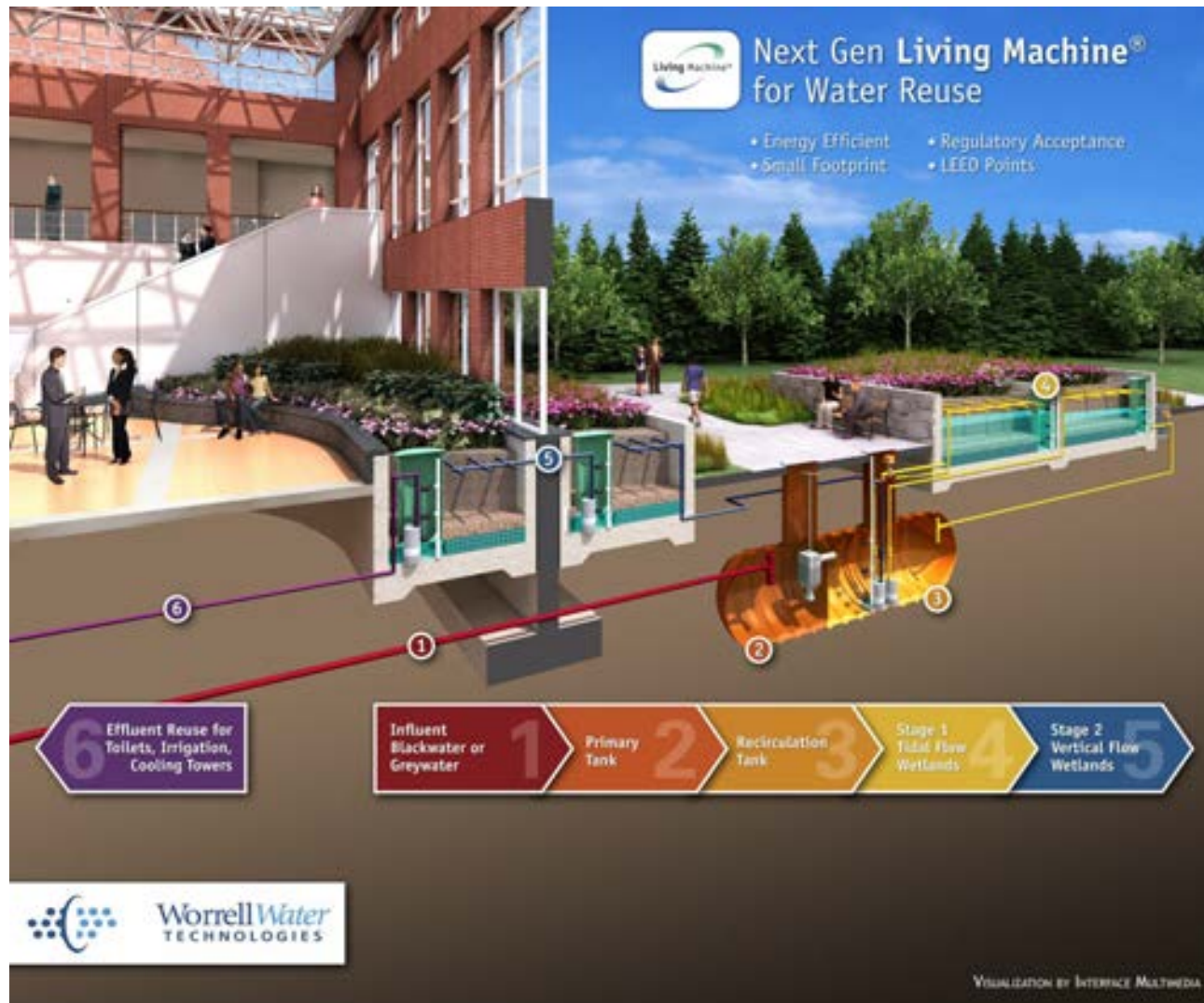


Break

Small Treatment Systems



Living Machine[®]



Living Machine[®]



Organica[®]



Biological Process Modeling

Wastewater Process Modeling Software



BIOWIN:
EnviroSim Associates, Ltd.
7 Innovation Drive
Suite 205
Flamborough, Ontario, Canada



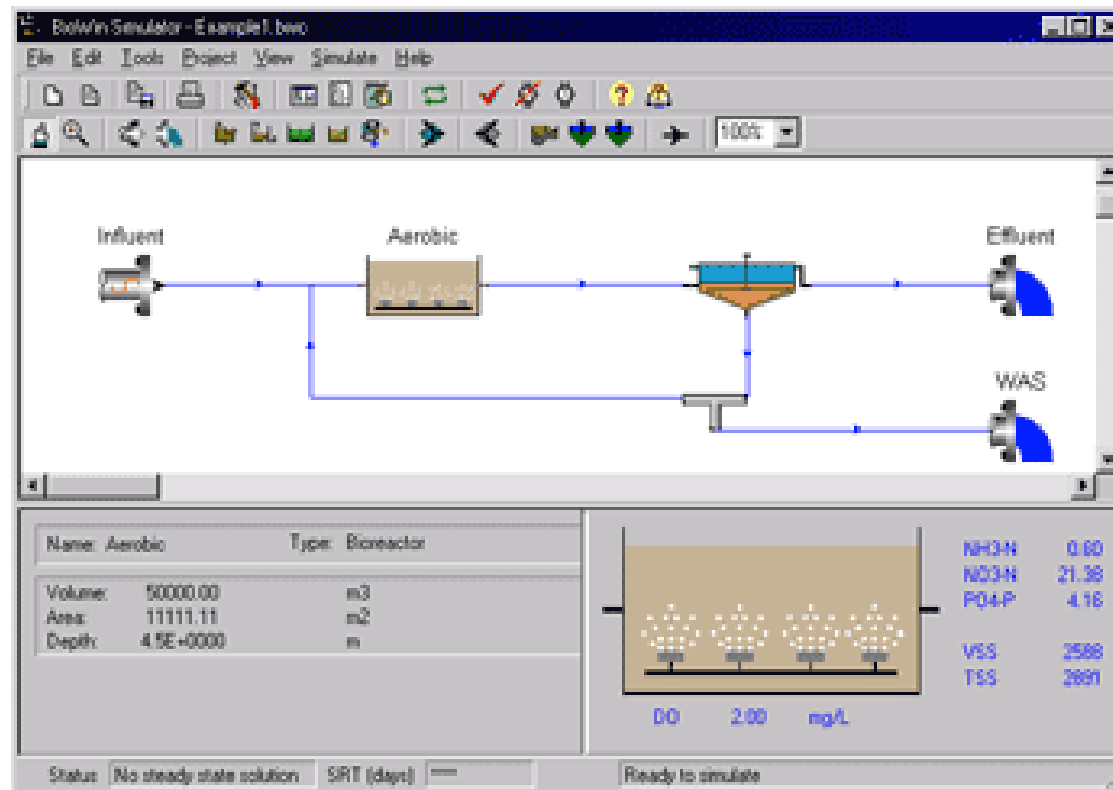
GPS-X:
Hydromantis ESS, Inc.
1 James Street South
Suite 1601
Hamilton, Ontario, Canada



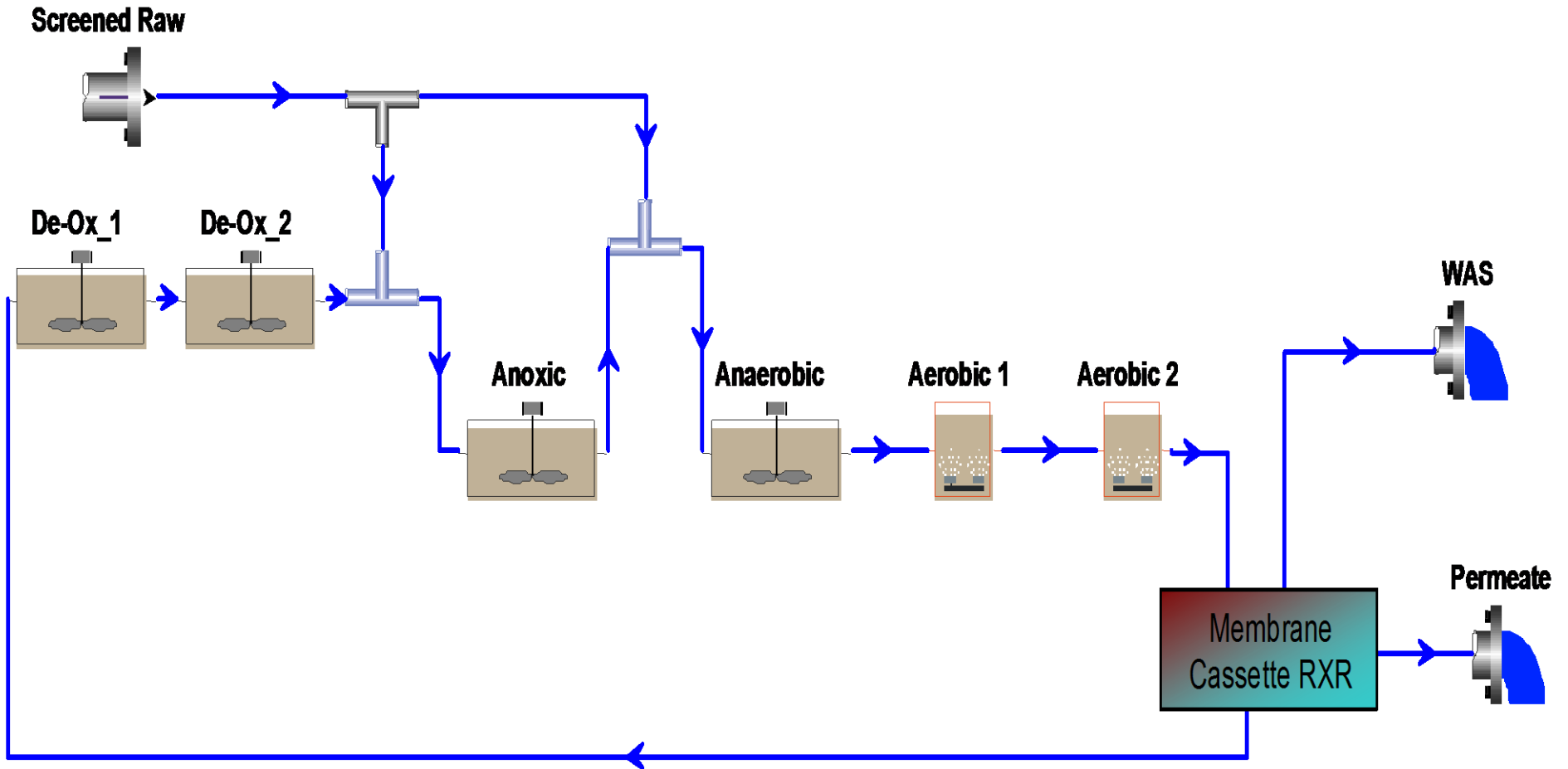
WEST:
Hemmis N.V.
K. Leopold III-Iaan 2
8500 Kortrijk
Belgium

Biological Process Modeling

Different process units can be included to "build" a specific treatment plant configuration and model any condition



BioWin Process Diagram



Break

Sludge Treatment

Sludge Treatment

– What is Sludge?

- Wastewater sludge comes from:
 - Primary Sludge: Settled solids from raw wastewater, mostly TSS, from Primary Settling Tanks
 - Secondary Sludge: Live and dead bacteria from biological treatment processes, which are settled in the Secondary Settling Tanks

Sludge Treatment

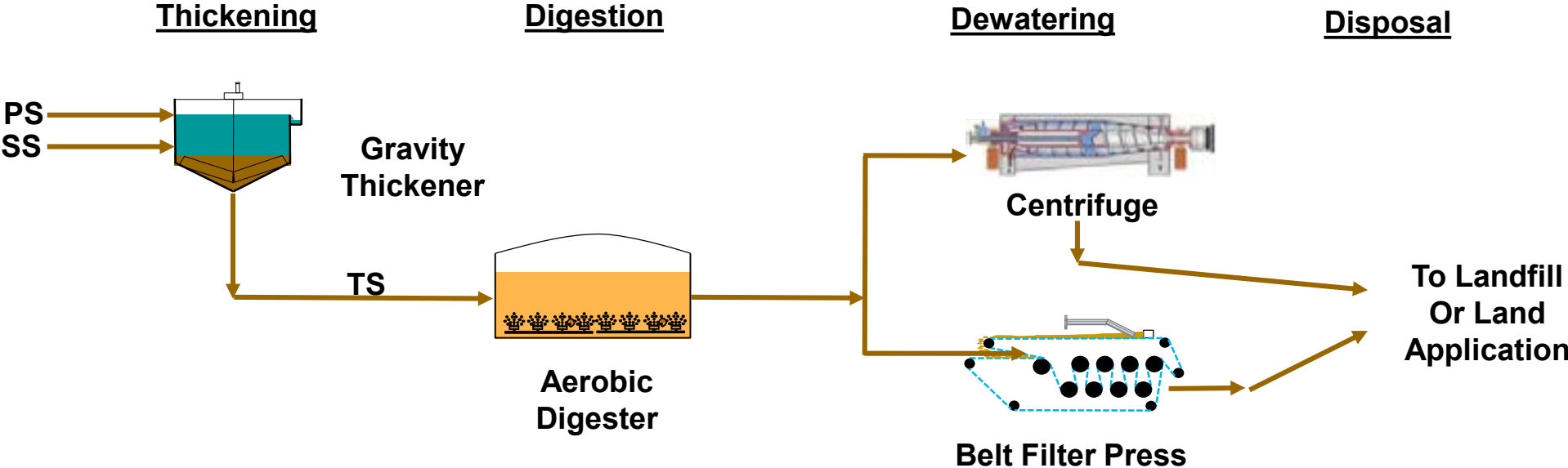
– Why treat sludge?

- Need to dispose of the sludge
 - Wastewater sludge smells
 - Contains high level of fecal bacteria
- Disposal Options
 - Burning
 - Recycle to land
- Sludge from the settlement tanks is low in solids contents, concentrations between 0.5% and 2% solids.
- Treatment will concentrate the solids and reduce the volume to be disposed
- Treatment will also reduce odors and the level of fecal bacteria

Sludge Treatment

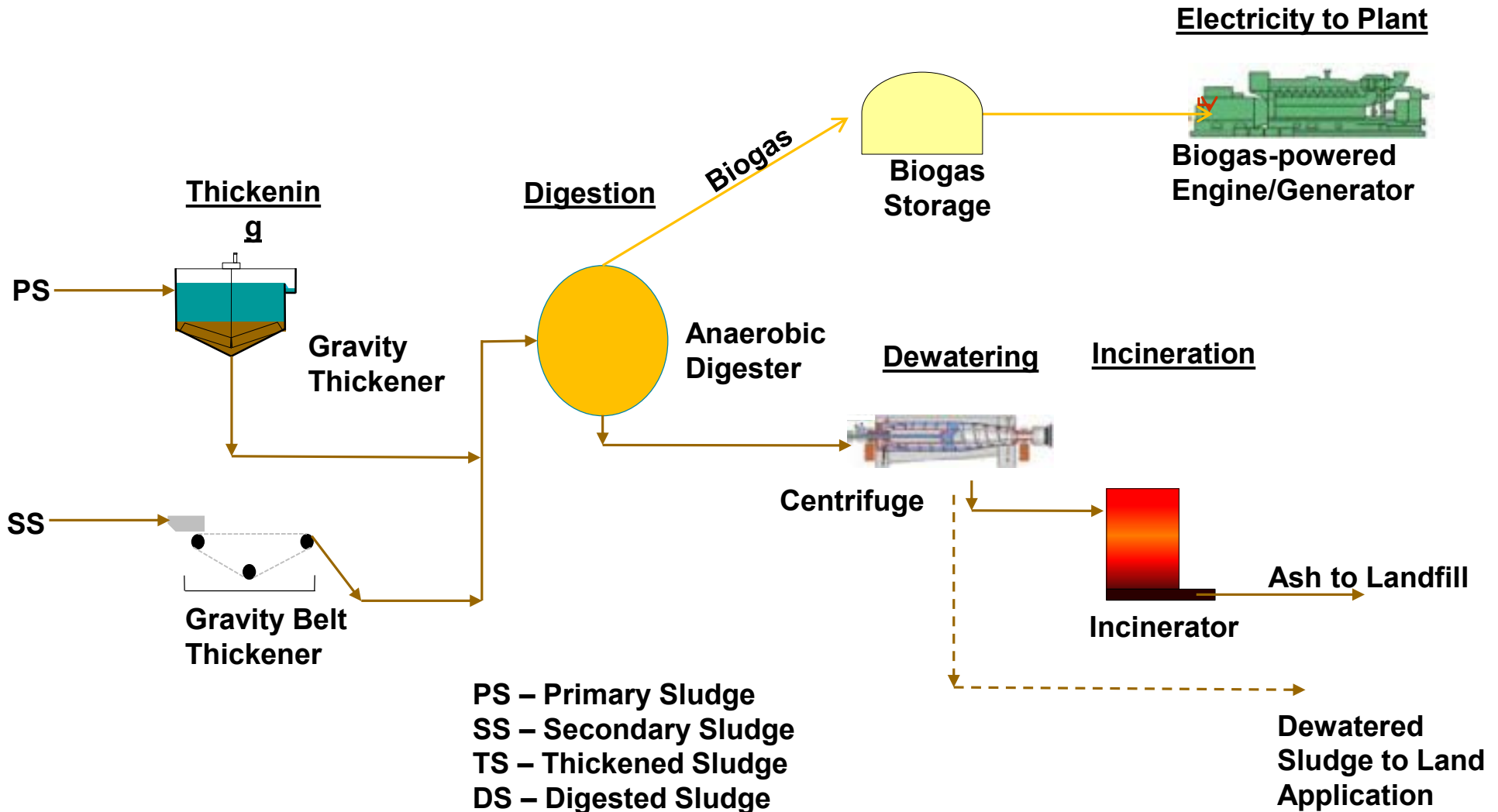
- Thickening
 - Gravity Thickening
 - Gravity Belt Thickening
 - Rotary Drum Thickening
 - Dissolved Air Flotation Thickening
- Digestion
 - Aerobic Digestion
 - Anaerobic Digestion
- Dewatering
- Drying
- Incineration

Sludge Treatment – Aerobic Digestion



PS – Primary Sludge
 SS – Secondary Sludge
 TS – Thickened Sludge
 DS – Digested Sludge

Sludge Treatment – Anaerobic Digestion

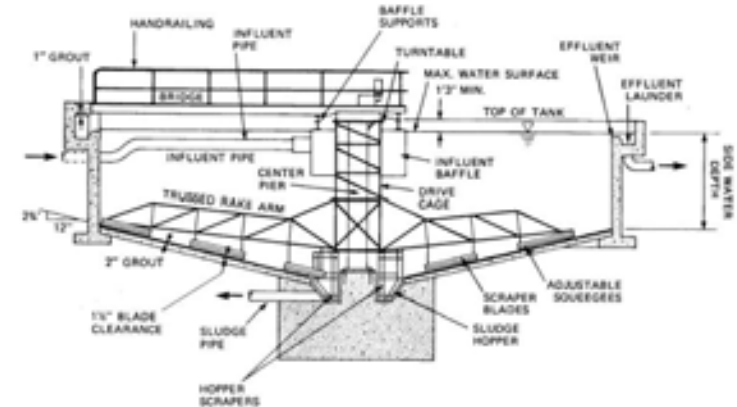


Sludge Thickening

Sludge Thickening

- Gravity Thickening

- Process similar to settlement tanks in the liquid stream process
- Works well for primary sludge but can be used for secondary sludge with polymer addition
- Requires cover and odor control in case of process upset
- Can increase solids from 1.5 – 2% to 4 – 6%



Sludge Thickening

- Gravity Thickening Design Parameters

Design Parameter	Range
Diameter	10 – 25 m
Sidewater Depth	3 – 5 m
Solids Loading Rate	100 – 150 kg/m ² /d (PS) 25 – 70 kg/m ² /d (Combined PS & SS)
Hydraulic Overflow Rate	15.5 – 31 m ³ /m ² /d (PS) 6 – 12 m ³ /m ² /d (Combined PS & SS)
Sludge Blanket Depth	0.5 – 2.5 m

Sludge Thickening

- Gravity Belt Thickening

- Liquid from sludge is removed through pores in woven plastic belt
- Works well for secondary sludge
- Polymer addition required for efficient operation
- Can increase solids from 0.5 – 2% to 4 – 8%



Sludge Thickening

- Gravity Belt Thickening Design Parameters

Design Parameter	Range
Belt Width	1 – 3 m
Solids Loading Rate	200 – 600 kg/m/hr
Hydraulic Overflow Rate	20 – 58 m ³ /m/hr
Polymer Dosage	3 – 7 kg of dry polymer/metric ton

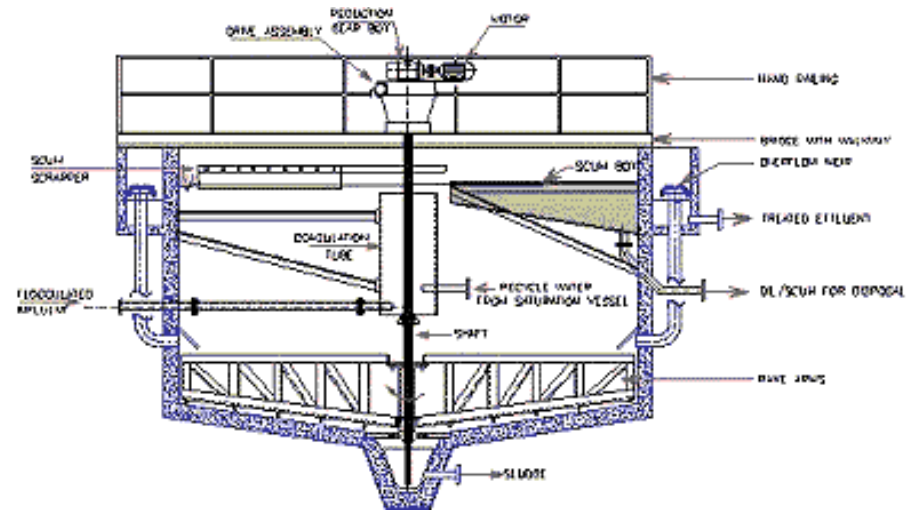
Sludge Thickening

- Rotary Drum Thickening
 - Slowly rotating drum aids removal of liquid from sludge and concentrates solids
 - Liquid from sludge is removed through pores in metal screen inside drum
 - Works well for both primary and secondary sludge
 - Polymer addition improves efficiency
 - Can increase solids from 0.5 – 2% to 4 – 8%
 - Up to 85 m³/hr capacity



Sludge Thickening

- Dissolved Air Flotation Thickening
 - Uses small air bubbles to which sludge particles attach and float to water surface
 - Works well for secondary sludge
 - Polymer addition required for efficient operation
 - Can increase solids from 0.5 – 2% to 4 – 8%
 - Requires additional support equipment (pressure vessels, air compressors and circulation pumps)
 - Solids loading rates
 - 1 – 6 kg/m²/hr without chemical addition
 - Up to 10 kg/m²/hr with chemical addition



Sludge Thickening

- Centrifuge Thickener
 - Performance by percent capture
 - Liquid from sludge is removed through centrifugal action
 - Works well for secondary sludge
 - Polymer addition required for increased solids content
 - Can increase solids from 0.5 – 2% to 3 – 8%



Digestion

Sludge Digestion

- Process
 - Reduces the concentration of organic solids in sludge
 - Results in less sludge to process, decreases operating time and reduces size of dewatering equipment
- Anaerobic Digestion
 - Uses heated sludge in a tank with a low concentration of air
 - Process produces methane gas which can be utilized to heat the sludge and for cogeneration
 - Results in varying degrees of destruction of harmful bacteria
 - Must be used if dewatered sludge is to be recycled
- Aerobic Digestion
 - Uses diffused air to reduce organic solids
 - Dewatered solids must be incinerated or transported to a landfill
 - Tanks can be either circular or rectangular

Egg-shaped Digesters



Conventional Anaerobic Digesters



Sludge Digestion

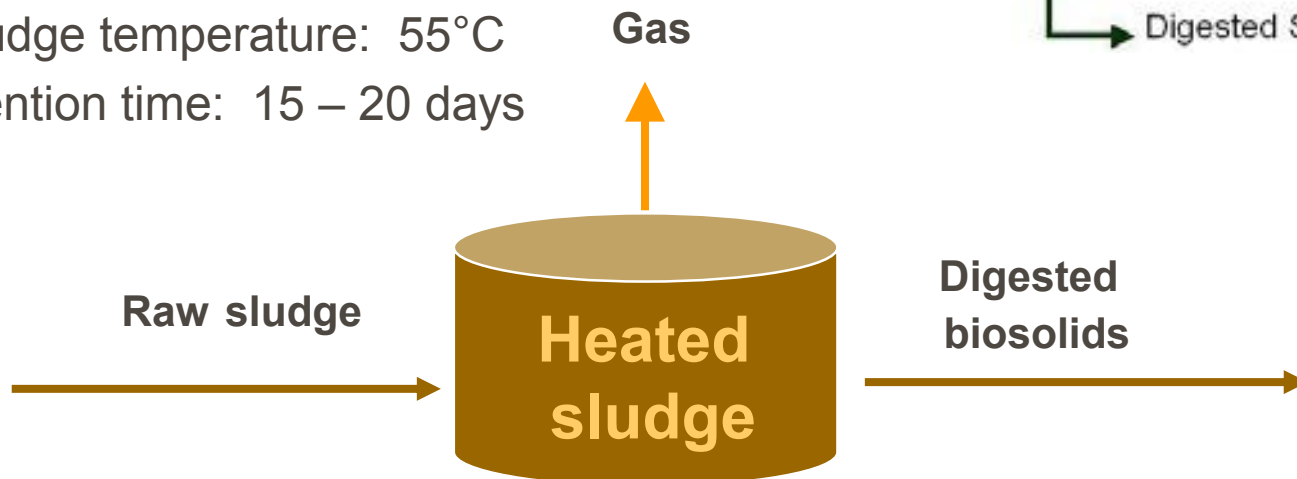
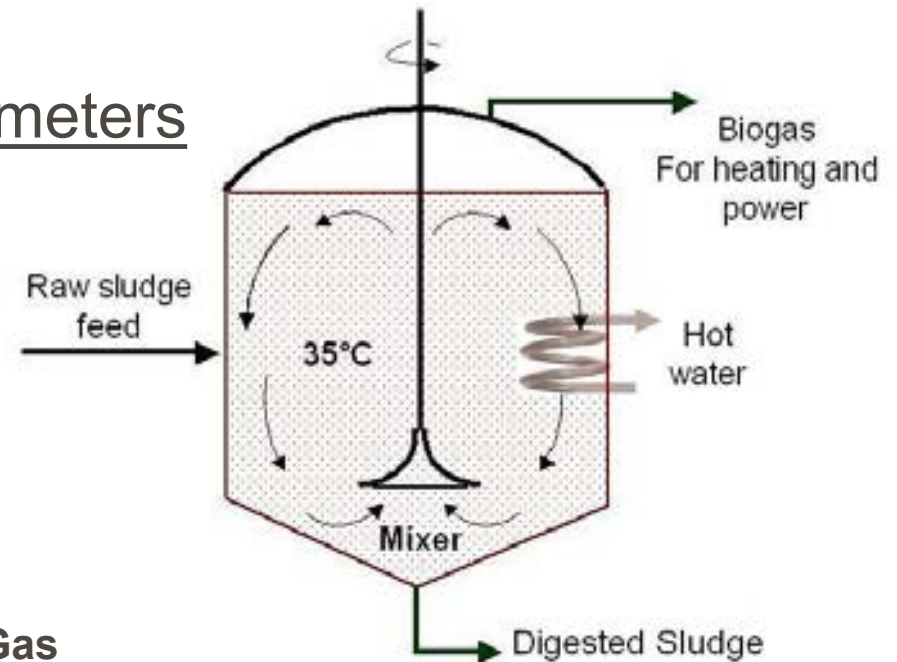
– Anaerobic Digestion Design Parameters

• Mesophilic Process

- Heated sludge temperature: 35°C
- Solids retention time: 15 – 20 days
- Solids Loading Rate: 1.6 – 4.8 kg/d/m³

• Thermophilic Process

- Heated sludge temperature: 55°C
- Solids retention time: 15 – 20 days



Sludge Digestion

– Aerobic Digestion Design Parameters

Design Parameter	Range
Volatile Solids Loading Rate	1.6 – 4.8 kg/d/m ³
Solids Retention Time	40 – 60 days
Diffused Air for Mixing	0.02 – 0.04 m ³ /min/m ³

Sludge Dewatering

Sludge Dewatering

– Centrifuge

- High speed rotating drum uses centrifugal force to remove liquid from sludge
- High capacity in a small footprint
- Solids and odors are completely contained within the drum
- Produces higher dry solids content than Belt Filter Press
- 70% moisture content cake



– Belt Filter Press

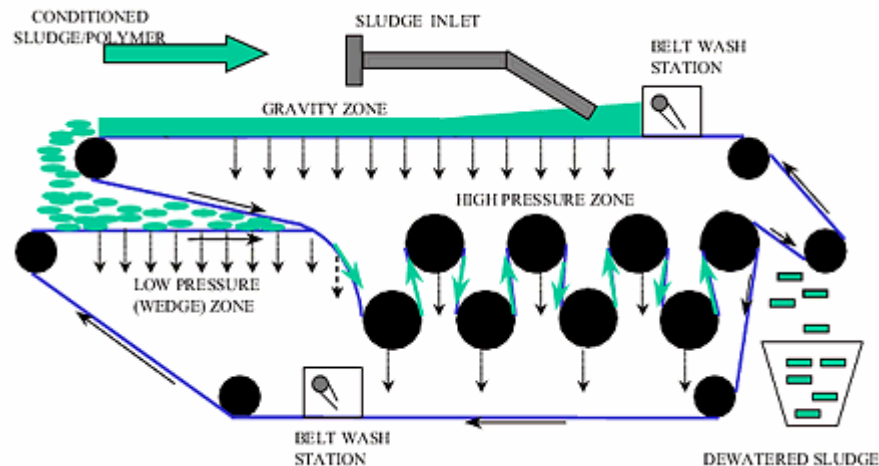
- Uses pressure to squeeze liquid through two woven plastic belts
- Requires more maintenance
- 70-80% moisture content cake



Sludge Dewatering

Belt Filter Press Design Parameters

Design Parameter	Range
Belt Width	0.5 – 3 m
Feed Rate	5 – 12 m ³ /hr/m
Solids Loading Rate	180 – 320 kg/hr/m
Polymer Dosage	4 – 10 kg of dry polymer/metric ton



Sludge Dewatering

- Dewatered sludge from Centrifuges and Belt Filter Presses is usually in the range of 20 – 30% dry solids
- Sludge can be burned in incinerators, trucked to a landfill or used as a soil amendment if it has been adequately digested



Sludge Drying

- Increases Solids to 90% or greater
- Reduces pathogens and vectors

In-vessel Thermal Drying



Sand Bed Drying



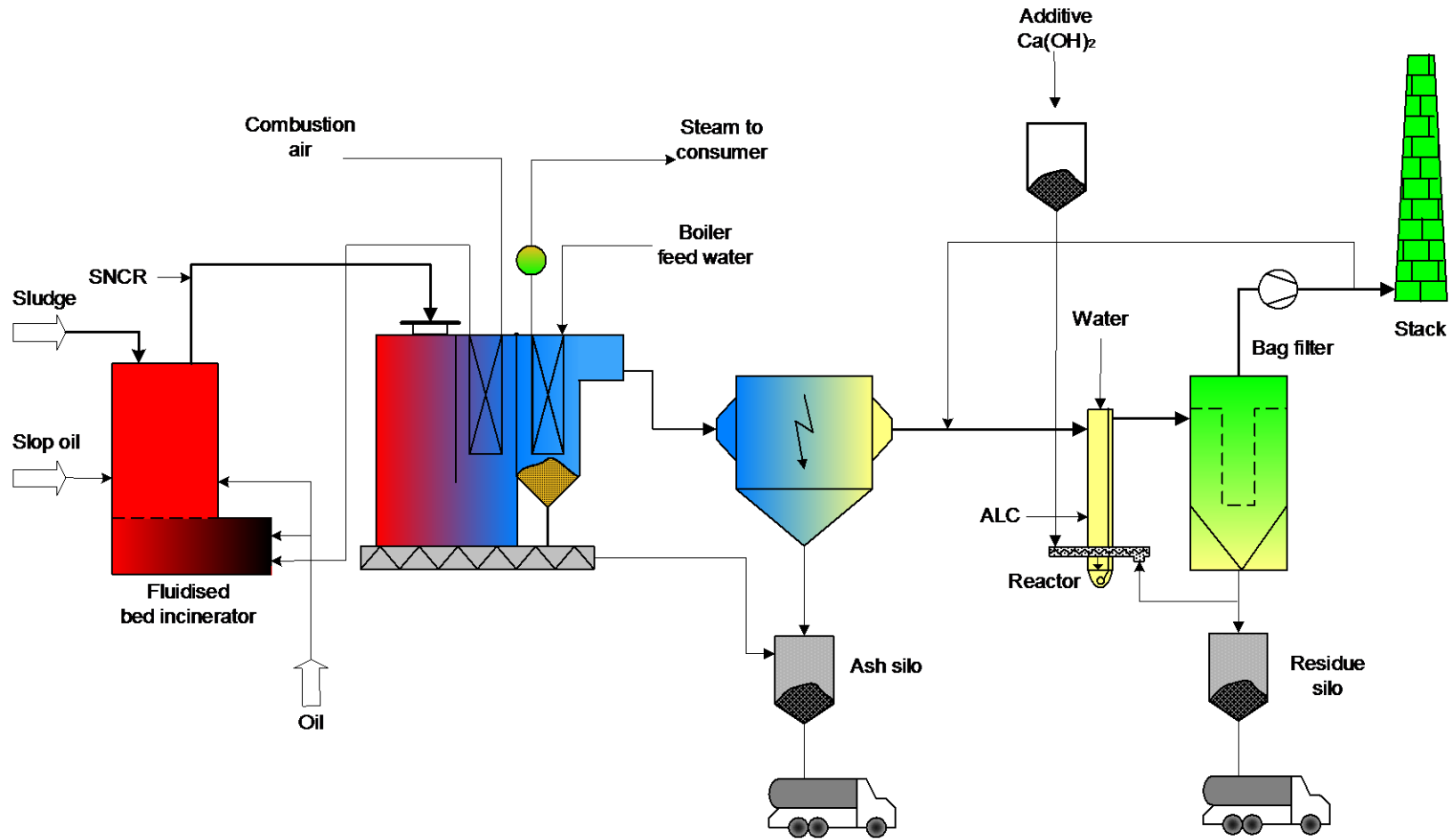
Incineration

Sludge Incineration

- Burns the dewatered sludge to produce ash, reducing the volume for disposal
- Destroys pathogens and toxic compounds making disposal safer



Sludge Incineration



Cogeneration

Cogeneration

- Also called Combined Heat and Power (CHP)
- Provides the opportunity to use biogas generated in Anaerobic Digestion Process
- Biogas can be collected and stored for use to:
 - Heat water used to maintain a suitable temperature in the digesters to sustain biological degradation
 - Power combustion engines to generate electricity which powers treatment plant equipment
 - Heat water to maintain a comfortable environment in buildings in cold climates

Cogeneration

Biogas Engine/Generator



Biogas Storage Dome

Sludge Treatment Summary

Sludge Treatment Summary

- Sewage sludge generally comprises settled solids and dead and living biomass
- It is treated to reduce volume for disposal, kill bacteria and reduce odors
- Treated sludge can be burned to further reduce the volume for disposal or can be applied on land as a soil amendment
- Belt thickeners, centrifuges and belt presses are used to remove water from the sludge to thicken & dewater with the addition of polymer
- Sludge can be digested at elevated temperatures to break down the volatile solids and produce gas for power generation, producing a stable sludge for disposal
- Incineration and gasification are ultimate disposal options

Thank You

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