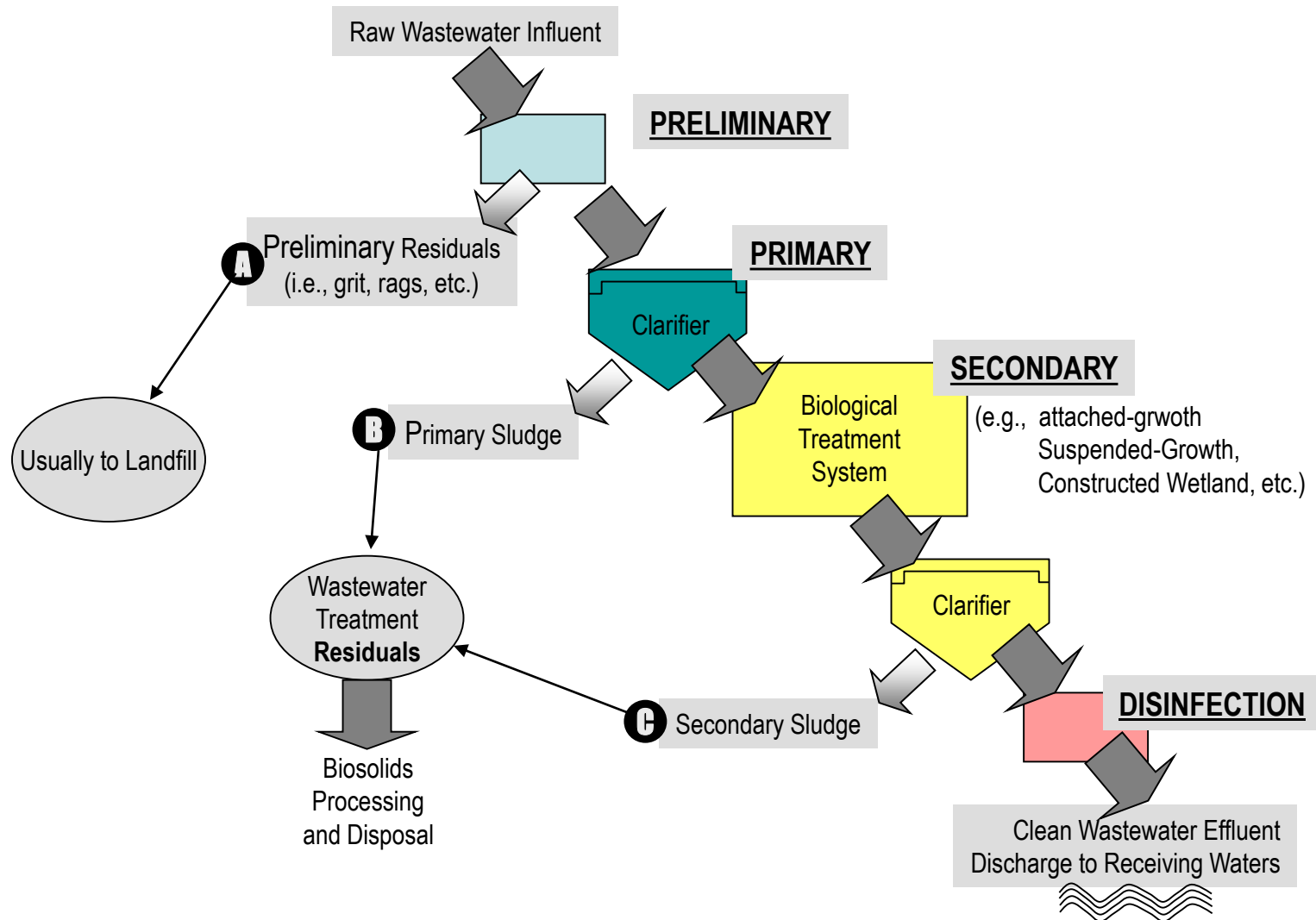


General overview of plant components



Biological wastewater (WW) treatment

- To remove the suspended solids & the dissolved organic load from the WW by using microbial populations.
- The microorganisms are responsible for
 - degradation of the organic matter
 - they can be classified into
 - aerobic (require oxygen for their metabolism)
 - anaerobic (grow in absence of oxygen)
 - facultative (can proliferate either in absence or presence of oxygen).

Biological wastewater (WW) treatment

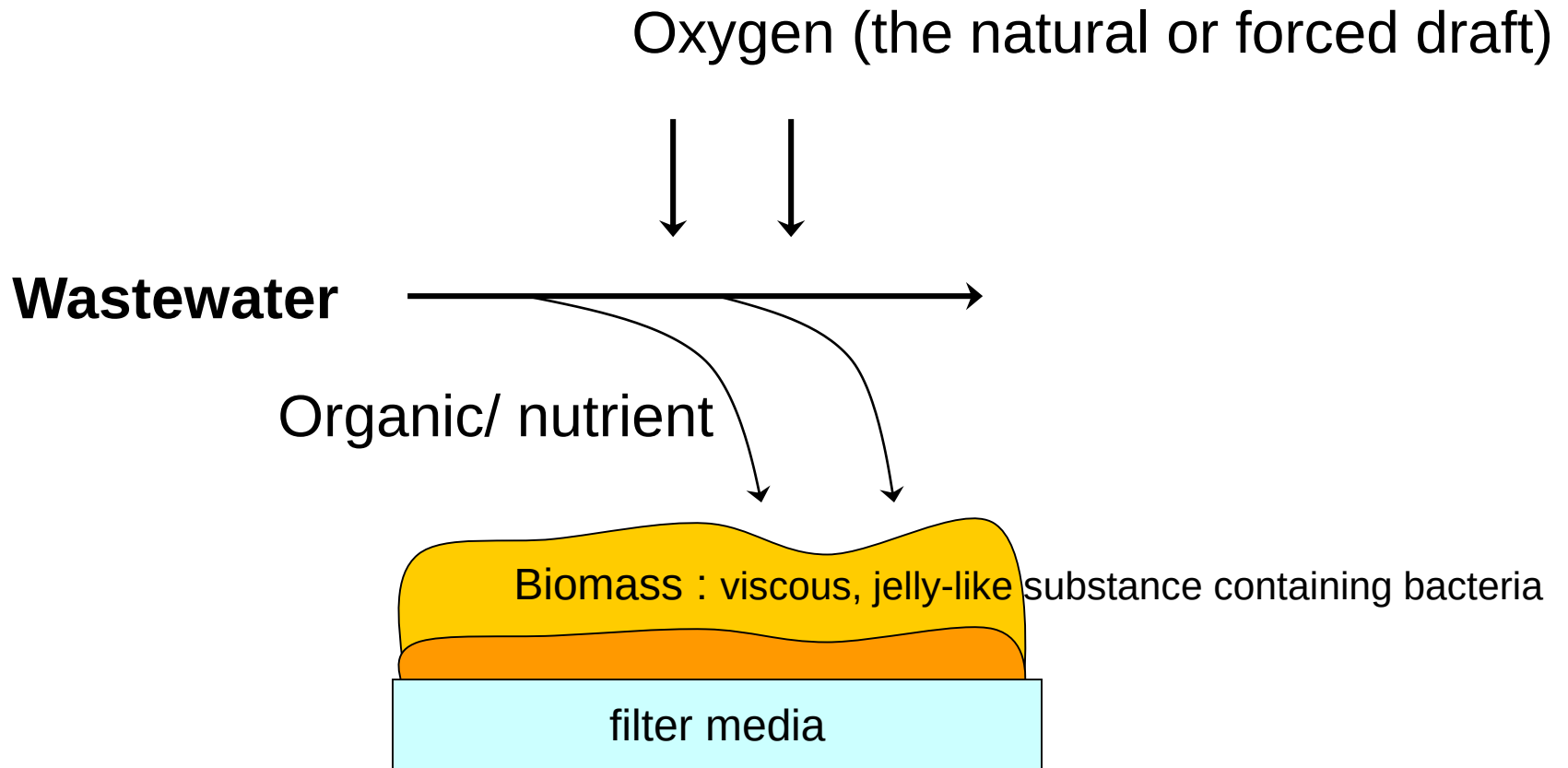
- If the micro-organisms are suspended in the WW during biological operation
 - suspended growth processes
 - Recycling of settled biomass is required.
- While the micro-organisms that are attached to a surface over which they grow
 - attached growth processes
 - The biomass attached to media (ex. rock, plastic, wood)
 - Recycling of settled biomass is not required.

Attached Growth Process

What can this process do?

1. Remove Nutrient
2. Remove dissolved organic solids
3. Remove suspended organic solids
4. Remove suspended solids

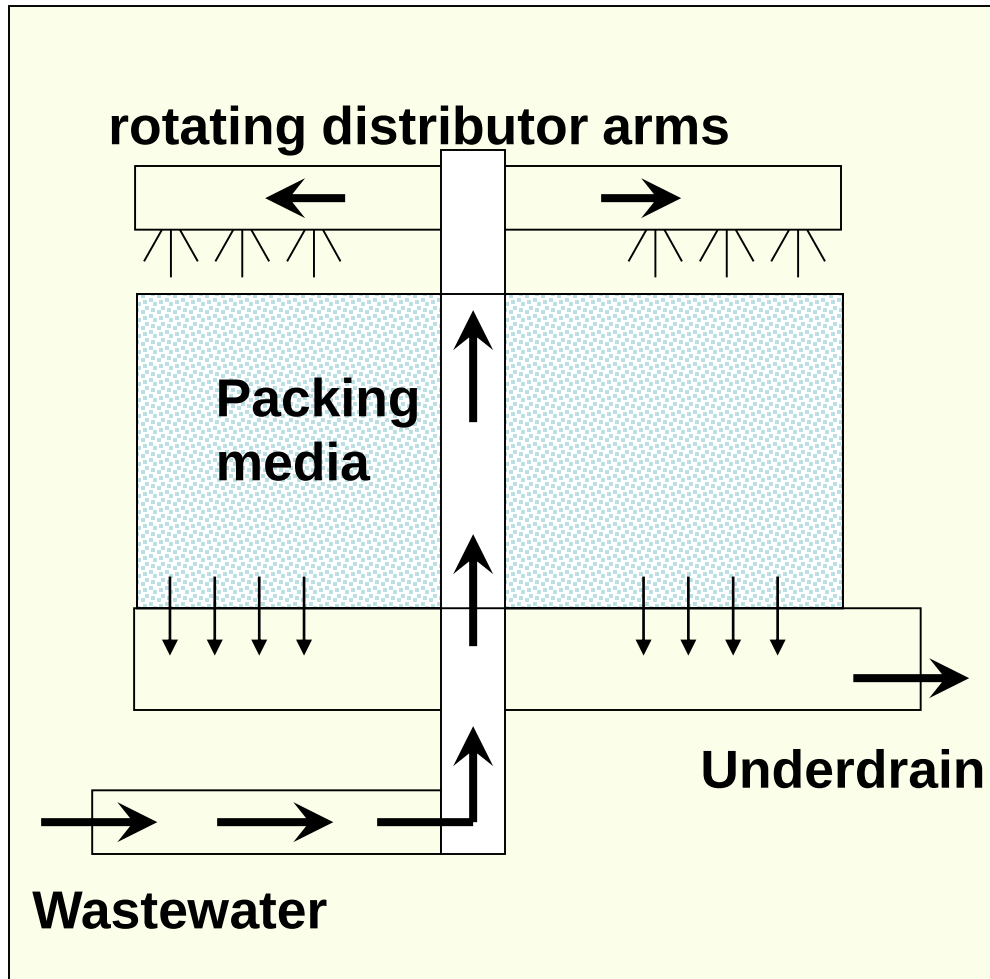
Cross-section of an attached growth biomass film



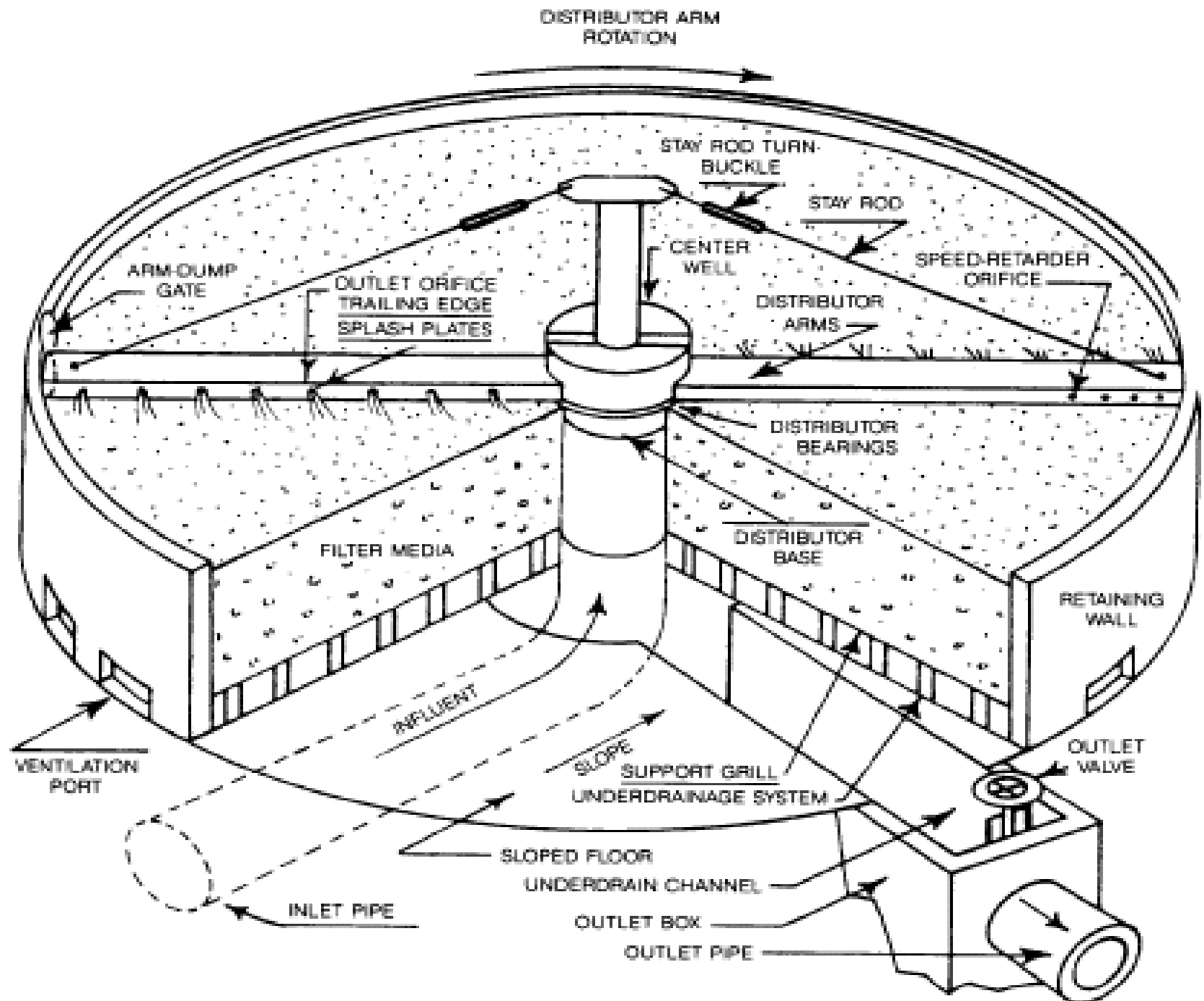
Attached Growth Process

- Trickling filter (TF)
- Rotating biological contactor (RBC)

Trickling Filter (TF)- side view



- TF consists of:
 - A rotating arm that sprays wastewater over a filter medium.
 - Filter medium: rocks, plastic, or other material.
- The water is collected at the bottom of the filter for further treatment.

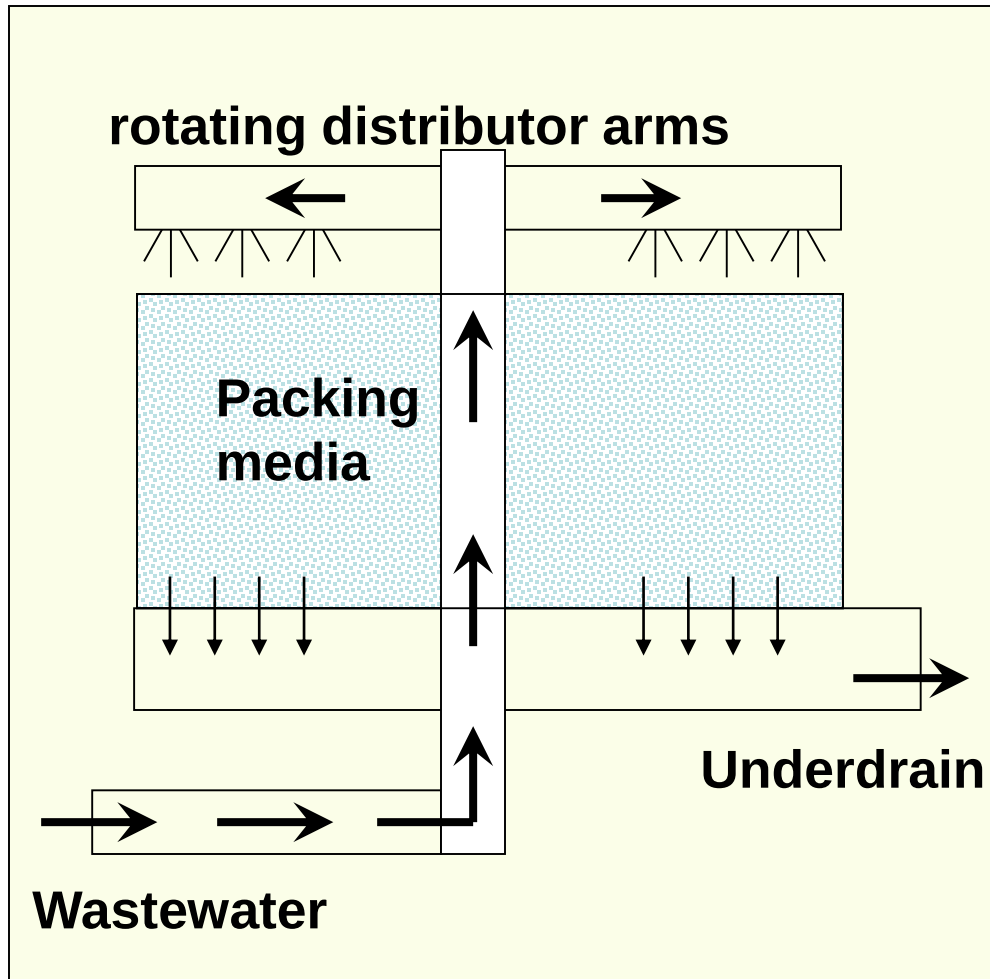




Design consideration

- Influent wastewater characteristics
- Degree of treatment anticipated (BOD & TSS removal).
- Temperature range of applied wastewater
- Pretreatment processes
- Type of filter media
- Recirculation rate
- Hydraulic and organic loadings applied to the filter
- Underdrainage and ventilation systems

Trickling Filter (TF)- side view



- TF consists of:
 - A rotating arm that sprays wastewater over a filter medium.
 - Filter medium: rocks, plastic, or other material.
- The water is collected at the bottom of the filter for further treatment.

Design consideration - Pretreatment

- Trickling filters shall be preceded by primary clarifiers equipped with scum and grease collecting devices, or other suitable pretreatment facilities.
- If fine screening is provided the screen size shall have from 0.03 to 0.06 inch openings.
- Bar screens are not suitable as the sole means of primary treatment.

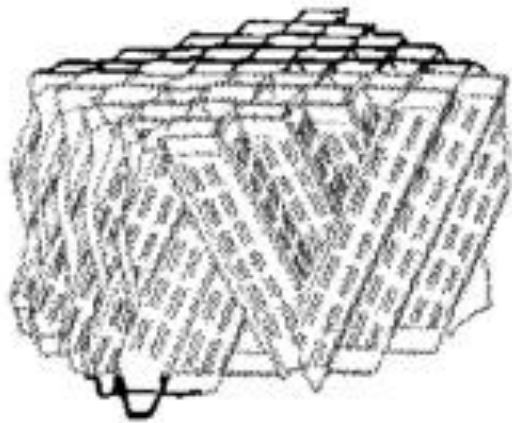
Design consideration

- Influent wastewater characteristics
- Degree of treatment anticipated (BOD & TSS removal).
- Temperature range of applied wastewater
- Pretreatment processes
- **Type of filter media**
- Recirculation rate
- Hydraulic and organic loadings applied to the filter
- Underdrainage and ventilation systems

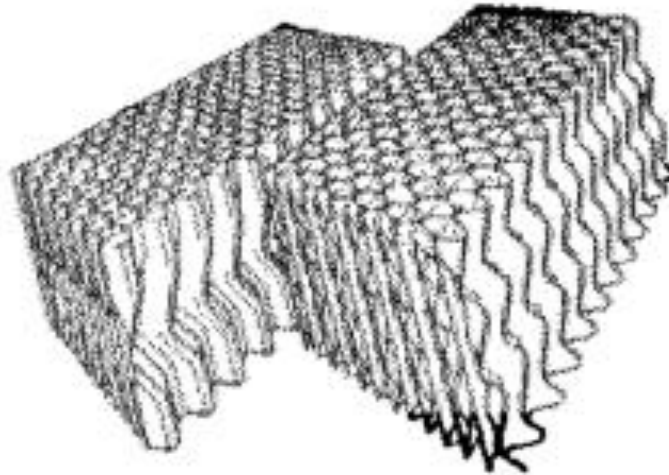
Filter media

- Crushed rock
 - Durable & insoluble
 - Locally available
 - But, reduce the void spaces for passage of air
 - Less surface area per volume for biological growth
- Plastic media
 - Random packing media
 - Modular packing media

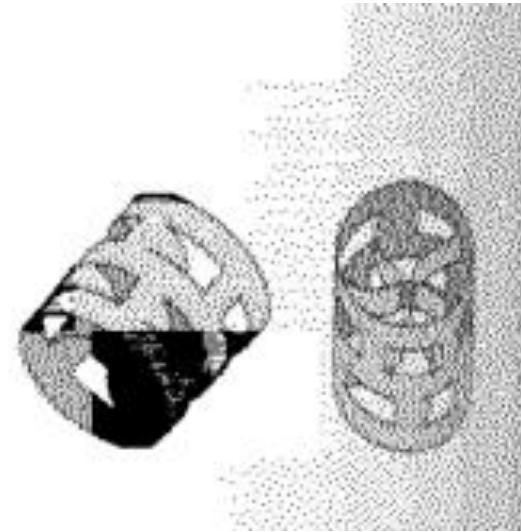
Filter media



Cross-flow



Tubular



Pall rings

Schematic diagrams of modular and random packed media used in fixed-film treatment systems (Source: Bordacs and Young, 1998)

Design consideration - Filter media

The ideal filter packing is material that

- has a high surface area per unit of volume
- is low in cost
- has a high durability
- has a high enough porosity so that clogging is minimized
- provides good air circulation

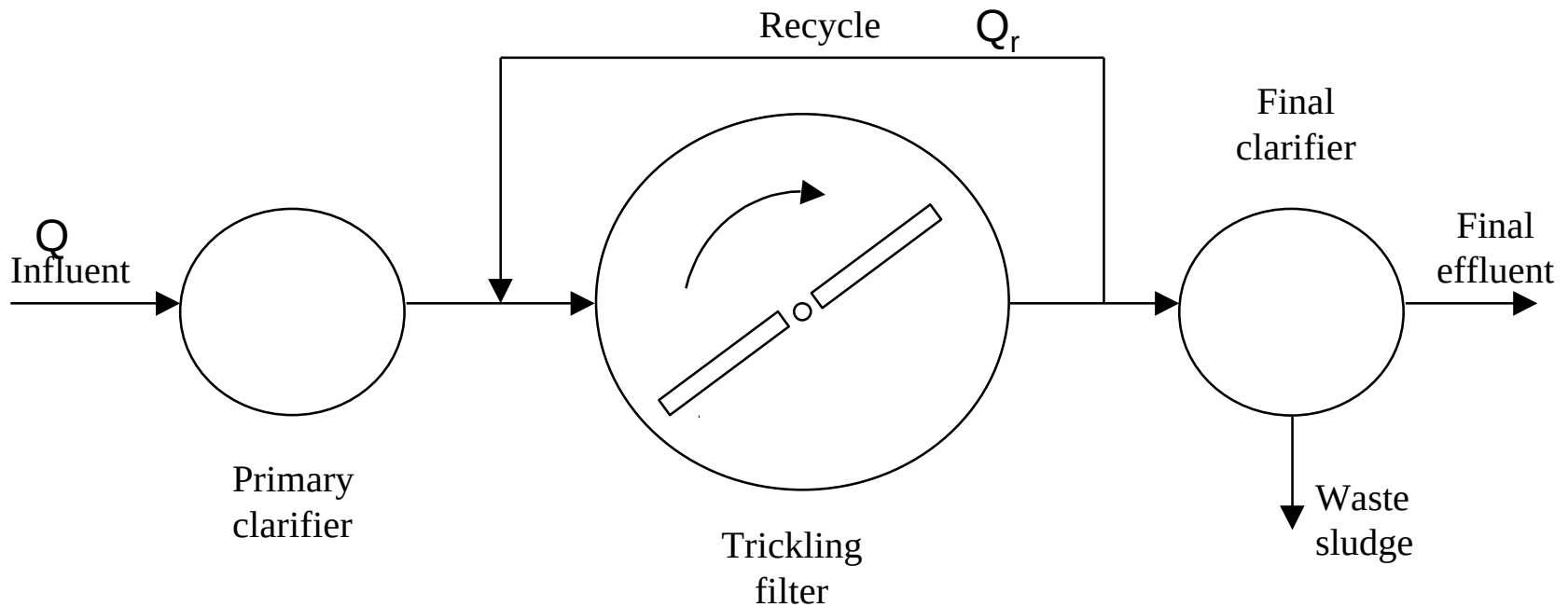
Design consideration

- Influent wastewater characteristics
- Degree of treatment anticipated (BOD & TSS removal).
- Temperature range of applied wastewater
- Pretreatment processes
- Type of filter media
- **Recirculation rate**
- Hydraulic and organic loadings applied to the filter
- Underdrainage and ventilation systems

Flow Diagram for Trickling Filters

Recirculation= A portion of the TF effluent recycled through the filter

Recirculation ratio (R) = returned flow (Q_r) / influent flow (Q)



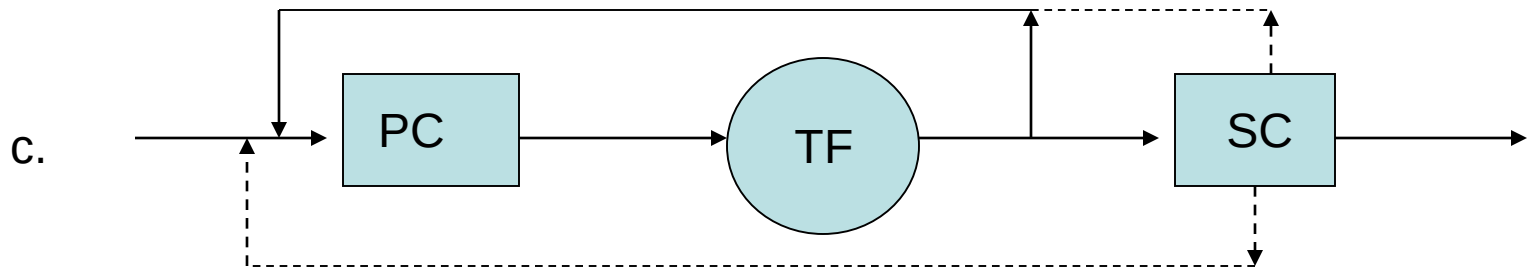
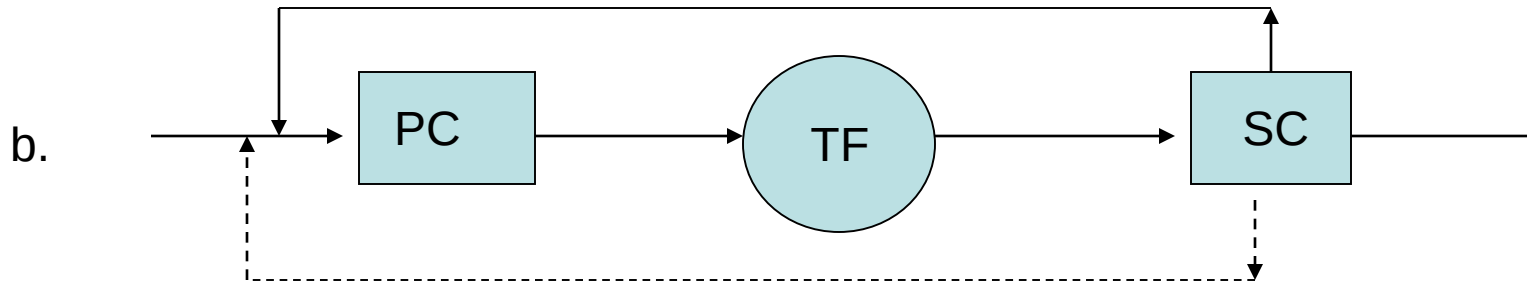
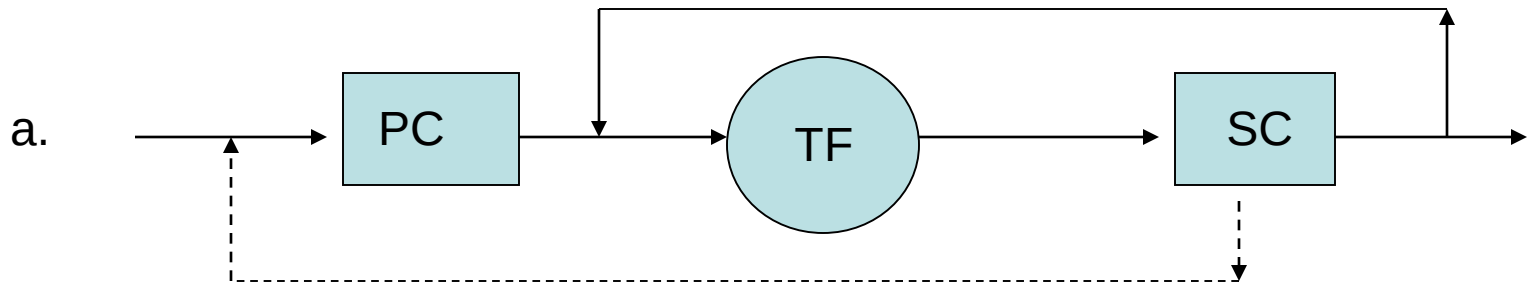
Trickling Filter Process



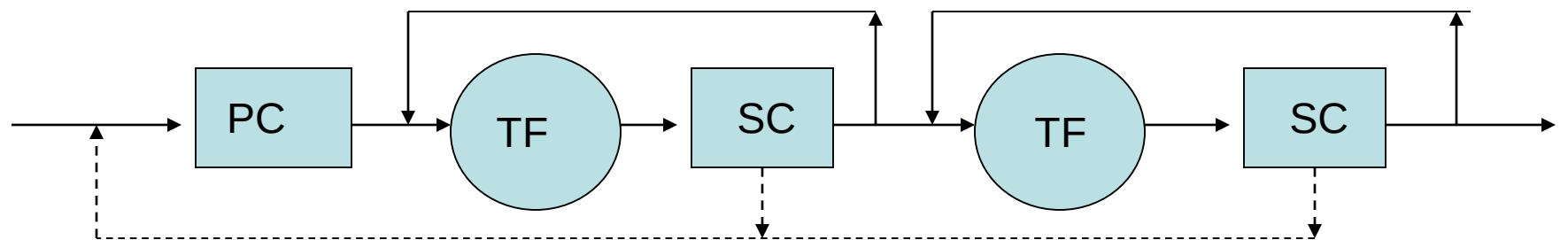
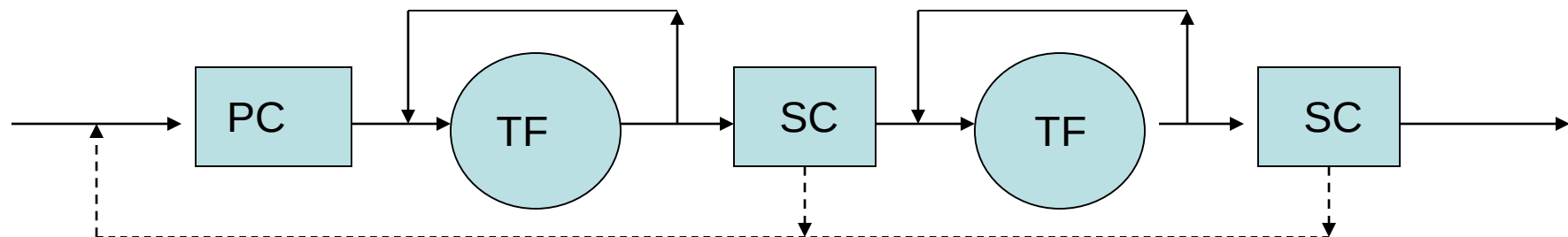
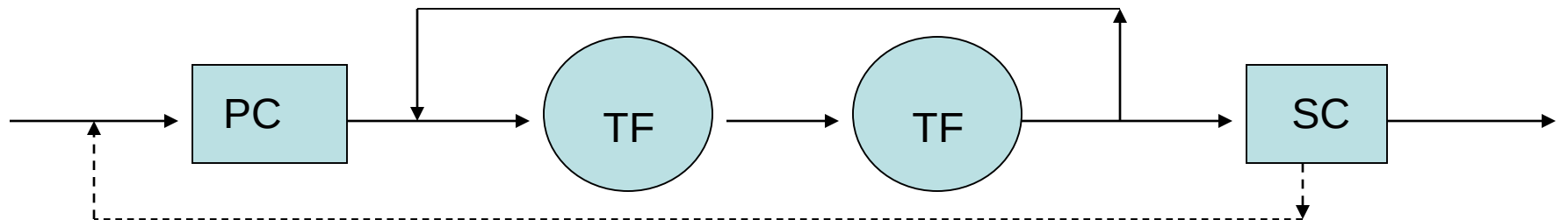
Design consideration - Recirculation

- Why is recirculation required?
 - maintain constant wetting rate
 - dilute toxic wastes
 - increase air flow
 - recirculation flow dilutes the strength of raw wastewater & allows untreated wastewater to be passes through the filter more than once.
- A common range for recirculation ratio
 - 0.5~3.0

Single stage



Two stage





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Design consideration

- Influent wastewater characteristics
- Degree of treatment anticipated (BOD & TSS removal).
- Temperature range of applied wastewater
- Pretreatment processes
- Type of filter media
- Recirculation rate
- Hydraulic and organic loadings applied to the filter
- **Underdrainage and ventilation systems**

Underdrain System

Two purposes:

- (a) to carry the filtered wastewater and the biomass lump (sloughed solids) from the filter to the final clarification process
- (b) to provide for ventilation of the filter to maintain aerobic conditions.
 - The underdrain system is generally designed to flow one-third to one-half full to permit ventilation of the system.

Ventilation systems

- In TF system,
 - Air is supplied by natural draft or forced draft fan.
 - The forced draft fans have been applied in order to provide the adequate oxygen.

Stone media filter

Stone media TF design

- Organic (BOD) loading rate:
 - Expressed as $\text{kg/m}^3/\text{d}$
 - Typically, 0.320-0.640 $\text{kg/m}^3/\text{d}$ for single-stage filters
 - Typically, 0.640-0.960 $\text{kg/m}^3/\text{d}$ for two-stage filters
- Ex) Influent BOD = 200mg/L, influent flow = 1.8 ML/d, diameter of the filter is 16 m & the depth of the filter is 2m. Calculate the organic loading rate.

Stone media TF design

- Hydraulic loading rate:
 - $\text{m}^3 \text{ wastewater/m}^2 \text{ filter} \cdot \text{d}$
 - the rate of total influent flow is applied to the surface of the filter media
 - Total influent flow = the raw WW + recirculated flow
 - Typically, $9.4 \text{ m}^3/\text{m}^2/\text{d}$
 - Maximum, $28 \text{ m}^3/\text{m}^2/\text{d}$
- Ex) Influent flow = 8.5 ML/d , the recirculation ratio is 2:1. Diameter of the filter is 16 m & the depth of the filter is 2m. Calculate the hydraulic loading rate.

Stone media TF design

- NRC (national research council) formula

$$E_1 = \frac{100}{1 + 0.4432 \sqrt{\frac{w_1}{VF}}}$$

First stage or single stage

where:

E_1 = BOD removal efficiency for first-stage filter at 20°C, %

w_1 = BOD load applied, kg/day

V = volume of filter media, m³

F = recirculation factor

Stone media TF design

- NRC formula

$$E_2 = \frac{100}{1 + \frac{0.4432}{1 - E_1} \sqrt{\frac{w_2}{VF}}} \quad \text{Second stage}$$

Where:

E_2 = BOD removal efficiency for second-stage filter at 20°C, %

E_1 = fraction of BOD removal in the first-stage filter

w_2 = BOD load applied, kg/day

V = volume of filter media, m³

F = recirculation factor

Stone media TF design

- NRC formula

$$F = \frac{1 + R}{(1 + R/10)^2}$$

where:

F = recirculation factor

R = recycle ratio

Stone media TF design

- The effect of temperature on the BOD removal efficiency

$$E_T = E_{20} (1.035)^{T-20}$$

where:

E_T = BOD removal efficiency at $T^\circ\text{C}$, %

E_{20} = BOD removal efficiency at 20°C , %

Stone media TF design

- Example 1
 - Calculate the BOD loading, hydraulic loading, BOD removal efficiency, and effluent BOD concentration of a single-stage trickling filter based on the following data:
 - Design assumptions:
 - Influent flow = 1530 m³/d
 - Recirculation ratio = 0.5
 - Primary effluent BOD = 130 mg/L
 - Diameter of filter = 18 m
 - Depth of media = 2.1 m
 - Water temperature = 18°C

Stone media TF design

- Example 2

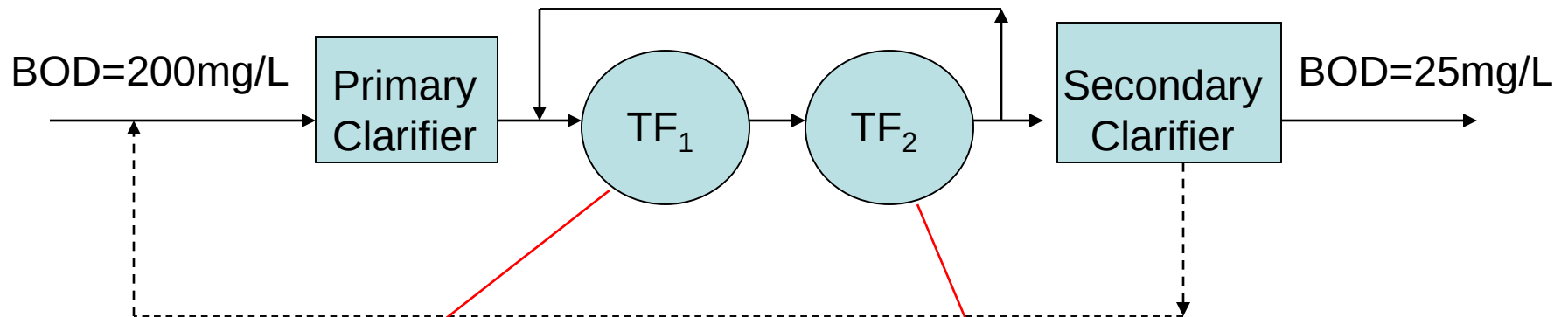
- A municipal wastewater having a BOD of 200 mg/L is to be treated by a **two-stage trickling filter**. The desired effluent quality is 25 mg/L of BOD. If both of the filter depths are to be 1.83 m and the recirculation ratio is 2:1, **find the required filter diameters**. Assume the following design assumptions apply.

- Design assumptions:

- Influent flow = 7570 m³/d
 - Recirculation ratio = 2
 - Depth of media = 1.83 m
 - Water temperature = 20°C
 - BOD removal in primary sedimentation = 35%
 - $E_1 = E_2$

Stone media TF design

- Example 2



$$E_1 = \frac{100}{1 + 0.4432 \sqrt{\frac{w_1}{VF}}}$$

$$E_2 = \frac{100}{1 + \frac{0.4432}{1 - E_1} \sqrt{\frac{w_2}{VF}}}$$

Plastic media

Plastic media

Schulze formula

- The liquid contact time (t) of applied wastewater

$$t = \frac{CD}{q^n}$$

Where:

t = liquid contact time, min

D= depth of media (m)

q = hydraulic loading, (m³/m²/h)

C, n = constants related to specific surface & configuration of media

Plastic media

- **hydraulic loading (q)**

$$q = \frac{Q}{A}$$

Where:

Q= influent flow rate L/min

A=filter cross section area m²

Plastic media TF design

Schulze formula

$$\frac{S_e}{S_o} = e^{(-kD/q^n)}$$

Where:

S_e = BOD concentration of settled filter effluent, mg/L

S_o = influent BOD concentration to the filter, mg/L

k = wastewater treatability and packing coefficient, $(L/s)^{0.5}/m^2$

D = packing depth, m

q = hydraulic application rate of primary effluent, excluding recirculation, L/m^2*s

n = constant characteristic of packing used (assumed to be 0.5).

Plastic media TF design

- Example 3

- Given the following design flow rates and primary effluent wastewater characteristics, determine the following design parameters for a trickling filter design assuming 2 reactors at 6.1 m depth, cross-flow plastic packing with a specific surface area of $90 \text{ m}^2/\text{m}^3$, a packing coefficient n value of 0.5, & a 2-arm distributor system. The required minimum wetting rate $= 0.5 \text{ L}/\text{m}^2 \cdot \text{s}$. Assume a secondary clarifier depth of 4.2m and k value is 0.187.

- **Design conditions**

Item	unit	Primary effluent	Target effluent
Flow	m^3/d	15,140	
BOD	mg/L	125	20
TSS	mg/L	65	20
Temp	$^{\circ}\text{C}$	14	

Plastic media TF design

- Example 3
 - Using the information presented in the previous slide, determine:
 - Diameter of TF
 - Volume of packing required.
 - Recirculation rate required