Training Program (23-24 Dec 2022)

on

Design on waste water treatment technology , equipment and SBR & MBBR system with Tertiary treatment technology

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SELF INTRODUCTION

- **Educational Qualifications** – Post Graduate in Polymer Engineering, & PGD in Business Management

- **Experience – Worked with many national & international companies as a business head and country head.**

- *Promoted technological products and system while* ***working with leading multinational organizations in India, Canada, Singapore & Middle East like Napier-Reid Canada, Hyflux Singapore, SPML Infrastructure as a business head and country head.***

- Presently associated with Aqwise Wise Water Technologies Ltd. **as a Country Head** to promote various technologies for water & waste water application like MBBR, IFAS , SBR ,Anaerobic Technology etc.
- Effectively imparted 20+ trainings on water & waste water, UF Technology, RO Technology, Water Recycling, SBR technology & Sludge Management and **attended 40+ seminars worldwide** as a Speaker & Delegate.
- Merits of having **various Papers Published** on latest techniques in **membrane technology, SBR Technology, UF Technology and various sludge treatment in water & Waste Water** in various magazines & journals

TOPICS TO BE COVERED

- Introduction to Wastewater Treatment Plant
- Type of wastewater, characterization, wastewater chemistry
- Design basis, fundamentals, treatment process, etc.
- Primary Treatment Processes:
- Screens, Grit removals, Oil & Grease removal system
- Coagulation & flocculation, sedimentation, chemical dosing, etc.

Cont..

- Secondary Treatment Processes:

- Introduction to biological treatment processes
- Aeration, ASP treatment & technology and process .

- Nitrification & Denitrification
- Clarifier, Equalization , Basic design calculation

- Basic engineering & design for
  ASP , SBR & MBBR technology & Process
  Basic design calculations

Cont…

- Disinfections
- Basics of Filtrations
- Basics of Membrane technology
- Drinking water standards and guidelines and process
- O&M practices

WATER CRISIS

- GLOBAL
- QUANTITY & QUALITY

REASONS FOR WATER CRISIS

- INAPPROPRIATE USE OF SURFACE WATER RESOURCES
- CHANGE IN HYDROLOGICAL CYCLE DUE TO HUMAN INTERVENTION
- OVER EXPLOITATION OF GROUNDWATER
- WATER WASTAGE AND POLLUTION

CURRENT WATER RESOURCE SCENARIO IN INDIA

- **Expanding Industrial Demand**
  Current - 167 Billion cubic metres
  2025 - 228 Billion cubic metres
  2050 – 500 Billion M3

- **Soaring Costs – production and treatment cost**

- **Rising Tariffs – across the world**

- **Water Loss :** 30 to 40%

BASIC WATER FACTS (INDIA)

INDIA HAS 18% OF WORLD’S POPULATION

BUT

IT HAS ONLY 4% OF THE WORLD’S WATER RESOURCES

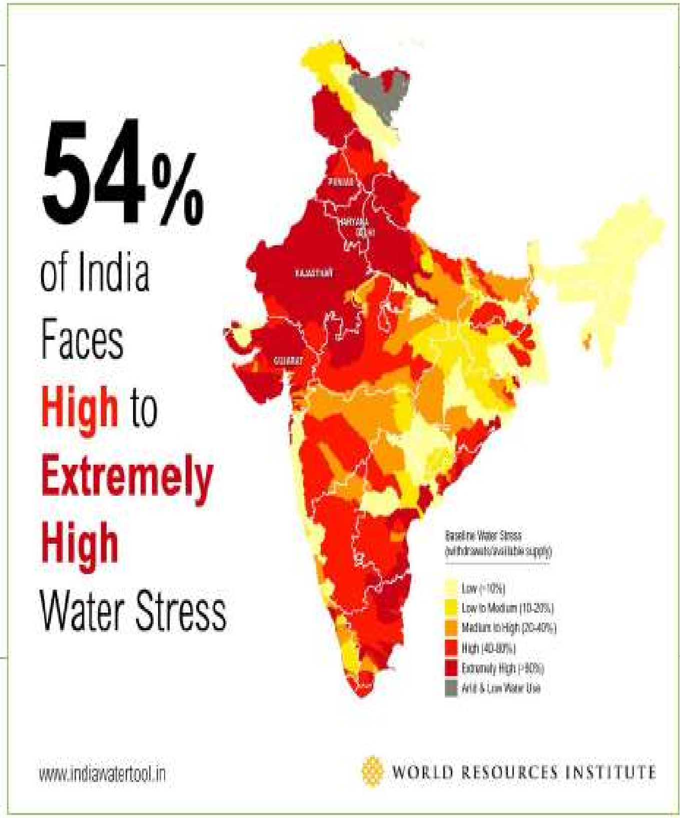
India Water Scenario

1

Post-independence, the population of the country has increased almost nearly fourfold. The economy of the country is also increasing due to urbanization and industrialization.

2

India is ranked 120th among 122 countries in a global water quality index. Nearly 70% of the country's water is contaminated. Just 30% of wastewater undergoes any sort of treatment.



3

NITI Ayog says - Twenty-one cities in India including Delhi, Bengaluru, Chennai and Hyderabad, affecting around 100 million people.

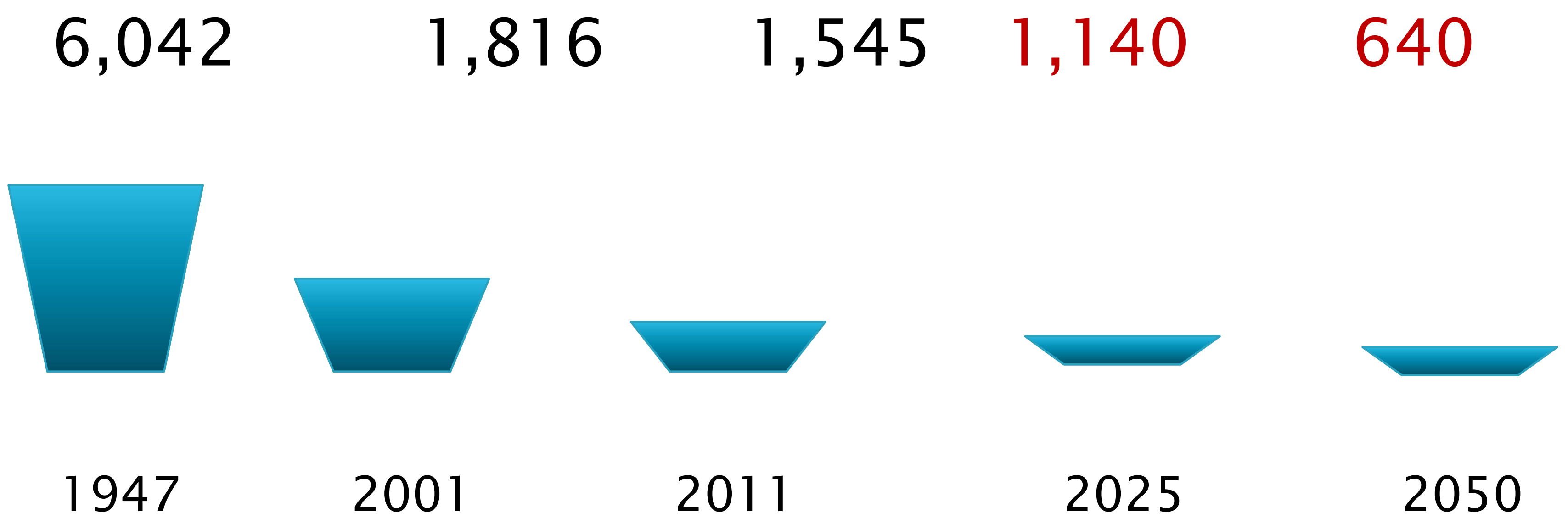
4

Per Capita Water Availability has decreased and there is clear deficit of fresh water even for drinking purpose.

CURRENT WATER RESOURCES SCENARIO IN INDIA

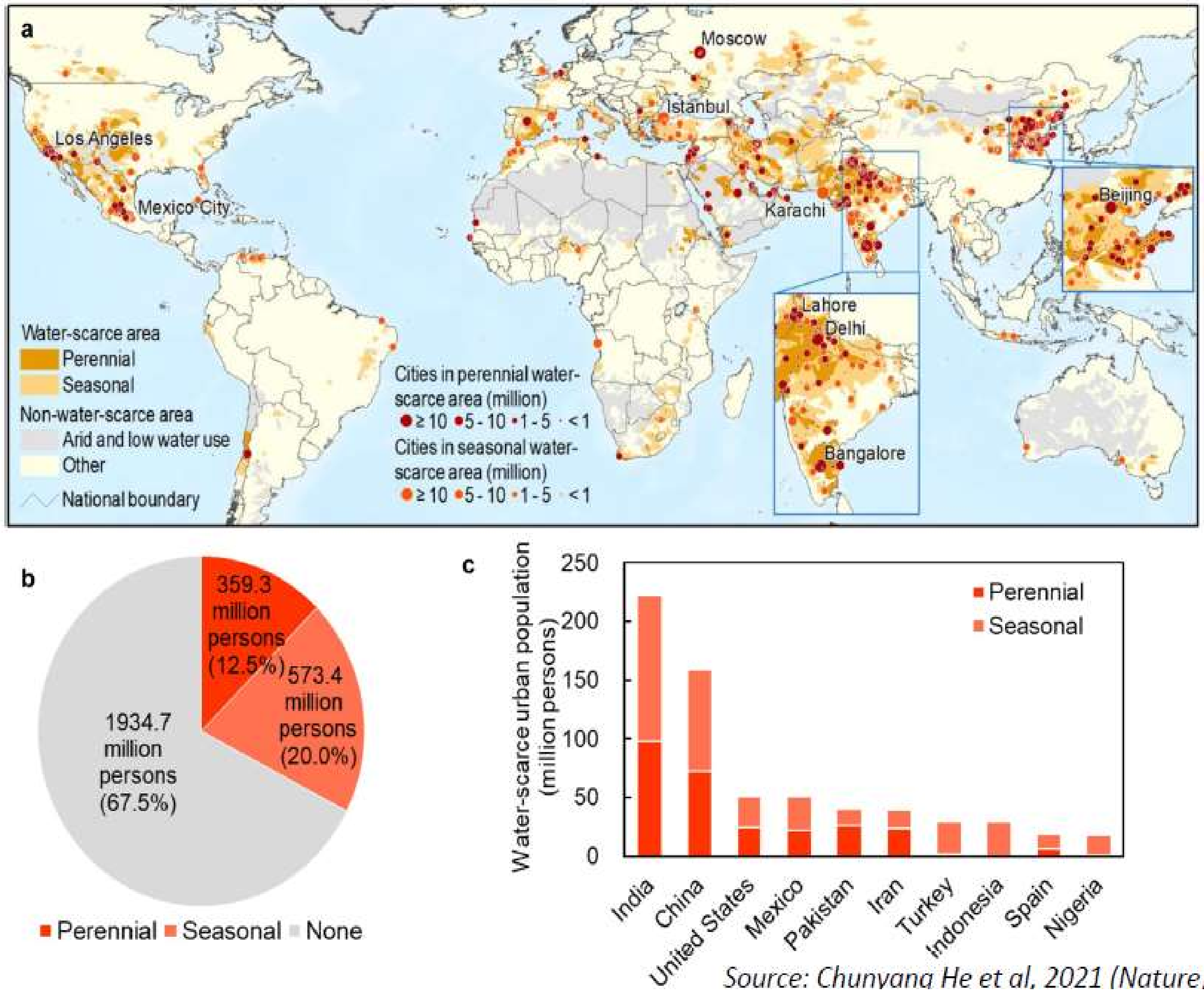
ANNUAL PER CAPITA AVAILABILITY OF WATER

(IN CUBIC METERS)



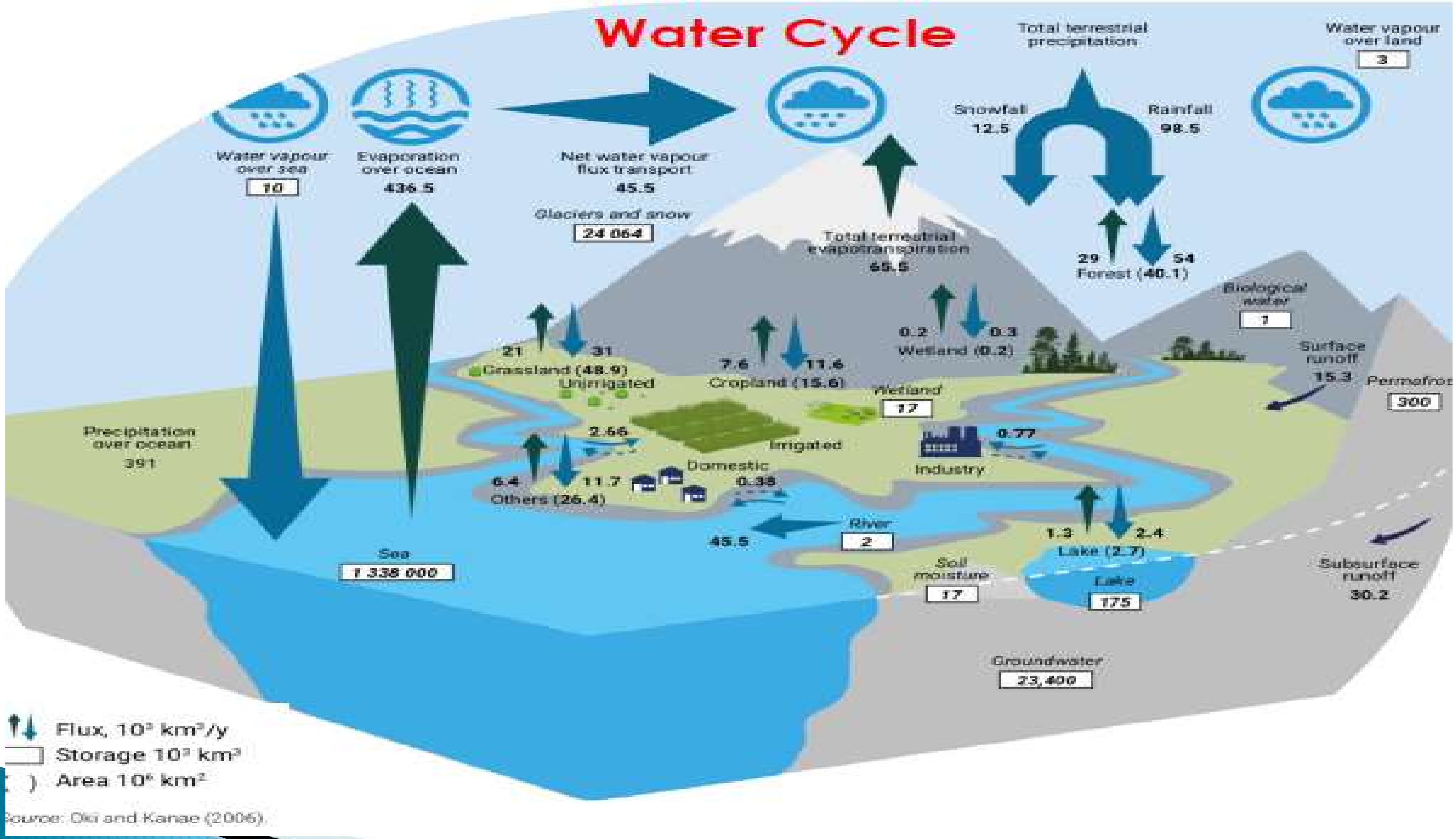
Global Water Security

- Freshwater availability (per capita) is decreasing
- Increasing risks of 'slow-onset disasters' such as water scarcity, droughts and famine due to climate change and mismanagement.
- Promoting water-use efficiency, water recycling and rainwater harvesting is becoming increasingly important.



Source: Chunyang He et al. 2021 (Nature)

Water Cycle



Water Cycle
Total terrestrial precipitation
Water vapour over land
3
Snowfall 12.5
Rainfall 98.5
Water vapour over sea
10
Evaporation over ocean
436.5
Net water vapour flux transport
45.5
Glaciers and snow
24 064
Total terrestrial evapotranspiration
65.5
29
54
Forest (40.1)
Biological water
1
0.2
0.3
Wetland (0.2)
21
31
Grassland (48.9)
Unirrigated
7.6
11.6
Cropland (15.6)
Wetland
17
Surface runoff
15.3
Permafrost
300
Precipitation over ocean
391
2.66
Irrigated
0.77
Industry
6.4
11.7
Domestic
0.38
Others (26.4)
River
2
45.5
1.3
2.4
Lake (2.7)
Sea
1 338 000
Soil moisture
17
Lake
175
Subsurface runoff
30.2
Groundwater
23,400
Flux, 10³ km³/y
Storage 10³ km³
( ) Area 10⁶ km²
Source: Oki and Kanae (2006).

SOURCES FOR WATER RECYCLE

- RAIN WATER
- STORM WATER
- SEWAGE WATER
- INDUSTRIAL WASTEWATER

SOURCE of water QUALITY

- RAIN WATER – PURE UNCONTAMINATED
- STORM WATER – LOW CONTAMINATION

  Suspended Solids
  Oil & Grease
  Agricultural Runoffs
  Chemicals

SOURCE of water QUALITY

- SEWAGE – LOW TO MEDIUM CONTAMINATION

    Physical

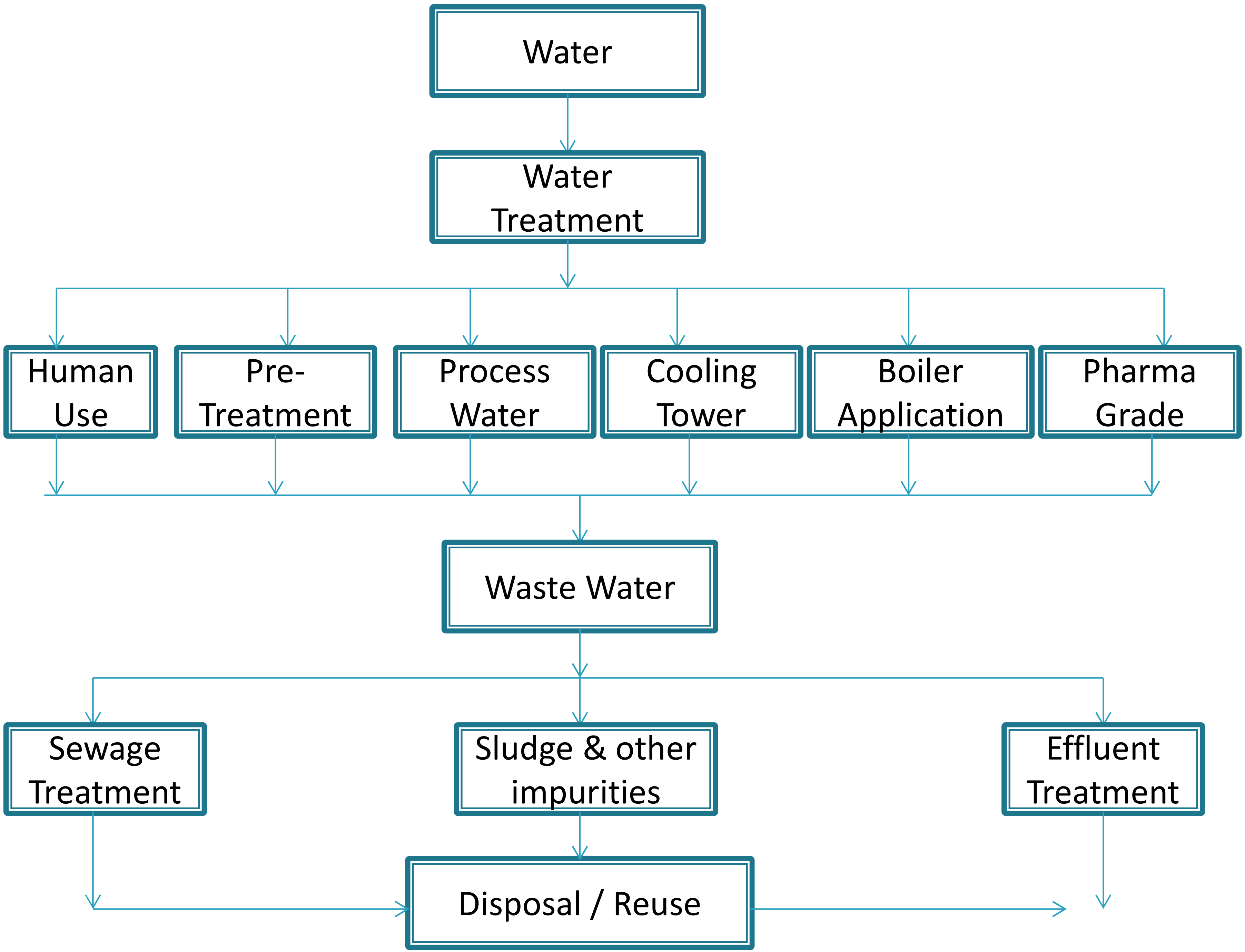
    Organic

SOURCE QUALITY

- INDUSTRIAL WASTEWATER

- MEDIUM TO VERY HIGH CONTAMINATION
    - Physical
    - Chemical
    - Organic

How is waste water generated ?



PARAMETERS

PHYSICAL

- Temperature
- Color
- Taste & Odor
- Suspended Solids
  Organic (volatile) , Inorganic
  Settelable, Floating
- Oil & Grease (Free & Emulsified)

PARAMETERS

CHEMICAL

- pH
- Acidity/Alkalinity
- Total Dissolved Solids (TDS)
- Chlorides
- Sulfates
- Total Nitrogen
- Total Phosphorus
- Heavy Metals : Cr, Ni, Pb, Zn etc.
- Toxic Chemicals : AS, CN etc.
- Chemical Oxygen Demand (COD)

PARAMETERS

BIOLOGICAL

- Biochemical Oxygen Demand (BOD)
- Bacterial Counts

BASIC UNDERSTANDING

Of

Waste Water

QUANTITY

SEWAGE

- There are considerable variations in the quantity of sewage during the day. with low flows at night. Day to day variations are relatively small
- The variation in sewage quantity is measured as the "peak factor". This factor is high for smaller communities and reduces as the communities grow larger.

INDUSTRIAL EFFLUENT

- Industrial wastewaters, on the other hand, have very large variations – hour to hour and day to day. It is, hence, necessary to measure the wastewater flows over a reasonable period of time to determine the design flows for various treatment units.

- A rough estimate of quantity of sewage and industrial wastewaters can be obtained from the data on water supply.

QUALITY

SEWAGE: The quality of sewage has relatively less variations than industrial wastewaters. But still it is better to analyze as many samples as possible as obtain as much comprehensive data as possible.

INDUSTRIAL EFFLUENT :For industrial wastewaters it is absolutely imperative that data is collected through analysis of a large number of samples or through analysis of data collected by the client over a reasonable period of time.

TYPICAL CHARACTERISTICS OF RAW SEWAGE

Parameter	Concentration mg/l
BOD	100 - 400
COD	200 - 800
Suspended solids	100 - 500
Total nitrogen (as N)	10 – 50
Ammonia (NH_3 as N)	10 – 30
Organic phosphorus (as P)	1 – 2
Inorganic phosphorus (as P)	3 – 10
Oils, fats and grease	50 - 100
Total inorganic constituents (Na, Cl, Mg, S, Ca, K, Si, Fe)	100
Heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn)	< 1mg/l each

CHARACTERISTICS OF COMMON WASTEWATERS

Parameter	Domestic Sewage	Fresh Milk	Milk Effluent	Brewery Effluent	Abattoir Effluent	Pharma* Effluent
BOD – mg/l	<500	2×10^6	$2 – 5 \times 10^3$	$5 – 15 \times 10^3$	$2 – 5 \times 10^3$	$5 – 10 \times 10^3$
COD – mg/l	300 – 800	3×10^6	$3 – 10 \times 10^3$	$20 – 50 \times 10^3$	$3 – 10 \times 10^3$	$20 – 60 \times 10^3$
Suspended Solids – mg/l	100 - 500		>1000	>1000	>2000	
Total N – mg/l	20 – 50		60 - 250	60 - 250	60 - 150	20 – 250
Total P – mg/l	2 – 15		10 – 50	10 – 50	10 – 30	2 – 150
FOG – mg/l	50 – 200	>2000	>200		>1200	
pH	6.5 – 8.8	7.5	2 - 12	5 – 8.5	6 – 8.5	2 - 12

* After solvent recovery

STP Limits as per NGT Guideline

Parameter	Unit	Limit
pH	s.u	5.5 – 9.0
BOD	mg/L	10
TSS	mg/L	20
COD	mg/L	50
Total Nitrogen	mg/L	10
Total Phosphorus	mg/L	1
Fecal Coliform	MPN/100 mL	230

Effects of Pollutants

Test Parameters	Measures	Desirable Limit	Effect on Receiving Water
pH	Acidity/alkalinity	6.5-8.0	Acidic/alkaline pH affects/kills aquatic flora and fauna
Temperature	Thermal Condition - hot/cold	Ambient+/- 5C.	Affects/kills aquatic flora and fauna
DO	DO level	> 2-4 mg/L	Low DO is harmful to aquatic organisms, flora and fauna and may kill living organisms.
Toxicity	Toxicity caused by metals and chemicals	Low	High conc kills aquatic organisms, flora and fauna.

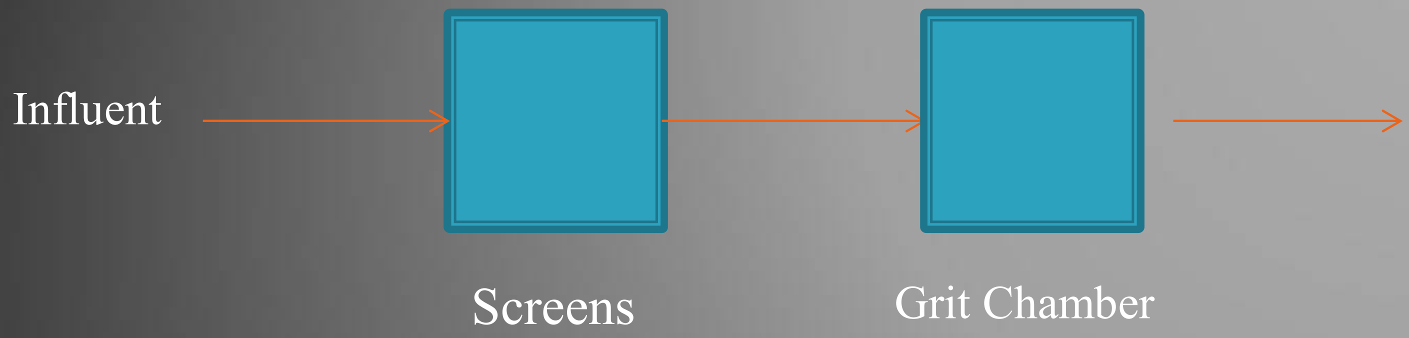
Effects of Pollutants

Test Parameters	Measures	Desirable Limit	Effect on Receiving Water
COD	Organics	< 50-250 mg/L	Increases bacterial growth; Depletes DO
BOD	Degradable Organics	< 10-30 mg/L	Increases bacterial growth; Depletes DO
TSS	Suspended/ Insoluble Solids	< 10-30 mg/L	Increase suspended solid conc, increases BOD, depletes DO
O&G	Oil and grease	< 10 mg/L	Increases BOD, Depletes DO, Affects photosynthetic activity of aquatic life,
Coliform	Microbial Counts	<100-400 MPN/100 mL	Affects Health
Total Nitrogen	Nutrients – Nitrogen	< 3-10 mg/L	Increases bacterial growth; Depletes DO
Total Phosphorus	Nutrients – Phosphorus	< 1 mg/L	Increases bacterial growth; Depletes DO

TREATED EFFLUENT QUALITY

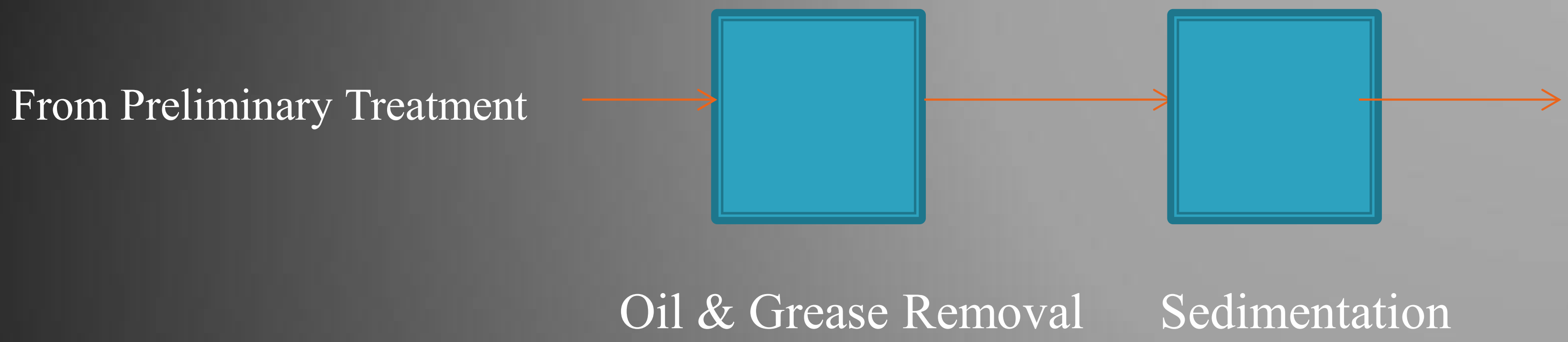
- Compliance standards as per CPCB/SPCB.
- Reuse/recycle standards/requirements

DEVELOPENT OF PROCESS FLOW DIAGRAM



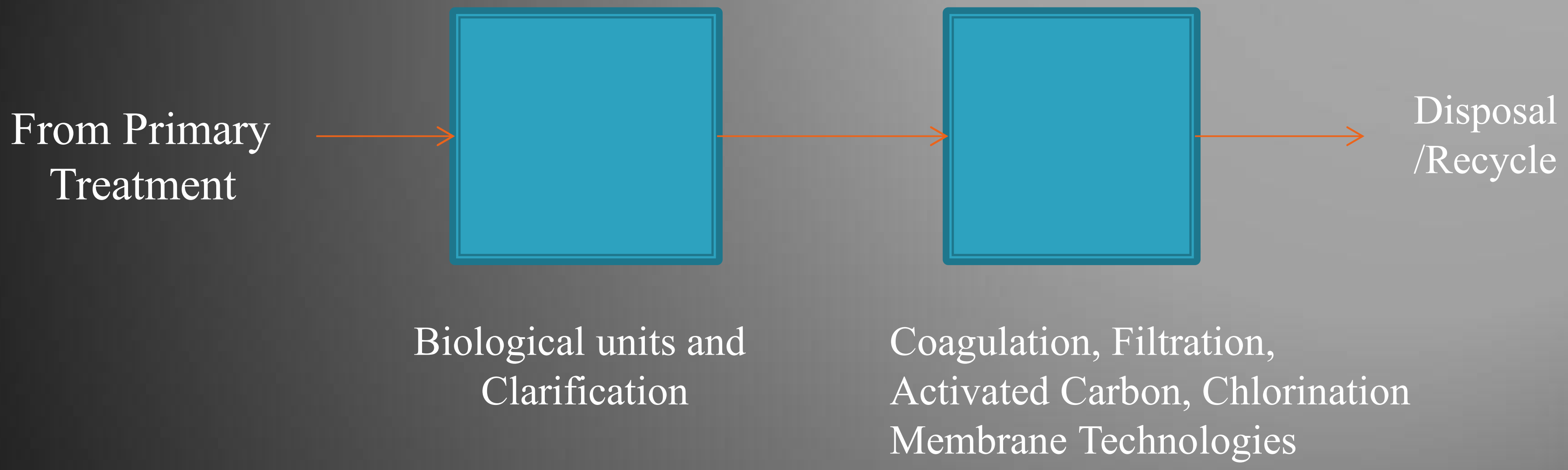
Preliminary Treatment for Waste water

DEVELOPENT OF PROCESS FLOW DIAGRAM



Primary Treatment

DEVELOPENT OF PROCESS FLOW DIAGRAM



Secondary & Tertiary Treatment

TREATABILITY STUDIES

- Once the process flow diagram is prepared it is necessary to determine the efficacy and efficiency of the various unit process in the laboratory and if necessary at pilot scale.

- This may not be necessary for sewage treatment if only compliance is required.

- For tertiary treatment, however, studies should be carried out.

- For industrial wastewaters it is absolutely essential.

EQUALIZATION

- Generally equalization is not needed in sewage treatment plants. For industrial wastewaters, however, equalization is the most important unit process.

- The industrial wastewater varies from hour to hour in quantity and quality which affects all the subsequent unit processes in terms of their efficiency.

NEUTRALISATION

- A pH range of 6.0 to 8.5 is most suited to provide protection to aquatic life
- pH affects the solubility of organic matter and availability of BOD
- pH affects the toxicity levels of metals

COAGULATION

- Stable Colloidal Suspensions
- Coagulants

    Aluminum salts, Ferrous and Ferric salts

    Sodium aluminate, Poly electrolytes

COAGULATION

Jar Test to

- Optimize Coagulant
- Optimize Dosage
- Optimize pH

BIOLOGICAL PROCESSES

- Aerobic and Anaerobic
- Suspended Growth and Immobilized Growth

TREATMENT PROCESSES

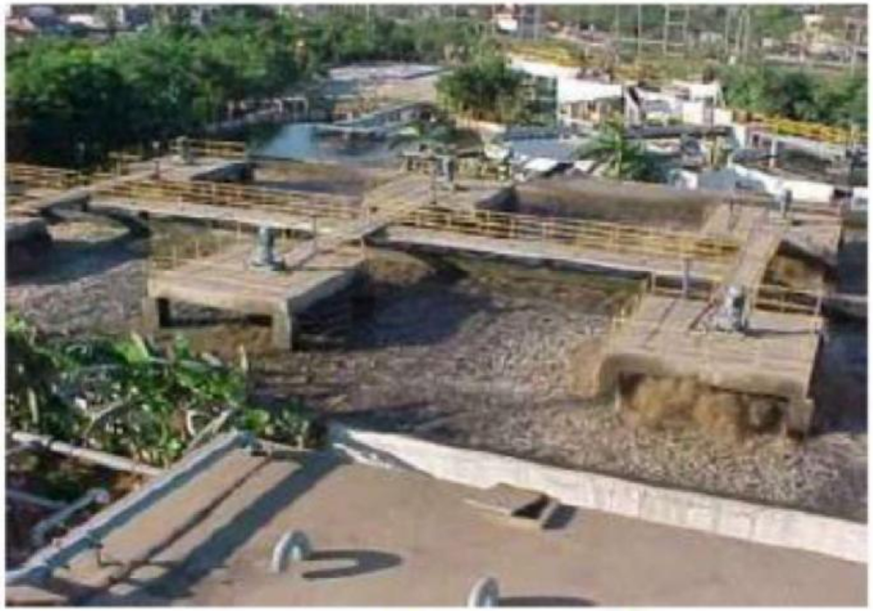
1. Screening
2. Grit Removal –for Sewage
3. Oil & Grease Removal
4. Equalization
5. Coagulation
6. Sedimentation
7. Biological Treatment
8. Tertiary Treatment
9. Sludge Treatment

EQUALISATION BASIN

BAR SCREEN

GRIT CLASSIFIER

PRIMARY CLARIFIER



AERATION TANK

SECONDARY CLARIFIER

PRIMARY TREATED WATER TANK

Secondary Treatment (biological)

Removes BOD

A Preliminary/Primary Treatment

Pollutant Removal	Equipment/Process
Solids	Screens
	Clarifier
	Sedimentation Tank
	DAF
	Coagulation & Flocculation
Grit	Grit Chambers
Oil & Grease	Grease Traps
	Surface Skimmer/Oil Separator
	DAF
Flow & Load Equalisation	Equalization Tank
pH/Acidity/Alkalinity	Neutralization Tank, Chemical Addition
Heavy Metals	Precipitation System
Hardness Removal	Precipitation
VOCs	Air Stripping

A Biological Treatment Technologies

Technology	BOD	BOD + Nitrification	BOD + N Removal	P Removal
CMAS	X	X		
Plug Flow	X	X		
Step Feed	X	X	X	
Contact Stabilization	X			
Separate Sludge	X	X	X	
Extended Aeration		X		
SBR	X	X	X	X
MLE			X	
4-stage			X	
5-Stage			X	X

Biological Treatment Technologies

Technology	BOD	BOD + Nitrification	BOD + N Removal	P Removal
MBR	X	X	X	X
MBBR/IFAS		X	X	X
Oxidation Ditch	X	X	X	X
RBC	X	X		
UASB	X			
Trickling Filter/Biotower	X	X		
Anaerobic Filter	X			
Anaerobic Contact Process	X			
Lagoons	X	X		

Tertiary Treatment Technologies

Technology	Pollutant Removed
Filtration	Solids
Carbon Filter	COD, Organics, Chlorine
Disinfection	Pathogens
Chemicals & Dosing	For Chemical Reactions
Chemical Precipitation	Inorganics, Heavy Metals
Coagulation & Flocculation	Solids
Oxidation	Toxics, Inorganics, organics, COD
Ion Exchange	TDS, specific Ions, Hardness

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Membrane Technologies

Technology	Pollutant Removed
Microfiltration	Solids, Microorganisms
Ultrafiltration	Solids, Microorganisms
Nanofiltration	Solids, Microorganisms
Reverse Osmosis	TDS, Solids, Microorganisms

Note: MBR is considered under Biological Treatment

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Sludge Treatment Technologies

Equipment/Technology	Function
Thickener/ Belt Thickener	Thickening
Belt Press/Filter Press/Centrifuge	Dewatering
Aerobic Digestion	VSS Destruction, Stabilization Class B Biosolid
Anaerobic Digestion	
Thermal Hydrolysis Process /Drying/Pasteurization/ Thermophilic Digestion/Other	Pathogen Free – Class A Biosolid

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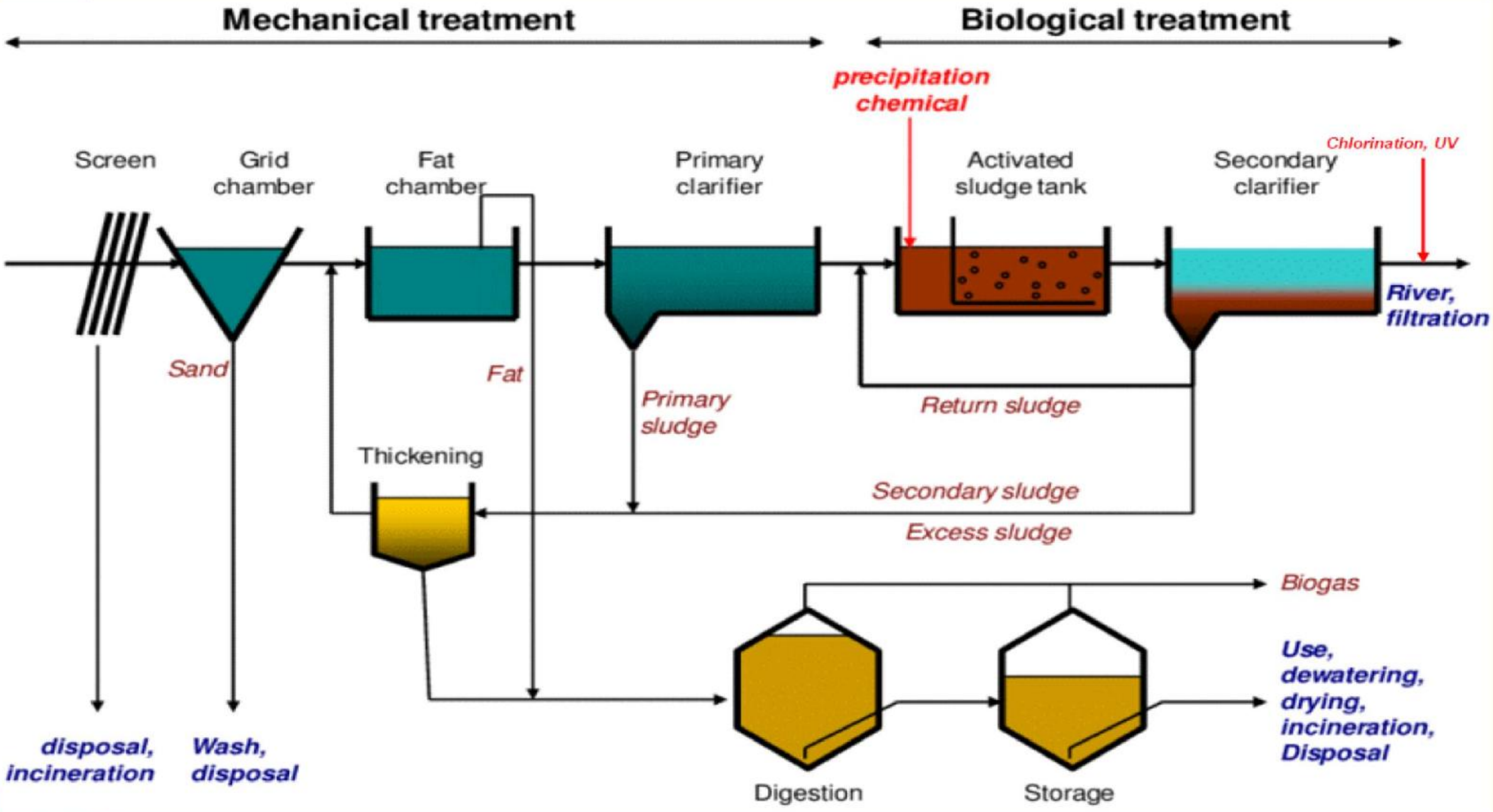
Stages of STP



SCREENING

- Bar/Coarse screens
- Medium screens
- Fine screens
- Manually cleaned
- Mechanically cleaned
- Automatic cleaning

Unit Processes - Screens

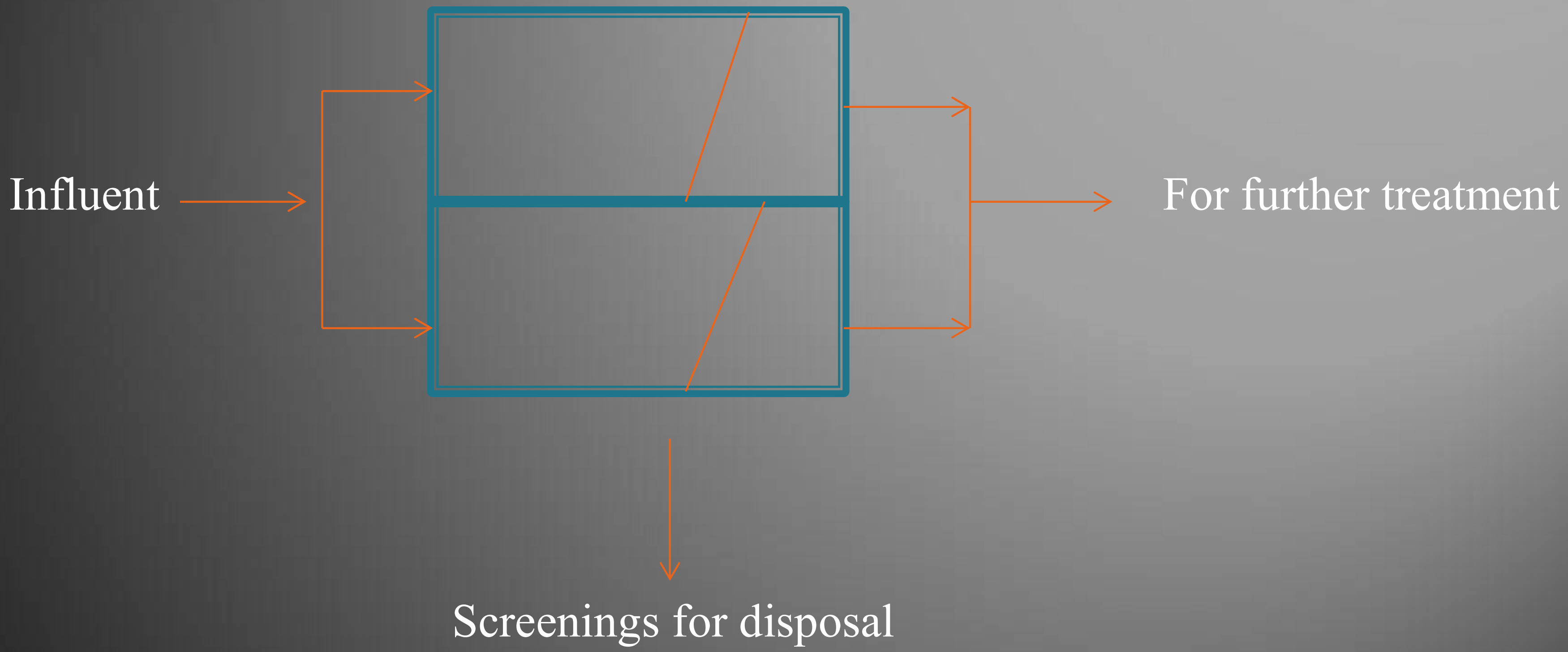
Screens

1. Manual Bar Screen
2. Automatic Bar screen

Some examples are :

1. Screen mat
2. Rotary Drum Screen
3. Inclined rake screen
4. Screens with various gaps or spacing

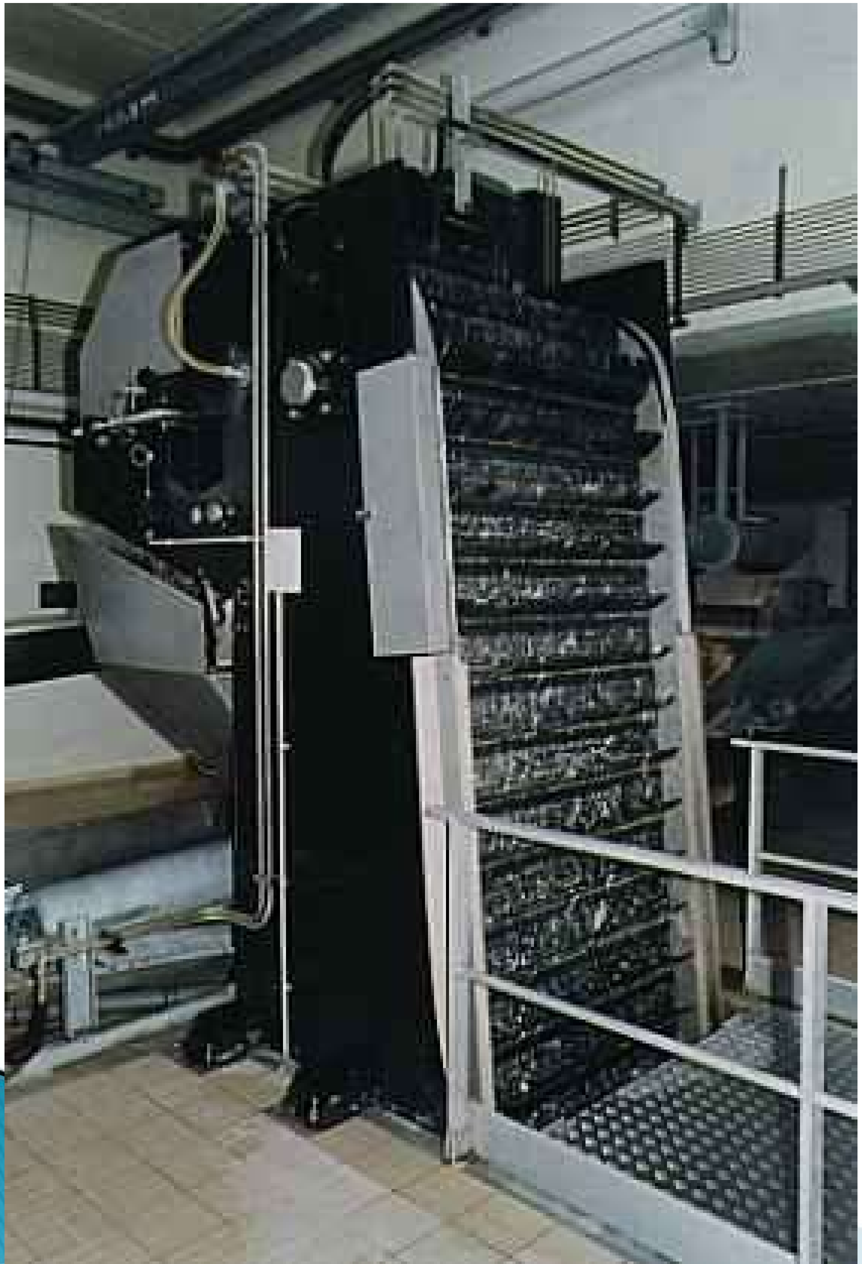
SCREENING



DESIGN CRITERIA

Design flow	–	Peak
Minimum number of units	–	2
Openings : Coarse	–	6 to 150 mm usually 50mm
Fine	–	Less than 6 mm
Velocities : Approach	–	0.45m/sec at average flow
Through open area	–	0.6 to 1.2 m/sec at peak flow
		not less than 0.3 m/sec at low flow

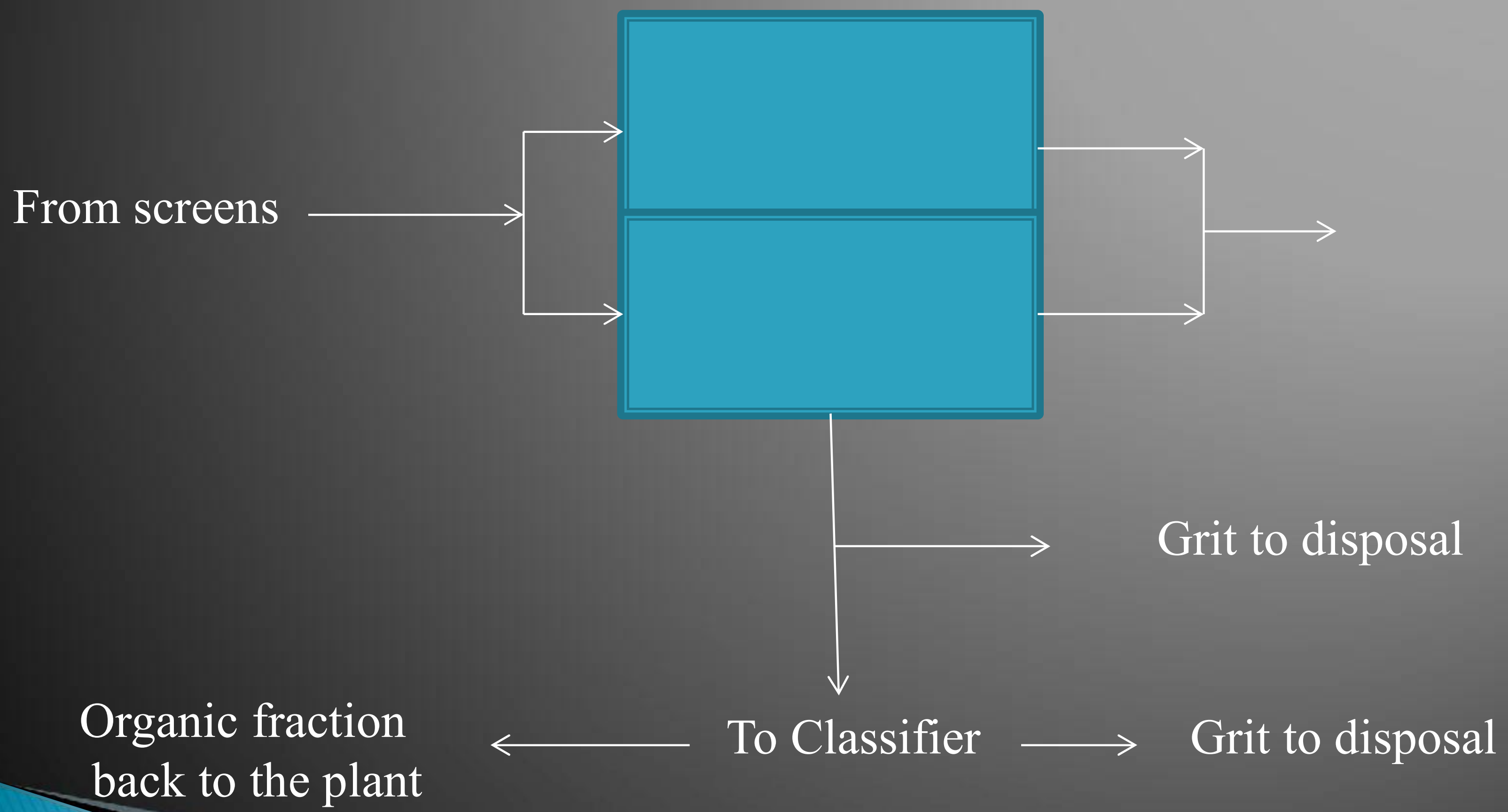
SCREENING



GRIT REMOVAL

- Grit is inorganic suspended matter
- Generally it is designed for particles with specific gravity of 2.65
- Could be simple rectangular tank or a mechanically scraped square tank (Detritor) and sometimes aerated
- A Classifier is used to separate the grit from organic matter

GRIT REMOVAL



DESIGN CRITERIA

Design flow – Peak

Minimum number of units – 2

Simple horizontal flow Detention 45 to 90 seconds, usually 60 seconds

Horizontal velocity – 15 to 40 cm/sec at peak usually 30 cm/sec

Have to provide a velocity control device like Parshall Flume Square tanks

Overflow rate – 700 m^3/m^2/day

(or use vendor design)

Classifier

Use vendor design

GRIT REMOVAL



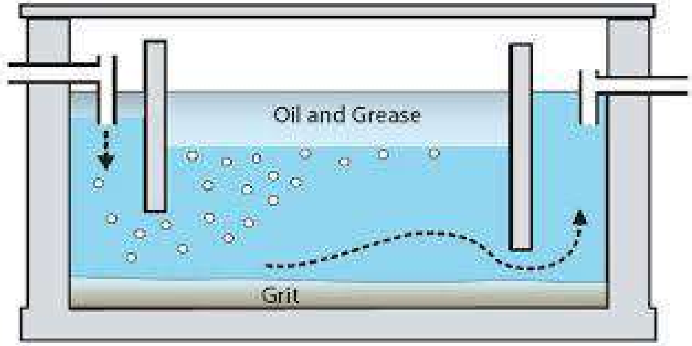

OIL & GREASE REMOVAL

Free Oil Removal : API, TPI / CPI, BELT SKIMMERS

Emulsified Oil Removal :Dissolved Air Floatation (DAF)

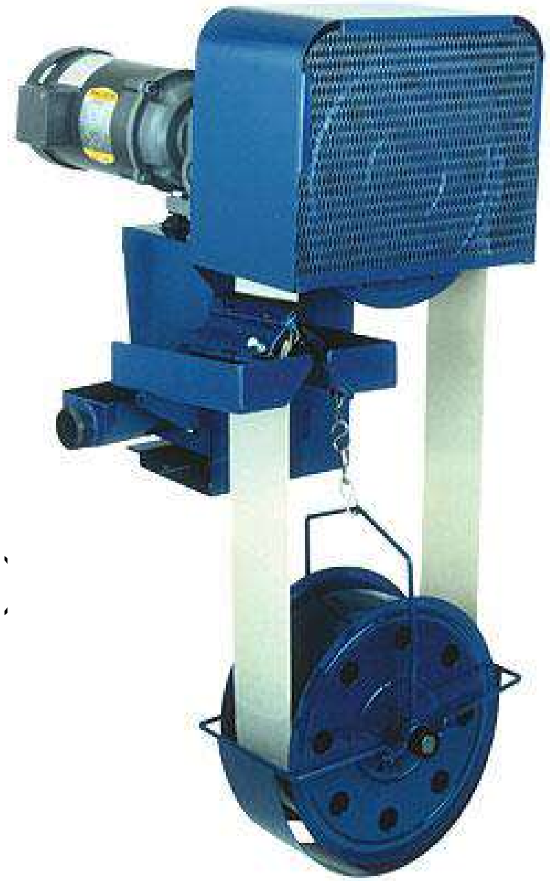
System incidentally reduces Suspended Solids alongwith Oil

FREE OIL REMOVAL



Belt Skimmer and Slotted Pipe Design Basis:

Oil and Grease content in Effluent
Flow
Selection of Belt material



Oil and Grease Chamber Design Basis:

Flow Retention Time:30 Mins
Length to Width Ratio:3:1
Calculation of Volume:(Flow x Retention)
SWD:1m

TPI / API DESIGN

(Tilted plate separator / American petroleum institute)

API

Design flow	:	Peak / Average based on sequence
Minimum no. of units recommended	:	2
Horizontal velocity	:	$\leq$55 m/hr @ peak flow
Recommended L:W / D:W ratio	:	Max 5:1 / Minimum 0.3 -0.5
Maximum width recommended	:	6 m
Maximum depth recommended	:	2.5 m
Oil globule size removal	:	150 micron and above

Parallel Plate Separator

Perpendicular distance between plates	:	0.75-1.5 inches
Angle of plate inclination from horizontal	:	45-60^{0}C
Oil globule size removal	:	60 micron and above
Oil removal / SS removal		60-70% / 33-68%

DAF DESIGN

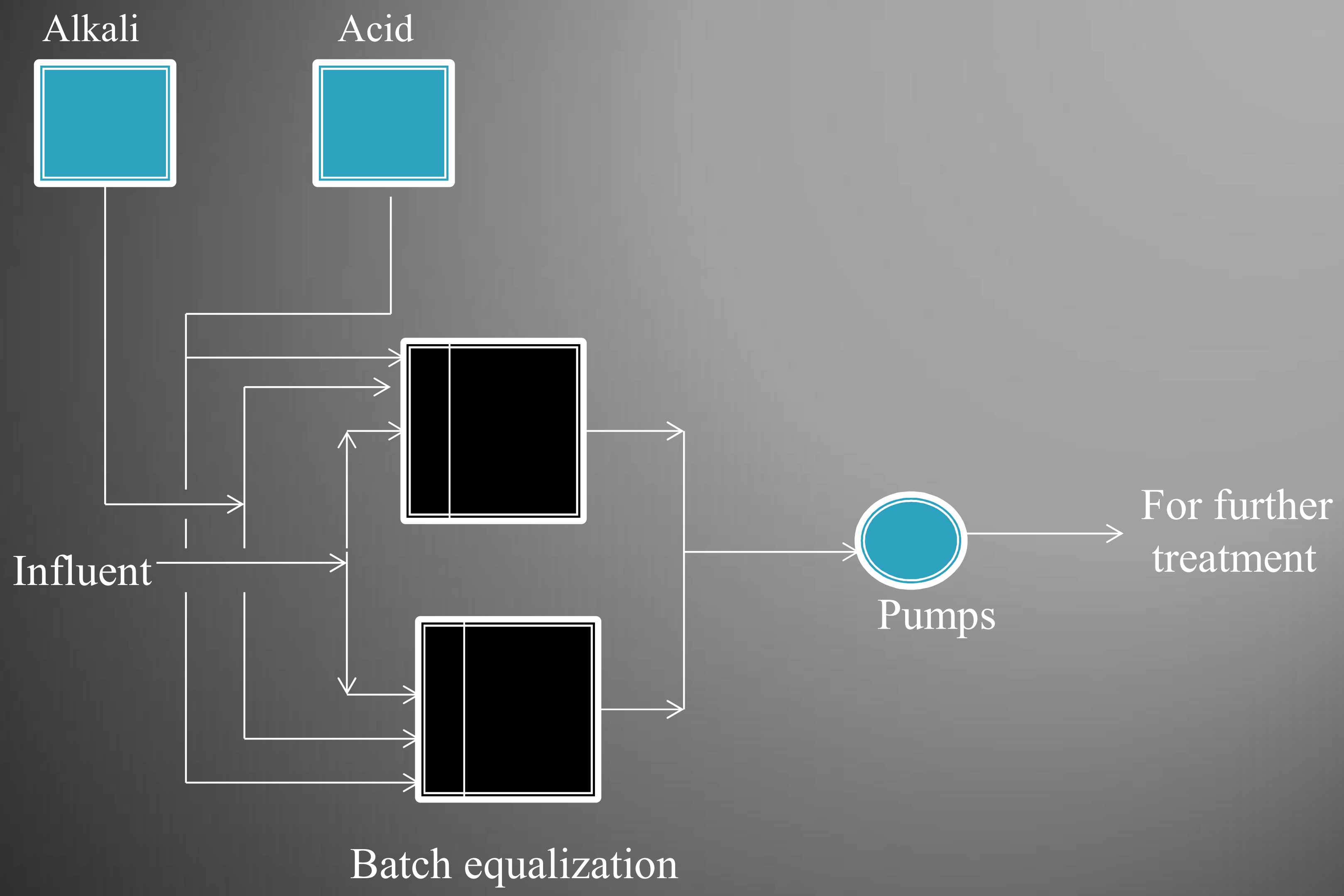
Design flow	:	Peak / Average based on sequence
Minimum no. of units recommended	:	2
Overflow rates	:	28–100 m^3/m^2/day
Rising velocity	:	1.9– 7 cm/min
Air : Solid ratio	:	0.05–0.06 ml air / mg solids
Recycle ratio	:	20–150%
Oil removal / SS removal	:	80– 90% /

EQUALIZATION

As seen earlier, the study in the variation of quality would provide the criteria for the sizing of the Equalization Tank

- Use a batch fill and draw system
- Provide mixing through aeration grid
- Use the tank as neutralization unit

EQUALIZATION



DESIGN CRITERIA

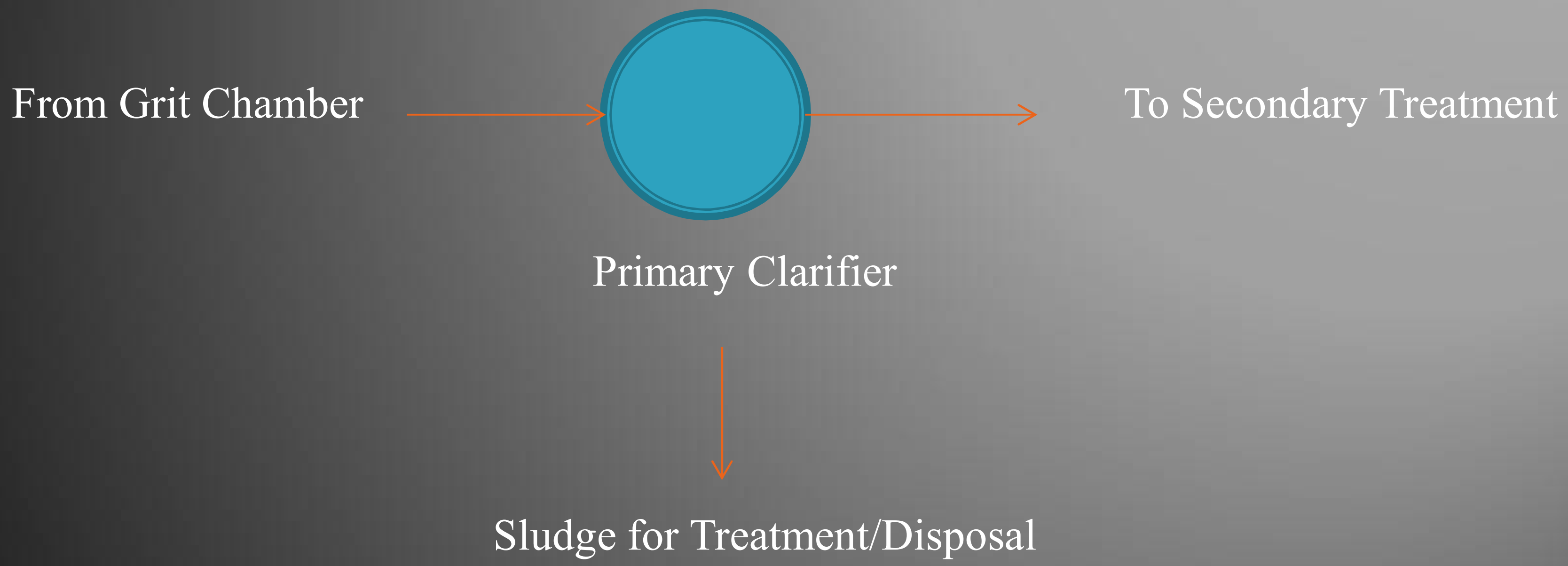
- Generally detention time should be 8 hours with two tanks providing total of 16 hours
- Plants with very large flows may provide 4 hours each with 8 hours total
- Very small plants may go up to 24 hours for each tank
- Tanks are operated on “fill & draw” batch process with one filling while the other is emptying
- Mixing is provided by aeration grid laid on the floor
- Neutralization, if needed, is carried out in these tanks
- Highly acidic effluents should be received in a portion of the tank lined with acid resistant tiles/material – pre neutralization section

Equalization Tank

SEDIMENTATION

- Total Suspended Solids
  - Organic
  - Inorganic
  - Settleable
- Settling Velocity
- Overflow Rate
- Solids Loading

PRIMARY CLARIFICATION



DESIGN CRITERIA

Design flow	–	Average
Minimum number of units	–	1
Detention time	–	1.5 to 2.5 hrs. Usual 2 hrs
Overflow rate	–	25 to 50 m^3/m^2/day

Usual 40 m^3/m^2/day for sewage

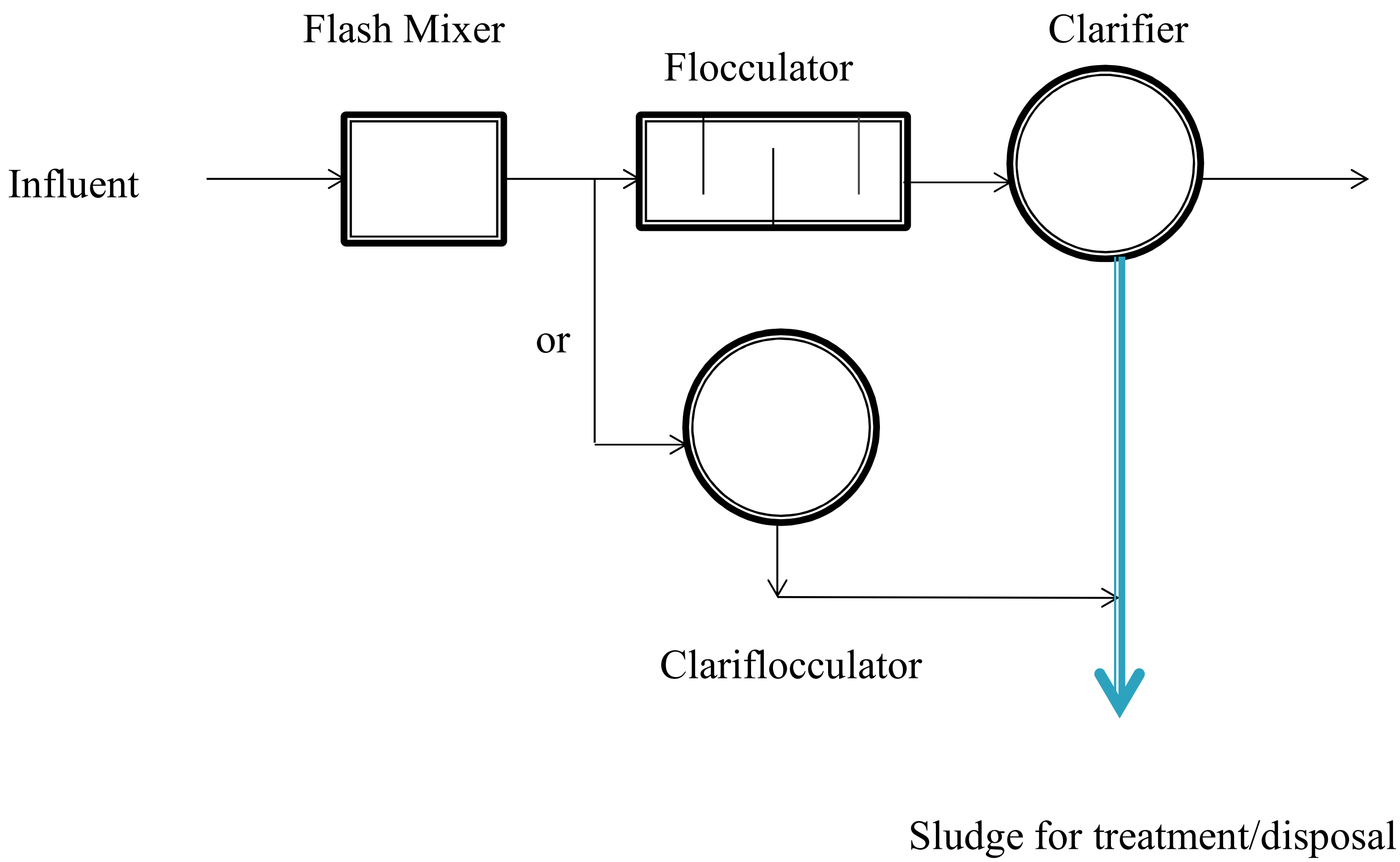
24 m^3/m^2/day for industrial wastewater

Expected removals

TSS	–	45 to 70 %
BOD	–	25 to 45 %

COAGULATION

- Need to mix coagulant rapidly to quickly disperse the coagulant – Flash mixing
- Increased opportunity for contact – Flocculation
- Sedimentation of flocs
- Flocculation and clarification may be combined – Clariflocculator


Flash Mixer
Flocculator
Clarifier
Influent
or
Clariflocculator
Sludge for treatment/disposal

DESIGN CRITERIA

Flash Mixer

Design flow	Average
Number of units	1
Detention time	30 seconds

Mixing by mechanical agitator – APPROX. 1000 RPM

Static mixers and other types of mixers also may be used.

Flocculator

Design flow	Average
Number of units	1
Detention time	30 minutes

Paddle agitator for slow mixing –11 RPM (0.3 TO 0.9M/SEC)

DESIGN CRITERIA

Clarifier	
Design flow	Average
Number of units	1
	2 for large plants

Overflow rate

<u>For Primary Settling Only</u>

25– 30 m^3/m^2/day (Avg)

50–60 m^3/m^2/day (Peak)

<u>For Primary Settling followed by Secondary treatment</u>

35– 50 m^3/m^2/day (Avg)

80–120 m^3/m^2/day (Peak)

Expected removals

TSS	80 to 90 %
BOD	10 to 30 %

Wherever treatability data is available use design criteria from such studies

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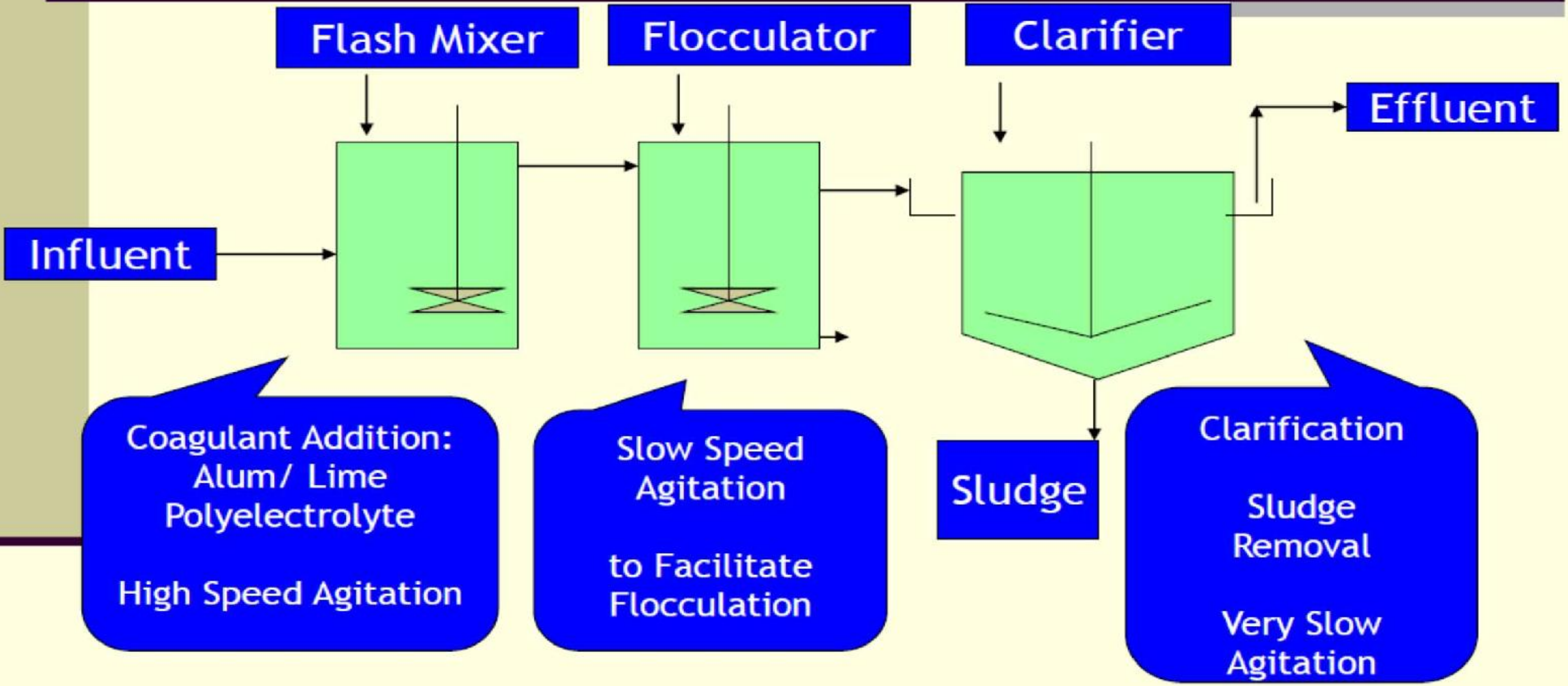
Coagulation and Flocculation



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Biological Treatment Technologies

- Anaerobic Treatment Technologies
- Aerobic Treatment Technologies

Biological Wastewater Treatment

- To remove the suspended solids & the dissolved organic load from the wastewater by using microbial populations

- The microorganisms are responsible for the degradation of the organic matter and can be classified into:
  - aerobic (require oxygen for their metabolism)
  - anaerobic (grow in absence of oxygen)

Objective of Biological Treatment

<u>The Removal of</u>:

- Organic Matter (BOD / COD)
- Suspended Solids
- Ammonical Nitrogen
- Nitrates & Phosphates
- Pathogens

The Aerobic process

- By aerobic micro-organisms In the presence of molecular oxygen

- Organic Matter + Oxygen = Carbon-dioxide + Water + New Cells

The Aerobic process

- Aerobic process ⮕ use of O_2
- Aerobic wastewater breakdown and by-products produced:

$$\text{Organic Matter} + \text{Aerobic Micro-organisms} + O_2 \Rightarrow \text{More Micro-organisms} + CO_2 + H_2O + \text{Energy}$$

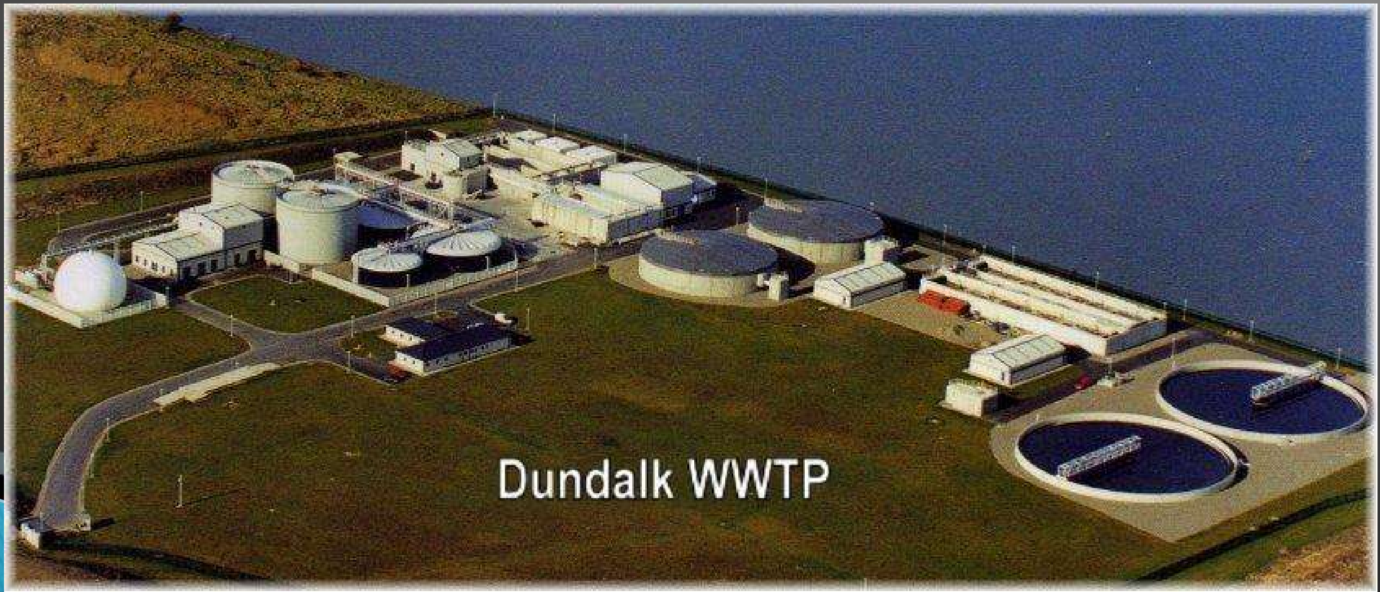
PRE CONDITIONS OF AEROBIC TREATMENT

- Food for Bacteria (Organic matter / BOD)
- Oxygen
- Temperature
- TDS
- Favourable pH
- O & G <5 mg/l
- Heavy metals / Toxic chemicals – Nil /Traces
- Nutrients

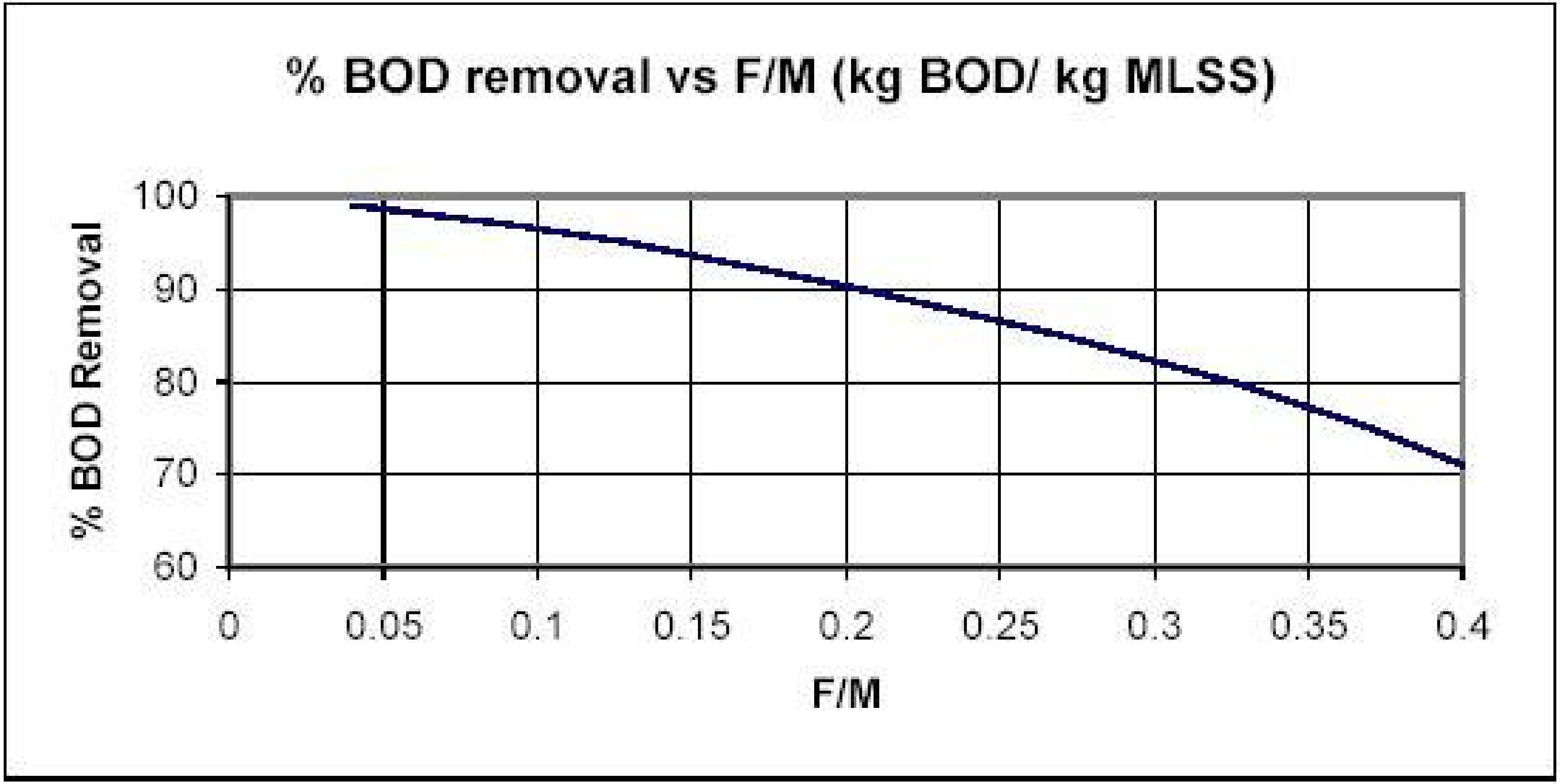
AEROBIC BIOLOGICAL TREATMENT

- Oxidation Ponds
- Aerated Lagoons
- Biological Filters
  - Trickling Filters
  - Rotating Biological Contactors
  - Biological Aerated Filters

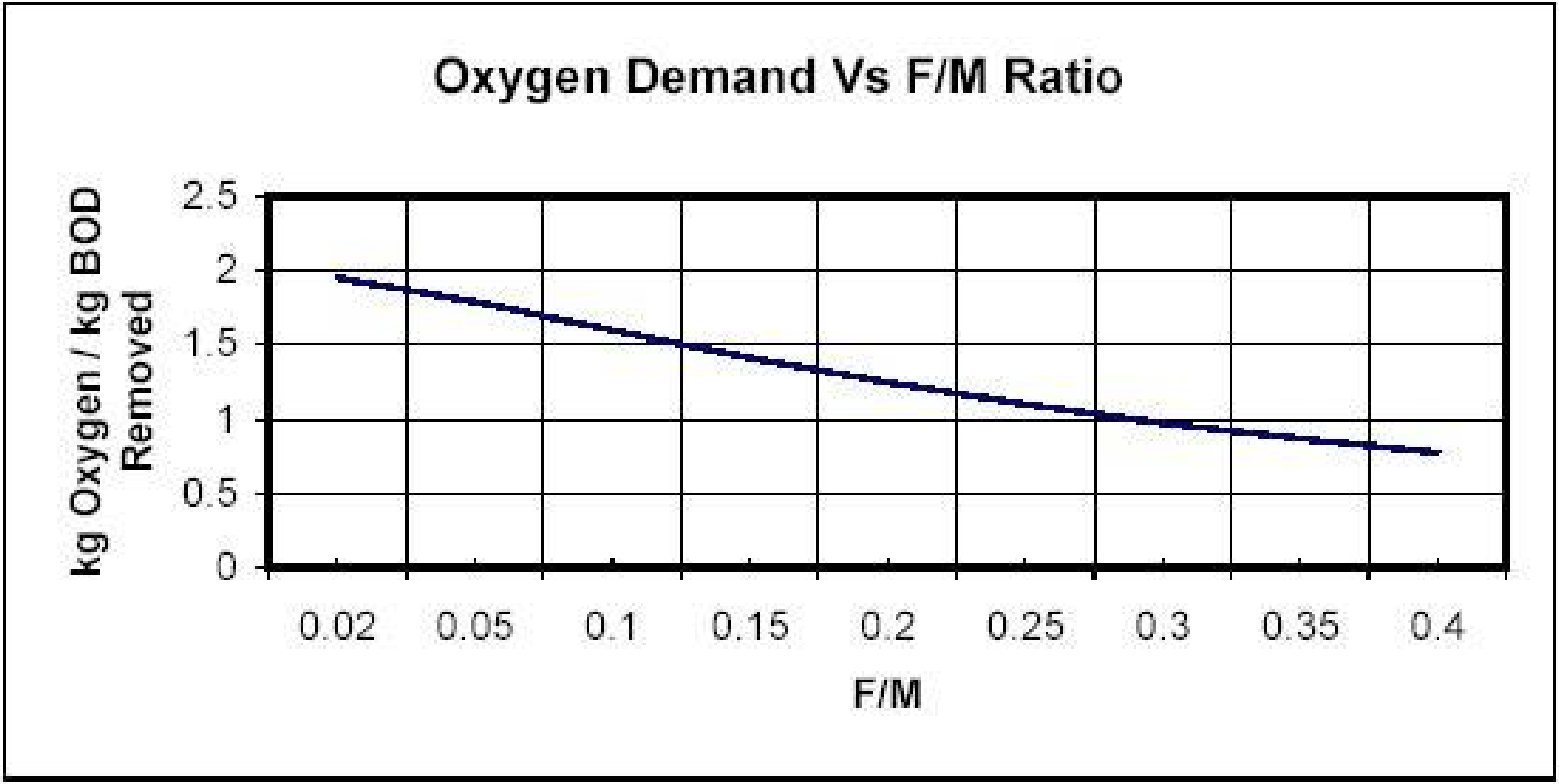
- Activated Sludge
  - SBR
  - Moving Bed Biological Reactors
  - Membrane Biological Reactors
- Biological Nutrient Removal



ACTIVATED SLUDGE PROCESS – LOADING



ACTIVATED SLUDGE PROCESS- OXYGEN



ACTIVATED SLUDGE PROCESS – AERATION

- Can be either
  - Mechanical Surface
    - Low Speed – 46 RPM
    - High Speed
  - Diffused Air
    - Coarse Bubble
    - Fine Bubble
  - Pure Oxygen

MECHANICAL SURFACE AERATION

DIFFUSED AIR AERATION

- Coarse or Fine Bubble
- Submerged header and lateral system for Air Distribution
- Ceramic dome or membrane diffusers

DISC DIFFUSER SYSTEM

FIG: Disc Diffuser Installation
(Photo Courtesy: Environmental Dynamics, Inc., U.S.A.)

TUBULAR DIFFUSER SYSTEM

FIG: Tubular Diffuser Installation
(Photo Courtesy: Environmental Dynamics, Inc., U.S.A.)

AIR REQUIREMENT – BLOWER & FINE BUBBLE DIFFUSER SYSTEM (RULE OF THUMB)

$$\text{Blower Capacity in } m^3/hr = \frac{\text{Kg BOD} * X}{1.2 * 0.21 * \alpha * \beta * 24 * \eta}$$

X - Kg oxygen / kg BOD considered (1-2 depending on wastewater strength)

1.2 - Density of air in kg / m^3

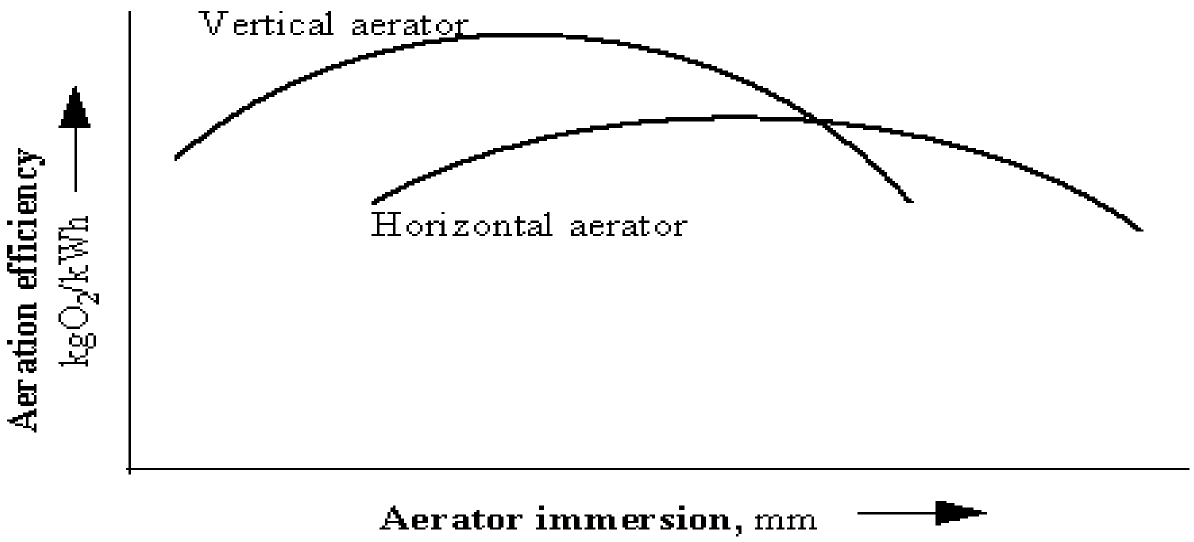
0.21 - Content of oxygen in air, %

α - Ratio of mass transfer coefficient in wastewater to tap water, Typical : 0.6.-0.9
(For Diffused Aeration : 0.4 -0.8 & Mechanical Equipment : 0.6-1.2)

β - A saturation factor used to correct for DO in wastewater
Typical : 0.7-0.95

η - Oxygen Transfer Efficiency
Typical : 5-6% per m of submergence depth

TRANSFER EFFICIENCY



Oxygen transfer coefficient is affected by the following factors:

- temperature
- mixing intensity
- tank geometry
- characteristics of the water

Aeration Device	Oxygen Transfer Rate, kgO_2/kWh
Fine bubble diffusers	2.0 - 2.5
Coarse bubble diffusers	0.8 - 1.2
Vertical shaft aerators	up to 2.0
Horizontal shaft aerators	up to 2.0

Aeration Diffuser

Aeration Cont…

SECONDARY CLARIFICATION

Design on the basis of solids loading

Solids Loading Rate

Conventional –100 to 150 kg solids/m^2/day

Extended –24 to 120 Kg solids/m^2/day

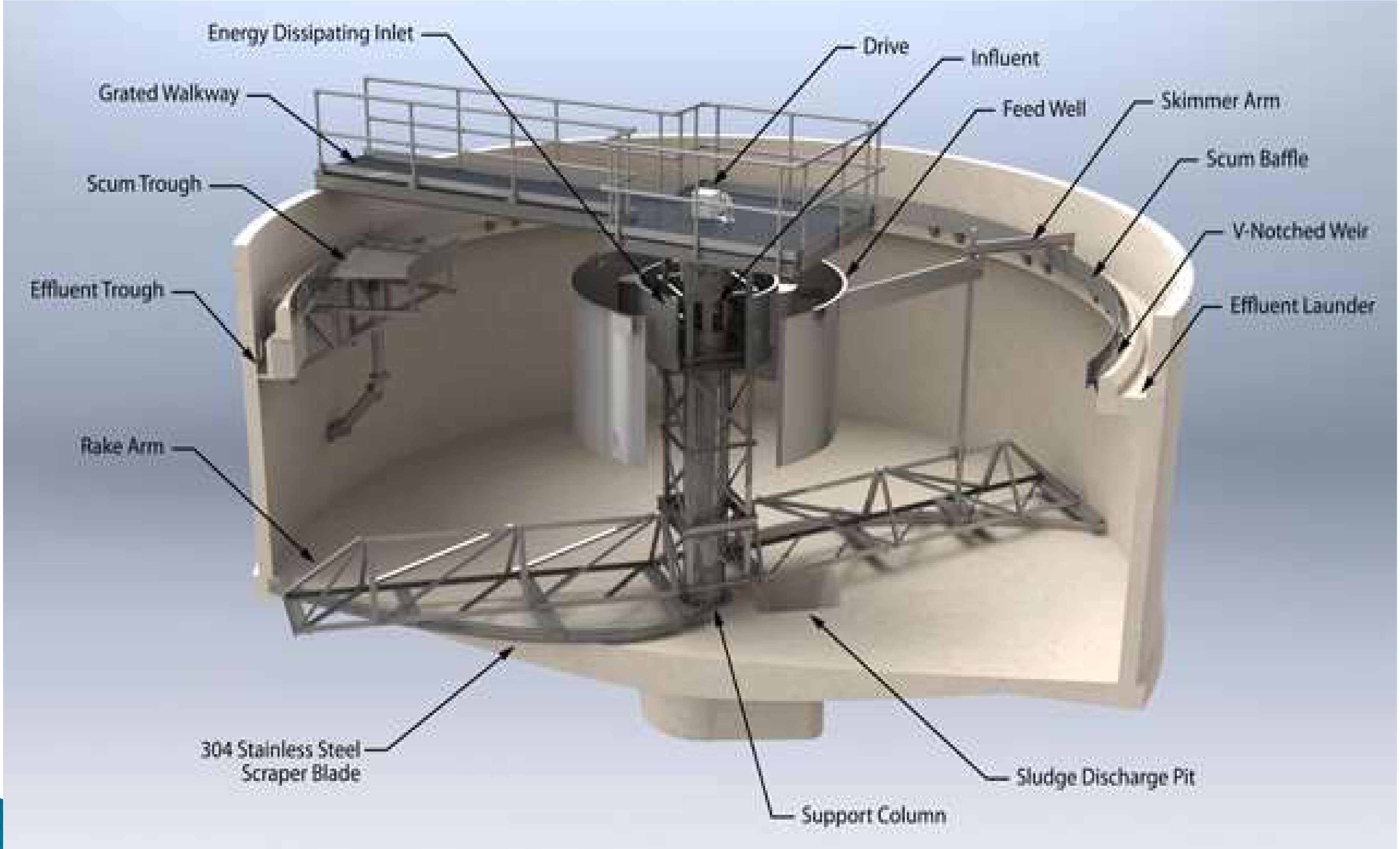
(Note: The flow includes the return sludge flow)

Hydraulic Loading Rate

Conventional – 15 to 50 m^3/m^2/day

Extended – 8 to 35 m^3/m^2/day

(Note: The flow includes the return sludge flow)


Energy Dissipating Inlet
Drive
Influent
Grated Walkway
Feed Well
Skimmer Arm
Scum Trough
Scum Baffle
V-Notched Weir
Effluent Trough
Effluent Launder
Rake Arm
304 Stainless Steel
Scraper Blade
Sludge Discharge Pit
Support Column

ADVANCED AEROBIC BIOLOGICAL TREATMENT

- ❖ Membrane Bioreactor (MBR)
- ❖ Sequential Batch Reactor (SBR)
- ❖ Moving Bed Bioreactor (MBBR)

Activated Sludge

Activated sludge refers to a mass of microorganisms cultivated in the treatment process to breakdown organic matter into carbon dioxide, water, and other inorganic compounds.

Definition by World Bank

http://water.worldbank.org/shw-resource-guide/infrastructure/menu-technical-options/activated-sludge

ACTIVATED SLUDGE PROCESS (ASP)

- Aerobic suspended growth process most widely used

- Process consists of Aeration Tank, Secondary Clarifier and system for returning and wasting sludge.

- Sequencing Batch Reactor (SBR) and Membrane Bio-Reactor (MBR) are fundamentally activated sludge processes

PROCESS DESIGN CONSIDERATION IN ASP

- Effluent Characteristics
- Selection of the reactor type
- Applicable kinetics relationships
- Solid retention time and loading criteria to be used
- Sludge production
- Oxygen requirement and transfer (Mixing energy)
- Nutrients requirements
- Other chemical requirements
- Settling characteristics

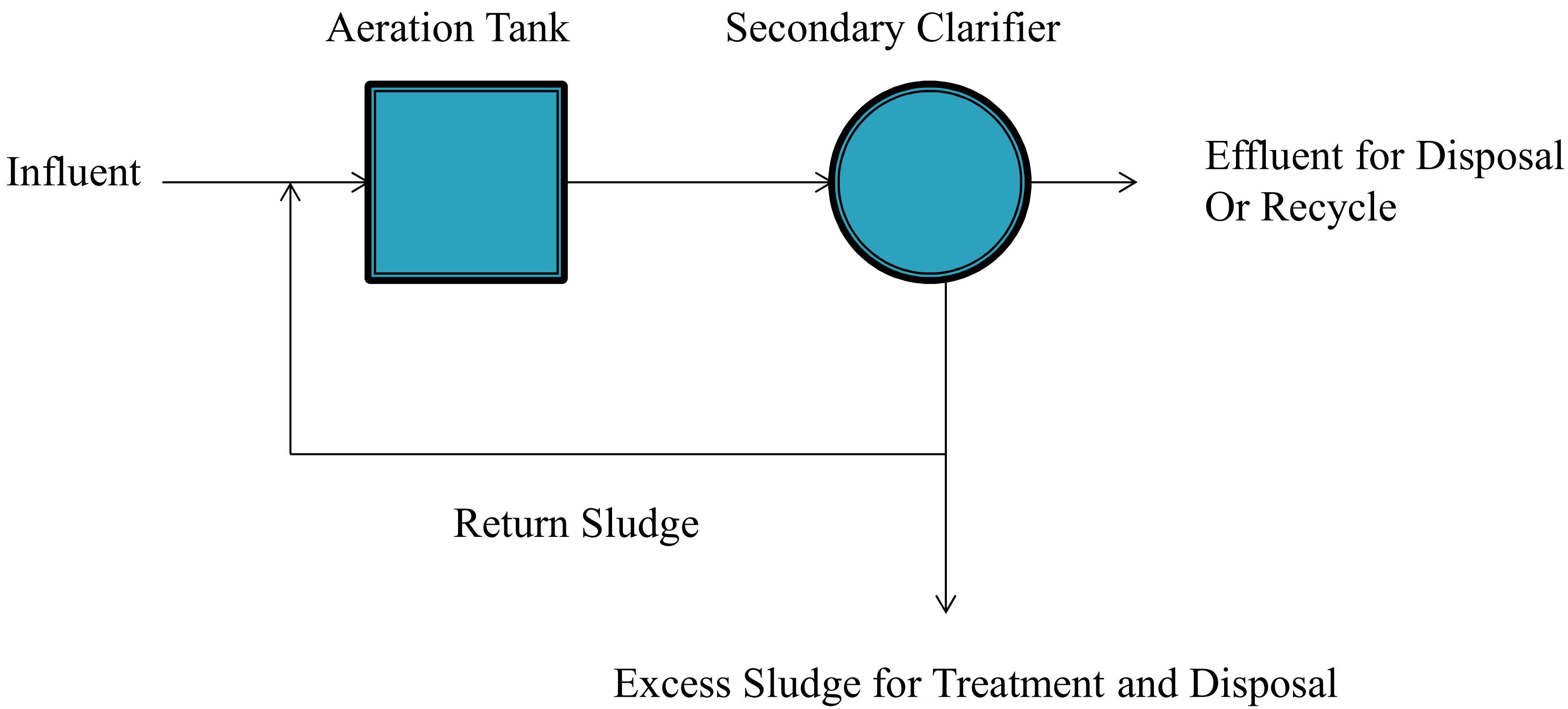
IMPORTANT DESIGN ASPECTS – ASP

- F / M
- HRT / SRT
- Oxygenation / Mixing
- Return sludge

CONTROLLING PARAMETERS – ASP

- Organic loading rate
- Oxygen supply
- Control and operation of the final settling tank
- Nutrient Availability (BOD:N:P: :100:5:1)

BASIC COMPONENTS OF ASP



DESIGN CRITERIA

Aeration tank

Design flow	–	Average
Number of units	–	1 (2 preferred)
Food: Microorganism Ratio(F:M)	–	0.05 to 0.30
Conventional	–	0.2 to 0.4
Extended Aeration	–	0.05 to 0.15
Mixed Liquor Suspended Solids (MLSS)	–	1500 to 5000 mg/L
Estimated excess sludge removed	–	0.10 to 0.30 kg/kg BOD
Nutrients BOD:N:P	–	100:5:1

Activated Sludge Process–Aeration Tank

- Effluents and mixed bacteria aerated in tank
- Bacteria are encouraged to grow by providing Oxygen, Food(BOD), Nutrients(N,P)
- Desired temperature is maintained
- Required retention time is provided

AERATION TANK

Oxygen requirement	–	1.0 – 2.0 kg/kg BOD
Aerators	–	Mechanical or Diffused
Oxygen transfer rate guarantee	–	Depends on vendor

(Safe is to assume 1kg of Oxygen/connected horse power)

Solids Retention Time (SRT)

Conventional	–	3 to 15 days
Extended aeration	–	20 to 40 days
Return Sludge volume as % of influent	–	25 to 100

Wherever treatability data is available use design criteria from such studies

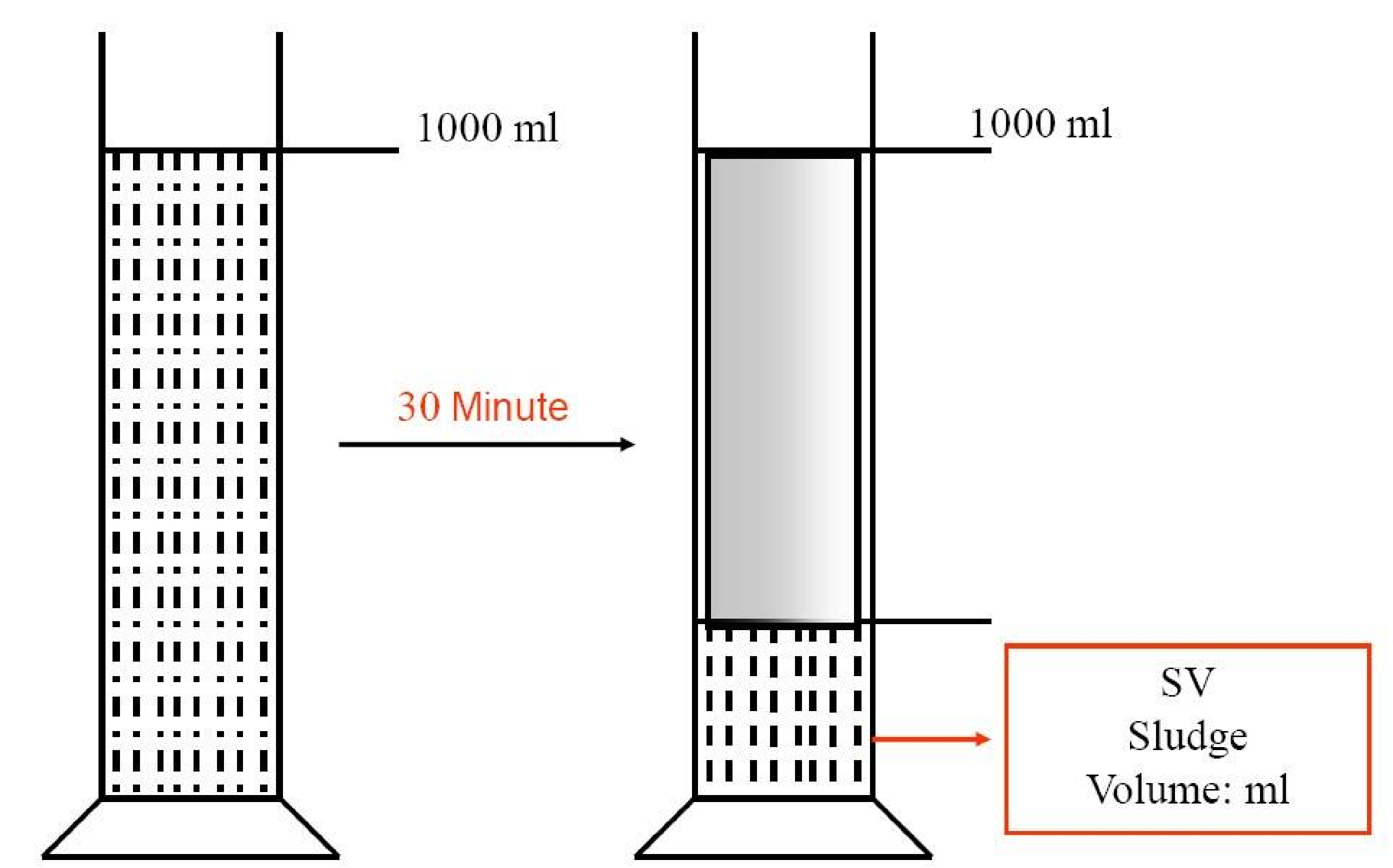
DETERMINING AERATION TANK VOLUME

$$V = \frac{Q * BOD}{MLSS * F/M * 1000}$$

Where

V	=	Volume of the aeration tank in m^3
Q	=	Flow rate in m^3/day
BOD	=	Biological oxygen demand in mg/l
MLSS	=	Mixed – liquor suspended solids in g/l
F/M	=	Food to microrganism ratio in d^{-1}

SLUDGE VOLUME INDEX (SVI)



The sludge volume index (SVI) is the volume in milliliters occupied by 1 g of a suspension after 30 min settling.

For routine operation, sludge settleability is determined by use of the sludge volume index (SVI) = SV 30 min (ml/l)* 1000 / MLSS (mg/l)

SLUDGE VOLUME INDEX (SVI)

-SVI typically is used to monitor settling characteristics of activated sludge and other biological suspensions

- Although SVI is not supported theoretically, experience has shown it to be useful in routine process control

SVI : 50 -100	Excellent
SVI : 100- 150	Good
SVI : 150-250	Just satisfactory
SVI > 300	Poor

- The microbial biomass produced in the aeration tank must settle properly from suspension so that it may be wasted or returned to the aeration tank
_

- Good settling occurs when the sludge microorganisms are in the endogenous phase, which occurs when carbon and energy sources are limited

SVI Cont.....

Filamentous growth

A common problem in the activated sludge process is filamentous bulking, this caused when excessive growth of filamentous microorganisms. The filaments produced by these bacteria interfere with sludge settling and compaction.

Filamentous bacteria are able to predominate under conditions of low dissolved oxygen, low nutrients and high sulfide levels

Sludge Retention Time (SRT) in Bio-Reactor

$$SRT = \frac{VX}{(Q-Qw)Xe + QwXR}$$

Where:

V= Volume, m3

X= Biomass concentration, mg/m3

Q= Inlet Flow rate, m3/sec

Qw= Waste Sludge flow rate, m3/sec

Xe= Concentration of biomass in the effluent, mg/m3

XR=Concentration of biomass in the return line from clarifier, mg/m3

BIOLOGICAL NUTRIENT REMOVAL

- Biological Nutrient Present : Nitrogen & Phosphorous

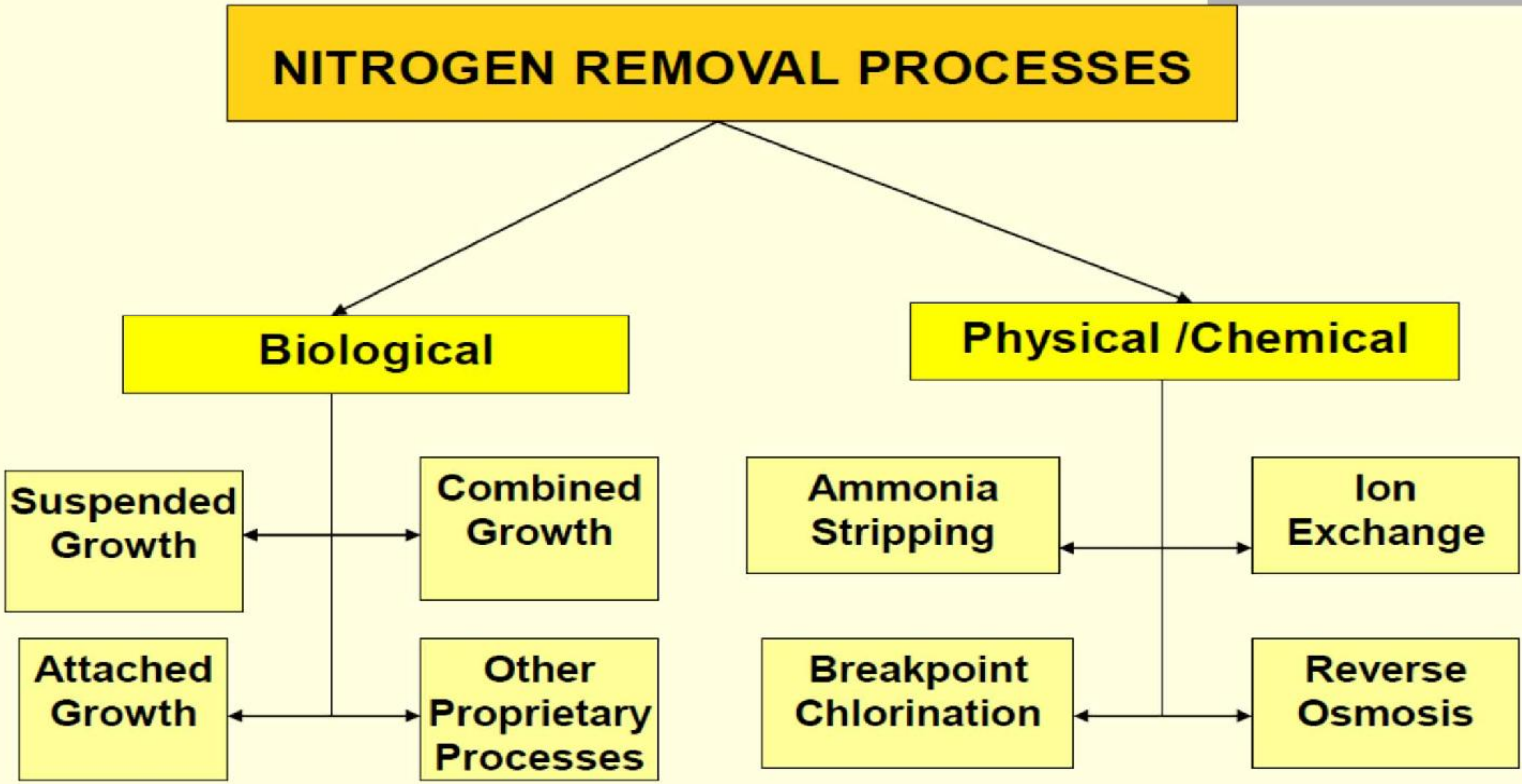
- Impacts of Nutrient & Necessity for its Removal
  - Increases aquatic growth (algae)
  - Increases DO depletion
  - Causes NH_4 toxicity
  - Causes pH changes
- Reduction / Removal Processes is required
  - Nitrification / Denitrification : Separate or Simultaneous

NITRIFICATION

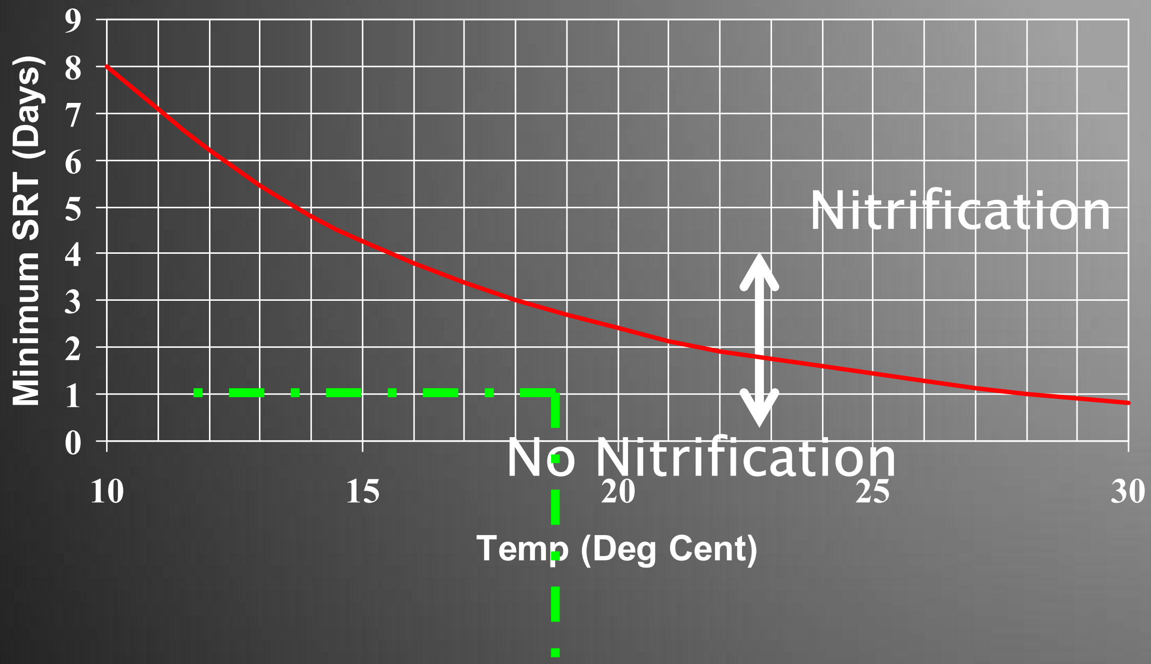
- NH_4^+ → *Nitrosomonas* → NO_2^-
- NO_2^- → *Nitrobacter* → NO_3^-

- Features
  - Aerobic process
  - Control by SRT (4 + days)
  - Uses oxygen → 1 mg of NH_4^+ uses 4.6 mg O_2
  - Depletes alkalinity → 1 mg NH_4^+ consumes 7.14 mg alkalinity
  - Low oxygen and temperature = Difficult to operate

a Nitrogen Removal Technologies



NITRIFIER MINIMUM AEROBIC SRT VARIES WITH TEMPERATURE



DENITRIFICATION

- Using methanol as carbon source:

$$6\ NO_3^- + 5\ CH_3OH \longrightarrow 3N_2 + 5\ CO_2 + 7\ H_2O + 6\ OH^-$$

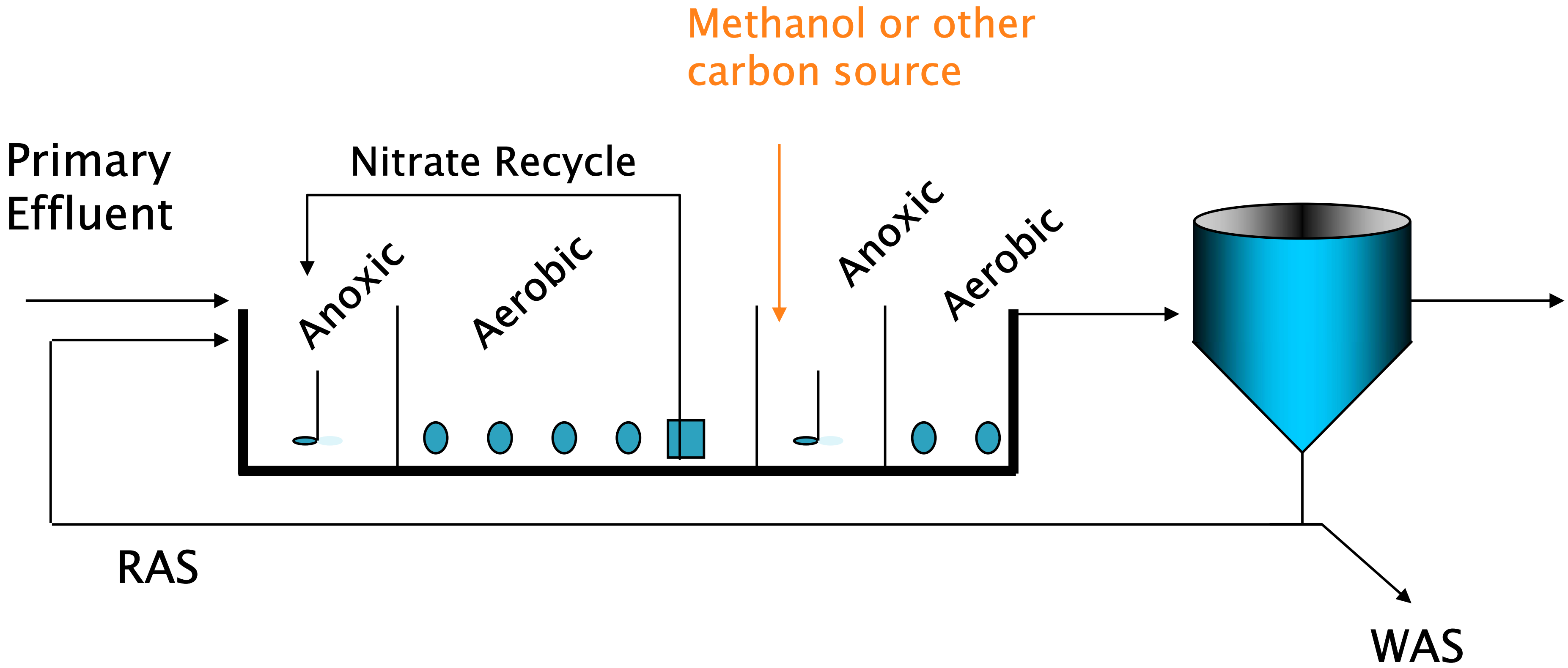
- Using an endogenous carbon source (Ethyl Cyanoacetate):

$$C_5H_7NO_2 + 4.6\ NO_3^- \longrightarrow 2.8\ N_2 + 5\ CO_2 + 1.2\ H_2O + 4.6\ OH^-$$

Requirements :

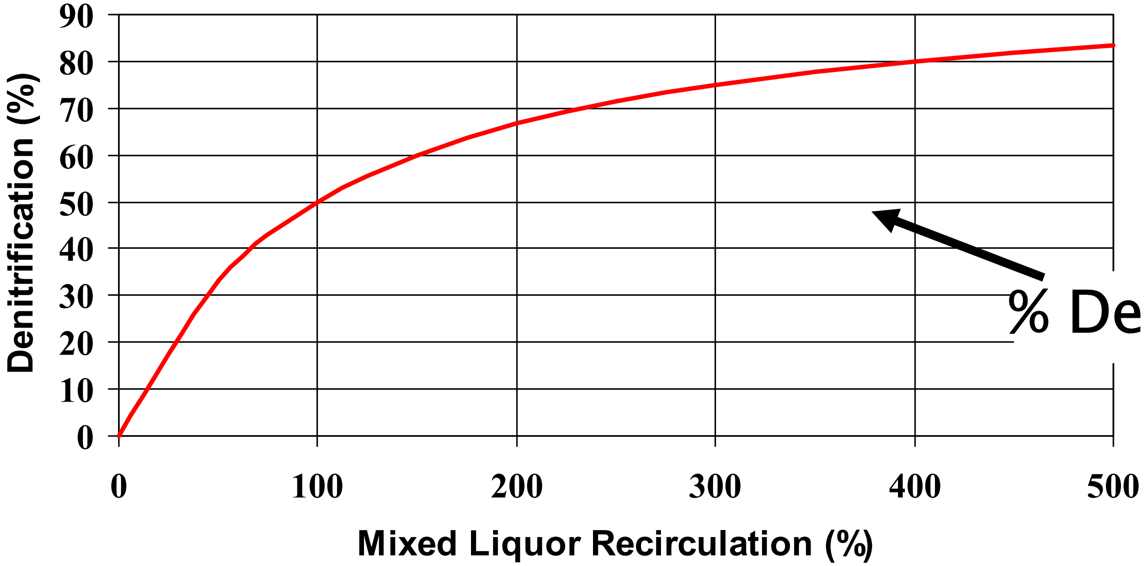
- Recycle flow rich in NO^-_3
- Fresh feed with Carbon source

DENITRIFICATION WITH SUPPLEMENTAL CARBON



DENITRIFICATION

Denitrification is Controlled by Mixed Liquor Recirculation



% Denit = R/(R+Q) * 100

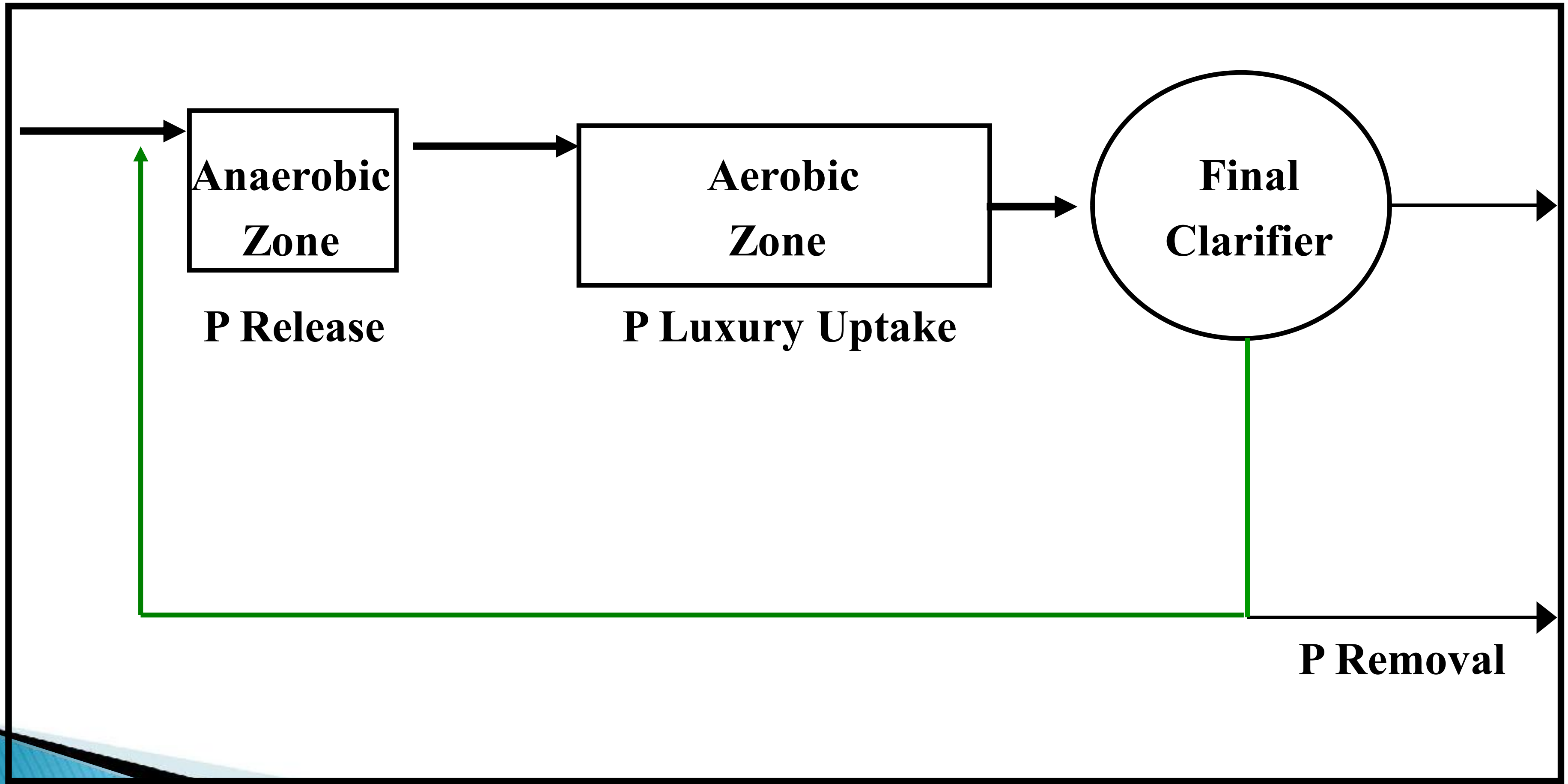
DENITRIFICATION

- Size based on Anoxic SRT
  - Typically 1 to 2 days (in some cases upto 4 days) depending on temperature

- Effective Denitrification
  - Sufficient Anoxic Volume (Anoxic SRT)
  - Sufficient Carbon
  - Sufficient mixed liquor recirculation

PHOSPHORUS REMOVAL

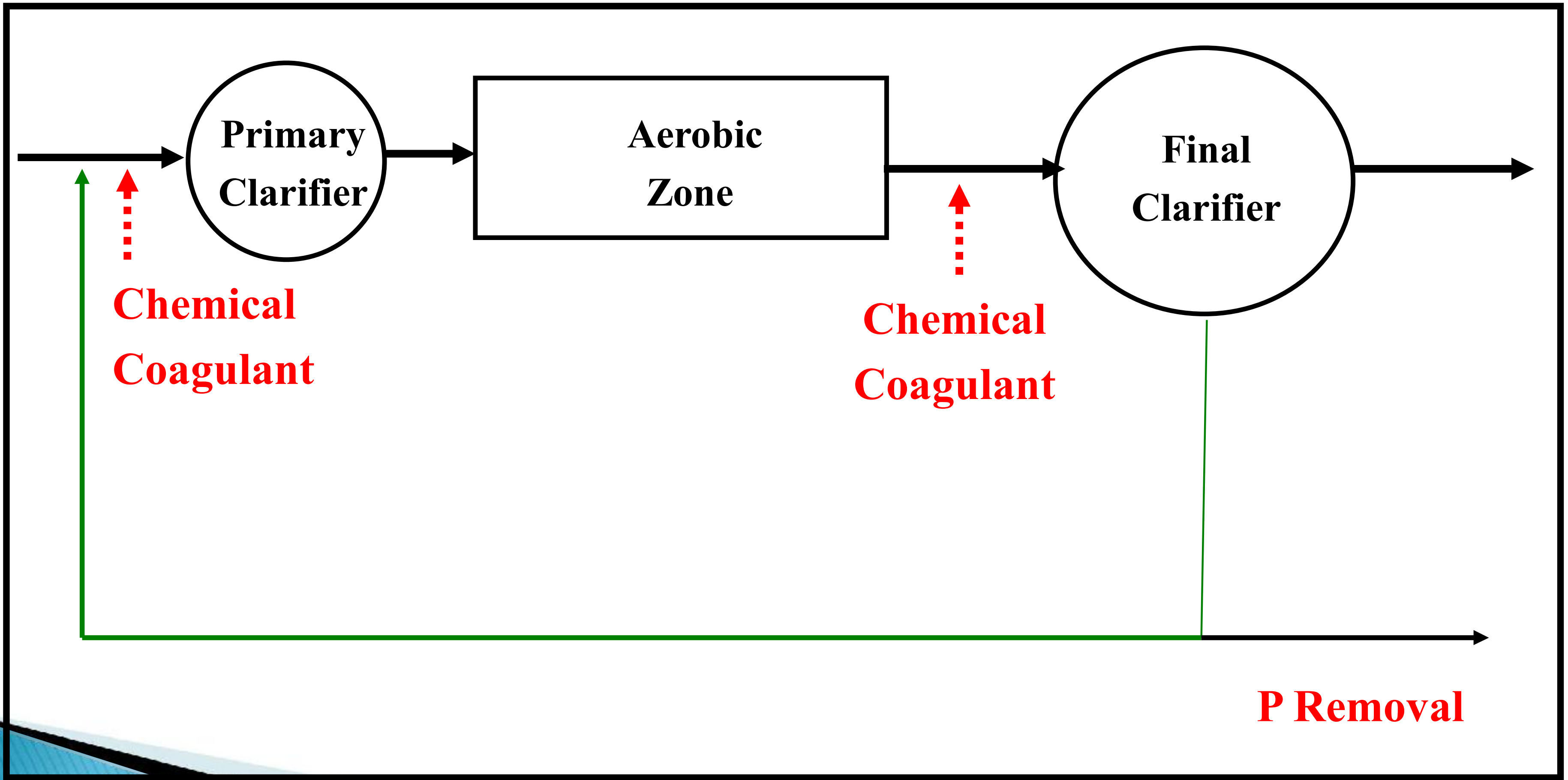
- Biological



Continued …

PHOSPHORUS REMOVAL

- Chemical



EFFECTIVE PHOSPHORUS REMOVAL

- Size based on SRT
  - Typically 7 to 10 days depending on temperature
- Effective Denitrification
  - Sufficient Anaerobic Volume (Anaerobic SRT)
  - Sufficient influent carbon
  - Competition between denitrification and phosphorous removal bacteria
- Sensitive to influent carbon
- Unstable process

BIOLOGICAL SLUDGE

- ALL Biological Treatment Processes produce sludge
- Biological Sludge comprises C, N, P and other trace elements
- Usually contains high proportion of water
  - 1 – 3% un-thickened
  - ~ 20% after centrifuge of filter belt press
  - 30 – 40% after plate and frame press
  - >80% after drying
- Sludge can be biologically active
- Can contain bacteria and viruses

Sludge Volume Calculations

- <u>Biological Sludge Production (Example with 1.4 mld STP)</u>
- SP_B = ADF x Y x (BOD_{in} – BODout) / 1000 = 1400 x 0.7 x (300 – 10) / 1000
- = 284 kg/day
- ADF – Daily Flow, m^3/d
- Y – Sludge yield, 0.7 kg dry sludge generated per kg of BOD removed
- 1000 – Conversion, g/kg
- <u>Chemical Sludge Production</u>
- SP_C = 0 kg/day

Cont...

- <u>Total Sludge Production</u>

- Total Sludge Production $SP = SP_B + SP_C$

  $= 284 + 0 = 284$ kg/day

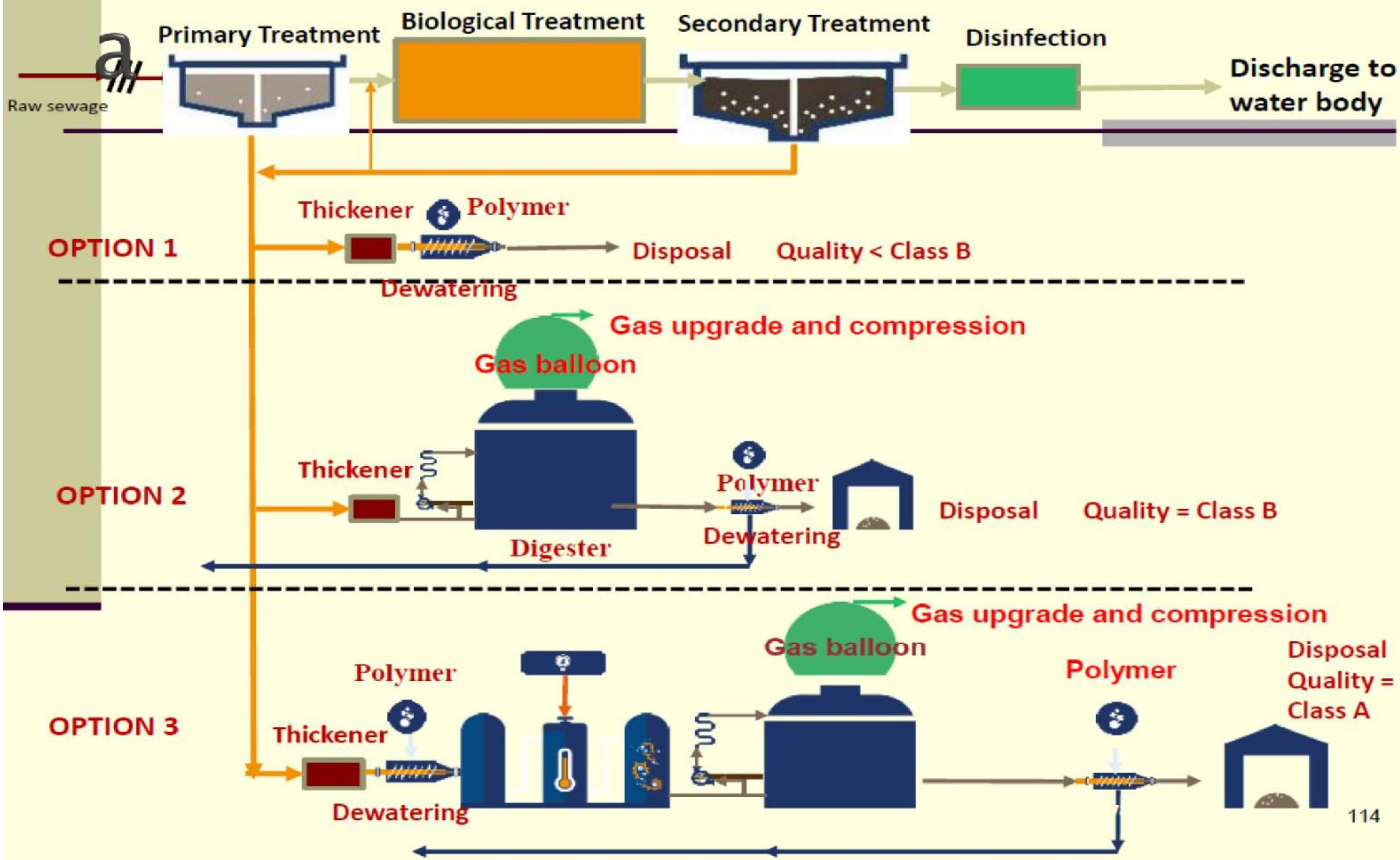
- <u>Sludge Waste Rate</u>

- Assume 0.85% solid content in sludge layer of SBR reactor when sludge settles, daily sludge waste rate:

- $Q_{WAS} = SP / 0.0085 / 1000$

  $= 284 / 0.0085 / 1000 = 33.41\ m^3/day$

Sludge Treatment



SLUDGE MANAGEMENT

Sludge Management has two components

- Volume Reduction
- Treatment

Volume Reduction

- Gravity Thickening
- Drying
- De-watering

Treatment

Chemical/Aerobic/Anaerobic digestion

DESIGN CRITERIA

Gravity Thickening	
Number of units	1
Solids loading	25 to 70 $kg/m^2/day$
(Combined primary & Waste Activated Sludge	Would thicken 0.5–1.5 % sludge to 4 to 6%
Overflow rate	6 to 12 $m^3/m^2/day$
Sludge Drying Beds	
Drying period	10 days
Sludge layer	30 cm
Total depth of bed	1 m

DESIGN CRITERIA

Dewatering

- Rotary Drum Filter

  Number of units 1 (for large plants minimum 2)

Design criteria is normally based on solids loading. Should be obtained from the vendor.

- Centrifuge

  Number of units 1 (for large plants minimum 2)

Design criteria is normally based on solids loading. Should be obtained from the vendor.

The primary and waste activated sludges could be treated to 16 to 24% solids

DESIGN CRITERIA

- Belt Filter Press

  Number of units 1 (for large plants minimum 2)

  Sludge loading rate 90 to 680 kg/m/hour

  Cake solids 18 to 28%

  (Primary and waste activated sludge)

- Recessed Plate Filter Press/ Vacuum Filter

  Design data to be obtained for the vendor

SLUDGE TREATMENT

- Chemical Stabilization– Lime Treatment
- High Rate Anaerobic Digestion

  Number of Units 1 (for large plants 2)

  Loading Rate – 1.6 to 4.8 kg Volatile solids/cum/day

  SRT – 20 days

  HRT – 30 – 40 days

SLUDGE TREATMENT

- Aerobic Digestion
  Number of Units 1 (for large plants minimum 2)

  Loading Rate –1.6 to 4.8 kg Volatile solids/cum/day

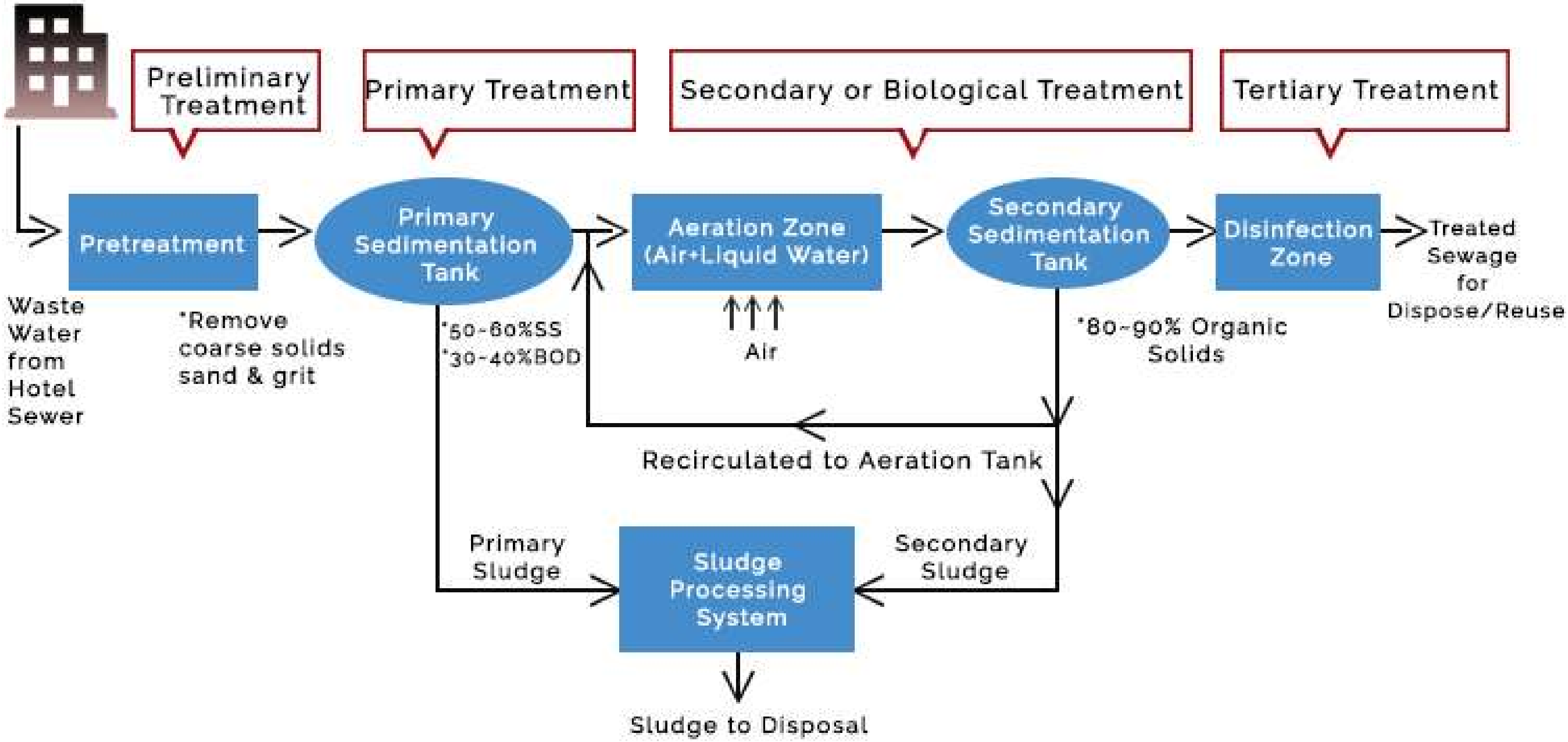
  SRT – 40 days

  Oxygen – 2.3 kg/kg VSS

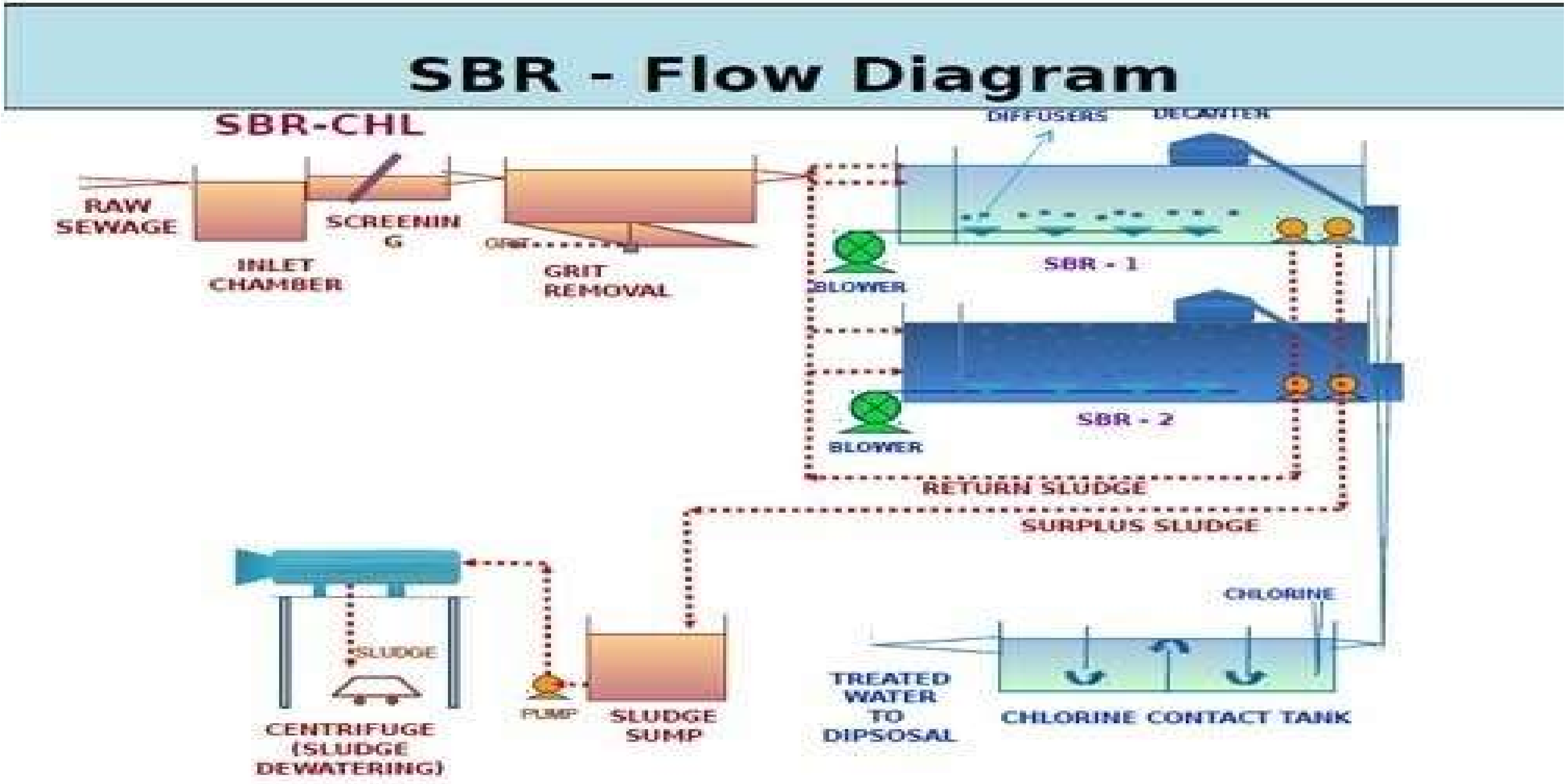
SBR TECHNOLOGY

View of SBR-STP Internals

Conventional Waste water Treatment Plant



SBR Technology based Treatment Plant.



SBR Process & Operation

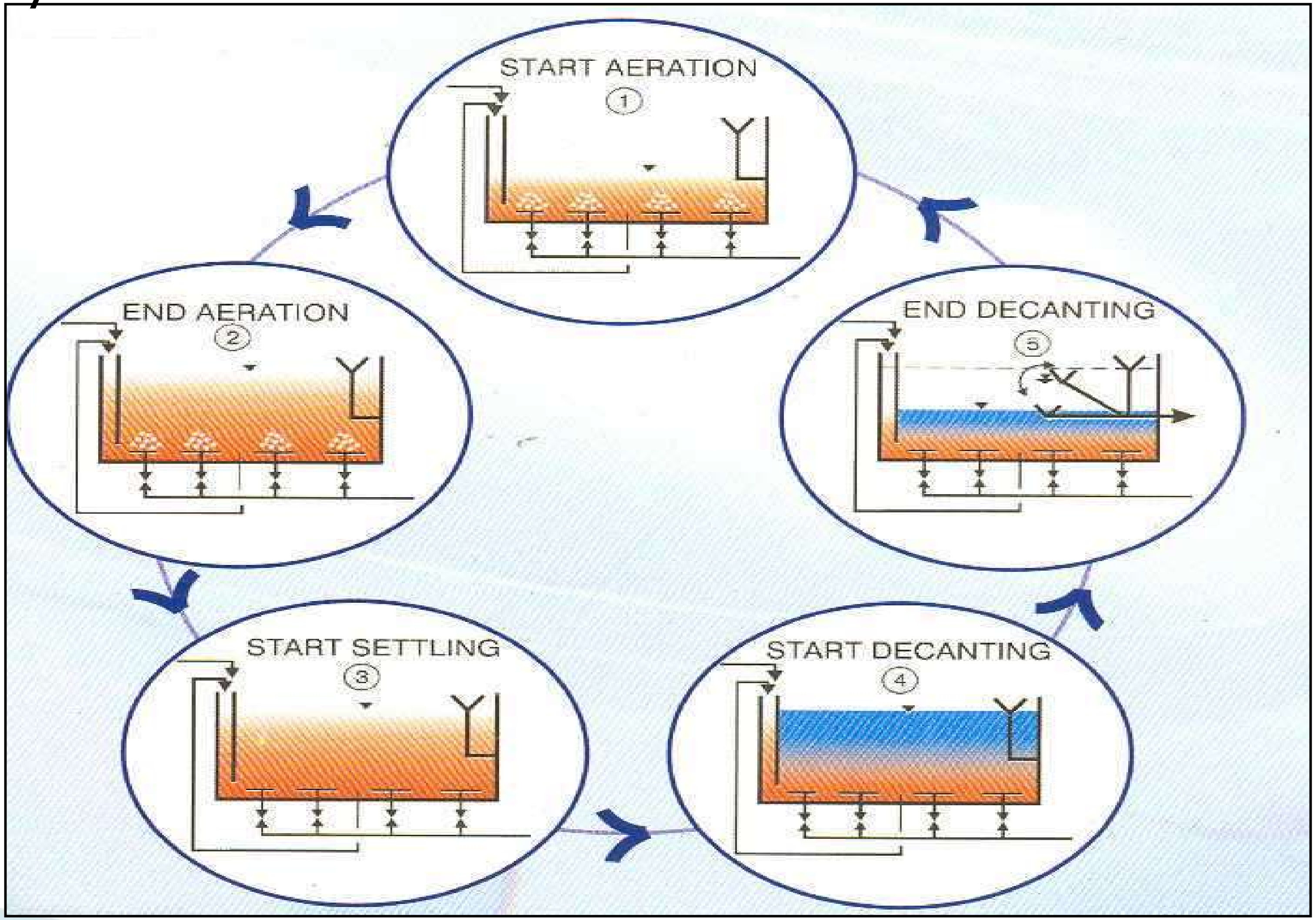
- A sequencing batch reactor (SBR) is a variation of the activated sludge process.
- SBR is a batch process with intermittent discharge, while conventional activated sludge process is a continuous process with uninterrupted feed and discharge
- Each reactor, through a time cycle, provides all of the processes of activated sludge treatment (biological reactions and water/solid separation) in one reactor.
- SBR tank carries out the functions of equalization, aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems.

SEQUENCING BATCH REACTOR

- Sequencing batch reactor (SBR) process is a fill-and-draw reactor with complete mixing during the batch reaction step
- SBR is a time-oriented system where each tank is filled for a discrete period of time and then operated as a batch reactor
- SBR operation is consists of five steps *viz.* Fill, React, Settle, Draw, and Idle phase
- SBR uses multiple steps in the same tank to take the place of multiple tanks in a conventional treatment system
- A typical SBR cycle time consists of about 4 to 6 hours.
  Fill & React : 25% + 25% , Settle: 25% ,Draw or Decant: 25%,

SEQUENCING BATCH REACTOR

Process Cycle of SBR:



SEQUENCING BATCH REACTOR

Advantages of SBR

- Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel
- Operating flexibility and control
- Minimal footprint
- Very high reduction rate for N & P
- Potential capital cost savings by eliminating clarifiers and other equipment

SEQUENCING BATCH REACTOR

STEPS FOR SBR SIZING

- Input Sewage Flow in cum/day.
- Decide Cycle Time, C in hrs.
- Provide Min 2 nos. of basins.
- Calculate No of Cycles per day.
- Find out Filling Volume per cycle.
- Find out Total Reactor Volume .
- Assume suitable SWD and Find out Area.

SEQUENCING BATCH REACTOR

Oxygen Requirement 1.2-2.0kg/kg BOD
Detention time 12 to 20 hours

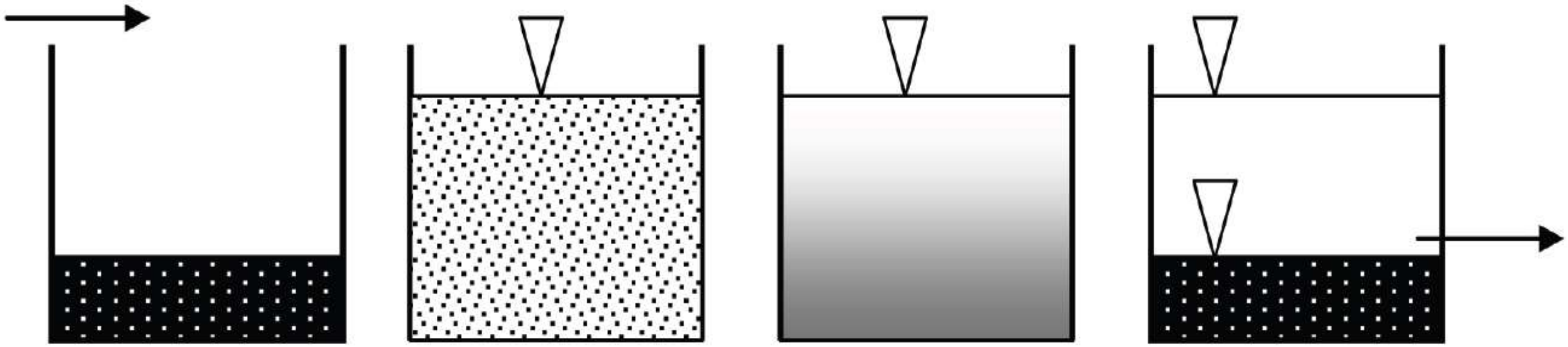
Sludge Formation
    Quantity 0.7 to 0.8 kg/kg BOD
    Strength =0.8 %
SRT   Normally 12- 20 days

Sludge Recirculation Pumps
    Capacity 50 -200% of feed flow
    Operation during fill and aeration (50% of time)

Sludge Wasting Pumps

Tank depth = sludge depth + 0.75 to1M safety + liquid volume of 2 hours of peak flow (depend on cycle time)

SBR Sequence



Fill
The sewage starts filling the basin. and aeration

Aerate
After filling, the basin is aerated and is also well mixed

Settle
Air supply is stopped and the basin contents settle

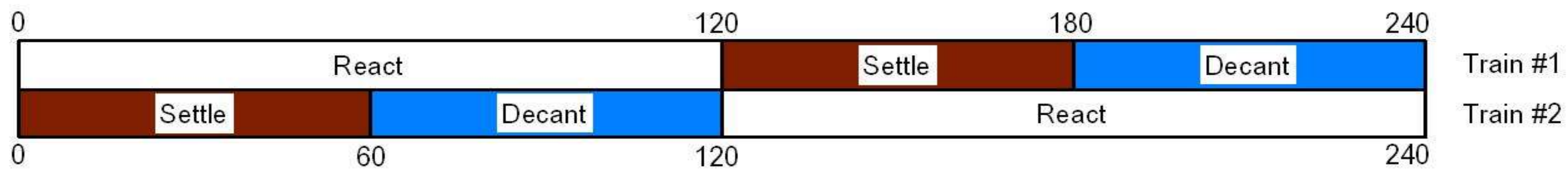
Decant
The settled supernatant is decanted for treated

Note: All the four steps shown above take place in the same tank one following the other on a time interval basis but are shown separately in this figure for easy understanding.

SBR Cycle

- Normally SBR Design in 4-6 hr cycle

- In 4 Hr cycle:
- First 2 Hr for Fill & Aeration
- One Hr for Settling
- One Hr for decanting



Typical SBR Process Parameter

Table 5.57 Typical process parameters for SBR configurations (for unsettled sludge)

S. No.	Parameters	Units	Continuous Flow and Intermittent Decant	Intermittent Flow and Intermittent Decant
1	F/M ratio	d^{-1}	0.05 - 0.08	0.05 - 0.3
2	Sludge Age	d	15 - 20	4 - 20
3	Sludge Yield	kg dry solids/ kg BOD	0.75 - 0.85	0.75 - 1.0
4	MLSS	mg/L	3,000 - 4,000	3,500 – 5,000
5	Cycle Time	h	4 - 8	2.5 - 6
6	Settling Time	h	> 0.5	> 0.5
7	Decant Depth	m	1.5	2.5
8	Fill Volume Base	-	Peak Flow	Peak Flow
9	Process Oxygen			
	BOD	kg O_2/kg BOD	1.1	1.1
	TKN	kg O_2/kg TN	4.6	4.6

* For Phosphorous ≤ 1 mg/L, after bio-P removal, metal precipitant (Fe^{3+} or Al^{3+}) shall be added. Sludge yield factor and sludge age not applicable for primary settled sewage; typical primary TSS removal 60%, BOD 30%.

Design Process for 45 MLD SBR Plant

Design Flow • Average flow • Peak factor • Peak flow	 45 MLD 2.25 times average flow 95 MLD
Influent Quality to SBR Basin • BOD • SS • TKN • TP • Faecal coliform	 250 mg/l 350 mg/l 45 mg/l 5 mg/l 10^6 MPN/100 ml
Effluent Quality of SBR Basin • BOD • SS • TKN • TP • Faecal coliform	 < 10 mg/l < 10 mg/l < 10 mg/l < 2 mg/l < 100 MPN/100 ml
No. of basins	4
Each basin area	1431 m^2
Basin foot print	127.5 m^2/1000 m^3/d
Decant volume	3377 m^3
Decanter loading	300 m^3/1000 m^3/d
Hourly flow rate	1875 m^3/h
Hourly flow rate to each basin	937 m^3/h
No. of cycles per day/basin • Filling and aeration • Settling phase • Decanting phase Total cycle time	8 90 min. 45 min. 45 min. 3 h
Hours of aeration time/day/basin	12 h
MLSS MLVSS F/M	4300 mg/l 3440 mg/l 0.08
HRT	16.30 h
SRT	14.86 days
Selector (Anoxic) Zone • Number of selector compartments/basin • Retention time in selector zone	1 50 min.
Disinfection • Chlorine dose after SBR Basin	 2.5 mg/l

Source: IIT Roorkee, August 2010

48 MLD SBR Decanter

Why SBR ???

- Advantages of SBR vs. Conventional Activated Sludge

- Enhanced Treatment Performance
- -High settling performance due to bio-selector and aerobic/anoxic /anaerobic cyclic sequences
  - Suppress filamentous bacteria thus lower potential for "sludge bulking"
  - Enhanced nutrient removal (Denitrification and Bio-P) without chemicals or separate tanks
  - Built-in equalization capacity preventing performance deterioration during surge conditions

Why SBR Cont..

- Smaller Footprint and Lower Construction Cost

- Equalization, biological treatment and clarification achieved in one tank

  - Return sludge pumping system or with submersible mixture
  - Rectangular tanks with common-wall design
  - Simple process, fast construction and installation

Why SBR Cont…

- Flexibility
- –Duration of cycle or sequences can be adjusted to accommodate variation in hydraulic flow or biological loading, e.g. shorter cycle for peak flow conditions, or shorter aeration time for lower loading.
- –Easy expansion with single rectangular tank design.
- –Automatic control system provides easy and flexible adjustment to operational parameters

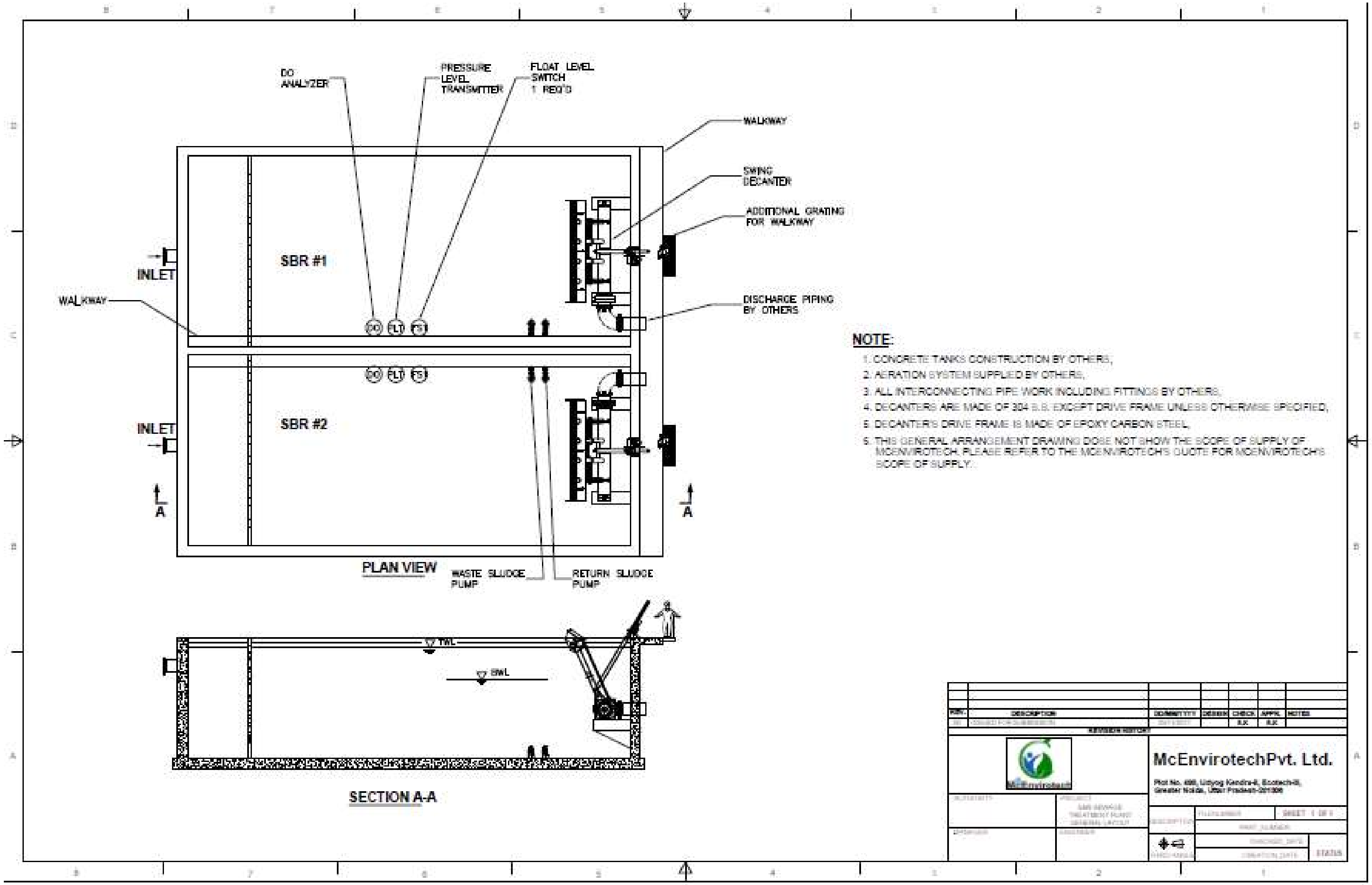
Why SBR Cont...

- Low O&M Cost
- –Better aeration control, denitrification, lower power consumption
- –Less and simpler equipment thus reduced maintenance
- –Automatic control adapting to changing conditions, with less operator attention
- – Biological N and P removal without need for chemicals

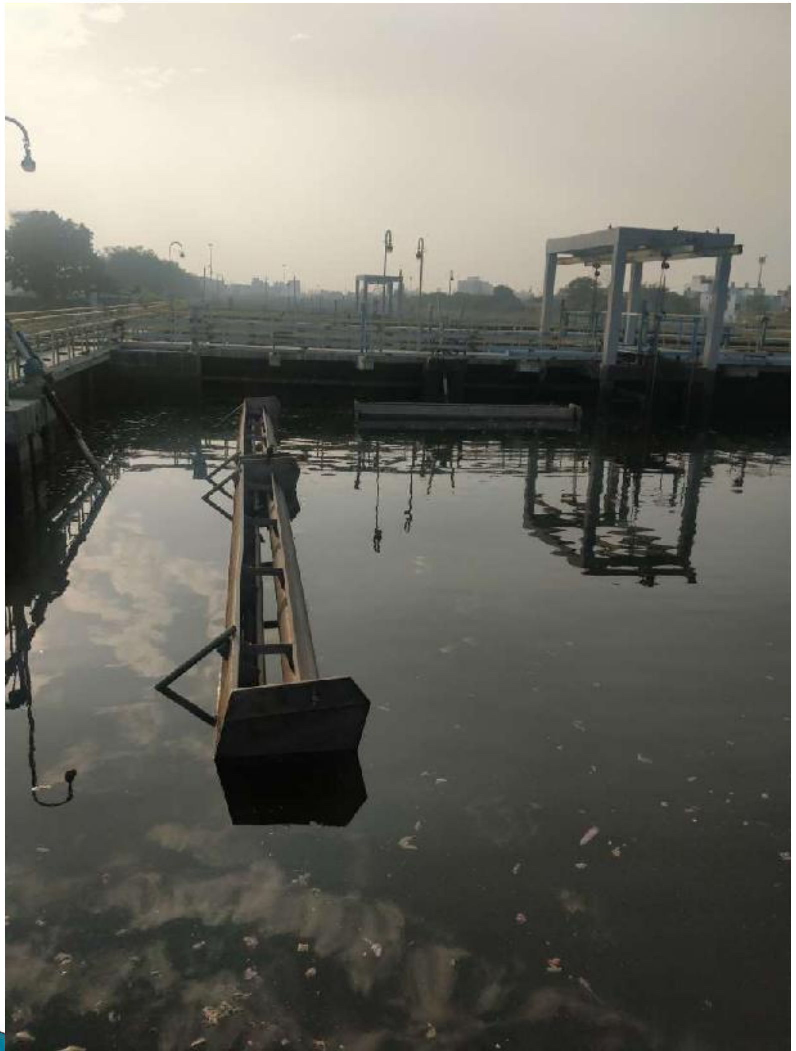
SBR Major Components

- Inlet Screen etc.
- SBR Reactor tank
- Aeration system – Diffuser
- RAS & WAS Pump
- Decanter
- Blower assembly
- Sludge treatment – Filter Press /Centrifuge etc.
- Control Panel

SBR Equipment arrangements



Some of SBR Decanter installations



SBR Process design steps

- Sizing of SBR Reactor

- Air requirement for the sbr process
- For BOD Removal
- For TN removal
- Oxygen credit if any

- Calculation of HRT, SRT, MLSS etc

- Sludge quantity

Sizing of SBR Reactor

Sizing of SBR Reactor (for each basin for 1.4 mld STP as example)

- BOD Load L_{BOD} = ADF x BODin / 1000 /2 = 1400 x 300 / 1000 /2 = 210 kg BOD/day/basin

- Food to Microorganism Ratio F/M F/M = 0.12 $kgBOD_5/kgMLSS/day$

- Sludge Volume Index SVI SVI = 120 mL/g = 0.12 m^3/kg

- Mass of Microorganism (Mmlss)

$$M_{bio} = \frac{L_{BOD}}{F/M} = \frac{210}{0.12} = 1750 \text{ kg}$$

Cont..

- $V_{MLSS} = M_{MLSS} \times SVI = 1750 \times 0.12 = 210\ m^3$
- Clear Water Volume at Average Daily Flow
- $V_{IN} = Q \times (CT)\ /2\ /24$
- $= 1400 \times (4)\ /2\ /\ 24 = 117\ m^3$
- Top Water Level TWL
- SBR tank depth is 5.5 m and design freeboard is 0.5 m.
- Top water level TWL = 5.5 – 0.5 = 5.0 m.

Cont..

- Basin/ Reactor Area
- $A = (V_{MLSS} + V_{WM}) / (TWL - BZ)$
- $= (210 + 117) / (5 - 0.75) = 76.94 \text{ m}^2$
- BZ – Buffer Zone, use 0.75 m
- Basin Dimensions
- The proposed dimensions of each SBR basin will be 10000 mm wide x 7700 mm long x 5500 mm deep, with total area of 77 m^2.

Calculations of HRT, MLSS & SRT

- Tank Volume at Top Water Level
- V_{TWL} = TWL x A = 5 x 77 = 385 m^3
- Hydraulic Retention Time at TWL
- HRT = 2 x V_{TWL} / Q = 2 x 385 / 1400 = 0.55 day = 13.20 hours
- 2 – Number of SBR basins , Q – Average daily flow
- MLSS at TWL
- MLSS = 1000 x M_{BIO} / V_{TWL} = 1000 x 1750 / 385 = 4545 mg/l
- 1000 – Conversion, g/kg

Cont…

- Sludge Retention Time SRT

- $$SRT = \frac{2 \times M_{BIO}}{SPb}$$

- $$= \frac{2 \times 1750}{284} = 12.32 \text{ days}$$

- 2 – Number of SBR tanks

MOVING BED BIOREACTOR (MBBR)

- A moving-bed biofilm reactor (MBBR) has been developed by a Professor Hallvard Ǿdegaard in the late 1980s at the Norwegian University of Science and Technology .

- Uses cylindrical shaped polyethylene carrier elements for biological growth

- MBBR does not require any return activated sludge flow or backwashing

- Excellent for BOD/COD removal and nitrification / denitrification in all types of wastewaters

MOVING BED BIOREACTOR (MBBR)

MBBR system consists of

- Bar screen
- MBBR aeration tank with suspended media
- Lamella / tube settler

MOVING BED BIOREACTOR (MBBR)

- Attached Growth Process

- Moving media to increase the contact time between the bacteria and the organics

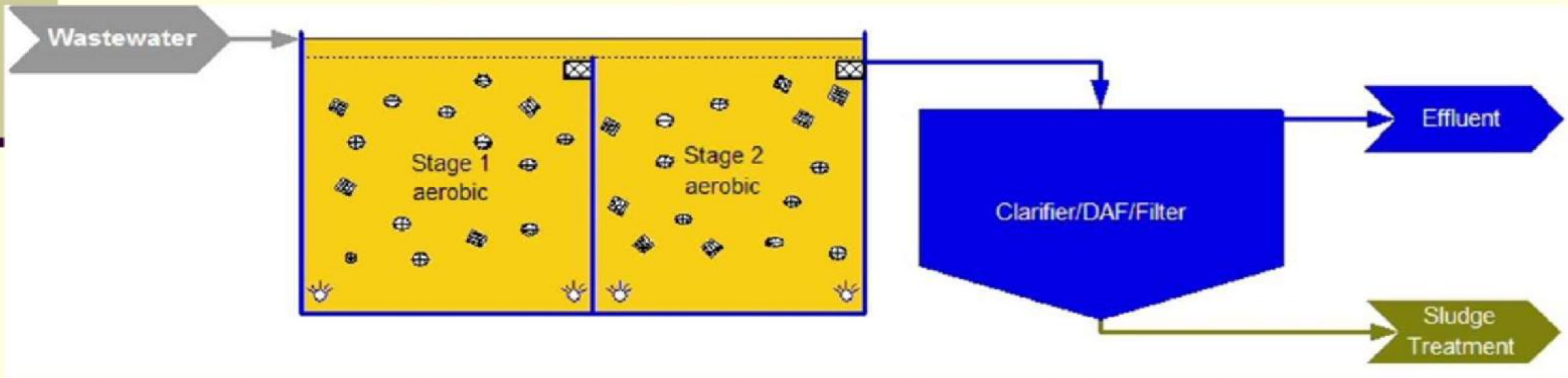
- High porosity media to provide large surface area for bacteria to attach and grow

- Requires comparatively lesser space than the conventional system

Moving Bed Biofilm Reactors (MBBR)

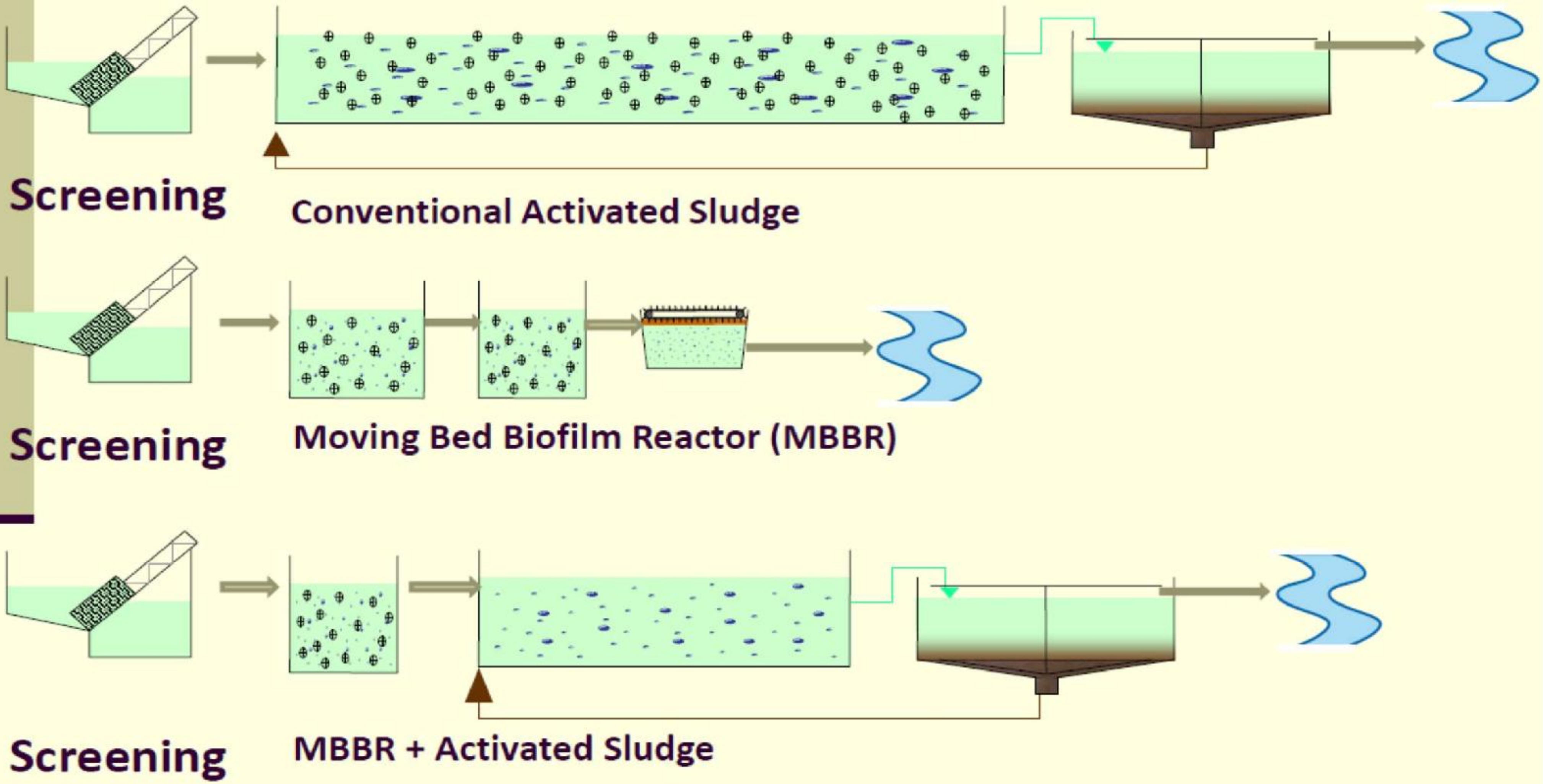
What is MBBR?

MBBR – Pure fixed film biological treatment system where a biomass grows on a fixed element to treat specific materials (BOD, NH3-N, NO3-N) and treatment train is separated into multiple reactors. System operates with NO Return Activated Sludge



Source: World Water Works

Schematic Comparison



Source: World Water Works

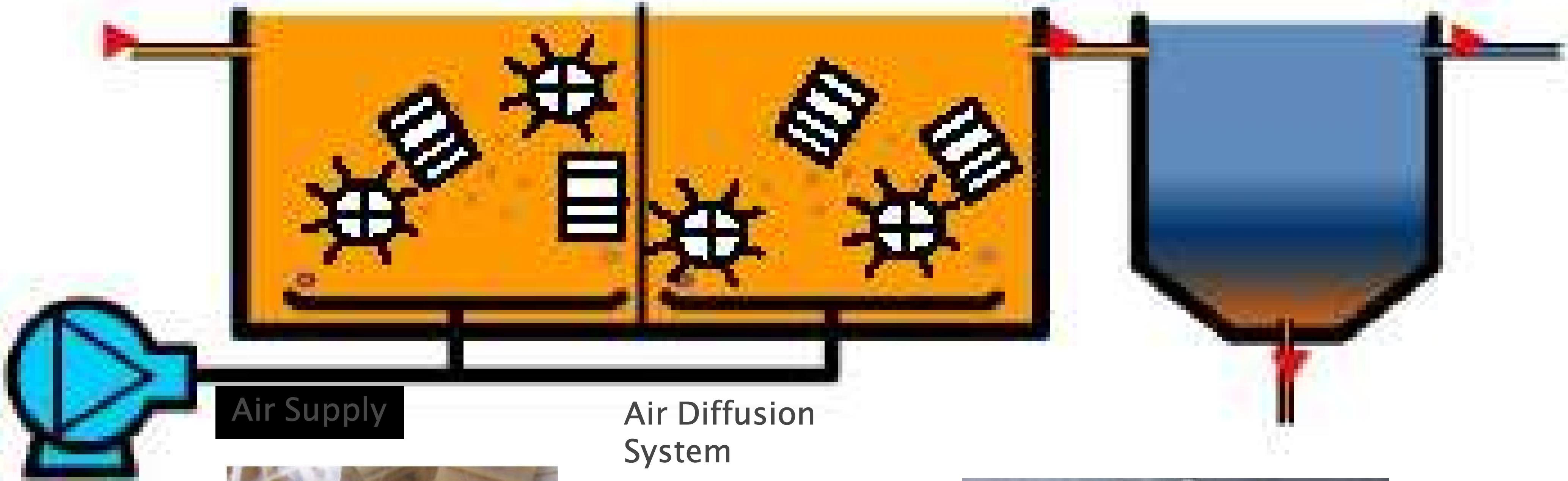
Volumetric Comparison

Source: World Water Works

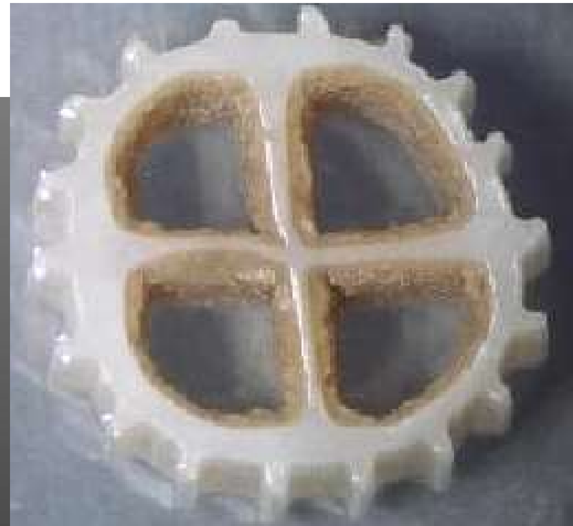
MBBR Aeration System

MBBR Screen

MBBR PROCESS

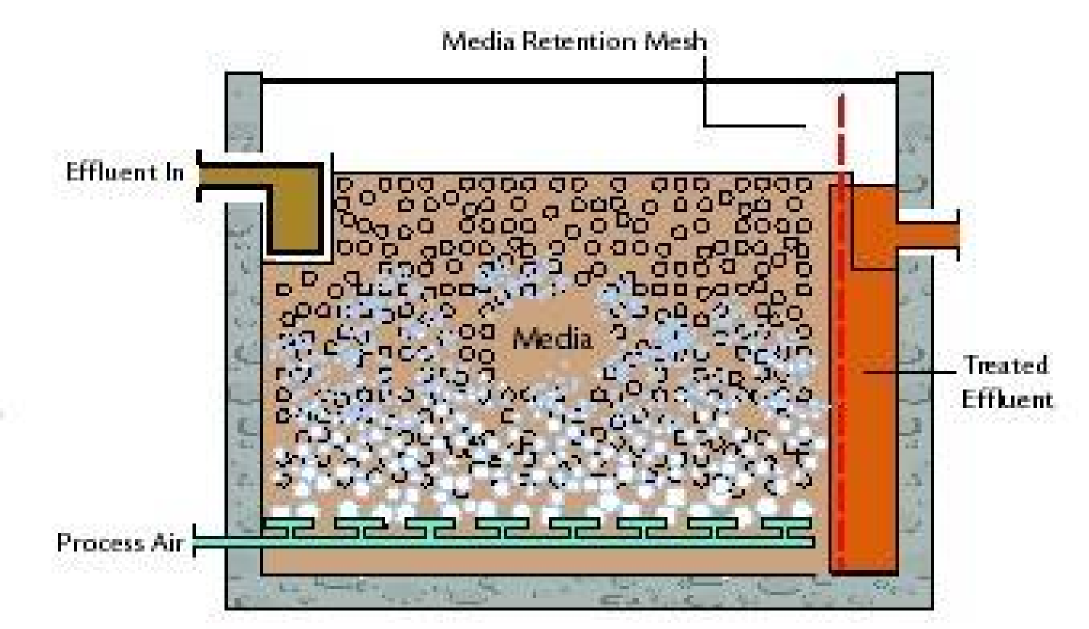


Specific Surface Area
500 – 800 m^2/m^3
10mm diameter



Aqwise MBBR / IFAS Media-Israel, manufactured at Germany (Total Surface area 1200 & 900 m2/m3)

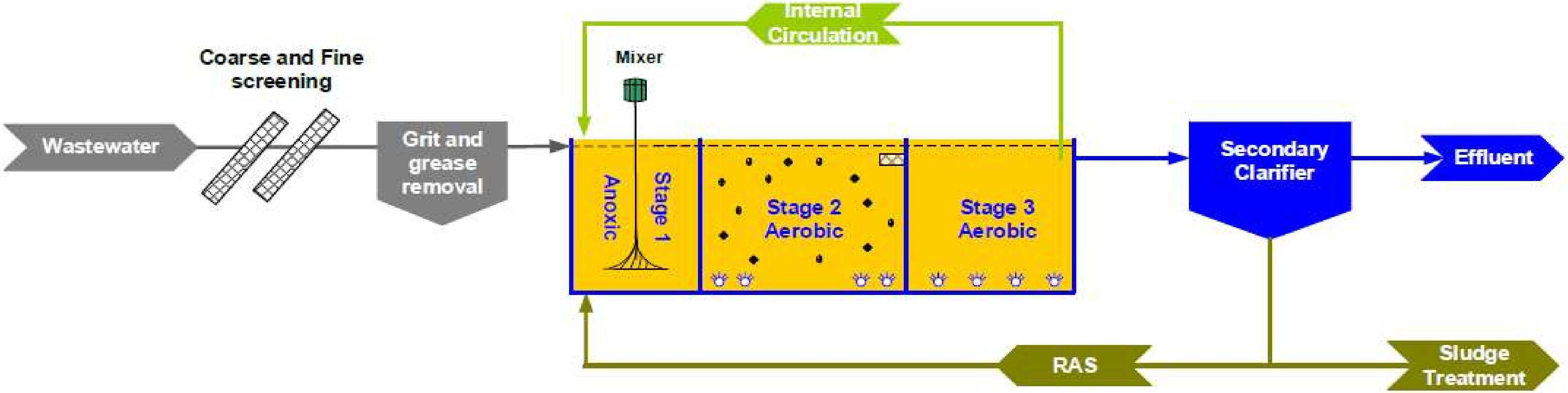
MOVING BED BIOREACTOR (MBBR)



Advantages of MBBR

- ✓ High Quality Effluent
- ✓ Small footprint
- ✓ Simplicity of Design, Installation and Operation
- ✓ Low Operating Costs
- ✓ Media and Biomass retained

Schematic IFAS / MBBR PFD



MOVING BED BIOREACTOR (MBBR)

Advantages of MBBR

- Compact
- Robust biofilm process
- Easy upgrading of existing plants
- Easy to operate and control
- No clogging of biofilm carriers
- No sludge return
- Low load on particle separation

The MBBR (moving bed biofilm reactor) process is an attached growth process that uses plastic carriers to provide a surface on which biofilm grows.

The plastic carriers are kept suspended in the aeration tank by an aerator for an aerobic process or by mechanical mixing for an anoxic or anaerobic process.

The plastic carriers are kept in the system by a sieve at the outlet of the tank.

The MBBR process doesn't require sludge recycle, because the biomass remains in the system attached to the plastic carriers.

The required reactor size for an MBBR process is typically significantly smaller than that for an activated sludge process treating the same wastewater flow, or for other common attached growth processes like the RBC or trickling filter.

It can be used for BOD removal, biological nitrification, biological denitrification, and biological phosphorus removal.

Primary clarification is typically used ahead of the MBBR tank. Secondary clarification is also typically used, but there is no recycle activated sludge sent back into the process, because an adequate microorganism population is maintained attached to the media.

MBBR – DESIGN CRITERIA

F : M	– 0.1 – 0.25
MLSS	– 5000 – 8000 mg/l
gm BOD /m^2 media	– 7.5 – 25
Kg BOD / m^3 of Tank Volume	– 0.6 – 3.2
% Fill	– 18– 60%
MBBR Media Specs.	– 250 – 1200 m^2/m^3 of media

Single Stage BOD Removal MBBR Process Design :

An MBBR single stage BOD removal process may be used as a free-standing secondary treatment process .

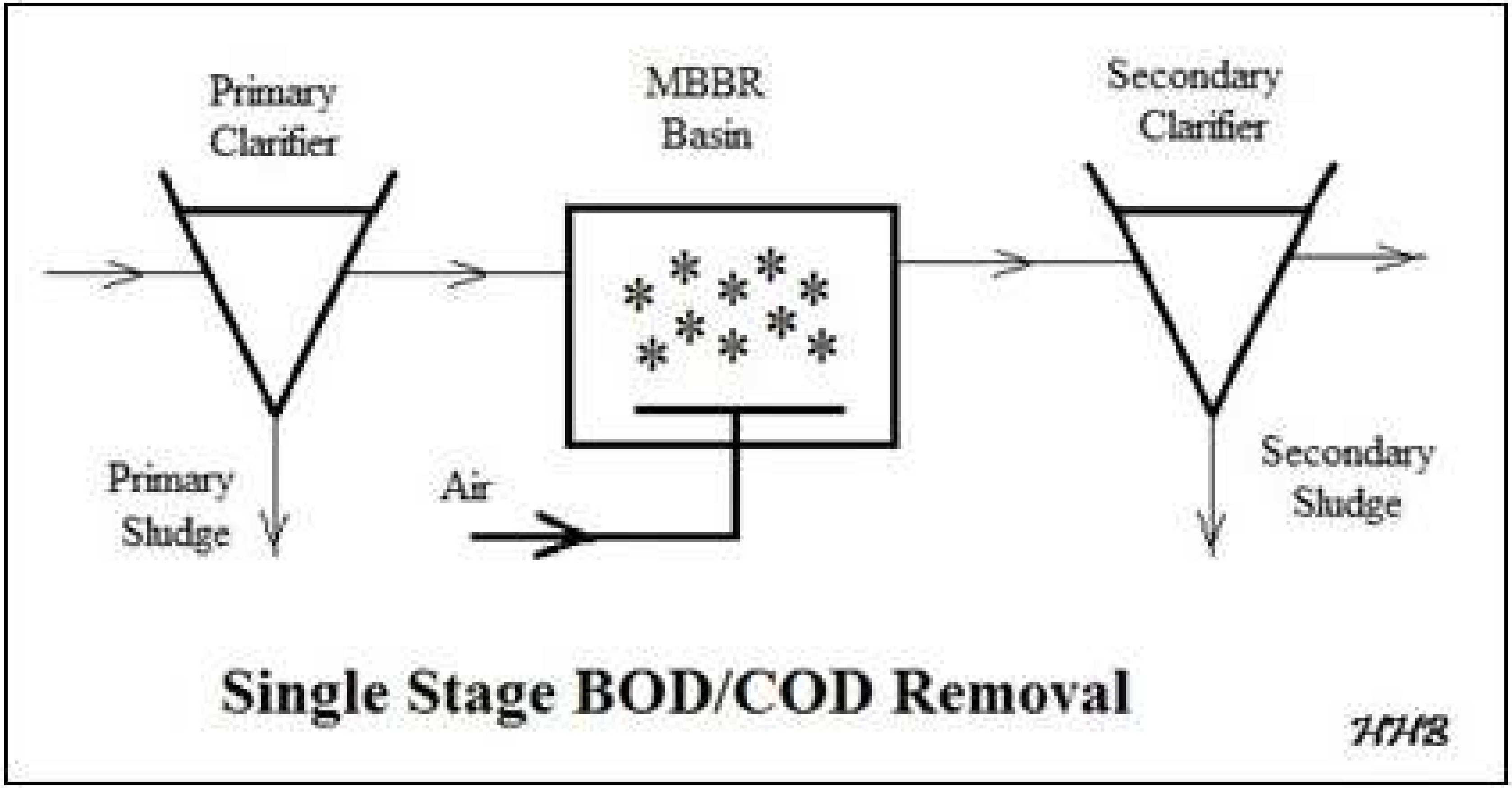
The key design parameter for sizing the MBBR tank is the surface area loading rate (SALR), typically with units of g/m2/day, that is g/day of BOD coming into the MBBR tank per m2 of carrier surface area.

Using design values for wastewater flow rate and BOD concentration entering the MBBR tank, the loading rate in g BOD/day can be calculated.

Then dividing BOD loading rate in g/day by the SALR in g/m2/day gives the required carrier surface area in m2.

The carrier fill %, carrier specific surface area, and carrier % void space can then be used to calculate the required carrier volume, tank volume and the volume of liquid in the reactor.

A typical flow diagram for a single stage MBBR process for BOD removal is shown in the figure below.


Primary
Clarifier
MBBR
Basin
Secondary
Clarifier
Primary
Sludge
Air
Secondary
Sludge
Single Stage BOD/COD Removal
HHB

Two-Stage BOD Removal MBBR Process Design Calculations

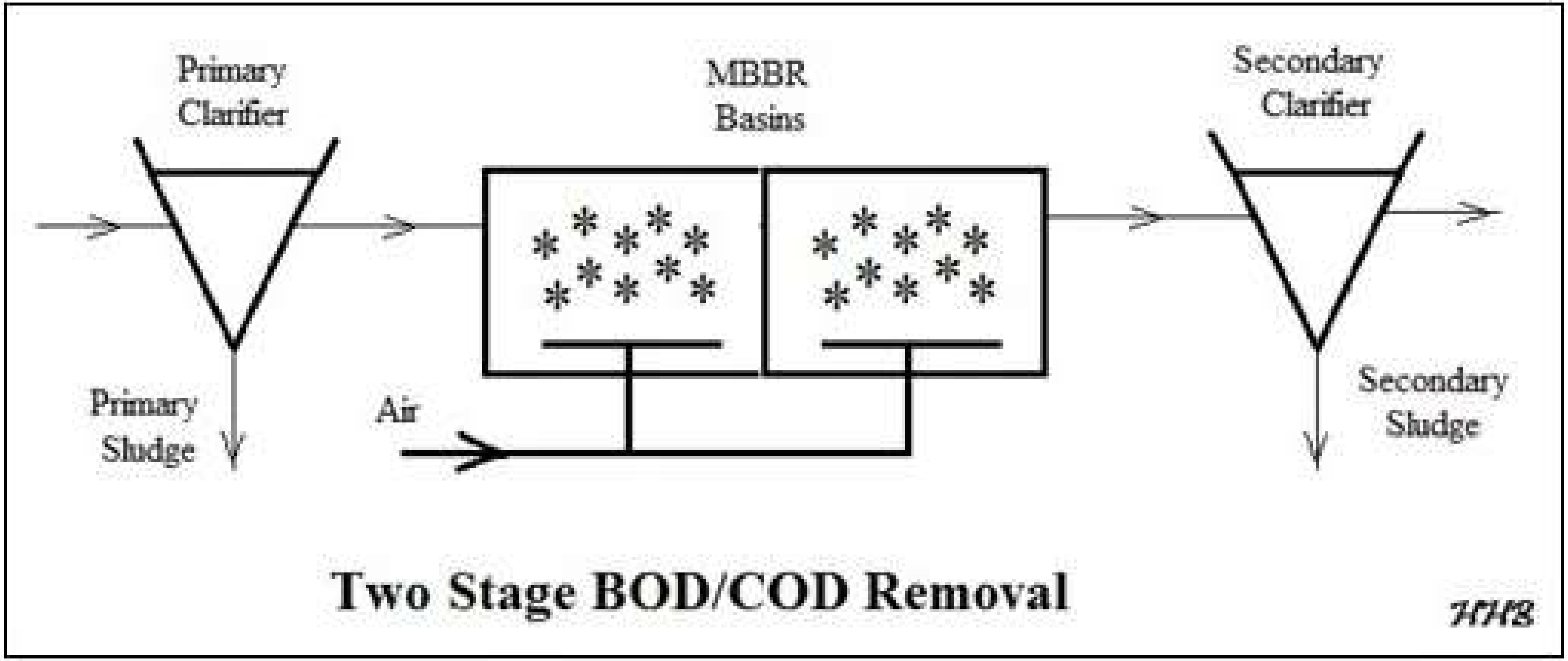
A two stage MBBR BOD removal process may be used instead of a single stage process.

In this case, a high SALR “roughing” treatment will typically be used for the first stage and a lower SALR will typically be used for the second stage.

This will result in less total tank volume needed for a two-stage process than for a single stage process.

Also, a two-stage MBBR process can typically achieve a lower effluent BOD concentration than a single stage MBBR process.

The process design calculations for a two stage MBBR process are essentially the same for each of the stages as for the single stage process.


Primary
Clarifier
MBBR
Basins
Secondary
Clarifier
Primary
Sludge
Air
Secondary
Sludge
Two Stage BOD/COD Removal
HHB

TWO STAGE BOD REMOVAL & NITRIFICATION PROCESS IN MBBR TECHNOLOGY:

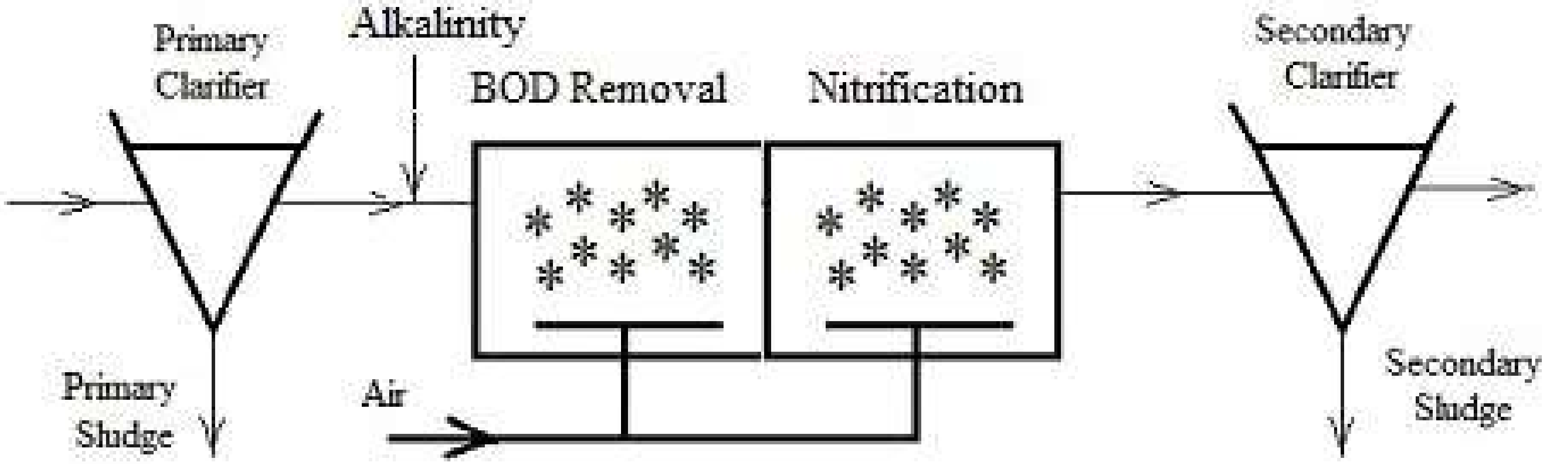
A two stage MBBR process may also be used to achieve both BOD removal and nitrification.

Nitrification with an MBBR process requires a rather low BOD concentration in order to favor the nitrifying bacteria in the biomass attached to the carrier.

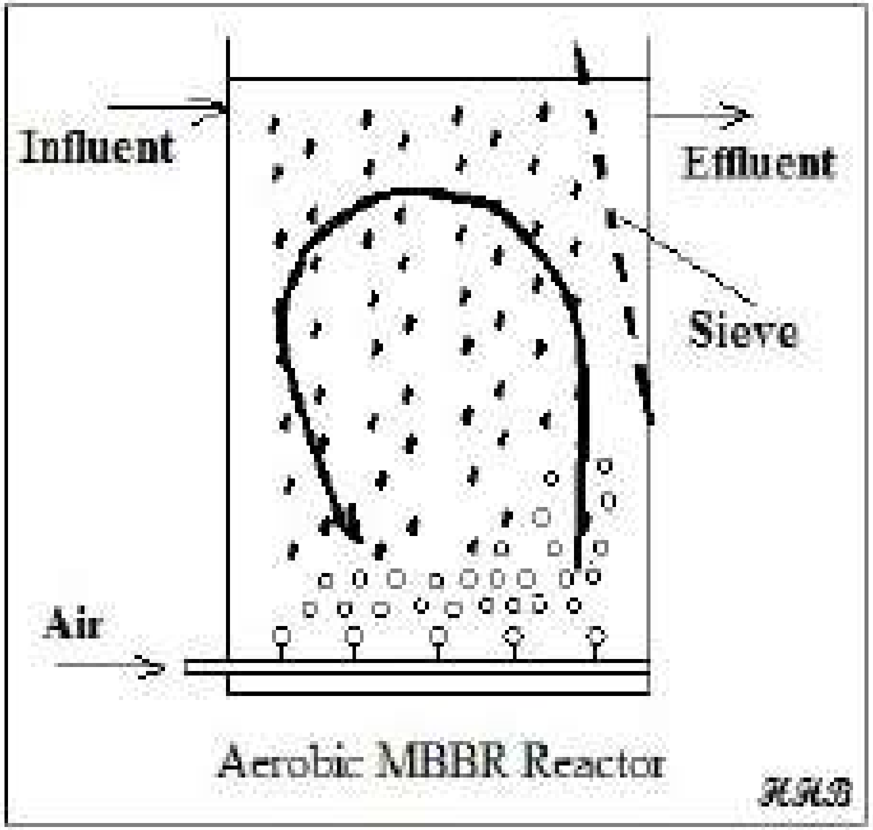
Thus, the first stage for this process is used for BOD removal and the second stage is used for nitrification.

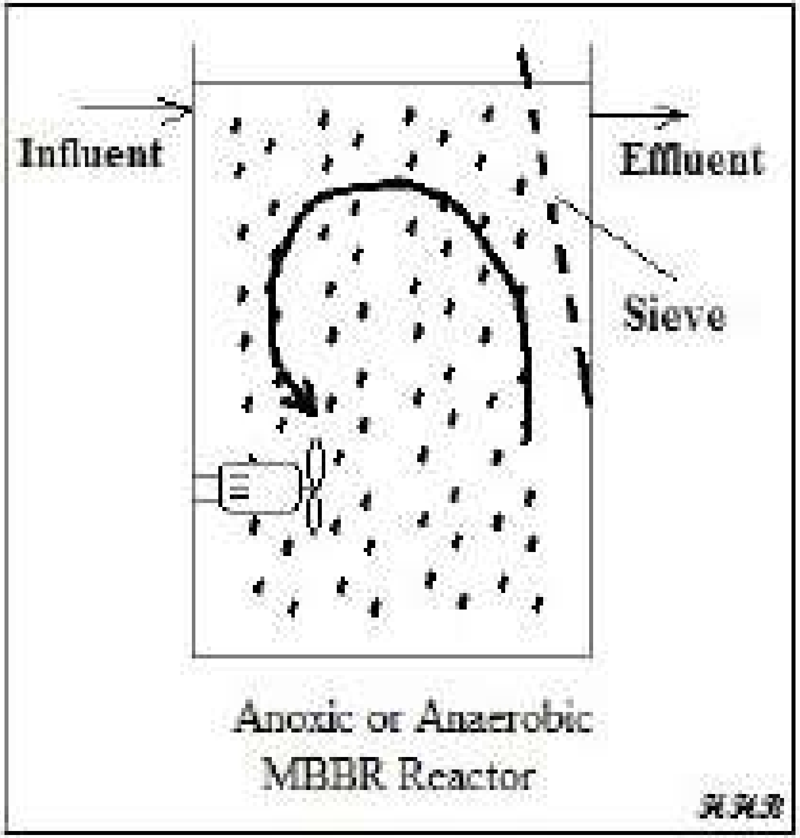
A typical flow diagram for a two stage MBBR process for BOD removal and nitrification is shown in the figure below.

As in the single stage nitrification process alkalinity is used for nitrification, so alkalinity addition is typically required.



Two-Stage BOD/COD Removal and Nitrification


Influent
Effluent
Sieve
Air
Aerobic MBBR Reactor
HHB


Influent
Effluent
Sieve
Anoxic or Anaerobic
MBBR Reactor
HHB

Single stage MBBR

Table 1. Typical Design SALR Values for BOD Removal

Typical Design Values for MBBR reactors at 15°C		
Purpose	Treatment Target % Removal	Design SALR g/m^2-d
BOD Removal		
High Rate	75 - 80 (BOD_7)	25 (BOD_7)
Normal Rate	85 - 90 (BOD_7)	15 (BOD_7)
Low Rate	90 - 95 (BOD_7)	7.5 (BOD_7)

Two Stage MBBR with BNR

Table 3. Typical Design SALR Values for Nitrification

Typical Design Values for MBBR reactors at 15°C		
Purpose	Treatment Target % Removal	Design SALR g/m^2-d
Nitrification		
BOD removal stage	90 - 95 (BOD_7)	6.0 (BOD_7)
Effl. NH_3-N > 3 mg/L	90 (NH_3-N)	1.00 (NH_3-N)
Effl. NH_3-N < 3 mg/L	90 (NH_3-N)	0.45 (NH_3-N)

Single stage MBBR design

- Example:
- A. With 1.5 MGD containing 175 mg/L BOD (in the primary effluent) is to be treated in an MBBR reactor.
- b) What would be a suitable design SALR to use for a target of 90-95% removal?
- c) If the MBBR carrier has a specific surface area of 600 m2/m3 and design carrier fill % of 40%, what would be the required volume of carrier and required MBBR tank volume?
- d) If the design carrier % void space is 60%, what would be the volume of liquid in the MBBR reactor?
- e) If the design peak hour factor is 4, calculate the average hydraulic retention time at design average wastewater flow and at design peak hourly wastewater flow.

- Solution:
- a) The BOD loading rate will be (1.5 MGD)(175 mg/L)(8.34 lb/MG/mg/L) = 2189 lb/day = (2189 lb/day)*(453.59 g/lb) = 993,000 g BOD/day
- 8.34 is the conversion factor from mg/L to lb/MG
- 453.59 is the conversion factor from lb to g

- b) From Table 1 above, a suitable design SALR value for BOD removal with a target BOD removal of 90-95% would be 7.5 g/m2/day

Cont..

- c) Required carrier surface area = (993,000 g/day)/(7.5 g/m2/day) = 132,403 m2.
-
- Required carrier volume = 132,403 m2/600 m2/m3. = 220.7 m3
- For 40% carrier fill: Required tank volume = 220.7 m3/0.40 = 551.7 m3.
-
- d) The volume of liquid in the reactor can be calculated as:
-
- tank volume – [carrier volume(1 – void %)],
-
- Thus the volume of liquid is:
- 551.7 – [220.7(1 – 0.60)] = 463.4 m3 = 463.3*(3.28083) = 16,365 ft3
-
- e) The HRT at design average waste water flow can be calculated as:
- HRTdes ave = reactor liquid volume x7.48 / [Qx106/(24x60)]
- = 16,365 x7.48 / [1.5x106/(24x60)] = 118 min
- HRTpeak hr = HRTdes ave/peak hour factor = 118/4 = 29 min

For Two stage MBBR design

- a) For the first stage:
- i) The BOD loading rate will be (1.5 MGD)(175 mg/L)(8.34 lb/MG/mg/L) = 2189 lb/day = (2189 lb/day)*(453.59 g/lb) = 993,022 g BOD/day
- ii) Required carrier surface area = (993,022 g/day)/(25 g/m2/day) = 39,721 m2.
- Required carrier volume = 39,721 m2/600 m2/m3. = 66.20 m3
- iii) For 40% carrier fill: Required tank volume = 66.2 m3/0.40 = 165,5 m3.
- iv) The volume of liquid in the reactor can be calculated as:

Cont..

- tank volume – [carrier volume(1 – void %)], Thus the volume of liquid is:
- 165.5 – [66.20(1 – 0.60)] = 139.02 m3. = 139.02(3.28083) = 4910 ft3

- v) The HRT at design average waste water flow can be calculated as:

- HRTdes ave = reactor liquid volume*7.48/[Q*106/(24*60)] = 4910*7.48/[1.5*106/(24*60)] = 35 min
- HRTpeak hr = HRTdes ave/peak hour factor = 35/4 = 9 min

- vi) Calculation of the estimated effluent BOD concentration from the first stage as shown above for the single stage process gives a value of 39 mg/L.
- b) For the second stage:

- i) The BOD loading rate will be (1.5 MGD)(39 mg/L)(8.34 lb/MG/mg/L) = 492.6 lb/day = (492.6 lb/day)*(453.59 g/lb) = 223,430 g BOD/day

Cont..

- ii) Required carrier surface area = (223,430 g/day)/(7.5 g/m2/day) = 29,791 m2.
- Required carrier volume = 29,791 m2/600 m2/m3. = 49.65 m3
- iii) For 40% carrier fill: Required tank volume = 49.65 m3/0.40 = 124.1 m3.
- iv) The volume of liquid in the reactor can be calculated as:
- tank volume – [carrier volume(1 – void %)], Thus the volume of liquid is: 124.1 – [49.65(1 – 0.60)] = 104.3 m3 = 104.3(3.28083) = 3682 ft3
- v) The HRT at design ave ww flow can be calculated as:
- HRTdes ave = reactor liquid volume*7.48/[Q*106/(24*60)] = 3682*7.48/[1.5*106/(24*60)] = 26 min
- HRTpeak hr = HRTdes ave/peak hour factor = 26/4 = 7 min
- Calculation of the estimated effluent BOD concentration from the second stage using the calculation procedure shown above for the single stage process gives a value of 3.0 mg/L.

Cont..

- Required carrier volume = 132,403 m2/600 m2/m3. = 220.7 m3
- For 40% carrier fill: Required tank volume = 220.7 m3/0.40 = 551.7 m3.

- d) The volume of liquid in the reactor can be calculated as:

- tank volume – [carrier volume(1 – void %)],

- Thus the volume of liquid is:
- 551.7 – [220.7(1 – 0.60)] = 463.4 m3 = 463.3*(3.28083) = 16,365 ft3

- e) The HRT at design average waste water flow can be calculated as:
- HRTdes ave = reactor liquid volume x7.48 / [Qx106/(24x60)]
- = 16,365 x7.48 / [1.5x106/(24x60)] = 118 min
- HRTpeak hr = HRTdes ave/peak hour factor = 118/4 = 29 min

Summary for single & 2 stage

- Solution: The results are summarized below:

	Single Stage Process	Two-Stage Process
MBBR Volume:	19,482 ft3	10,228 ft3
Carrier Surf. Area:	132,403 m2	69,512 m2
Est. Effl. BOD:	13 mg/L	3 mg/L

- Note: that the two-stage process requires only about half of the tank volume and half of the carrier quantity in comparison with the single stage process, while achieving a significantly lower estimated effluent BOD.

MEMBRANE BIOREACTOR

- It is an activated sludge process that uses a membrane system which replaces the traditional gravity sedimentation unit

- MBR consists of –

  (1) Biological unit responsible for the biodegradation

  (2) Membrane module for the physical separation of the treated water from mixed liquor

- MBR is configured as:

  (1) Integrated or submerged membrane, involves membranes that are internal to the bioreactor

  (2) External or recirculated membrane, involves recirculation of the mixed liquor through a membrane module outside of bioreactor

MEMBRANE BIOREACTOR

Advantages of MBR Over Conventional Systems

- Excellent effluent quality
- Optimum control of the microbial population and flexibility in operation
- Enables sensitive, slow-growing species (nitrifying bacteria, bacteria capable of degrading complex compounds) to develop and persist in the system even under short SRTs
- Improved oxidation of higher molecular weight soluble compounds
- Able to handle fluctuations in nutrient concentrations

MEMBRANE BIOREACTOR

Other Advantages

- Space requirements, approximately 25–50% of conventional treatment
- It is simple to operate, requiring significantly less operator attention and time
- Disinfection requirements are reduced or eliminated
- Effluent virtually free of suspended solids
- Very low effluent nutrient (nitrogen and phosphorus) concentrations are achievable

MEMBRANE BIOREACTOR

Other Advantages (*Continued*)

- The effluent quality is suitable for recycle and reuse without further treatment

- Produces an effluent that is suitable for a reverse osmosis system, which may be required to remove dissolved solids (salts)

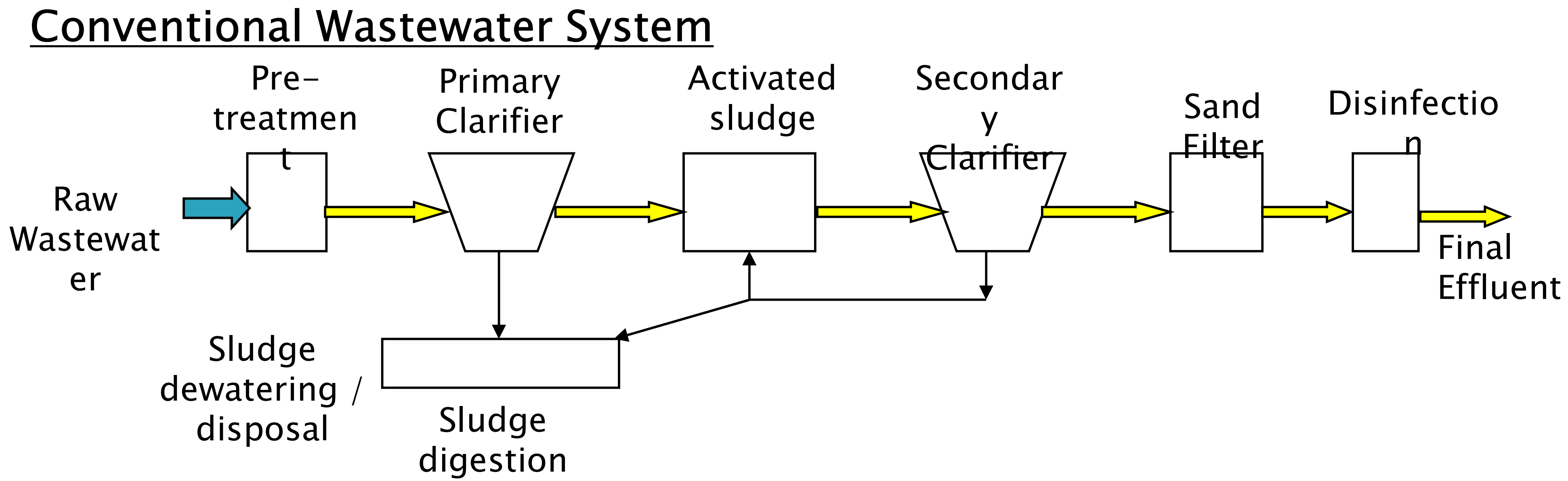
- Modular design for easy expansion

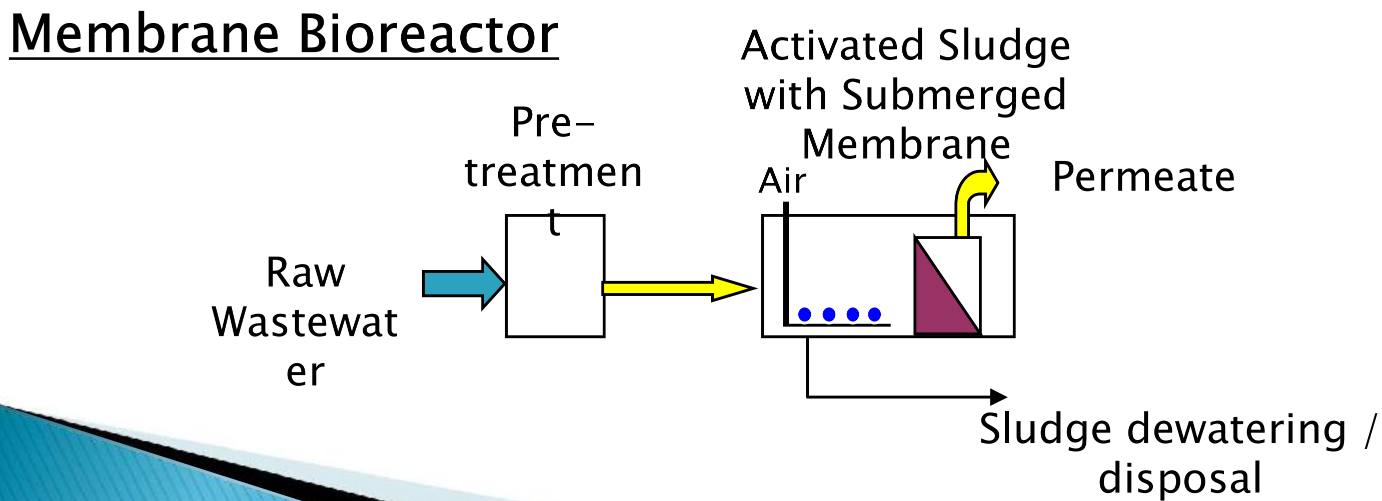
MEMBRANE BIOREACTOR

Disadvantages of MBR

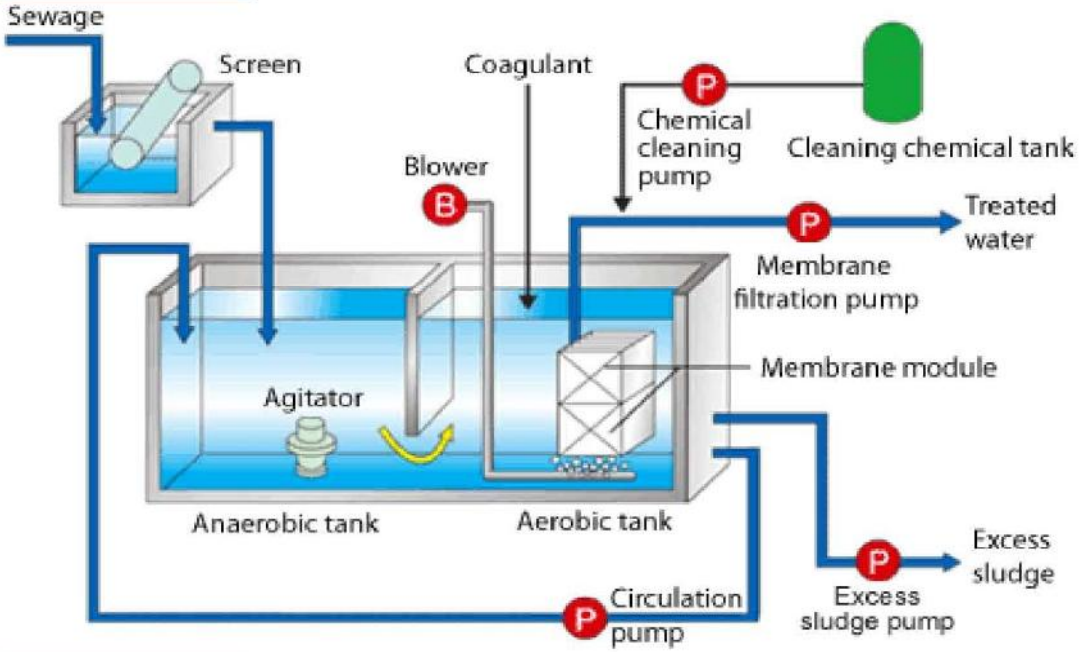
- High capital costs due to expensive membrane units
- High energy costs due to the need for a pressure gradient have characterized the system
- Frequent cleaning of the membranes stops the operation and requires clean water and chemicals
- Since the MBR retains all suspended solids and most soluble organic matter, waste-activated-sludge may exhibit poor filterability and settleability properties
- At high SRTs, inorganic compounds accumulating in the bioreactor can reach concentration levels that can be harmful to the microbial population or membrane structure

MEMBRANE BIOREACTOR





Membrane Bio Reactor - MBR

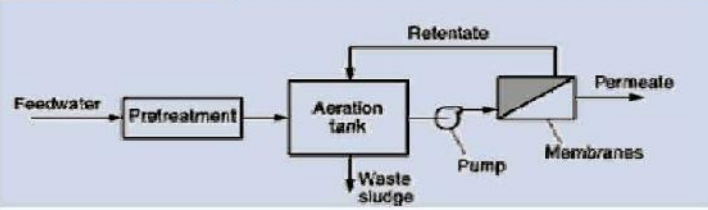


MBR is a hybrid wastewater treatment technology:

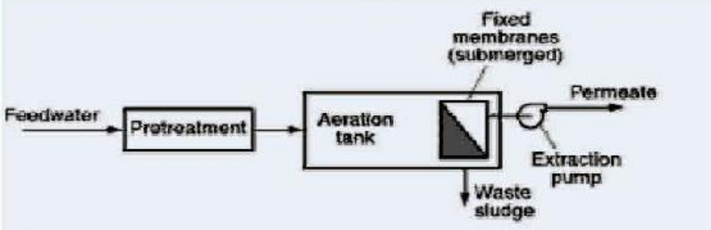
1. Biological treatment by activated sludge and
2. Physical treatment by membrane filtration

Making treated water suitable for re-use.

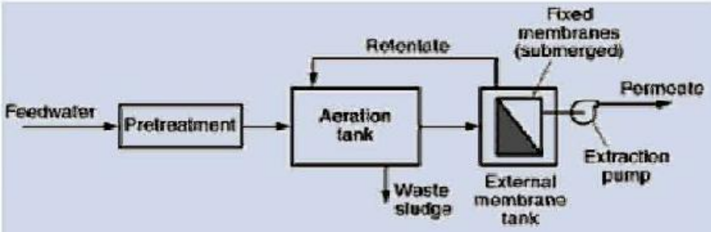
Different Configurations and Types



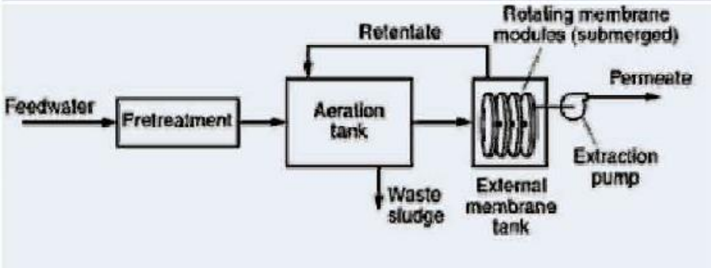
With External pressure-driven membranes



Integrated submerged



With external submerged

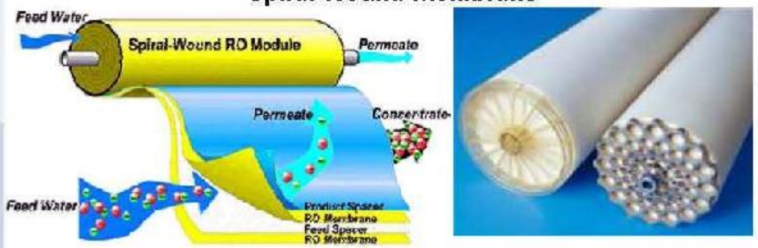


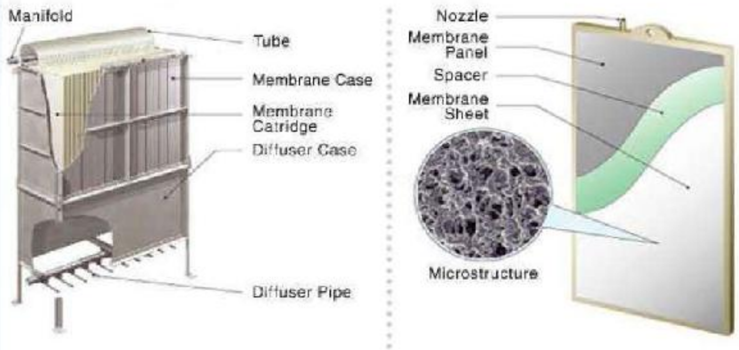
With external submerged rotating membrane

Tubular Type Membrane

Hollow Fiber Membrane

Spiral Wound Membrane

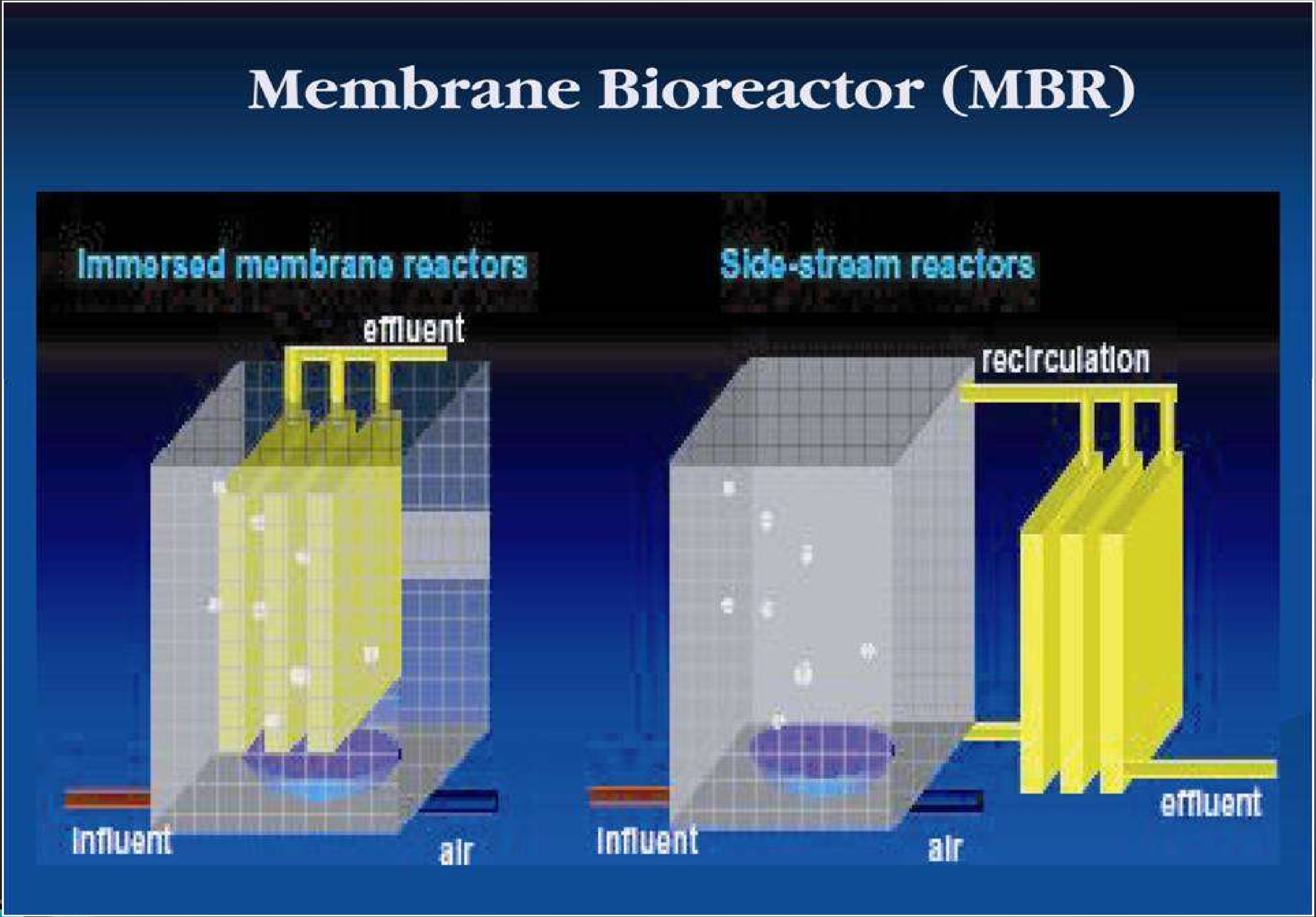




MEMBRANE BIOREACTOR

Membrane
modules

MEMBRANE BIOREACTOR



MBR – DESIGN CRITERIA

PRE- AERATION TANK :

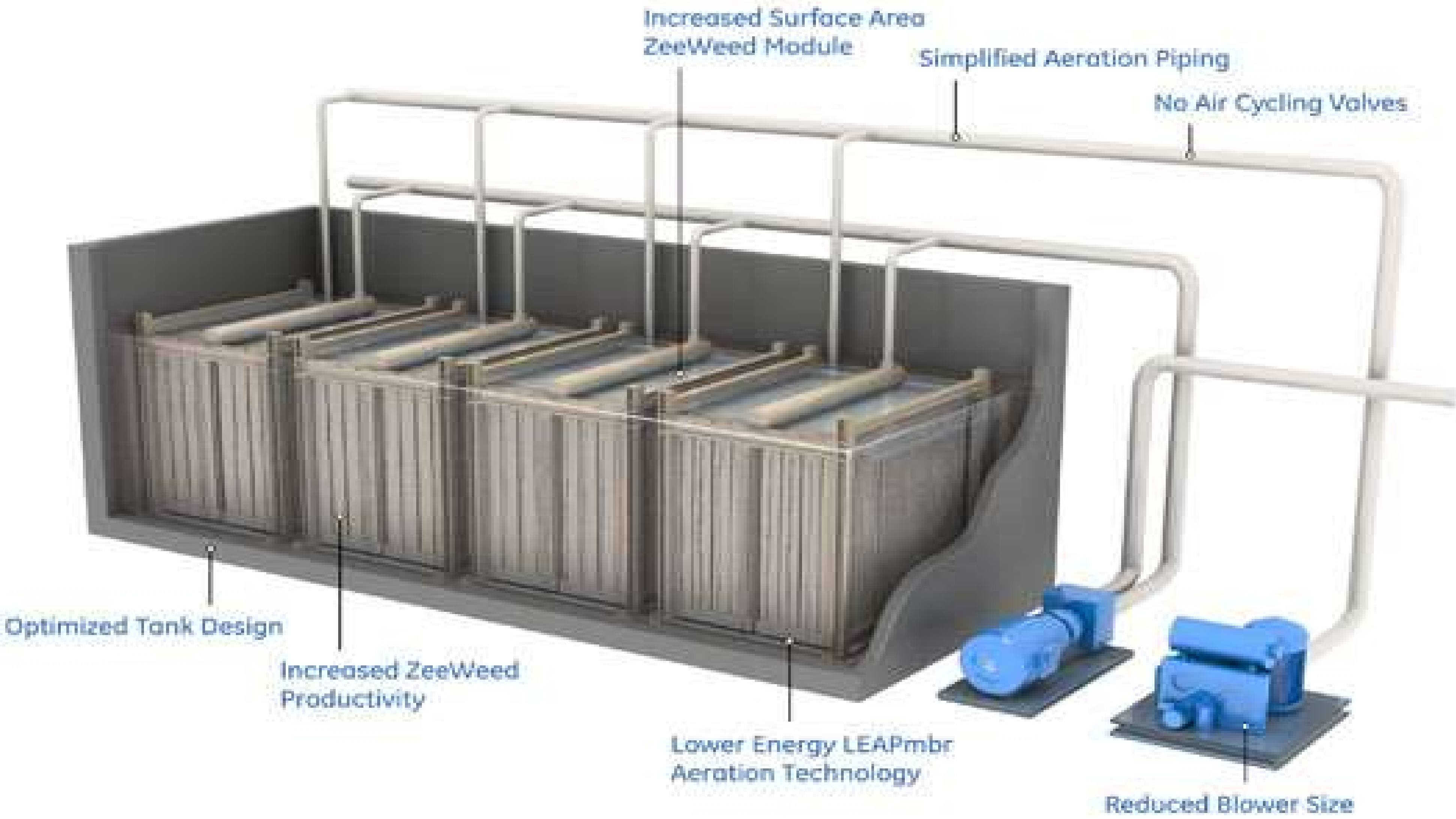
Design Basis – F/M : 0.05-0.25

Fine Screens : 1-2 mm opening

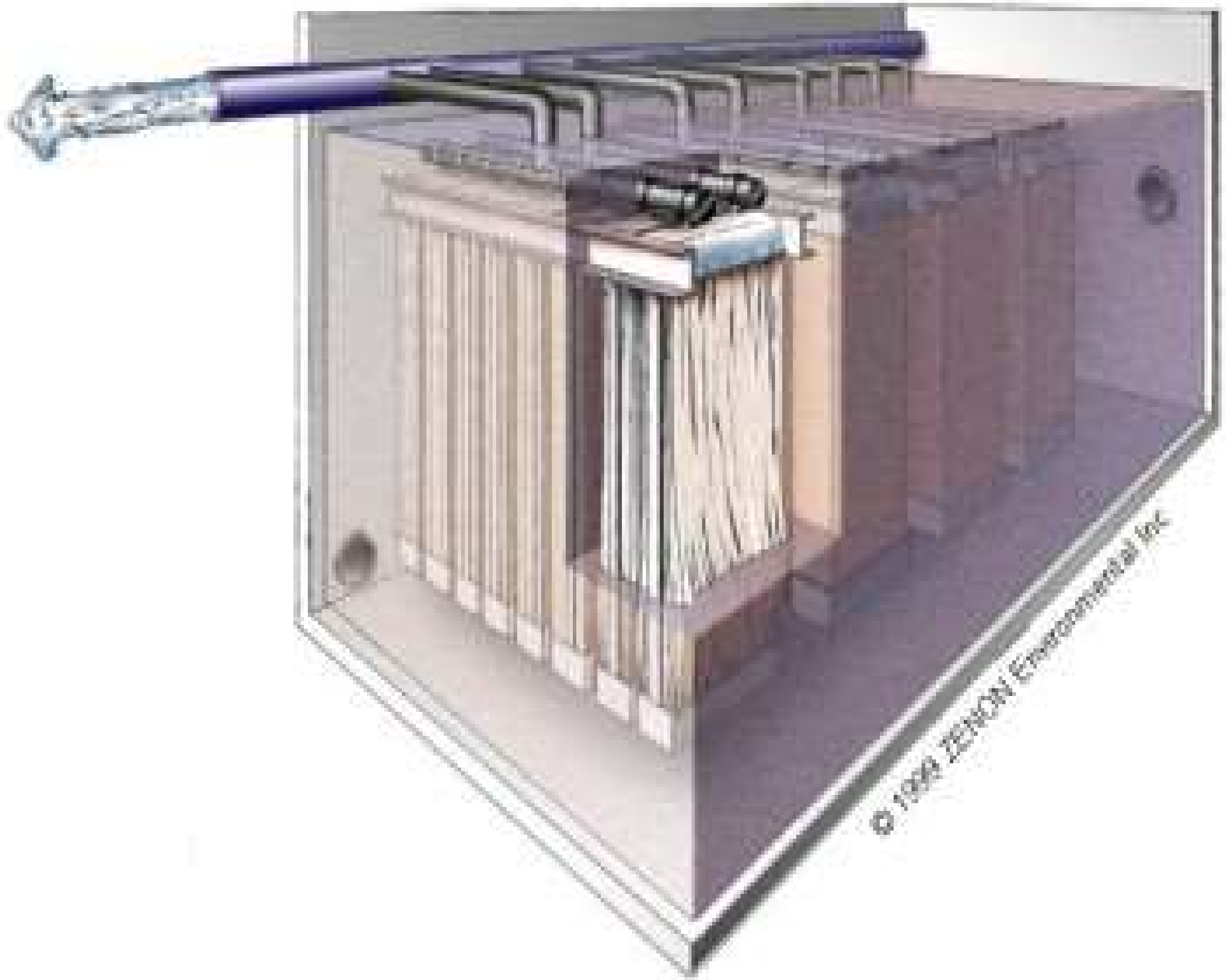
MBR Tanks : Minimum 2

Membrane Flux Rate :

Flat Sheet : 12-25 lmh
Hollow Fibre : 10 – 20 lmh
Sewage : 18 lmh
Industrial :8-10 lmh


Increased Surface Area
ZeeWeed Module
Simplified Aeration Piping
No Air Cycling Valves
Optimized Tank Design
Increased ZeeWeed
Productivity
Lower Energy LEAPmbr
Aeration Technology
Reduced Blower Size

MEMBRANE TECHNOLOGY



- Very High Loading Rates
- Small Footprint
- High Quality Treated Effluent
- Pathogen Removal

TERTIARY TREATMENT

High Rate Solids Contact Clarifier –TSS, Hardness, Colloidal Silica

Disinfection

Pressure Sand Filter –TSS

Activated Carbon Filter –Residual COD

Dual Media Filters –TSS/ Residual COD

Ultrafiltration –Organics which may foul RO membrane

Reverse Osmosis –TDS

DISINFECTION

CHLORINE DISINFECTION: NaOCl / Onsite / Chlorine Tonner

- Recommended Dosage : 5 mg/l in terms of Chlorine (max.)

ULTRAVIOLET DISINFECTION

- UV dose is the product of UV light intensity and time. Dose is sometimes referred to as fluence

  Dose = Intensity x Time = millijoules/(sec)(cm^2) x time = mJ/cm^2

  (Note : 10 J/m^2 = 1,000 microWsec/cm^2 = 1 mJ/cm^2)

- Maximum recommended lamp distance is 20 cm
- No detention time is envisaged and system can be online though recommended detention time is 5-10 secs.
- As per general industry standards, radiant dose of 50-100 mJ/cm^2 should be adequate for disinfection requirement

OZONE DISINFECTION

- Recommended Dosage : 5 -8 mg/l max

PRESSURE SAND FILTRATION

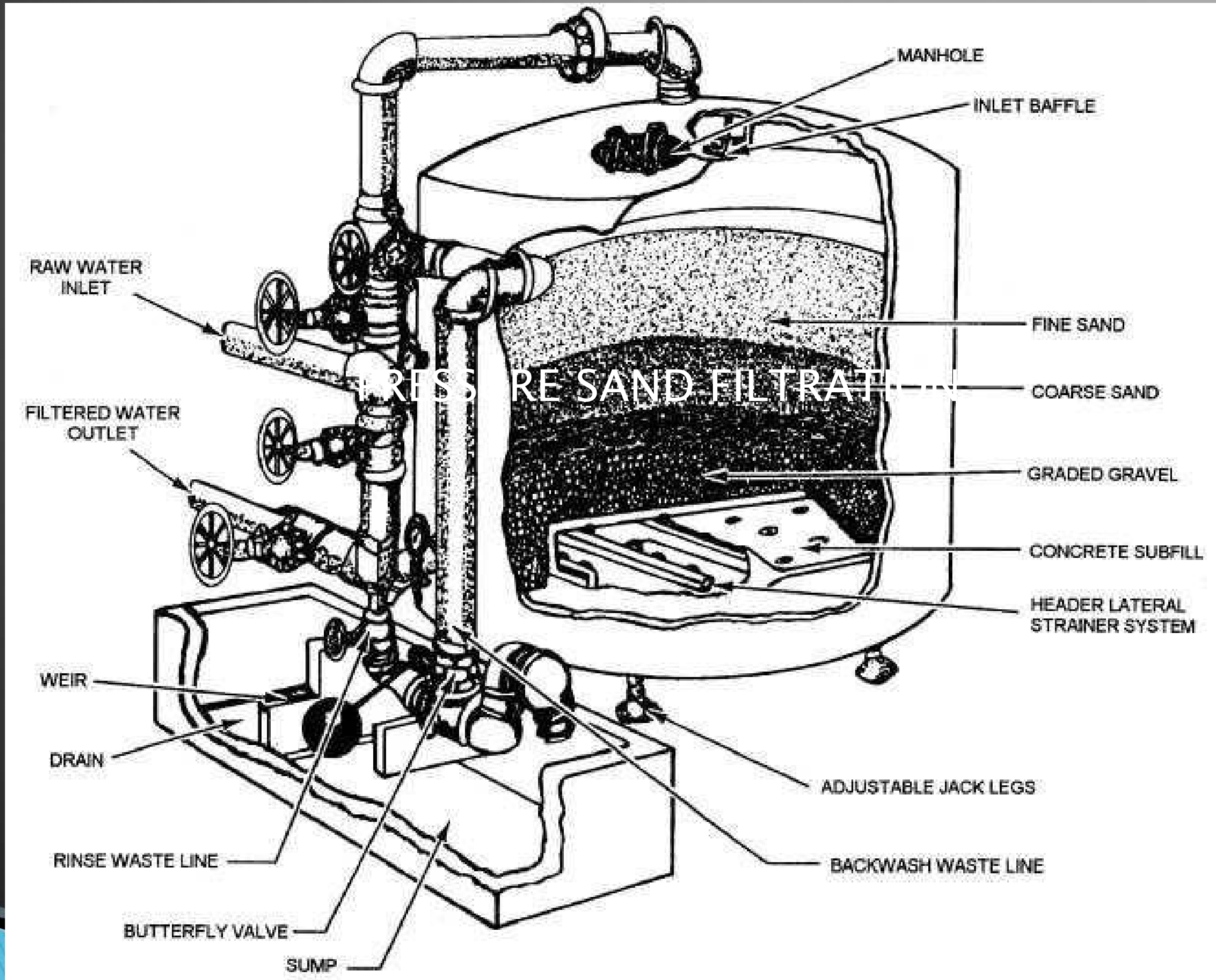
Flow of biologically treated effluent (clarified) through a bed of granular media

• Operating principles: mechanical straining and physical adsorption

• Water fills the pores of the filter medium, and the impurities are adsorbed on the surface of the grains or trapped in the openings

- Loading – 12 m3/m2/hr

PRESSURE SAND FILTRATION



PRESSURE SAND FILTRATION

ACTIVATED CARBON FILTER

Operates on Adsorption principles

- Due to high degree of micro porosity, activated carbons provide a huge surface area
- Adsorption directly related to the surface area of the media
- The ACF consist of Activated Carbon granules supported by very fine quartz filter media
- Loading – 10 m3/m2/hr

DUAL MEDIA FILTER

- Loading – 10 – 15 m3/m2/hr

MEMBRANE TYPES

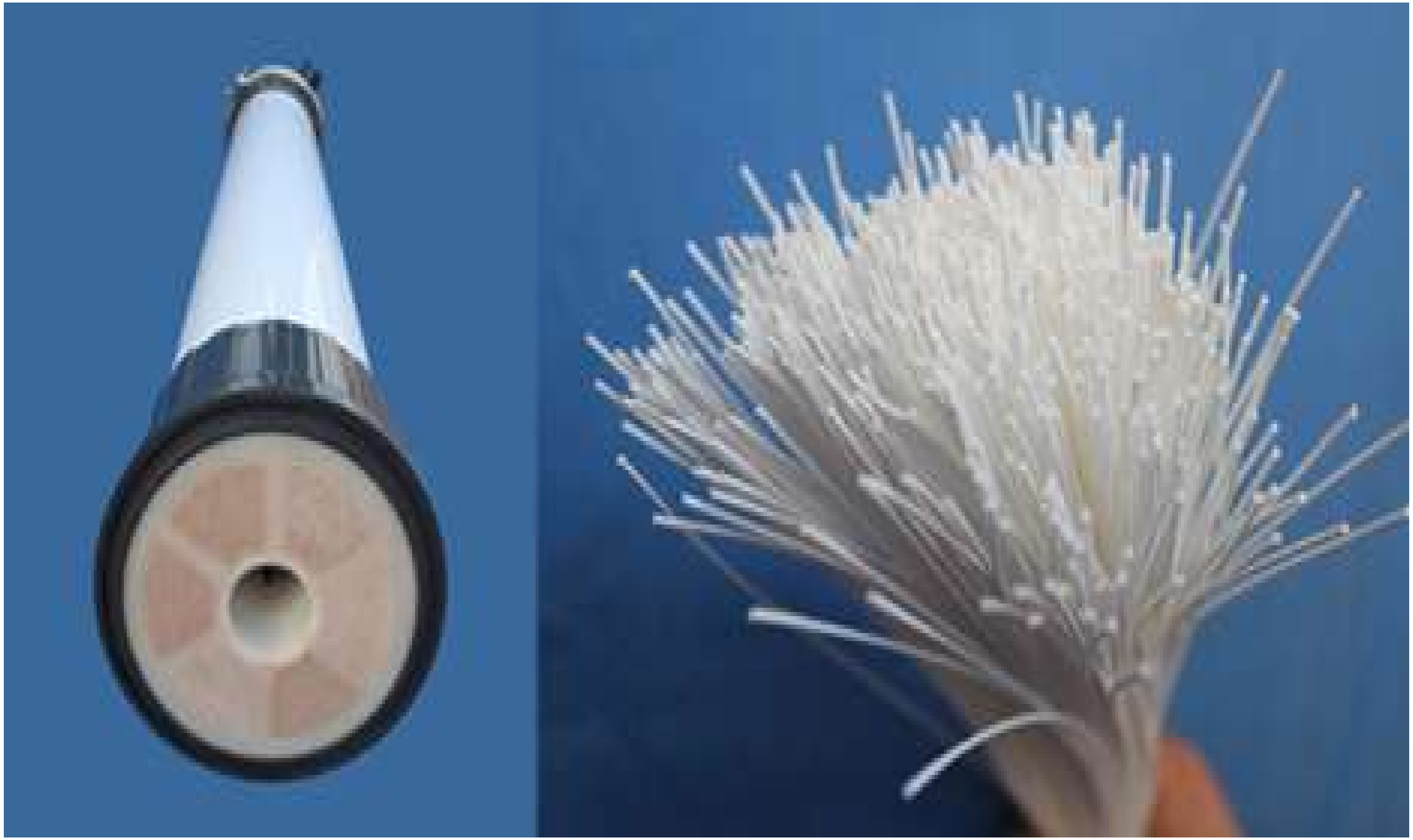
MEMBANE PROCESSES

- MICRO FILTRATION
- ULTRA FILTRATION
- NANO FILTRATION
- REVERSE OSMOSIS
- ELECTRO DIALYSIS

RO Membrane at a Glance

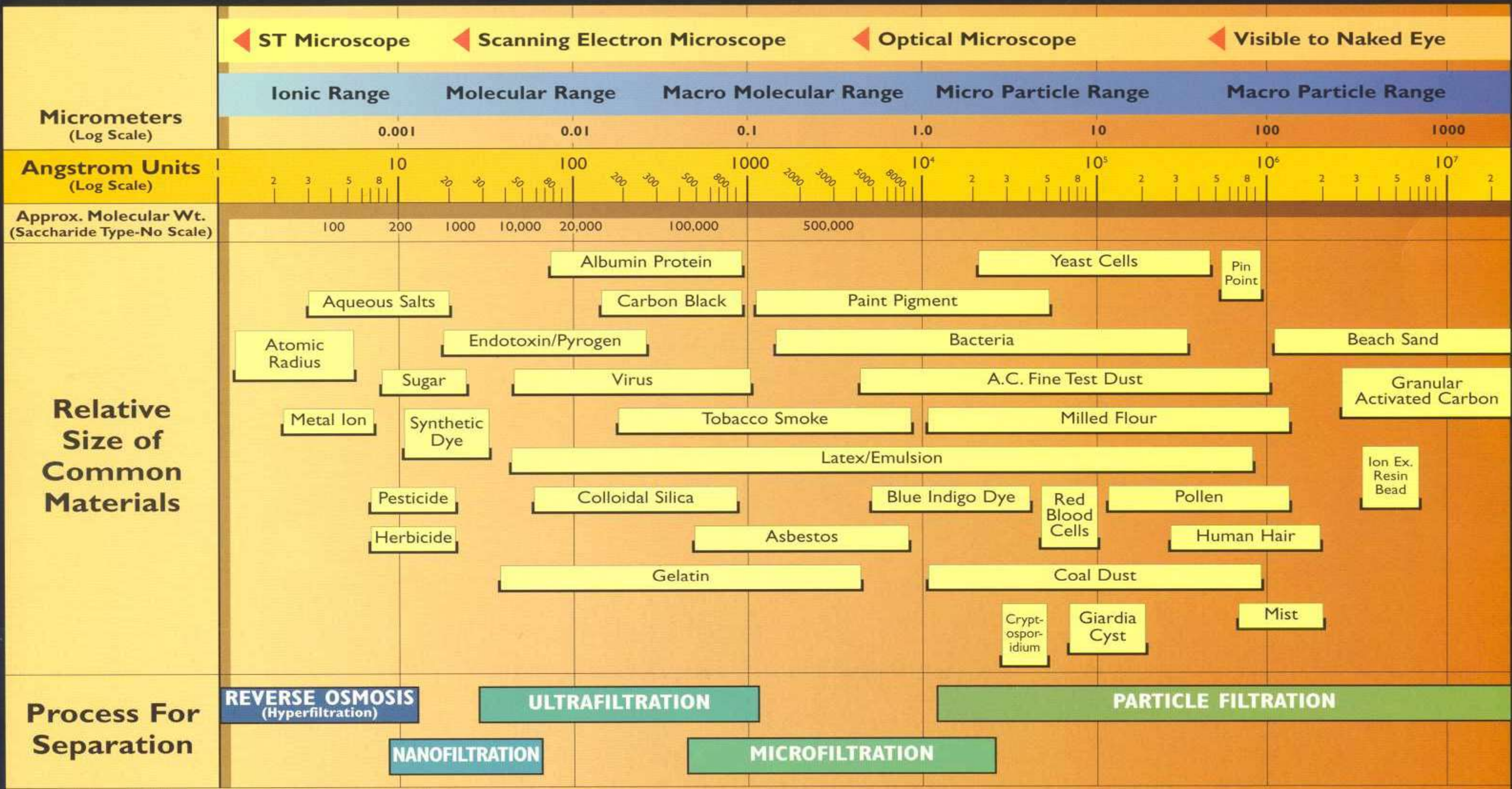
- Domestic & Industrial

UF Membrane



Micron/ Cartridge Filters

OSMONICS The Filtration Spectrum



Note: 1 Micron (1×10^{-6} Meters) ≈ 4×10^{-5} Inches (0.00004 Inches)
1 Angstrom Unit = 10^{-10} Meters = 10^{-4} Micrometers (Microns)

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MEMBRANE FILTRATION PROCESSES A – COMPARISION

Description	Granular Media Particle Filtration	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Application	Removal of residual Suspended solids	Removal of colloidal particulate matter	Removal of particulate matter in macromolecular and molecular range.	Removal of Hardness and DBP	Removal of inorganic dissolved solids and soluble silica.
Separation Range	10 microns and above	0.1 to 10 microns	0.01 to 0.1 microns	0.001 to 0.01 microns	less than 0.001 microns
Molecular Weight Cut-off		> 100,000 Daltons	10,000 - 100,000 Daltons	1,000 - 100,000 Daltons	
Operating pressure	minimum 2 kg/cm2	1-4 kg/cm2	2-7 kg/cm2	6 kg/cm2	10 kg/cm2 & above
Rejection of	Macroparticles usually visible to the naked eye.	Sand, silt, clays, Giardia amblia and Cryptosporidium cysts, algae, partial removal of bacteria but no viruses.	Sand, silt, clays, Giardia amblia and Cryptosporidium cysts, algae, bacteria, humic substances, colloidal silica	Hardness & Viruses	Dissolved solids due to inroganic contaminants including removal of hardness and alkalnity, dissolved silica
Virus removal	No virus removal	MF is not an absolute barrier to viruses. MF to be combined with disinfection process in order to provide total barrier to	UF provideds total barrier to most viruses. However for total virus inactivation disinfection required.	Absolute barrier to cysts and viruses.	Absolute barrier to cysts and viruses.
TOC removal	Possible via adsorption on anthracite or GAC	No removal	Limited removal	TOC to be removed during pretreatment. TOC tolerance 2 to 5 ppm as C.	TOC to be removed during pretreatment. TOC tolerance 2 to 5 ppm as C.

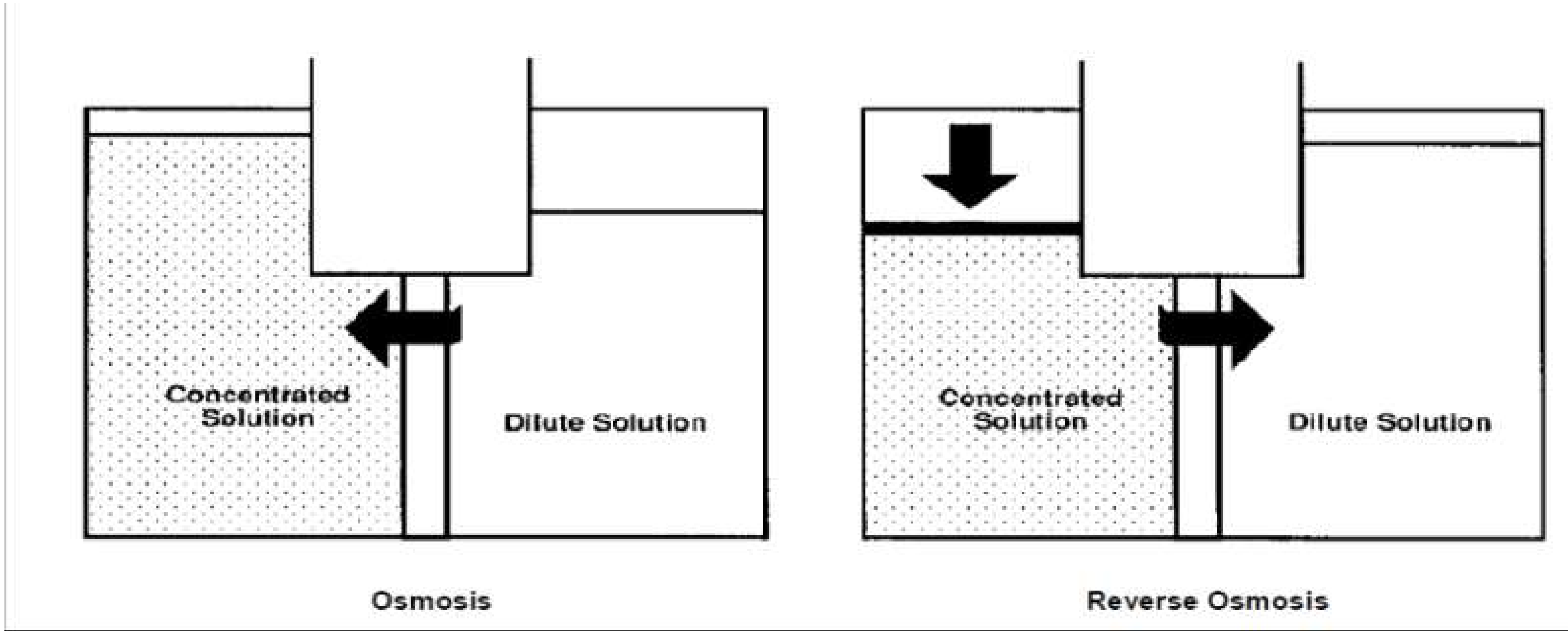
MEMBRANE FILTRATION PROCESSES
A – COMPARISION

Description	Granular Media Particle Filtration	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Water Quality Acheivable	5-10 NTU	1 NTU	0.1 NTU	< 0.1 NTU	< 0.1 NTU
Mode of filtration	Dead-End	Dead-End	Dead-End / Crossflow	Crossflow	Crossflow
System Recovery	90 to 95 %	85 to 90 %	85 to 90 %	80 to 85 %	70% and above for brackish water
Waste stream	5 to 10%	10 to 15 %	10 to 15 %	15 to 20 %	20 to 30 %
Energy Consumption	0.2 kW.hr/m2	0.4 kW.hr/m3	3.0 kW.hr/m3	5.3 kW.hr/m3	10.2 to 18.2 kW.hr/m3
Flux	9720-14400 LMD	405-1600 LMD	405-815 LMD	200-815 LMD	320-490 LMD
Drawbacks	Lowest energy requirement	Moderate energy requirement	Moderate energy requirement	Energy intensive	Energy intensive
	Usually clarification required prior to filtration	Particle filtration pretreatment	Prefiltration using MF required	Extensive pretreatment including dechlorination	Extensive pretreatment including dechlorination
	Efficient operation dependent on effective pretreatment				
	Chlorine tolerated	Chlorine tolerated	Chlorine tolerated	Poor chlorine tolerance.	Poor chlorine tolerance.
	No virus removal. Disinfection required to effect the same.	Partial virus removal. Disinfection required for complete virus removal.	No complete removal of TOC. Disinfection by-products not removed.	Hardness removal- total virus removal & removal of DBP	Can remove NDMA and other related organic compounds
					Considerable brine generated which requires separate treatment

WATER POLISHING TREATMENT

- Unit processes decided primarily on basis of water quality required (0.1 NTU)
- 0.1 NTU Turbidity cannot be achieved using Microfiltration Membranes
- Ultrafiltration required to achieve 0.1 NTU
- UF membranes available in Hollow Fibre and Tubular configurations
- UF capable of handling TOC up to a certain extent
- Total Virus Inactivation by UF

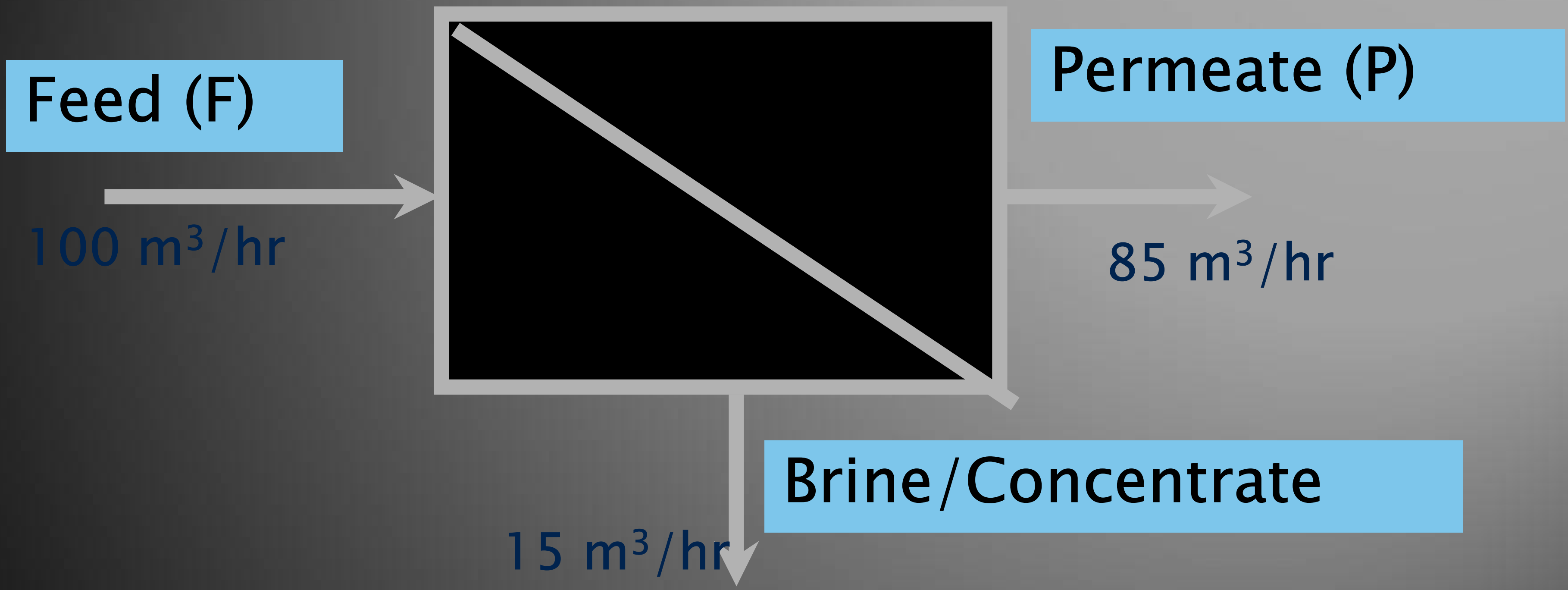
PRINCIPLE OF REVERSE OSMOSIS



By applying pressure that exceeds the osmotic pressure, the reverse effect occurs. Fluids are pressed back through the membrane, while dissolved solids stay behind.

Reverse Osmosis (RO) is a membrane process of purification which removes most of the total dissolved solids (TDS).

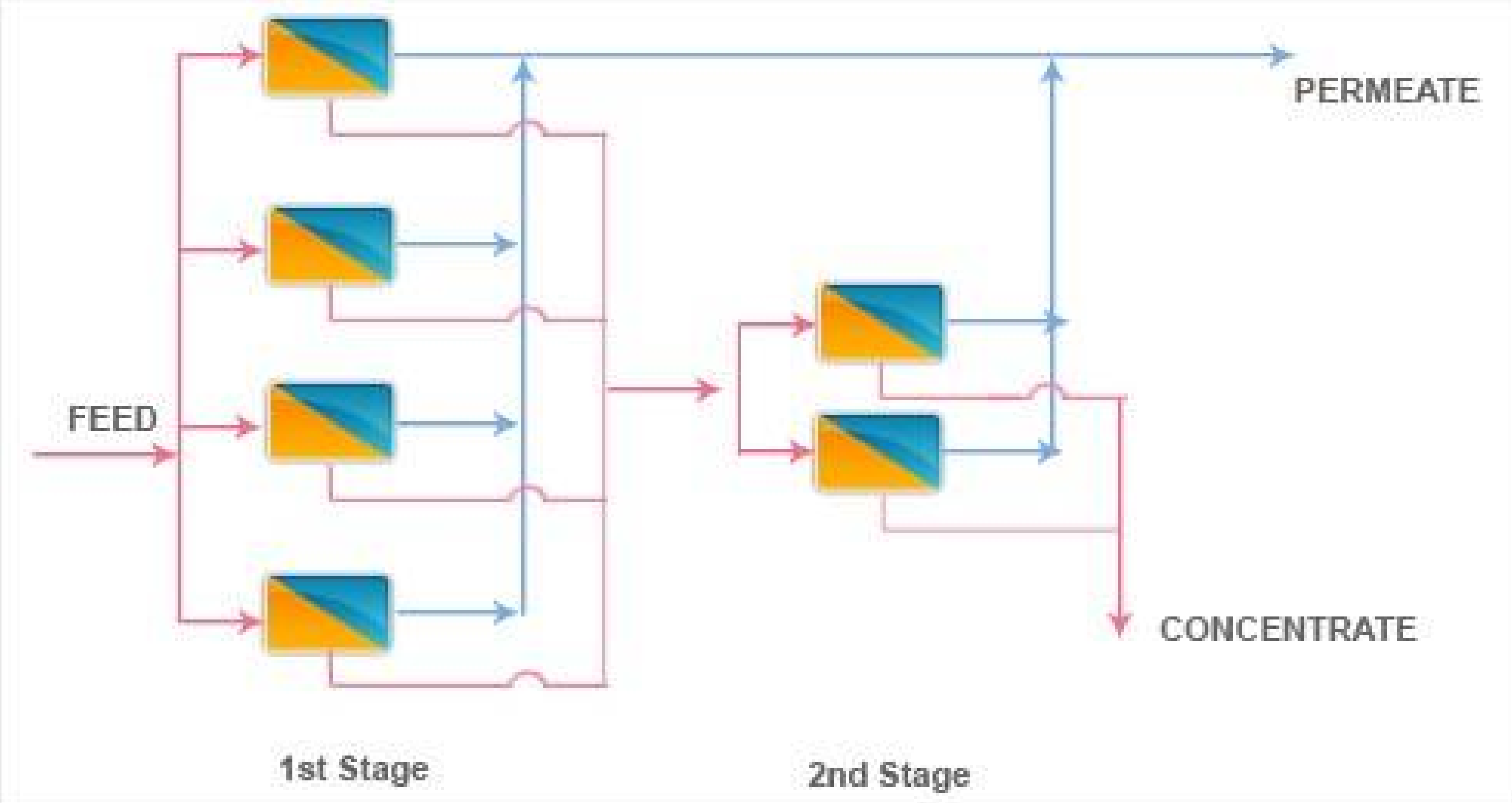
REVERSE OSMOSIS



% Recovery = 85/100 x 100 =85%

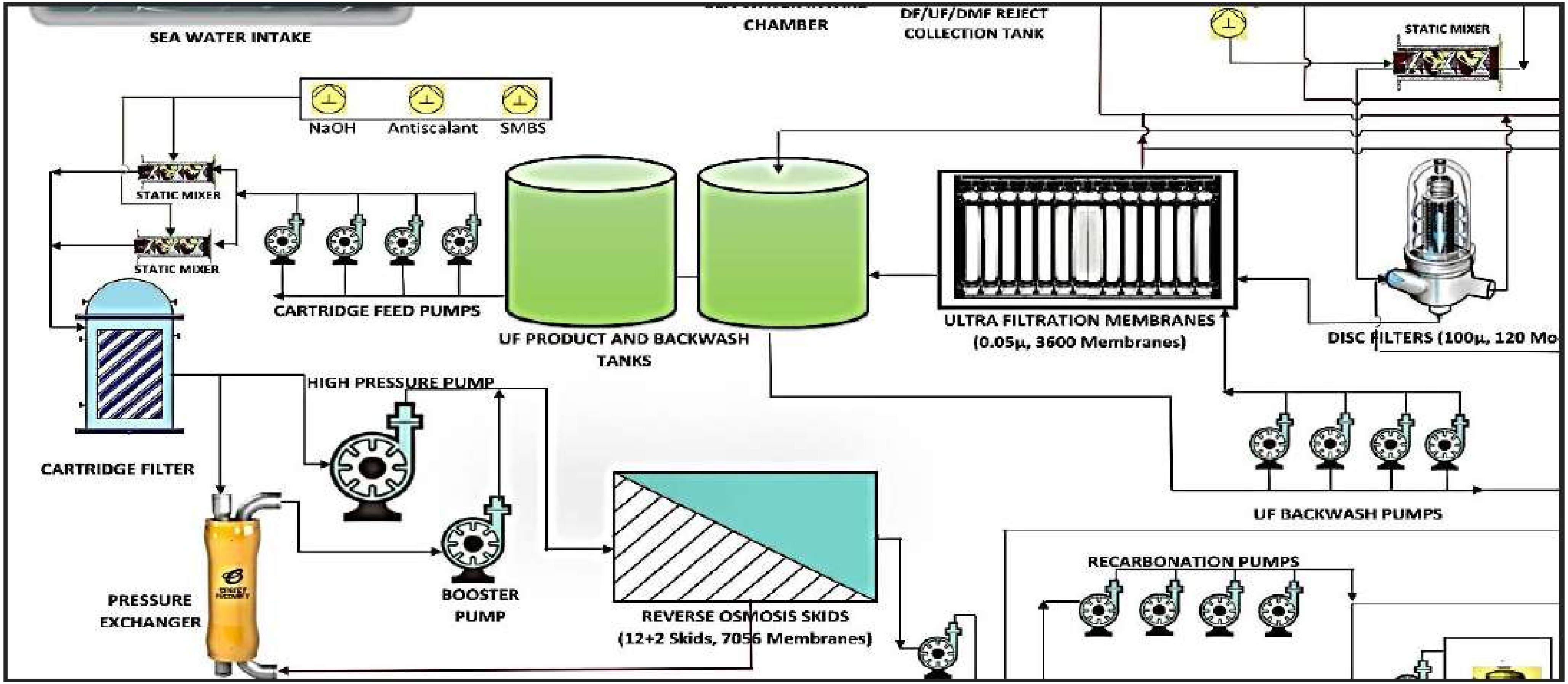
% Recovery = P/F x 100

TWO STAGE RO SYSTEM



TWO STAGE SYSTEM

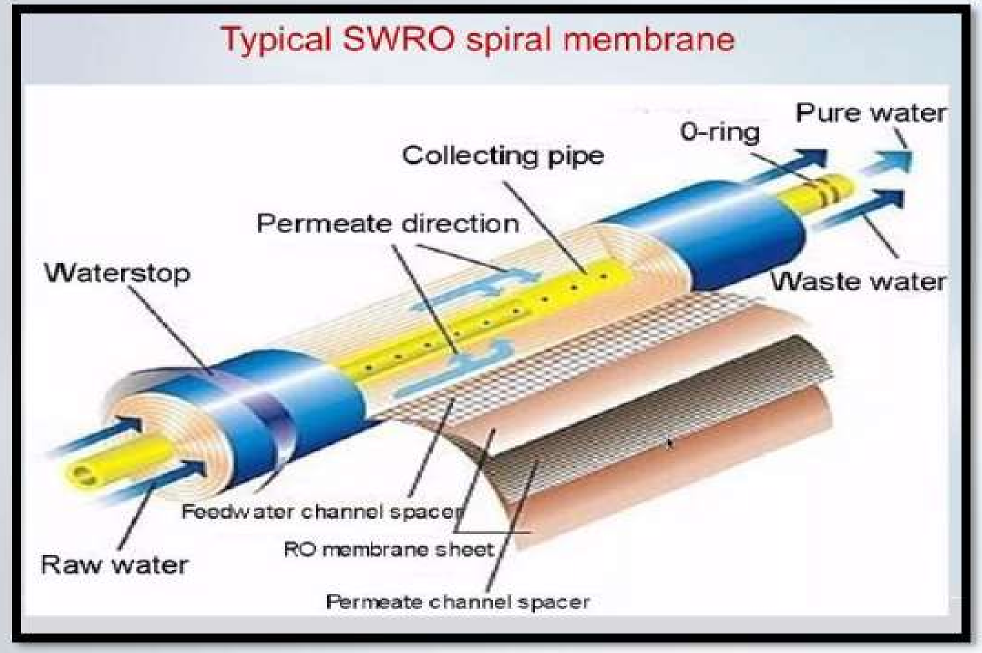
Typical RO System PFD

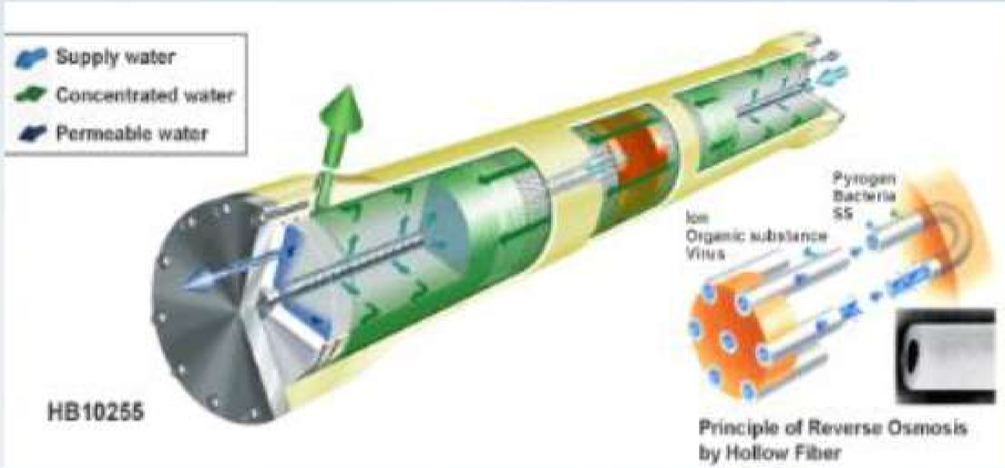


Morphology of RO Membrane

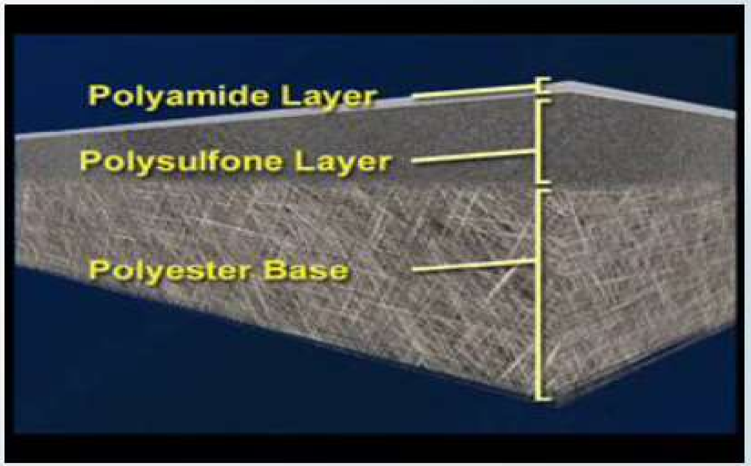
RO Membranes

- ❖ **Spiral wound membranes**
- ❖ **Hollow fiber membranes**





Hollow Fine Membranes- TOYOBO



- 8" Spiral Membrane area increased from 300 ft^2 to 480 ft^2
- Membrane dia increased from 8" to 16"

Spiral wound membrane sheet section

RO MEMBRANE FOULING

- Potential deposition and accumulation of constituents in the feed stream on the membrane – silica scales
- Biological fouling: Various microorganisms can deposit on membrane surface
- Antiscalents are added to prevent scaling where as alkali is used to control fouling
- It is necessary to dechlorinate the effluent as chlorine affects the membrane

UF & RO DESIGN CONSIDERATIONS

ULTRAFILTRATION

BOREWELL WATER	–	UPTO 60 LMH
RIVER WATER	–	UPTO 65 LMH
TREATED EFFLUENT	–	30 –35 LMH

REVERSE OSMOSIS

TDS UPTO 3000 MG/L	–	MAXIMUM 30 LMH
TDS UPTO 10000 MG/L	–	MAXIMUM 22 LMH
TDS ABOVE 10000 MG/L	–	MAXIMUM 13 LMH
TREATED EFFLUENT	–	15-17 LMH

ULTRAFILTRATION (UF) MEMBRANES

- Membranes:
  - Hollow Fibre capillary
  - MOC : Poly Ether Sulphone (PES) or Polyvinylidene Fluoride (PVDF)
- Used as pre-treatment to RO
- Less pressure, less footprint area
- Limitations : High cost, replacement required

Membrane

Module

Rack

ADVANTAGES OF RO

- Attractive at places where there is water scarcity & permeate water is recycled/reused in industry
- Treated water quality is excellent for recycle in industrial processes
- Consistent treated water quality
- Considerably reduces the volume of waste streams

LIMITATIONS OF RO

- High capital cost
- Limited recoveries (50-85 percent) at one stage
- Reject disposal challenges
- High operating cost due to higher energy consumption of high pressure pumps
- Replacement of membranes after 3 years

BIS STANDARD ON DRINKING WATER

Drinking Water Quality Standards

WATER QUALITY PARAMETERS AND BIS STANDARDS FOR VARIOUS CHEMICAL AND BIOLOGICAL CONSTITUENTS

S.No.	Parameters	Drinking water IS 10500 : 2012	
		Permissible Limit	Maximum Limit
1	Odor	Agreeable	Agreeable
2	Taste	Agreeable	Agreeable
3	pH	6.5 to 8.5	No relaxation
4	TDS (mg/l)	500	2000
5	Hardness (as CaCO3) (mg/l)	200	600
6	Alkalinity (as CaCO3) (mg/l)	200	600
7	Nitrate (mg/l)	45	No relaxation
8	Sulfate (mg/l)	200	400
9	Fluoride (mg/l)	1	1.5
10	Chloride (mg/l)	250	1000
11	Turbidity (NTU)	5	10
12	Arsenic (mg/l)	0.01	0.05
13	Copper (mg/l)	0.05	1.5
14	Cadmium (mg/l)	0.003	No relaxation
15	Chromium (mg/l)	0.05	No relaxation
16	Lead (mg/l)	0.01	No relaxation
17	Iron (mg/l)	0.3	No relaxation
18	Zinc (mg/l)	5	15
19	Fecal Coliform (cfu)	0	0
20	E. Coli (cfu)	0	0

WHO GUIDELINES ON DRINKING WATER

- Arsenic 10 μg/L   Barium 10 μg/L   Boron 2400 μg/L
- Chromium 50 μg/L Fluoride 1500 μg/L
- Selenium 40 μg/L Uranium 30 μg/L

- **Organic species:**
- Benzene 10 μg/L Carbon tetrachloride 4 μg/L 1,2-Dichlorobenzene 1000 μg/L
- 1,4-Dichlorobenzene 300 μg/L 1,1-Dichloroethane 30 μg/L
- 1,2-Dichloroethene 50 μg/L Dichloromethane 20 μg/L
- Di(2-ethylhexyl)phthalate 8 μg/L 1,4-Dioxane 50 μg/L
- Edetic acid 600 μg/L Ethylbenzene 300 μg/L
- Hexachlorobutadiene 0.6 μg/L Nitrilotriacetic acid 200 μg/L
- Pentachlorophenol 9 μg/L Styrene 20 μg/L
- Tetrachloroethene 40 μg/L Toluene 700 μg/L
- Trichloroethene 20 μg/L Xylene 500 μg/L

TYPICAL PROCESS SCHEME FOR DRINKING WATER PLANT

- Water from sources → Disinfection -> Filtration ->ACF ->Micron Filter ->
  UF ->RO->Disinfection →Distribution

RO Operating Cost

Operating cost detailes				RO I ST stage			
Overall operating cost per lit of product water							
	M3/hr	hrs	m3 / day	m3/ year	350		
Input flow	30	20	600	210000			
Output	22.5	20	450	157500			
Annual Power							1139600
Annual Chemicals							344400
Annual Membrane replacement							500000
Annual Catridge replcaement							24000
Man power							140000
Total cost							2148000
Cost Rs. per m3 of water produced	100	1000	0.1	157500		1.36	13.64
Power cost		kw each	nos.	Total kw	Op.hrs x 24 x 350	Rs./kw	Rs/year
Raw water pump		3.7	1	3.7	25900	5.5	142450
Dosing pump		0.1	2	0.2	1400	5.5	7700
High pressure pump		25.7	1	25.7	179900	5.5	989450
Total				29.6			1139600
Chemical cost							
Dosage	mg/lit	kg or lit/day	yearly	Rate /kg			Rs/year
Anticsalanet	4	2.4	840	400			336000
Ant bactrial shut off	0	0	0	20			0
Acid / Alkali	2	1.2	420	20			8400
							344400
Membrane	Total	Nos. replaced per year	Replacement Period years	Rs. / Membrane	Total Rs.		
RO	30	10	3	50000	500000		
Catridge	Nos. replaced per year	Replacement Period	Rs. / Cartridge	Total Rs.			
5 Micron Cartridge	48	Monthly	500	24000			
Man Power	Nos	Rs/day		Total			
	1	400		140000			

COMPARISON OF ASP/MBR/MBBR/SBR TECHNOLOGY

Description	Activated Sludge Process (ASP)	Membrane Bio Reactor (MBR)	Moving Bed Biological Reactor (MBBR)	Sequential Batch Reactor (SBR)
End use	Gardening	Recycle	Gardening, flushing	Gardening, recycle
SRT	Not sensitive to low SRT	Sensitive to low SRT, can cause membrane fouling	Not much sensitive	Highly sensitive as can affect the quality of treated water
Pretreatment	Coarse screening	Fine screening is must	Coarse screening	Coarse screening
Peak flow	Well addressed	Troublesome to handle	Addressed	Well Addressed
Safety	Good as electrical connections are not inside tank	Good	Good	Good as controlled by PLC
Capital cost	Low	High	Intermediate	Intermediate
Operating cost	Low	High due to maintenance of membranes	Moderate	Moderate
Man power	Skilful	Highly skillful since fully automated	Skillful	Highly skillful since filly automated

Comparison of Secondary Technologies

Parameters	ASP	TF	UASB+FPU	UASB+EAS	SBR	MBR	MBBR
OVERALL HRT (WHOLE SYSTEM)	12 -14 hrs	13 -14 hrs	1.33 -1.5 days	14 -18 hrs	14 -16 hrs	12 -14 hrs	8 -12 hrs
BOD REMOVAL, %	85 -95	80 -90	80 -88	80 -95	90 -95	95 -98	85 -95
COD REMOVAL, %	80 -90	85 -90	80 -85	80 -90	88 -96	95 -100	80 -90
TSS REMOVAL, %	85 -90	75 -85	80 -85	85 -90	90 -96	98 -100	85 -95
FAECAL COLIFORM REMOVAL, LOG UNIT	upto 3 < 4	upto 2 < 3	upto 1 < 2	upto 2 < 4	upto 2 < 4	upto 6 < 7	upto 2 < 4
AVERAGE AREA REQUIRED (M^2/MLD)	1,820	1,620	1,800	1,450	300	800	450
BIOGAS GENERATION M3	55 -70	55 -70	35 -50	35 -50	Nil	Nil	Nil
BIO -ENERGY GENERATION (KWH)	25 -35	25 -35	20 -30	20 -30	Nil	Nil	Nil
ECONOMIC LIFE IN YEARS	30	30	30	30	30	30	30

(Source: MoEF, 2004, 2005 and 2006, UPJN 2006, N. Sato et al. 2006, N. Khalil et al. 2006, EPA USA 2000, Urban Plan Consulting & Engg. Pvt. Ltd., New Delhi, 07)

1. Disinfection through Chlorination technique is considered for all the technologies except where not required. Land required is also included.
2. Manpower requirement varies from technology to technology. Annual cost for each category is taken as per the NRCD norms.
3. Assumed Land Cost- Rs 9 lacs/ acre

Role of Operator

Role of Operator

- **Responsible for running the STP properly and efficiently**

  - Understanding the technology, process and equipment thoroughly
  - Ensuring the WWTP meets effluent limits
  - Monitoring and Sampling
  - Reading gauges and meters
  - Recording and interpreting of data
  - Preparing and submitting Reports

Role of Operator

- **Responsible for running the STP properly and efficiently**

  - Identifying gaps and carrying out investigations
  - Carrying out studies and improvements
  - Maintaining inventory of equipment and spare parts
  - Performing routine maintenance and repairs
  - Painting equipment and buildings
  - Maintaining facility grounds
  - Liason/explaining with Regulatory authorities, management, public
  - Budgeting
  - Other

Monitoring, Sampling
&
Controls

Monitoring

- **Monitoring Plan (Sampling, Analysis and Monitoring Plan)**
- **Pollutants to be Monitored is driven by:**
  - **- Limits**
  - **- Raw Wastewater Characteristics**
  - **- Process Performance – e.g., Removals of pollutants**
  - **- Process Control – e.g., MLSS, MLVSS, pH**
  - **- Information and Investigation**
- **Pollutants & Parameters**
  - **- Process or Unit Specific**
  - **- Flow, Temp, pH, Pressure, Levels, ORP etc**
  - **- BOD, COD, metals, nitrogen, phosphorus etc**
  - **- Frequency**
- **Location**
  - **– Inlet, Outlet, intermediate of Unit process or system**

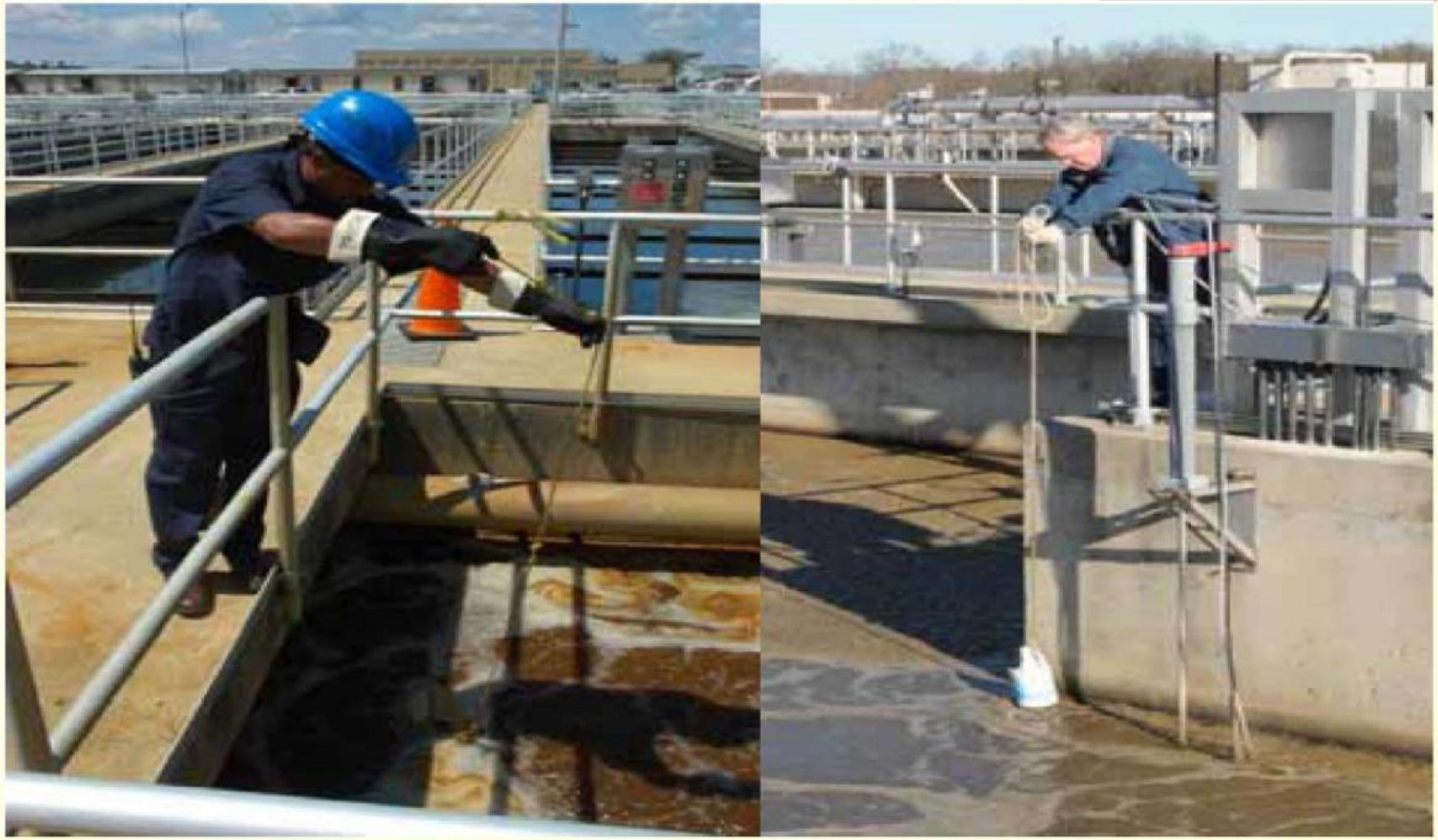
Sampling, Analysis and Reporting

- **Sampling**
  - Grab, Composite
  - Glass bottles for Oil & Grease
  - Temperature and pH
- **Sample Preservation**
  - Time – how long?
  - Acidic for metals
  - Temperature
  - Other – follow procedure
- **Analysis – Standard Methods**
- **Reporting – NH3 as N or NH3? Metals Compounds as metal?
  Total Nitrogen as N or NH3? BOD3 or BOD5?**

Sampling Fundamentals

- Representative sample
- Well mixed Location
- Sample containers must be marked properly
- Preservation

Grab Sampling



Source: Wastewater Treatment Training Manual, WEF, 2009

Composite Sampling

Source: Wastewater Treatment Training Manual, WEF, 2009

Activated Sludge Sampling Plan

Sampling Location	Analysis	Use	Frequency	Type
Primary Effluent	BOD	PP	D	C
	TSS	PP	D	C
	pH	PC	D	G
Mixed Liquor	DO	PC	D	G
	Temperature	PC	D	G
	TSS	PC	D	C
	VSS	PC	D	C
	NO3-N	PC	W	G
Return Sludge	TSS	PC	D	C
Secondary Clarifier Effluent	BOD	PP	D	C
	TSS	PP	D	C
	DO	PP	D	G
	Fecal Coliform	PP	D	G
	Chlorine Residual	PP	D	G
	pH	PP	D	G
	TKN	PP	W	G
	NH3	PP	W	G
	NO2-N	PP	W	G
	NO3-N	PP	W	G

Source: MOP 11, WEF, 2007

Activated Sludge Sampling Plan

- D = Daily
- W = Weekly
- M = Monthly

- C = Composite Sample
- G = Grab Sample

- PC = Process Control
- PP = Process Peformance

Process Control & Monitoring

- Controls - Manual, Semi-Automatic, Automatic
- Controls – Local, Remote, Both
- Automatic
  - PLC, SCADA
  - Set Point
- Automatic
  - Better Control
  - Low Operating Cost
  - High Capital Cost
- Instrumentation & Sensors
  - Online measurement
  - Manual Sampling and Analyses
  - Backup

WASTEWATER TREATMENT AND PURIFICATION TECHNOLOGIES

"The significant problems we face today cannot be solved at the same level of thinking we were at when we created them"

Albert Einstein

Any Questions

Contact Details

THANK YOU

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