Secondary treatment (Biological treatment).

Introduction:

1. Purpose: the objective of secondary treatment is to oxidize or remove organic matter (soluble or colloidal) by using microorganisms.

2. Secondary treatment usually consists of biological conversio of dissolved and colloidal organics into biomass that can be removed by sedimentation.

3. In biological treatment, microorganisms use the organics in wastewater as a food supply and convert them into biological cells.

4. Aerobic Process:

$$\text{organic matter} + O_2 + \text{Nutrients} \xrightarrow[\text{Bacteria}]{\text{Aerobic}} \text{stable organic matter} \downarrow + CO_2 + H_2O + \text{New Cells}$$

5. The most common methods of biological treatment are:
   * Trickling Filters.
   * Activated Sludge.
   * Oxidation Ponds.

Classification of Biological Process:

* Attached growth process

Microorganisms grow on inert solid media (Rock, gravel or plastic media) ⟶ e.g. Trickling Filters, RBC, ...

* Suspended growth process

Microbial growth is maintained in suspension by employing either mechanical or natural mixing ⟶ e.g. Activated sludge.

Types of biological Process :

• Aerobic Oxidation (Decomposition)

organic matter + O_2 $\xrightarrow{\text{Aerobic Bacteria}}$ Stable matter ↓ + CO_2 + H_2O + + New Cells.

- Stable Reaction
- Needs high requirement of Oxygen (Power).
- Quick reaction
- Produce stable matter

• Anaerobic Decomposition :

organic matter $\xrightarrow{\text{Anaerobic Bacteria}}$ Stable matter ↓ + CO_2 + H_2O + NH_3 + CH_4 + H_2S .

- Slow Reaction.
- Inefficient
- Cause odors.
- Unstable products.

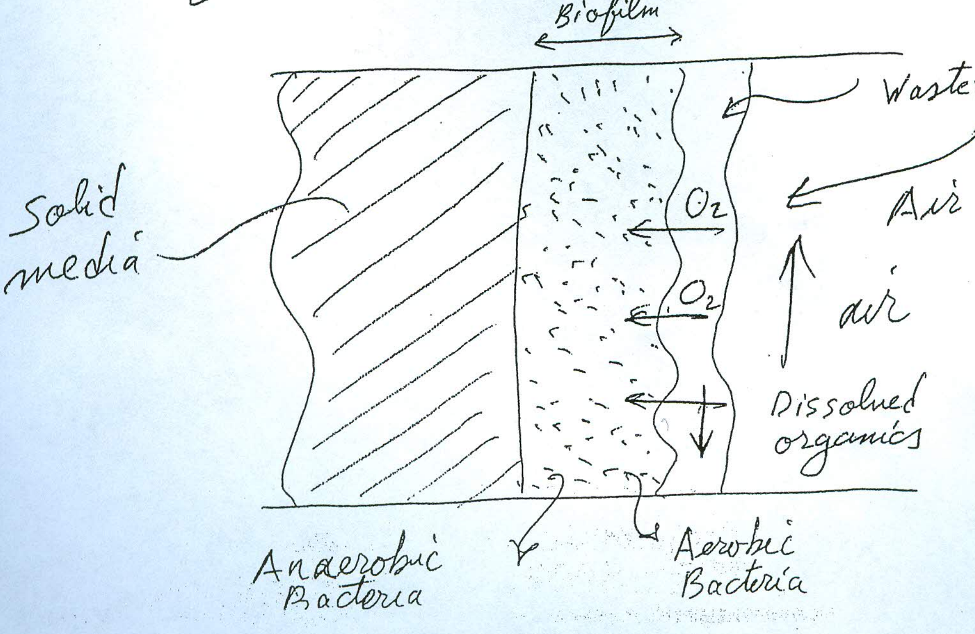
• Anoxic Decomposition :

Microorganisms use bound O_2 as in NO_3 or SO_4 to oxidize organics.

organic matter + NO_3 or SO_4 $\xrightarrow{\text{Anoxic}}$ Stable matter ↑↓ + ...

Trickling Filters.

- The name Trickling Filters is applied to a reactor in which randomly packed solid media provide surface area for biofilm growth and void space help ventilation.
- When wastewater is contacted with the media, the organism attach themselves to it and grow into dense films of a viscous jellylike nature.
- Wastewater passes over this film in thin sheets and removal of organics is occuried as a result of biological aerobic reaction through adsorption process.
- As the slime layer increases in depth, the amount of oxygen becomes limited and anaerobic activity stablished.
- When the slime layer becomes very thick, anaerobic activity predominate, the attachment mechanism is weakened and then the slime layer sloughs off under hydraulic loading (sloughing).



BioFilters Media:

- Rock or gravel media → Trickling filters → depth 1→2.5 m
- Plastic media → BioTowers → depth 4–12 m.

Filter Media Characteristics:

Should have:

1. High surface area per unit volume.
2. Sufficient void space.
3. High durability.
4. Inert and chemically stable.

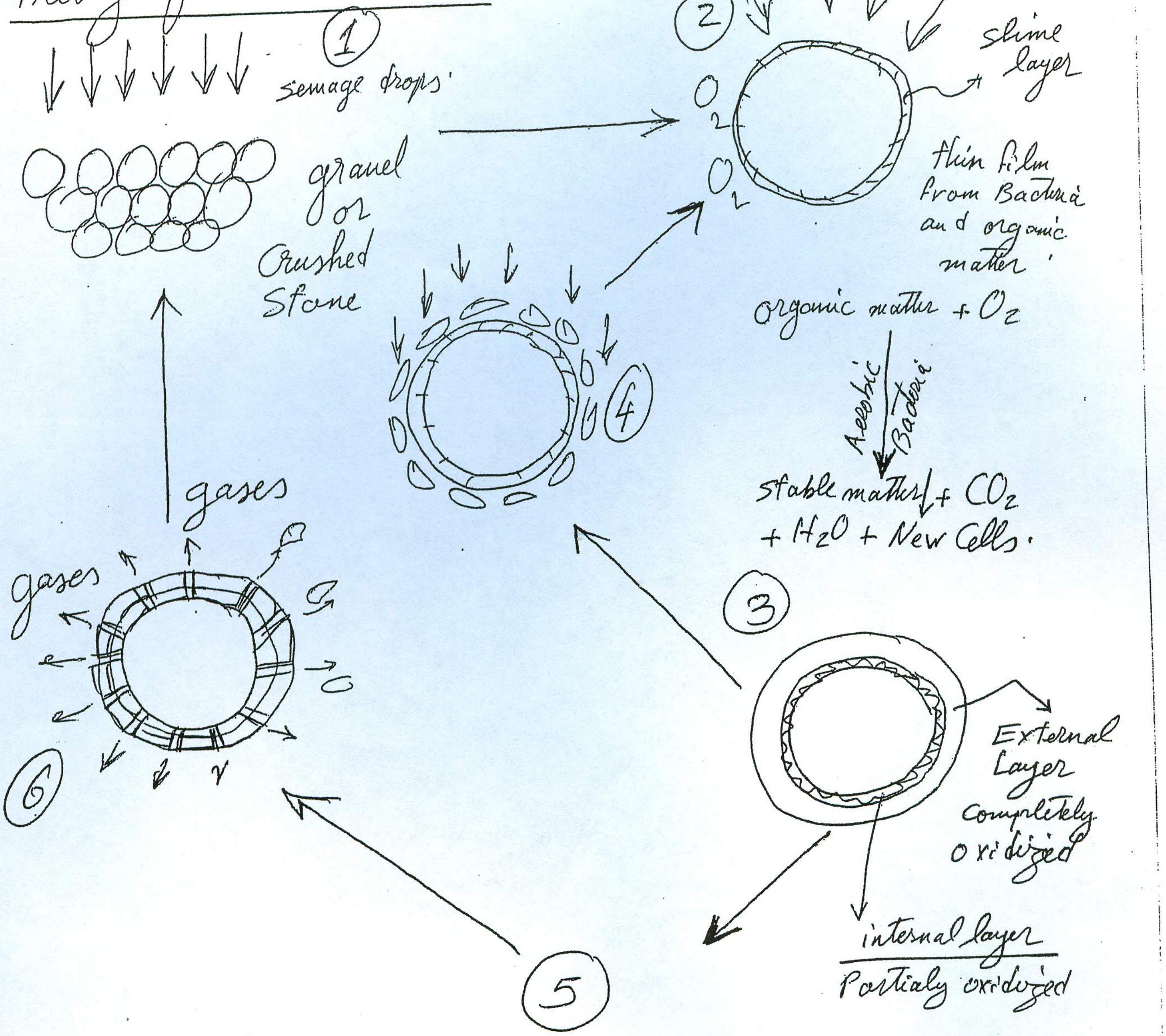
Types of filter media:

Filter Media

- Conventional (Natural Media) (Rock, Gravel; ...)
- Synthetic Media (Plastic)
  - Random: Rings, spheres, short tubes
  - Modular: corrugated sheets

Mechanism Of Treatment (Purification) Action :

Theory of BOD Removal :

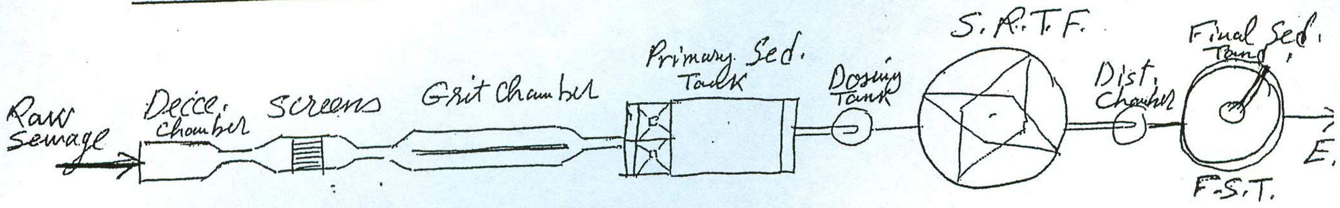


organic matter $\xrightarrow[\text{Bacteria}]{\text{Anaerobic}}$ stable matter + CO_2 + NH_4 + H_2S + NH_3 + New Cells

Trickling Filter Classification

1. Standard (Low) Rate Trickling Filter.
2. High Rate T. Filters.
3. Biotowers.

[I] Standard Rate T. Filters: (S.R.T.F.)



(Flow Line Diagram in S.R.T.F. Sewage Treatment Plant.)

Design Criteria:

1- Allowable Organic load (L) = 70 ⟶ 250 gm BOD / m^3 gravel . D

2- Max. allowable hydraulic load = 1 ⟶ 3 $m^3/m^2/day$.

3- Depth = 2 ⟶ 3 m.

4- Overall efficiency:

$$= \left(\frac{\text{Raw Sewage } BOD_{conc.} - \text{Eff. } BOD_{conc}}{\text{Raw Sewage } BOD_{conc.}}\right) \times 100$$

5- Combined Efficiency:

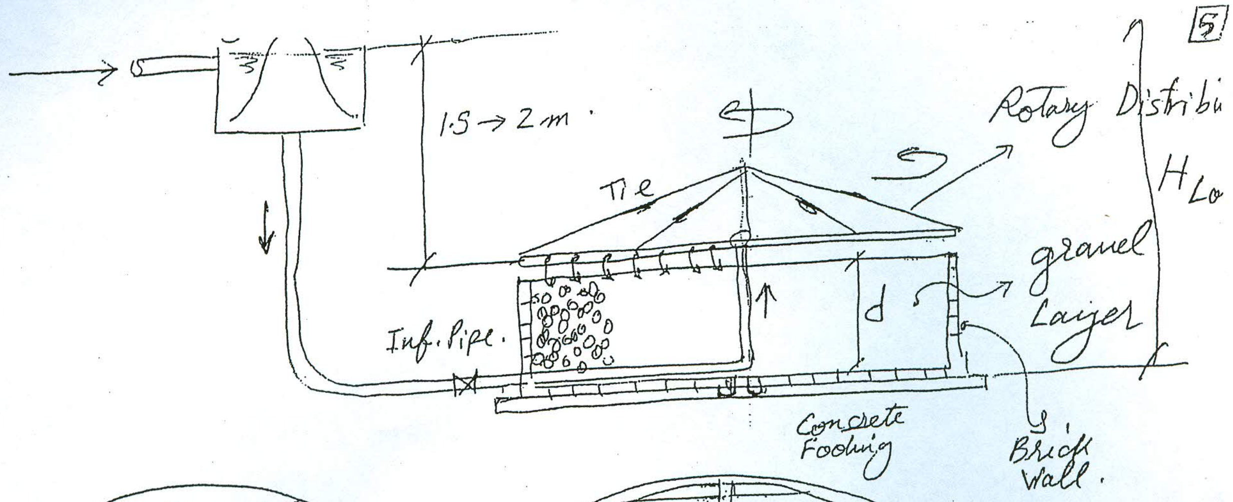
$$= \left(\frac{\text{Primary Treated } BOD_{conc.} - \text{Eff. } BOD_{conc}}{\text{Primary Treated } BOD_{conc.}}\right) \times 100$$

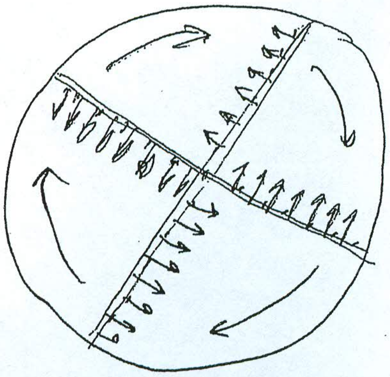
$$\therefore E = \frac{100}{1 + 0.0085\sqrt{2.75(L)}}$$

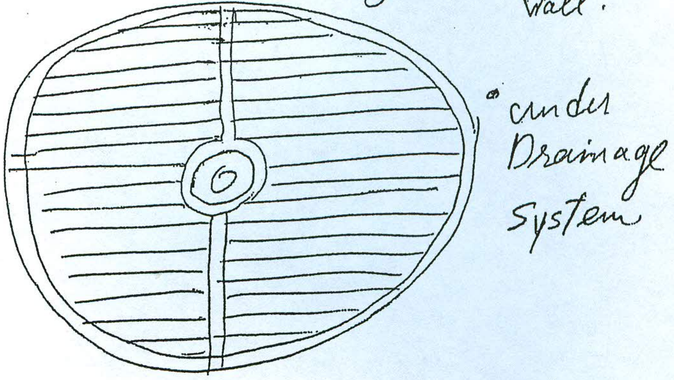
NRC Eq.
* National Research Council

6- Head on rotary arms = 1.5 ⟶ 2 m.

7- Max Diameter = 40 m.







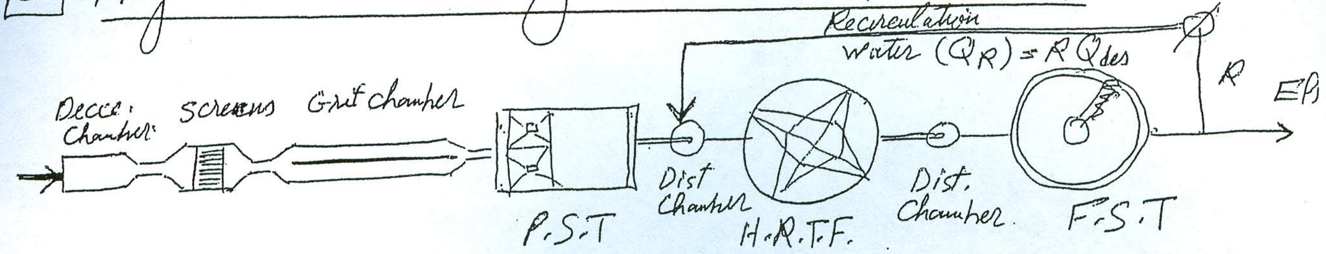
S.R.T.F. Advantages:

1- Min operation and Maintenance Cost.
2- No. need for high skilled operators.
3- High efficiency.
4- Low energy consuming

S.R.T.F. Disadvantages:

1- Flies and odor problems
2- High Construction cost.
3- Low hyd. load.
4- Flow is not uniform,
5- Clogging problems.
6- large area required

[2] High Rate Trickling Filter: (H.R.T.F.) [6]



(Flow line in H.R.T.F. sewage Treatment Plant.)

Recirculation Advantages:

1. Allow continous dosage to the filters
2. Prevent fly growth.
3. Dilute influent organic ld.
4. Return some of active bacteria.
5. Contact Time is increased.
6. Increases the wetting efficiency.
7. Prevent bad odor.

Design Criteria:

1. Allowable Organic Load (L) = 400 → 2000 gm BOD/m^3 gravel. day.
2. Max. allowable hyd ld. = 10 → 30 $m^3/m^2/day$.
3. Overall Efficiency:

$$= \left(\frac{\text{Raw Sewage BOD}_{conc.} - \text{Eff. BOD}_{conc.}}{\text{Raw Sewage BOD}_{conc.}}\right) \times 100$$

4. Combined Efficiency. (E):

$$E = \frac{100}{1 + 0.0085\sqrt{2.7\,L/F}}$$

Where, F = Recirculation Factor $= \dfrac{1+R}{(1+0.1R)^2}$.

Where R = Recirculation Ratio = 0.5 → 4.5

- Depth $= 0.9 \longrightarrow 2$ m.
- $\phi_{max} = 35 \longrightarrow 40$ m.
- Overall Efficiency $= 75 \longrightarrow 85\%$.
- Combined Efficiency of (T. Filters + F.S.T.).

$$\%E = \frac{100}{1 + 0.0085\sqrt{2.7\, L/F}}$$

$$F = \frac{1 + R}{(1 + 0.1R)^2} \quad \text{Recirculation Factor.}$$

$$R = \frac{Q_R}{Q_d} \qquad R = 0.5 \longrightarrow 4.5 \quad \text{Recirculation Ratio}$$

~~xample~~(1)

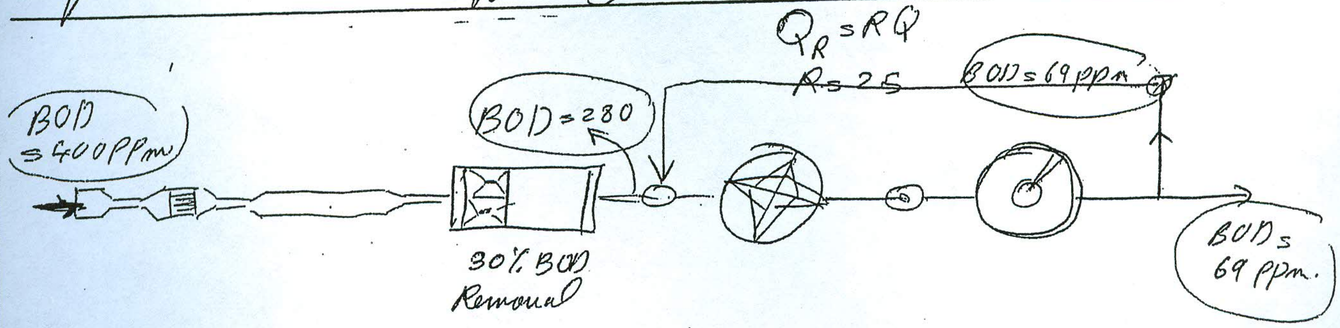
Given: $Q_{design} = 8000\ m^3/day$. (H.R.T.F.)

Influent BOD $= 400$ ppm.

$L = 1200\ kg/1000m^3.d$.

$R = 2.5$

Required: Overall efficiency & H.R.T.F $\rightarrow$ Design (n & ϕ & d).



$$E = \frac{100}{1 + 0.0085\sqrt{2.7\, L/F}}$$

$$F = \frac{1+R}{(1+0.1R)^2} = 2.24.$$

$\therefore E = 75.5\%$

$\therefore$ BOD after P.S.T $= 400(1-0.3) = 280$ ppm.

BOD after F.S.T $= 280(1-0.755) = 69$ ppm.

Overall efficiency $= \frac{400 - 69}{400} * 100 = 83\%$.

Total organic ld $= \frac{280 \times 8000}{1000} + \frac{69 \times 2.5 \times 8000}{1000}$

$= 3620$ Kg/d.

$\therefore$ 1000 m^3 ⟶ 1200 Kg/d.

$\therefore$ Volume Req. ⟵ 3620 Kg/d.

$\therefore$ Volume $= \frac{3620 \times 1000}{1200} = 3016{,}66\ m^3$.

Take Depth $= 1m$.

Total Area $= 3016{,}66\ m^2$.

max $\Phi = 35m$ $\therefore$ $a = 962\ m^2$.

$\therefore n = \frac{\text{Total Area}}{a} \simeq 4$

$\therefore$ Actual $a = 754\ m^2$.

$\therefore$ Actual $\Phi = 31\ m$.

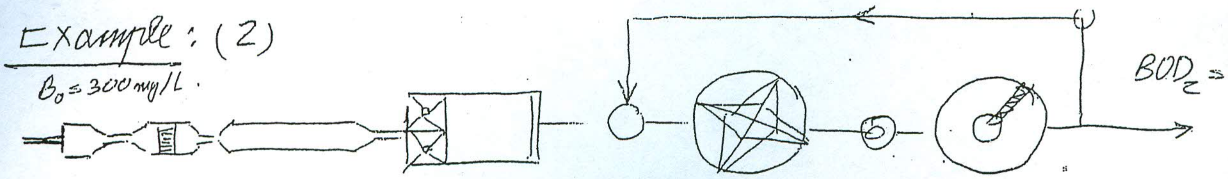
Check hyd. ld $= \frac{Q_d + Q_R}{n \times a}$

$= \frac{8000 + 20000}{4 \times 754.16}$

$= 10\ m^3/m^2/day$.

Example: (2)

$B_o = 300\ mg/L$.



$BOD_2 = 45\ mg/l$

Given: $Q_d = 6000\ m^3/day$.

$BOD_0 = 300\ mg/L$

Eff. $BOD_2 = 45\ mg/L$.

$R = 2$

Required: Allowable Organic ld & HRTF → Design (n & d).

BOD_1 after PST $= 300\,(1-0.3) = 210\ mg/L$.

$$\therefore E = \frac{100}{1 + 0.0085\sqrt{2.7\,L/F}}$$

where $F = \dfrac{1+R}{(1+0.1R)^2} = 2.08$.

$$\therefore E = \frac{210 - 45}{210} = 78\%.$$

$$\therefore 78 = \frac{100}{1 + 0.0085\sqrt{2.7\,\frac{L}{2.08}}}$$

$\therefore L = 838\ Kg\ BOD/1000\ m^3/d$.

$$\therefore T.O.L. = \frac{6000 \times 210}{1000} + \frac{6000 \times 2 \times 45}{1000}$$

$= 1800\ Kg_{BOD}/d$.

$1000\ m^3 \longrightarrow 838\ Kg\ BOD/d$.

Volume $\longleftarrow 1800\ Kg\ BOD/d$.

$$\therefore Volume = \frac{1800 \times 1000}{838} = 2148\ m^3$$

Assume Depth = 1 m. $\therefore$ Total Area $= \dfrac{Volume}{depth}$

$= \dfrac{2148\ m^3}{1\ m}$

$= 2148\ m^2$.

Assume $\phi = 35\ m$ $\therefore a = 962\ m^2$.

$\therefore$ Total number (n) $= \dfrac{2148}{962} = 2{,}2$ Tak $n = 2$

$\therefore a_{act.} = \frac{2148}{2} = 1074 \; m^2$

$\therefore \phi_{Actual} = \sqrt{\frac{1074 \times 4}{\pi}} = 37 \; m$

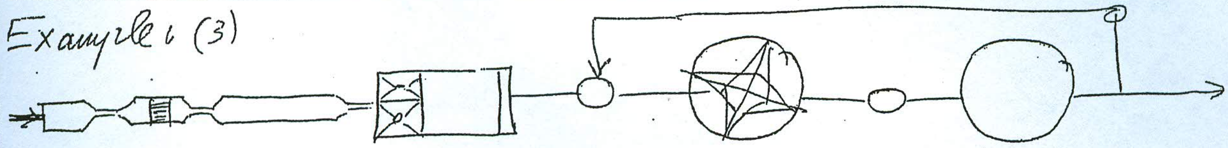
<u>check. hyd. ld.</u>

$hyd.\,ld. = \frac{Q_d + Q_R}{n \times a}$

$= \frac{6000 + 2 \times 6000}{2 \times 1074}$

$= 8.4 \; m^3/m^2/day \; \therefore O.K$

Example (3)



Given: $Q_d = 8000 \; m^3/day$

$BOD_5 = 400 \; mg/L$

Combined Efficiency = 75%

$R = 2$

% removal in PST = 30%

Req. Overall Efficiency & HRTF ⟶ design (n, ϕ, d)

BOD_1 after PST $= 400(1-0.3) = 280 \; mg/L$

BOD_2 after FST $= 280(1-0.75) = 70 \; mg/L$

$\therefore$ Overall efficiency $= \frac{400-70}{400} = 0.825 = 82.5\%$

$F = \frac{1+R}{(1+0.1R)^2} = 2.08$

$\therefore 75 = \frac{100}{1 + 0.0085\sqrt{2.7\frac{L}{2.08}}}$

$\therefore L = 1176 \; Kg \; BOD/1000m^3/day$

$\therefore T.O.L = \frac{8000 \times 280}{1000} + \frac{8000 \times 2 \times 70}{1000} = 3360$ check Kg BOD/day

تكمل في الكتاب ص (٢)

* Comparison between Trickling Filters and activated sludge.

Trickling Filters	Activated Sludge.
• Attached Growth	• Suspended Growth.
• Natural Aeration	• Artificial Aeration.
• Organic ld = 70 → 2000 gm/m³/d	• 450 or 700 or 900 gm/m³/d.
• Water level is in under drainage system.	• Water level covers aeration Tank.
• Losses in head = 1 → 1.5 m + gravel depth	• 0.2 → 0.3 m.
• T = Few seconds	• T = 4 → 8 hrs.
• Overall efficiency 70 → 80%	• 90 → 99%.
• Combined efficiency 75 → 85%	• 95 → 99.9%.
• Aerobic + Anaerobic Action	• Only Aerobic Action.
• Several Media	• Only returned sludge as media