CDD- Consortium DEWATS Disemination

Decentralised Wastewater Treatment System

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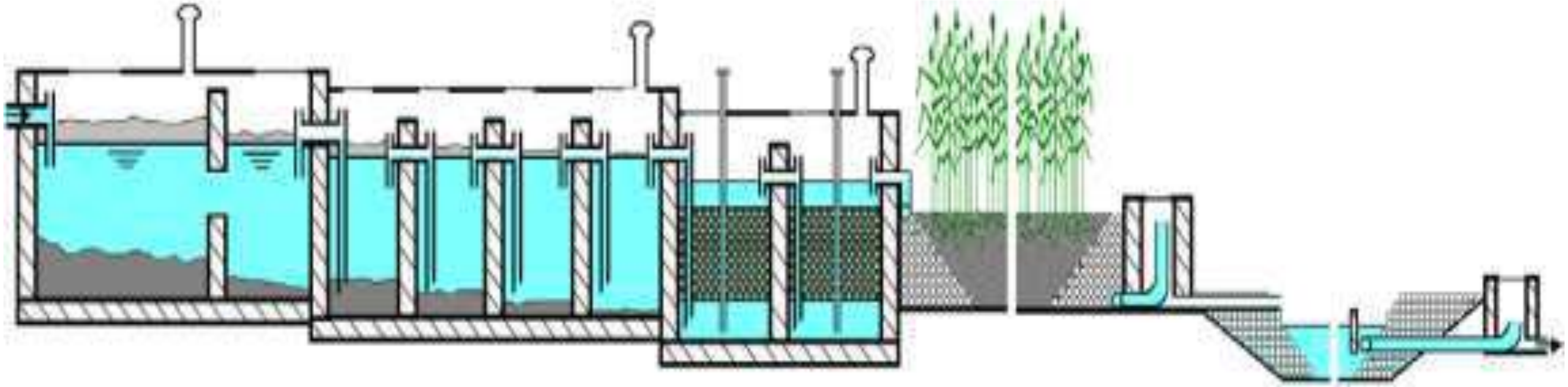
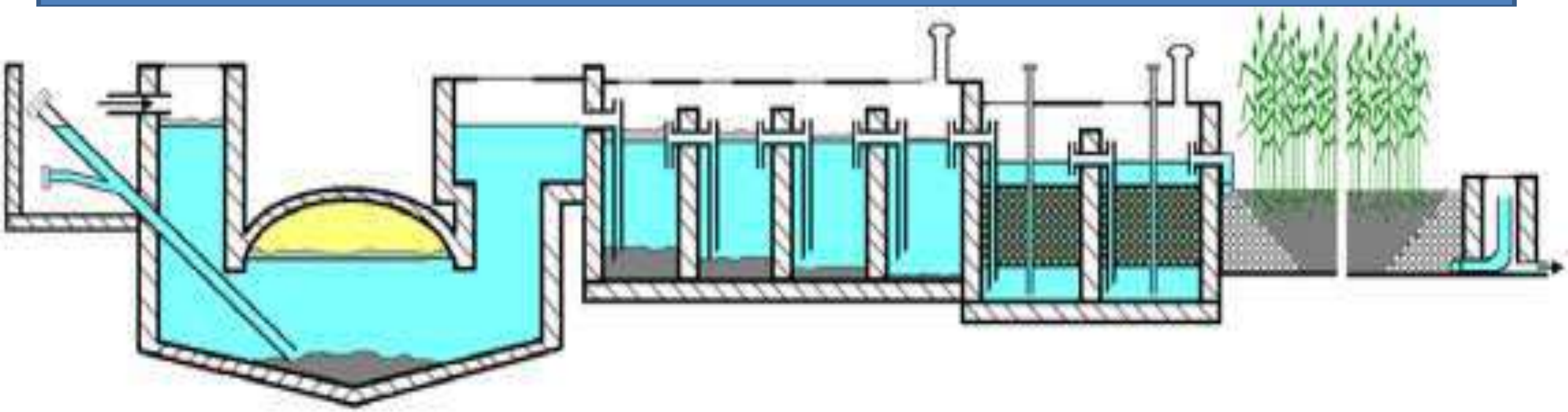


settler – ABR – AF – PGF – polishing pond (not true to scale)



fixed dome biogas settler – ABR – AF – PGF (not true to scale)

Design Parameters, Peak & Daily Flow

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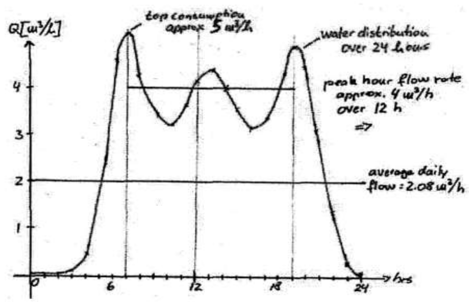
Peak flow

Example: Residential areas

- Slum with 890 inhabitants (equivalent to 180 households of averagely 5 persons)
- Water supply: 70 lpcd
- Wastewater generation: 56 lpcd (80% of water supply)
- Wastewater flow: 50m³/d (56 lpcd * 890 cap)
- Average daily flow: 50m³ / 24h = 2.08m³/h



- 00-05: Sleeping
- 05-08: Showering, toilet, cooking, dish washing
- 08-12: Working
- 12-14: Cooking, toilet, dish washing
- 14-18: Working
- 18-22: Cooking, dish washing, shower, toilet
- 22-24: Sleeping

❖ **HH wastewater calculation**
- Number of users: 5, Per capita =135 L
- Total W/S= **5*135=675** L,% Opert^{n}:=.8
- Total w/w quantity= 5*135 **L*80%= 540L**

❖ 10 seator Public toilet w/w calculation
- Number of users : 200
- W/S per capita = 10 Litres
- Total w/w quantity = 200 * 10 = 2000 Lit:

- **Daily Flow assumed : 15 m³**
- Average daily flow : 15 m³/ 24h= **0.625** m³/h
- Hours of most flow **(peak hour) : 8 h**
- Peak hour flow rate : 15 m³/ 8h= **1.875** m³/h

❖ Peak hour usage for :
- Residential housing colony: 8 to 10 h
- Bus stand toilet: 12 to 16 h
- Community toilet: 4 to 6 h
- Institution like offices: 4 to 6 h
- Factories : 2 to 4 h

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Organic load

Typical composition of untreated domestic water

contaminant	unit	low strength	medium strength	high strength
total solids (TS)	mg/L	390	720	1230
total dissolved solids (TDS)	mg/L	270	500	860
total suspended solids (TSS)	mg/L	120	210	400
biochemical oxygen demand (BOD)	mg/L	110	190	350
chemical oxygen demand (COD)	mg/L	250	430	800
total nitrogen (TN)	mg/L	20	40	70
total phosphorus (TP)	mg/L	4	7	12
oil & grease	mg/L	50	90	100
total coliforms	no/ 100mL	$10^6 – 10^8$	$10^7 – 10^9$	$10^7 – 10^{10}$
faecal coliforms	no/ 100mL	$10^3 – 10^5$	$10^4 – 10^6$	$10^5 – 10^8$

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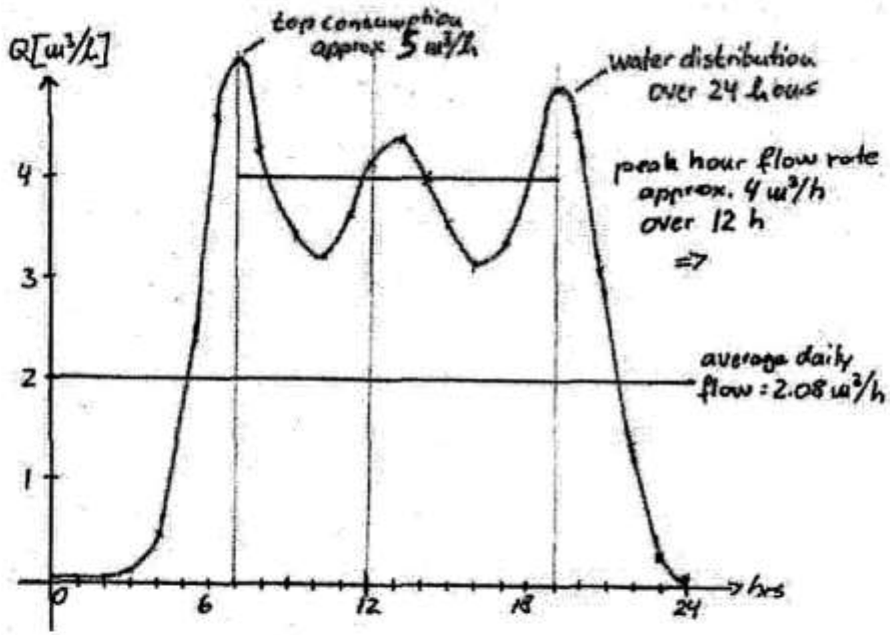

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faecal coliforms	no/ 100mL	$10^3 - 10^5$	$10^4 - 10^6$	$10^5 - 10^8$

Design Parameters for Settler

1

Thumb Rules

1. Sludge volume l/g BODrem=0.005 BODr
2. SS/COD ratio = 0.35 - 0.55 – 0.42
3. Surface load =0.6 m^3/m^2 w/w peak flow
4. CH4 produced /kg COD rem=0.35 m^3/kg
5. Height of scum layer = 0.2 – 0.3 m
6. Hydraulic Retention Time = 1.5 – 2.0 hrs
7. Length to width ratio = 2.1 – 3.1
8. Outlet water depth = 1.8 – 2.2 m
9. 1st & 2nd Chamber ratio

   If 2 Chams, 1st Cham = 2/3 of total length

   If 3 Chams, 1st Cham = 1/2 total length.

11. Assure wall opening bet. under scum & sludge top, have MH, Water tight, Vent

15. Desludging interval = 18 – 24 months

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Calculate

Wastewater production per capita (starting with No.of persons)						
user	BOD5 per user	water consump. per user	COD / BOD5 ratio	daily flow of wastewater	BOD5 concentr.	COD concentr.
given	given	given	given	calcul.	calculated	approx.
number	g/day	litres/day	mg/l / mg/l	m^3/day	mg/l	mg/l
310	**40**	**135**	**2.00**	**33.48**	**370**	**740**

- **Determine Daily flow of wastewater in m^3**
- **Determine BOD, COD Concentration in mg/l**

1. Daily flow: *310 * 135 * 0.8* = *33.48m³*
2. BOD concentration
   - *310 cap * 40 g/cap*d / 33.48m³/d* = *370 mg/L*
3. COD concentration
   - *370 mg/L * 2* = *740 mg/L*

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Organic load

Loading rates for each module

	Baffled reactor	Anaerobic pond	Anaerobic filter	Aerobic pond	Maturation pond	Water hyacinth pond
BOD_5 (kg/m_3*d)	6.00	0.3 – 1.2	4.00	0.11	0.01	0.07
BOD_5 removal	85%	70%	85%	85%	70%	85%
Temperature optimum	30°C	30°C	30°C	20°C	20°C	20°C

(source: Sasse, pg 67)

- Too high loading rates might lead to "poisoning" and collapse of the process.
- Too low loading rates, incoming wastewater does not meet with sufficient bacteria for decomposition

Calculate

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3. COD concentration
   - *370 mg/L * 2* *= 740 mg/L*

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(source: Sasse, pg.67)

- Too high loading rates might lead to "poisoning" and collapse of the process.
- Too low loading rates, incoming wastewater does not meet with sufficient bacteria for decomposition

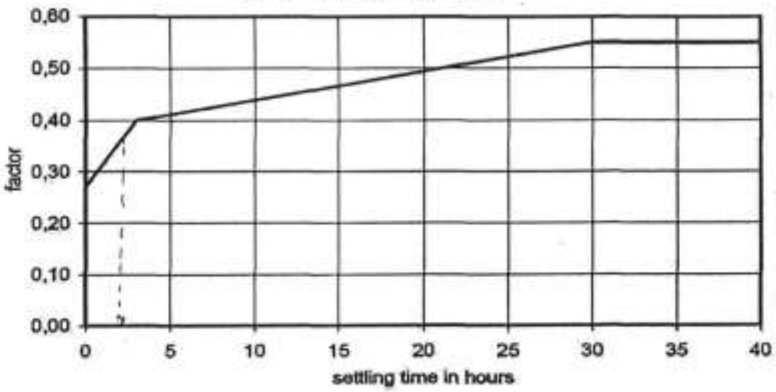
Settler Design

E. Calculation

a. Removal of Organic Pollutants (BOD & COD removal)

1. Determine ***max flow at peak hours*** (m^3/h) = $\frac{\text{volume of wastewater } (m^3)}{\text{time of most wastewater flows } (h)}$
2. Determine ***COD/BOD ratio*** = *COD in* (mg/l) / *BOD in* (mg/l)
3. Determine ***factor COD removal*** **to HRT**(refer graph below)

COD removal in settlers



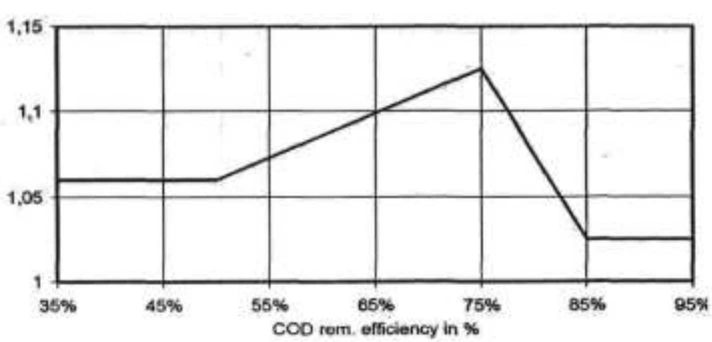
HRT < 1:
*Factor = HRT*0.3*
HRT < 3:
Factor = $\frac{(HRT-1)\cdot 0.1}{2}+0.3$
HRT < 30:
Factor = $\frac{(HRT-1)\cdot 0.15}{27}+0.4$
HRT ≥ 30:
Factor = 0.58

COD rem. rate= $\frac{\text{SS/COD * factor HRT}}{\text{Surfece Load } m^3/m^2}$

COD out = (1- COD rem rate) * COD

4. Determine ***COD removal rate*** = $\frac{\text{(SS/COD ratio) * factor HRT}}{\text{Surface load } (m^3/m^2)}$
5. Determine ***COD out*** (mg/l) = *(1 – COD removal rate)* * *COD in* (mg/l)
6. Determine ***factor efficiency ratio of BOD removal to COD removal***.

simplified curve of ratio of efficiency of BOD removal to COD removal



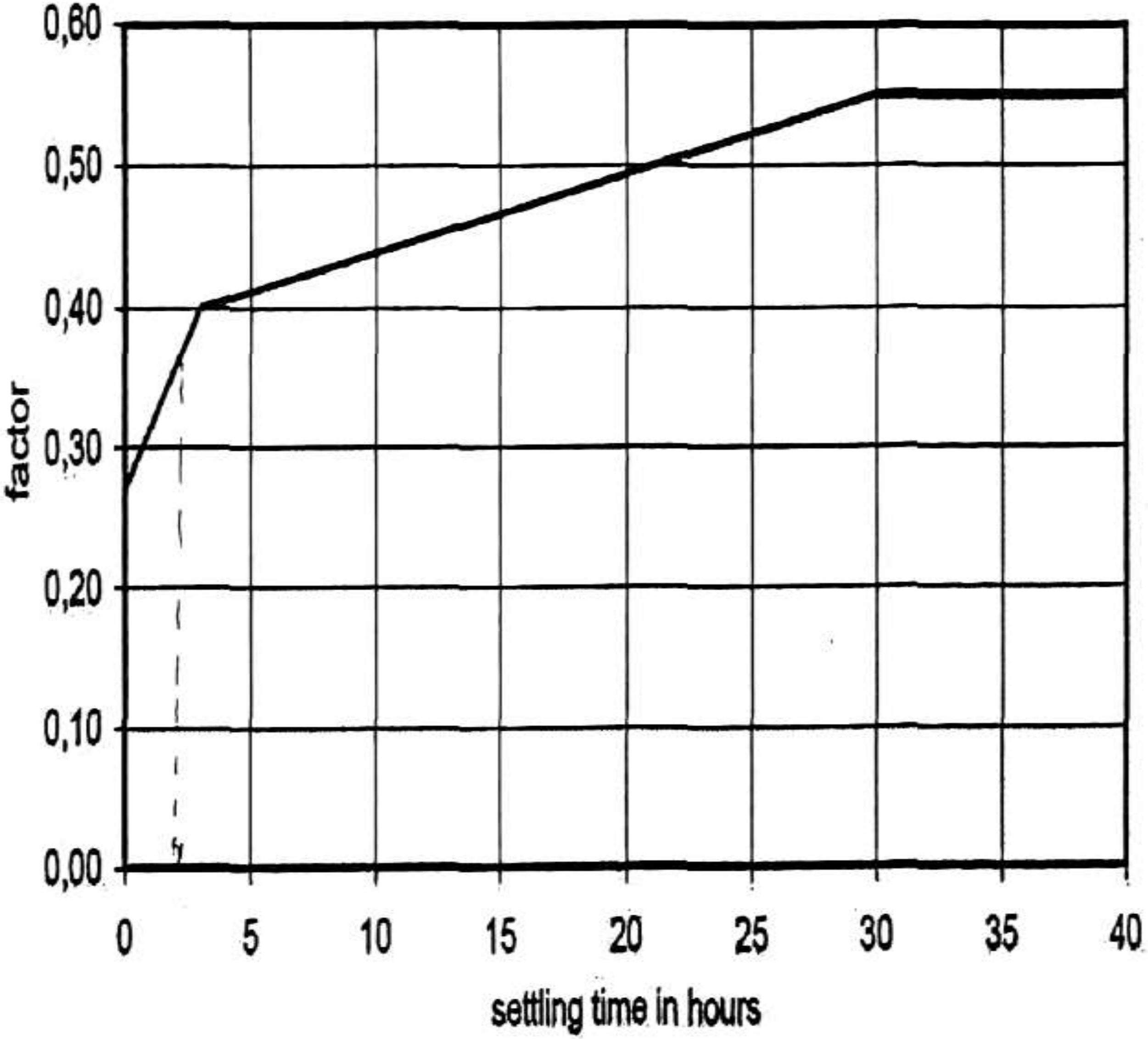
$BOD_{rem} = COD_{rem}$ * factor

COD_{rem} < 0.5:
factor = 1.06
COD_{rem} < 0.75:
factor = $\frac{(COD_{rem}-0.5)\cdot 0.065}{0.25}+1.06$
COD_{rem} < 0.85:
factor = $1.125 - \frac{(COD_{rem}-0.75)\cdot 0.1}{0.1}$
COD_{rem} ≥ 0.85:
factor = 1.025

BODrem rate = f (eff BODrem/COD) * CODrem Rate

BOD out (mg/l) = (1- BODrem rate) * BOD in (mg/l))

COD removal in settlers



HRT < 1:

$$Factor = HRT*0.3$$

HRT < 3:

$$Factor = \frac{(HRT-1)*0.1}{2}+0.3$$

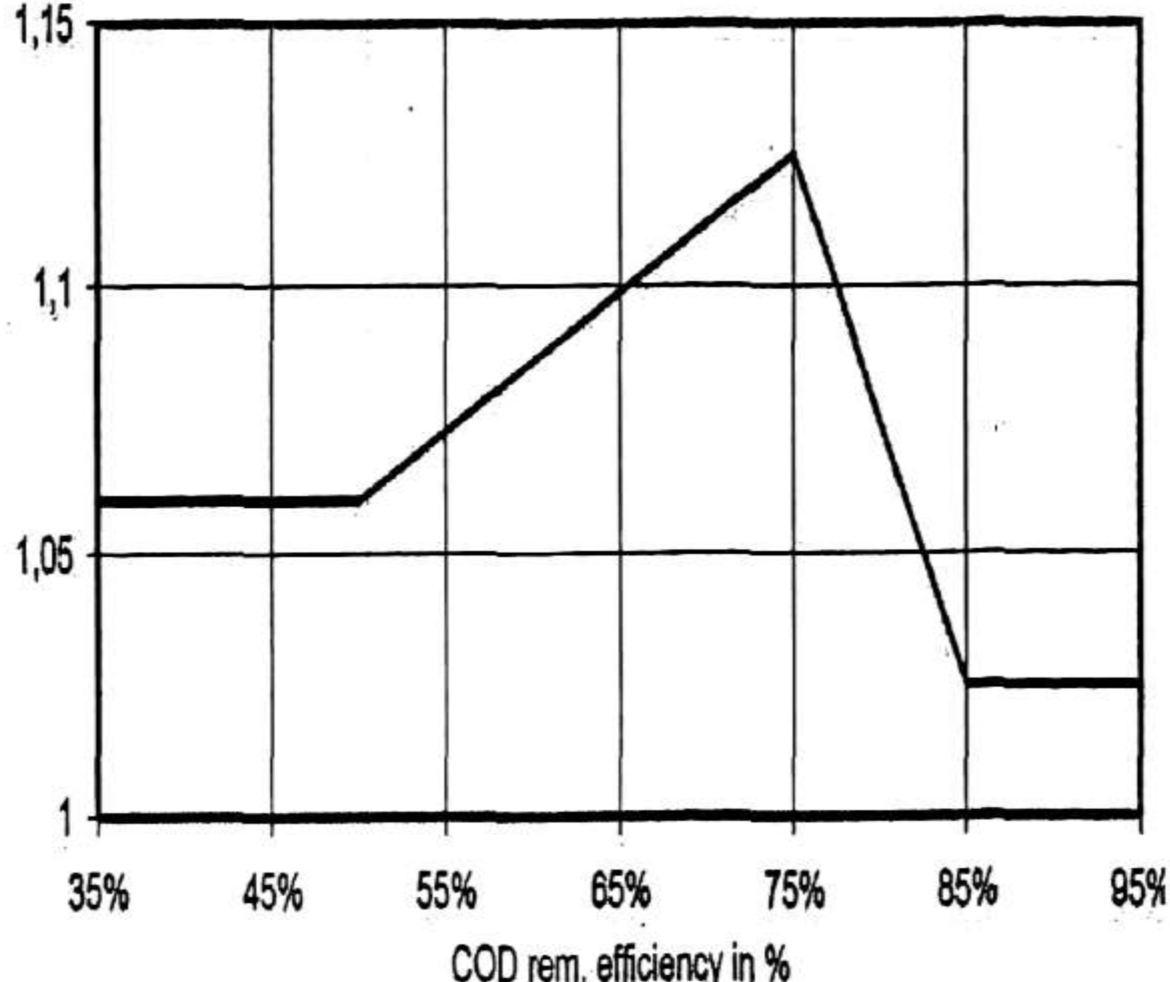
HRT < 30:

$$Factor = \frac{(HRT-1)*0.15}{27}+0.4$$

HRT ≥ 30:

$$Factor = 0.58$$

simplified curve of ratio of efficiency of BOD removal to COD removal



$BOD_{rem} = COD_{rem} * factor$

$COD_{rem} < 0.5$:

factor = *1.06*

$COD_{rem} < 0.75$:

$$factor = \frac{(COD_{rem}-0.5)*0.065}{0.25}+1.06$$

$COD_{rem} < 0.85$:

$$factor = 1.125 - \frac{(COD_{rem}-0.75)*0.1}{0.1}$$

$COD_{rem} \geq 0.85$:

factor = *1.025*

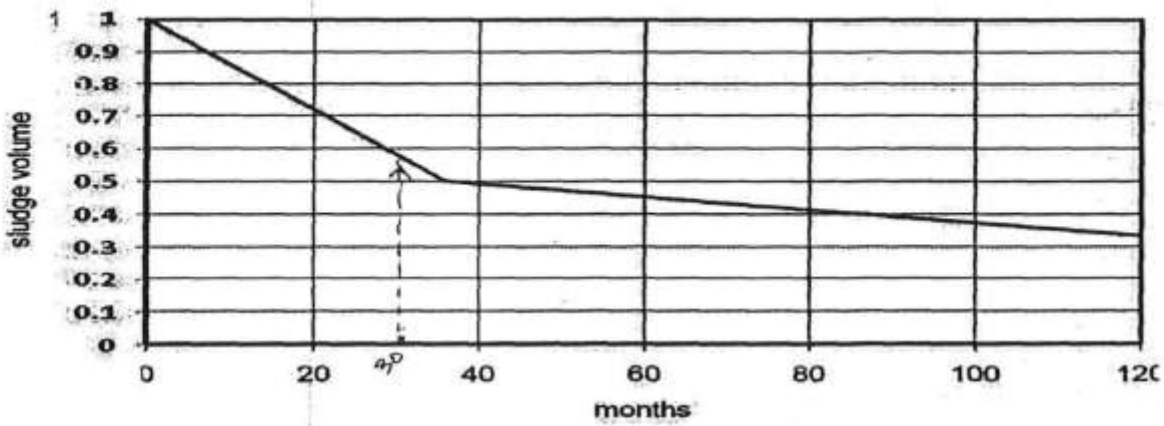
Settler Design

7. Determine ***BOD removal rate*** = *factor efficiency of BOD removal to COD removal * COD removal rate*
8. Determine ***BOD out*** (mg/l) = *(1 – BOD removal rate)* * *BOD in* (mg/l)

b. Determination of Sludge and Storage volume

9. Determine ***factor reduction of sludge volume during storage***

reduction of sludge volume during storage



SRT<36
Factor =1-(SRT*0.014)
SRT<120
Factor =0.5-(SRT-36)*0.002
SRT≥ 120
Factor =1/3

10. Determine ***sludge volume per BOD removal*** (l/g BOD)= *factor sludge reduction * sludge volume* (l/g BOD rem)
11. Determine ***BOD reduction*** (g/m3) or (mg/l) = BOD in (mg/l) – BOD out (mg/l)
12. Determine ***sludge volume from BOD reduction*** (m3/m3) =

$$\frac{\text{Sludge volume per BOD removal (l/g BOD rem)} * \text{BOD reduction (g/ m3)}}{1000\ \text{l}}$$

13. Determine ***sludge volume*** (m3) = sludge volume BOD reduction (m3/m3) * daily wastewater volume (m3/day) * Desludging Intervals (Months)* 30 days

c. Determination Total Settler Volume

14. Determine ***water volume*** (m^3) = *HRT* (h) * *max flow at peak hours* (m^3/h)

Calculations

Sludge Vol = f SR * sludge volume (l/g BODrem) BOD reduction mg/l = BODin mg/l – BODout

SV (Sludge Volume) form BODreduction(m3/m3)[1]; = SV BOD redn:(m3/m3) * D w/w (M3/d)
1000 l

SV (m3)=SV BOD redn: (m^3/m^3)*daily w/w(m^3/d) * desludging intervals (months)* 30 d

Water Volume (m^3)= **HRT** (h) * **MFAPH** (max flow at peak) (m^3/h)

Total Settler **V= Scum Vol+ Water Vol + SV m^3**

Total calculation are 25 steps:

Determine Biogas (CH_4)

- Determine COD reduction (g/ m^3) or mg/l) ---→ Convert COD red: to kg/m^3

- **Determine.CH_4 produced= COD redu^n:(kg/ m^3) * wastewater flow(m^3)*CH_4 /Kg CODrem m^3/kg**

- Determine Biogas produced (CH_4-70%, CO2+ H2S=30%). Bio Gas generate=CH_4 pro m3/0.7

- Determine Bio Gas dissolved in m^3; 50% dissolved = Bio Gas produced (m^3) * 0.5

Calculations (Settler)

15. Determine ***water volume + sludge volume of ST*** (m^3) = *sludge volume* (m^3) + *water volume* (m^3)
16. Determine ***Setter surface area (m2)*** =
$$\frac{\text{Sludge Volume (m3) + Water Volume (m3)}}{\text{Chosen outlet depth}}$$
17. Determine ***scum volume*** (m3) = Surface area (m2) * Scum height (m)
18. Determine ***Total Settler Volume*** (m3) = Sludge Volume (m3) + Water Volume (m3) + Scum Volume (m3)

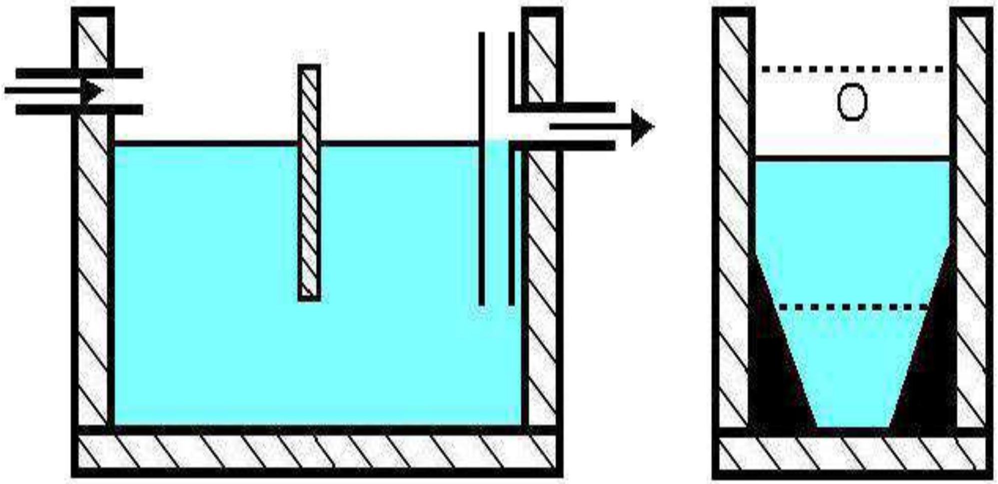
d. **Determination Chamber Sizes**

19. Determine ***required 1^st^ chamber inner length*** (m) =
$$\frac{(2/3) * \text{Volume of ST (m3)}}{\text{Chosen inner width (m) * chosen water depth (m)}}$$
20. Determine (choose) ***1^{st} chamber inner length*** (m) ≥ required length (m).
21. Determine ***required 2^{nd} chamber inner length*** (m) = *required 1^{st} chamber inner length* (m) / 2
22. Determine (choose) ***2^{nd} chamber inner length*** (m) ≥ required length (m)..
23. Determine inner surface ***area*** (m^2) = chosen inner *width* (m) * (chosen *1^{st} chamber inner length* (m) + chosen *2^{nd} chamber inner length* (m))
24. Determine ***Actual volume of settler*** (m^3) = *(area* (m^2) * *water depth* (m)

e. **Determination Biogas Generation**

25. Determine ***Biogas generation*** (m^3/day) =
    - Determine COD reduction (g/m^3) or (mg/l) = *COD in* (mg/l) – *COD out* (mg/l)
    - Convert COD reduction to kg/m^3 = (*COD reduction* (g/m^3)) * (1 m^3/1000 g)
    - Determine CH_4 produced = (*COD reduction* (kg/m^3) * *wastewater flow* (m^3) * *CH_4 produced per Kg COD removal* (m^3/kg))
    - Determine Biogas produced (m^3); CH_4 =70%, CO_2 + H_2S=30%;
      Amount of CH_4 produced is 70% of the amount of Biogas generated (100%).
      Hence Biogas generated = (*CH_4 produced* (m^3) */ 0.7)*
    - Determine Biogas dissolved (m^3); 50 % dissolved = *Biogas produced* (m^3) * *0.5*

Grease Trap



Grease trap

Kind of treatment:

- flotation
- Use Tee to maintain scum

Wastewater type:

- wastewater with high fat and oil contents
- not adequate for faecal matter

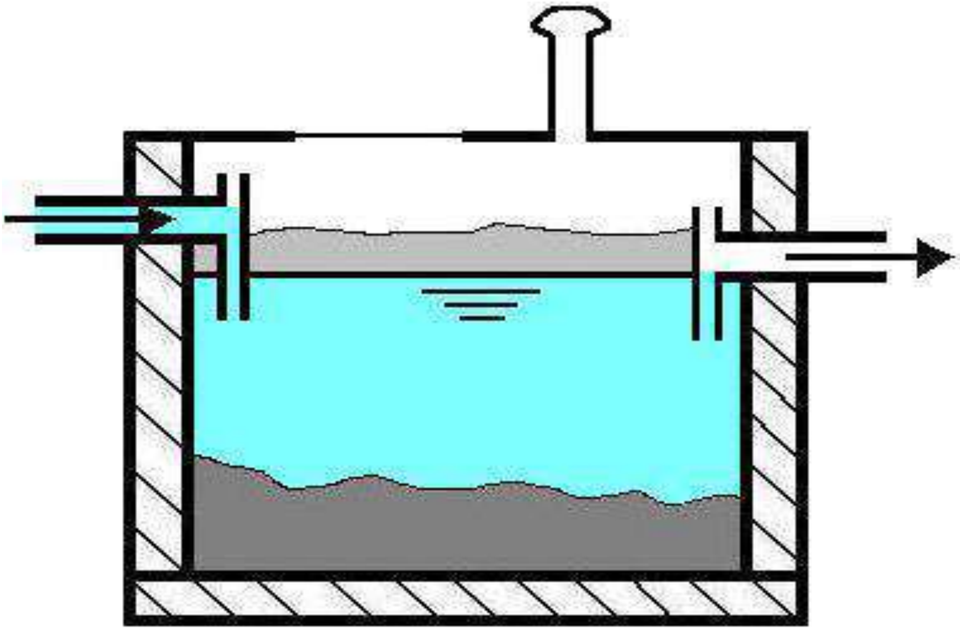
Advantages:

- simple and durable
- little space requirement

Disadvantages:

- only pre-treatment
- need for continuous cleaning

1- A Settler (and Septic Tank)



Settler

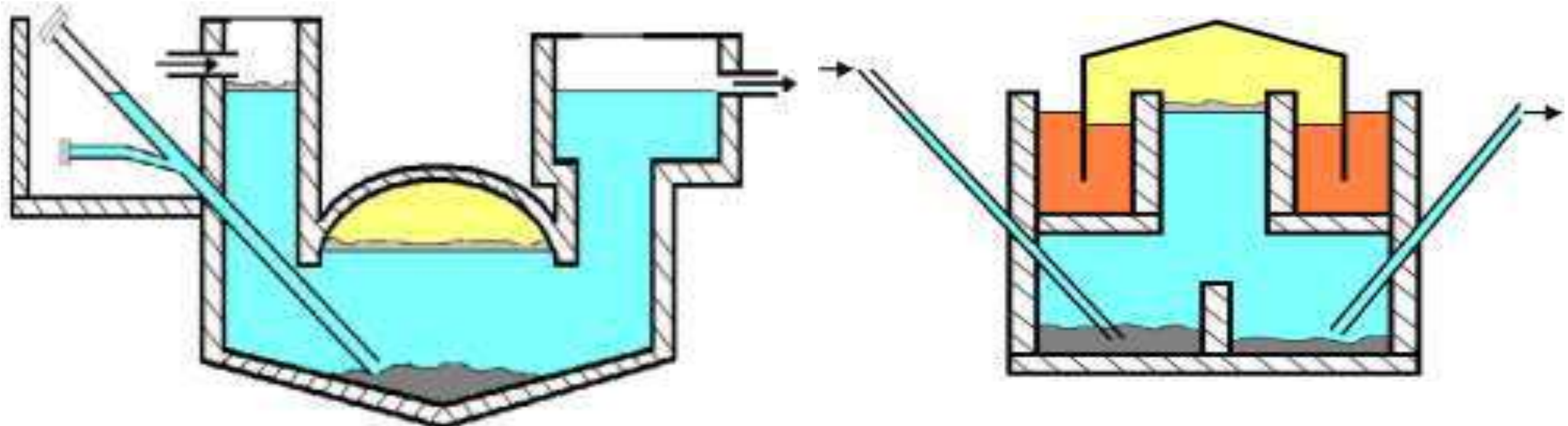
Kind of Treatment:
- sedimentation / flotation
- sludge stabilization

Wastewater Type:
- wastewater of settleable solids, especially domestic

Advantages:
- simple and durable
- little space requirement, not visible (underground)
- very low investment & O&M cost

Disadvantages:
- low treatment efficiency (only pre- or primary treatment)
- only very moderate reduction of infectious organism

1-B Biogas Settler



Fixed-dome biogas settler(l) and floating dome biogas settler (r)

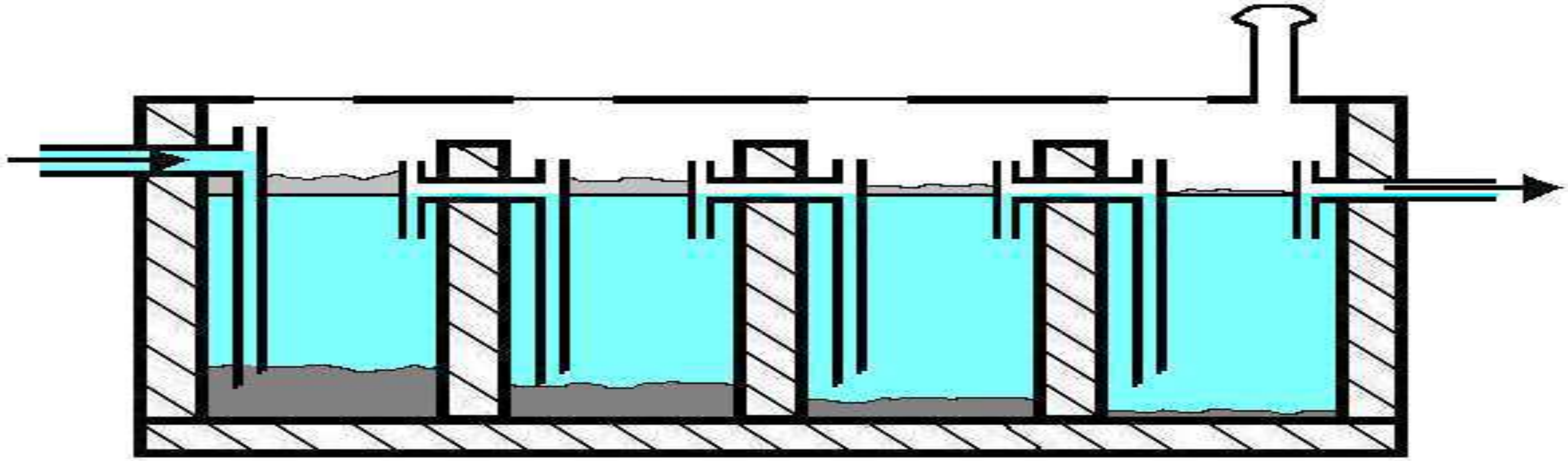
Kind of Treatment:
- anaerobic degradation of suspended and dissolved solids
- sludge stabilization

Wastewater Type:
- domestic and industrial wastewater of high BOD/COD

Advantages:
- simple and durable
- resistant against organic and hydraulic shock loads
- no pre-treatment necessary
- little space requirement (underground)
- biogas use

Disadvantages:
- costly in construction (gas-tight)
- requires special construction skills (dome)
- not suitable for weak, municipal wastewater (mixed with grey water)
- effluent smells (anaerobic process)

2. Anaerobic Baffle Reactor (ABR)



Four-chamber anaerobic baffled reactor (ABR)

Kind of Treatment:

- anaerobic degradation of suspended and dissolved solids

Wastewater Type:

- pre-settled domestic and industrial wastewater of narrow COD/BOD ratio
- suitable for **strong industrial** wastewater

Advantages:

- **simple to build, operate & durable**
- resistant against organic & hydraulic s.loads
- high treatment efficiency
- **little space requirement (underground)**
- hardly any blockage
- relatively cheap compared to AF

Disadvantages:

- requires **larger space for construction than AF** (not economical for large plants)
- less efficient with **weak wastewater**
- **longer start-up** phase than AF

Design Calculations (ABR)

Anaerobic Baffle Reactor

Thumb Rules

1. SS/COD ratio–Domestic: **0.35–0.55–0.42**
2. Sludge Volume –5-10% of volume of ABR
3. CH_4–produced /Kg CODrem–0.35 m^3/kg
4. Scum volume 10 l/cap
5. **HRT**– not <8 hrs, better **16-20 hrs**, if > 20 hrs, pollution removal is very minimum

1. Length to height ration – **0.4**
2. Distance bet: pipes - not exceed 0.30 m
3. Nos of Chambers – **At least 4 chambers**
4. Outlet water depth- **1.8 m- 2.2 m**
5. Up-flow velocity **– 0.9 – 1.2 m/h**
6. Organic load - < 6 kg/m^{3*} day BOD

Note: Calculation 25 Steps

G - BODrem to strength

G – BODrem – Temp:

G – BODrem to no of upflow chambers

G – BODrem to HRT

Effect of org. overloading to BODrem

G- Eff. Ratio (BODrem/CODrem)

Design Calculations (ABR)

E. Calculations

a. *Determination of Chamber sizes and numbers*

1. Determine ***BOD in and COD in*** (mg/l) *(outlet ST).*
2. Determine ***max peak flow per hour*** (m^3/h) = $\frac{\text{volume of wastewater } (m^3)}{\text{time of wastewater flows (h)}}$
3.
4. Determine ***required max. length of chamber*** (m) = (*water depth at outlet* (m) * *0.4*)
5. Determine **(choose) actual length => required maximum length**
6. Determine ***required min. width of chamber*** (m) =
   $\frac{\text{Max peak flow per hour } (m^3)}{\text{up-flow velocity (m)) * length of chamber (m)}}$
7. Determine **(choose) actual width => required minimum width**
8. Determine ***actual up-flow velocity*** (m/h) =
   $\frac{\text{Max peak flow per hour } (m^3/h)}{\text{Actual length (m) * actual width (m)}}$

Check!!! Actual up-flow velocity is best below 1 m/h!!!
If up-flow velocity is above 1 m/h, adjust width and length!!!

b. *Determination of number of chambers required*

9. Determine ***number of chambers.***

Check!!! Minimum no. of chambers is 4!!!. Adjust according to requirement of the outlet effluent quality

c. *Determination of sludge and storage volume*

10. Determine ***actual volume of ABR*** (m^3) = ((*chosen length* (m) * chosen *width* (m) * chosen *depth* (m))* *number of chambers*)
11. Determine ***sludge volume*** (m^3) = (0.05 * (*actual volume of ABR* (m^3)))
12. Determine **water volume** (m^3) = (*actual volume of ABR* (m^3) - *sludge volume* (m^3))
13. Determine ***HRT*** (h) = $\frac{\text{water volume of ABR } (m^3)}{\text{[daily wastewater flow } (m^3) \text{ / 24 (h)]}}$

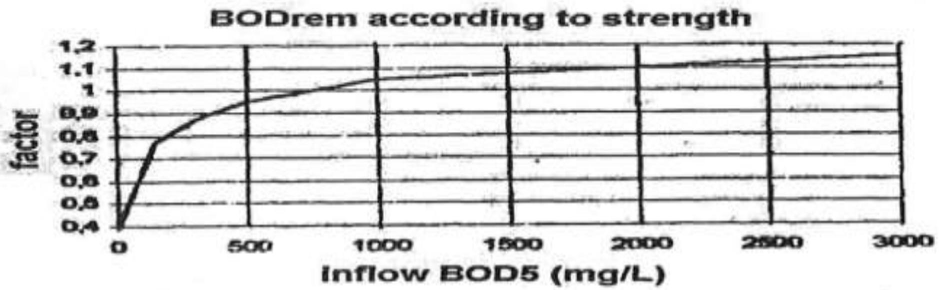
Check!!! HRT should be below 20 hrs for an economically-viable treatment!!!
Prioritize actual up-flow velocity!!!

d. *Removal of Organic pollutants (BOD and COD removal)*

14. Determine ***organic load BOD*** (kg/m^3*day) =
    $\frac{\text{BOD in } (g/m^3) \text{ or (mg/l) * max peak flow per hour } (m^3/h) \text{ * 24 (h)}}{\text{actual volume of ABR } (m^3) \text{ * 1000}}$

Check!!! Organic load < 6 kg/m3*day BOD!!!

15. Determine *factor strength*.



BOD_{in} < 150 mg/L:
factor = BOD_{in}*0.37/150+0.4

BOD_{in} < 300 mg/L:
factor = (BOD_{in} -150)*0.1/150+0.77

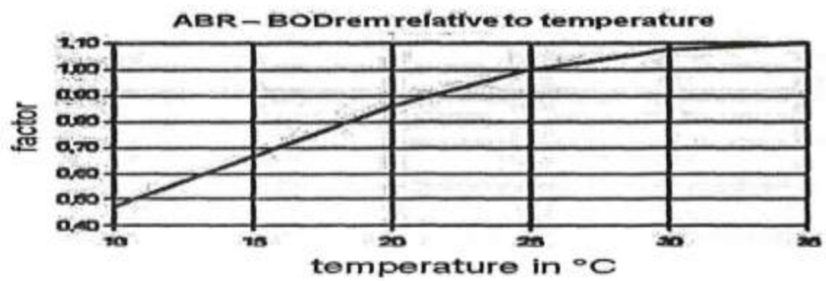
BOD_{in} < 500 mg/L:
factor = (BOD_{in} -300)*0.08/200+0.87

BOD_{in} < 1000 mg/L:
factor = (BOD_{in} -500)*0.1/500+0.95

BOD_{in} < 3000 mg/L:
factor = (BOD_{in} -1000)*0.1/2000+1.05

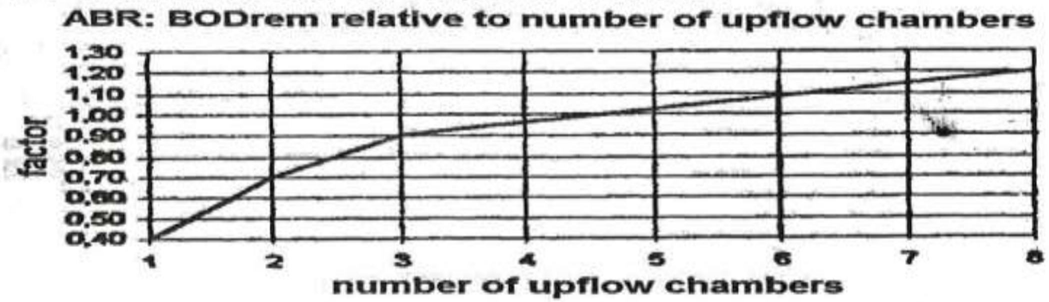
BOD_{in} ≥ 3000 mg/L:
factor = *1.15*

16. Determine *factor temperature*.



Temp<20° C
Factor= (temp-10)*0.39/20+ 0.47
Temp<25° C
Factor= (temp-20)*0.14/5+ 0.86
Temp<30° C
Factor= (temp-25)*0.08/5+1.0
Temp<35° C
Factor= (temp-30)*0.08/5+1.08
Temp ≥ 35° C
Factor= 1.1

17. Determine *factor no. of up flow chambers*.



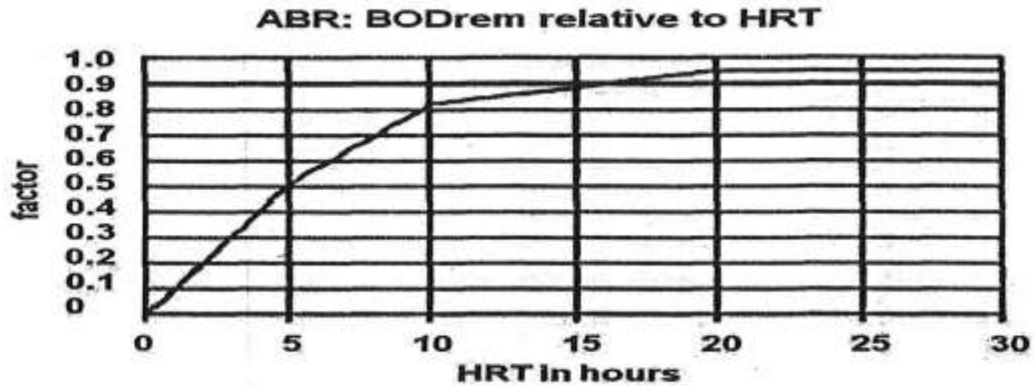
no = 1:
factor =0.4

no = 2:
factor =0.7

no = 3:
factor =0.9

no > 3:
*factor =(no-3)*0.06+0.9*

18. Determine *factor HRT*.



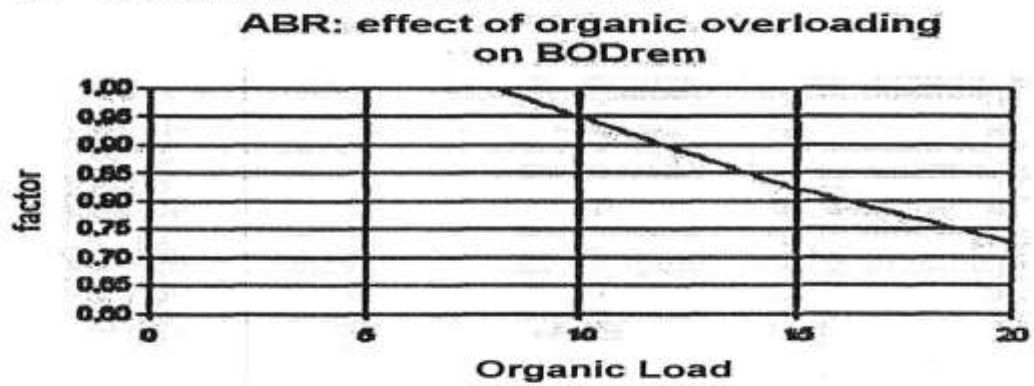
HRT < 5h
Factor = HRT*0.5/5

HRT < 10h
Factor = [(HRT-5)*0.32/5] + 0.5

HRT < 20h
Factor = [(HRT-10)*0.13/10] + 0.82

HRT ≥ 20h
Factor = 0.95

19. Determine ***factor organic load.***



20. Determine ***BOD removal rate by factors*** = (*factor strength * factor temperature * factor no. chambers * factor HRT * factor organic load*).

21. Determine **applied BOD removal rate**

   1. Applied BOD removal rate=$BOD_{rem\ by\ factors}$, , if $BOD_{rem\ by\ factors} < 0.8$

   Else

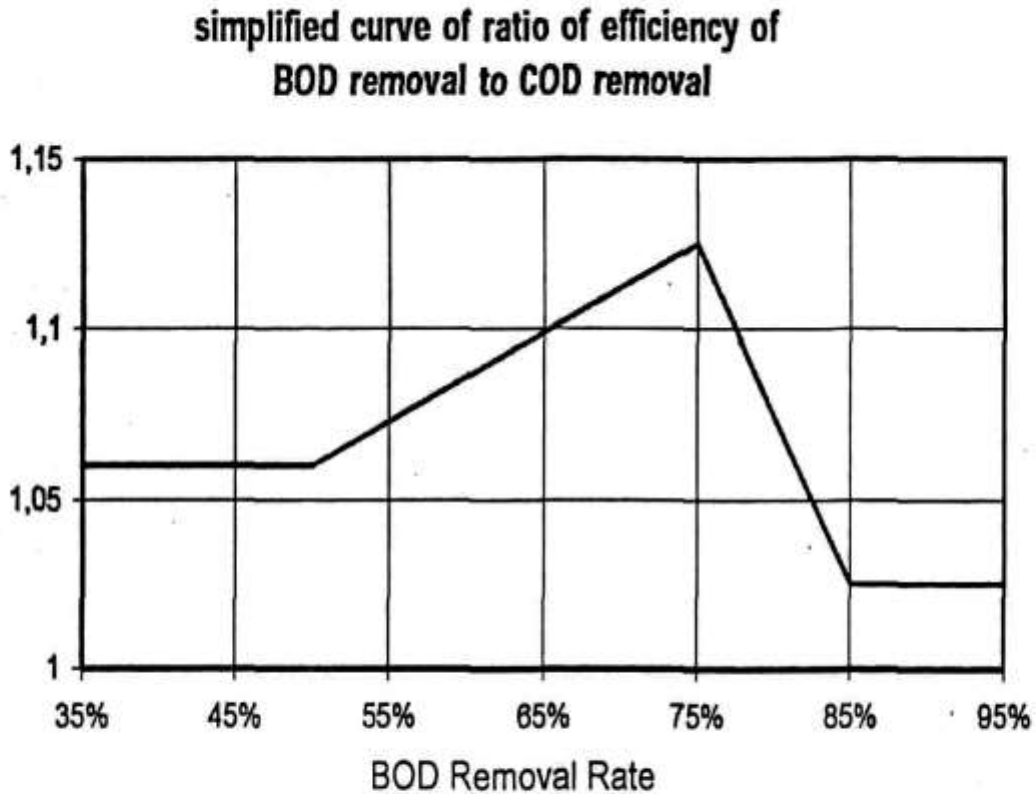
   ($BOD_{rem\ by\ factors}$*[1-0.37*($BOD_{rem\ by\ factors}$-0.8)])

   2. If $BOD_{rem\ by\ factors}$ or ($BOD_{rem\ by\ factors}$*[1-0.37*($BOD_{rem\ by\ factors}$-0.8)]) or BOD removal rate by factors > 0.95

   Applied BOD Removal rate = 0.95

22. Determine ***BOD out*** (mg/l) = *(1 -* Applied BOD Removal rate*) * BOD in* (mg/l)

23. Determine ***factor efficiency COD removal to BOD removal.***



$BOD_{rem} < 0.5$:
factor = *1.06*

$BOD_{rem} < 0.75$:
factor = $(BOD_{rem}-0.5)*0.065/0.25+1.06$

$BOD_{rem} < 0.85$:
factor = $1.125-(BOD_{rem}-0.75)*0.1/0.1$

$BOD_{rem} \geq 0.85$:
factor = *1.025*

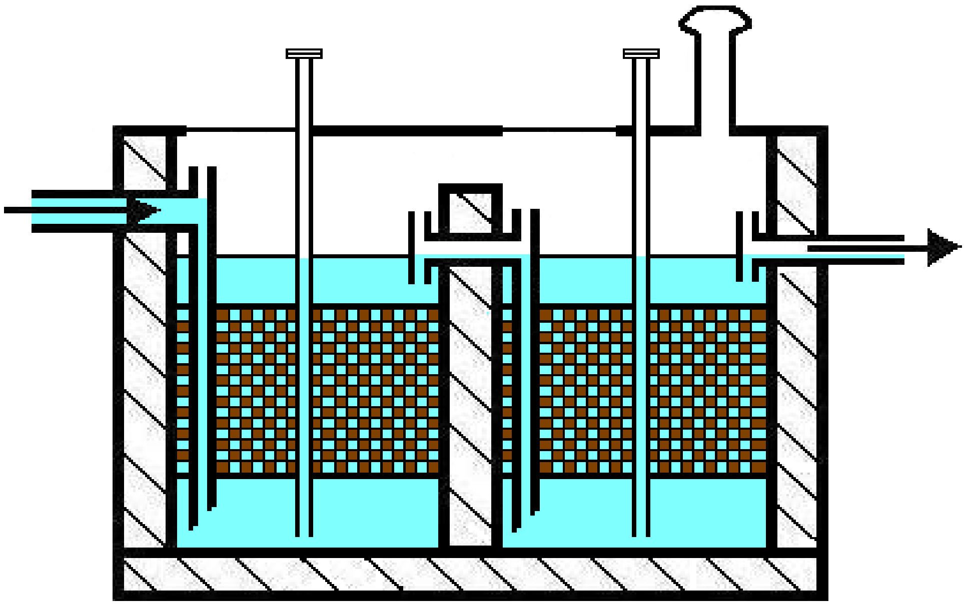
$$BOD_{rem} = COD_{rem} * \text{factor}$$
$$COD_{rem} = BOD_{rem} / \text{factor}$$

24. Determine ***total COD removal rate*** =

$$\frac{\textit{Total BOD removal rate}}{\textit{Factor efficiency COD removal to BOD removal}}.$$

25. Determine ***COD outlet*** (mg/l) = (*1 – total COD removal rate) * COD in* (mg/l)

5. Anaerobic Filter (AF)



Two-chamber anaerobic filter (AF)

Kind of Treatment:

- **anaerobic** degradation of **suspended & dissolved solids**

Wastewater Type:

- **pre-settled domestic and industrial** wastewater of **narrow COD/BOD** ratio

Advantages:

- **simple and durable** if wastewater is properly pre-treated
- **high treatment** efficiency
- **little space** requirement (underground)
- **reliable and robust**

Disadvantages:

- **costly in construction** (special filter material)
- **blockage** of filter possible
- effluent **smells slightly** (anaerobic process)

Design Calculations (AF)

Eff. Ratio (BODrem/CODrem) G

Thumb Rules

1. SS/COD ratio– Domestic: 0.35–0.45–0.42
1. HRT – 24-48 hrs
2. Filter height – 0,75 – 1 m
3. Specific surface of filter medium 80 -120 m^2/ m^3
5. Voids in the filter mass 30-45%
6. Size of filter 8-14 cm dia,cinder
7. Up-flow velocity Max 2m/h
8. Organic load <4 kg/m^3 *day COD
9. Outlet water depth – 1.8- 2.2 m
10. CH_4–produced /Kg CODrem– 0.35 m^3/kg

Note: Calculation 19 steps

CODrem to Tem Graph

CODrem to WW strength G

CODrem to SFSurface G

CODrem to HRT G

CODrem to Organic Load G

Eff. Ratio (BODrem/CODrem) G

Design Calculations (AF)

E. Calculation

a. *Determination of Chamber sizes and numbers*

1. Determine ***BOD in and COD in*** *(outlet ABR).*
2. Determine **max peak flow per hour** (m^3/h) = $\frac{\textit{volume of wastewater } (m^3)}{\textit{Time of wastewater flows } (h)}$
3. Determine ***filter height*** (m)
4. Determine ***no. of chambers***.

Check!!! Minimum no. of 1 to 2 chambers! Adjust according to requirement of the outlet effluent quality

5. Determine ***net volume of AF reactor*** (m^3) =
   - ***Effective filter chamber height***= *depth of filter chamber (m) – [filter height (m) * (1 - voids in filter mass)]*
   - ***net volume of AF reactor*** (m^3) = *Length of each chamber (m) * width of filter chamber (m)* effective filter chamber height * number of filter chamber*

6. Determine ***HRT inside AF reactor*** (h) = $\frac{\text{net volume of AF reactor (m3)}}{[\textit{Daily wastewater flow } (m^3) / 24 \ (h)]}$

Check!!! As a stand alone treatment, normal HRT in AF is 24 – 48 hrs!!!

7. Determine ***max velocity in filter voids*** (m/h) =

$$\frac{\textit{max peak flow per hour } (m^3/h)}{\textit{Width of filter chamber } (m) * \textit{length of each chamber } (m) * \textit{voids in filter mass}}$$

Check!!! Max velocity in AF is 2 m/h!!!

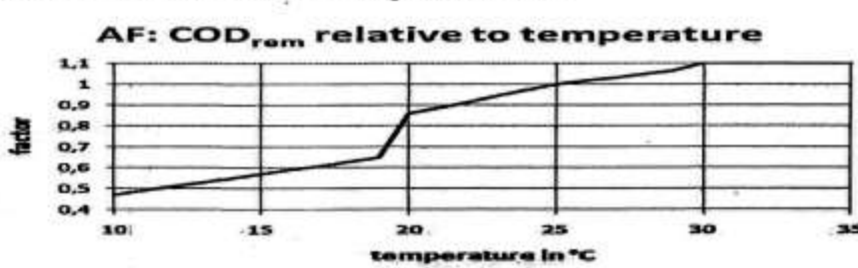
b. *Removal of Organic pollutants (BOD and COD removal)*

8. Determine ***organic load on AF COD*** (kg/m^3*day) =

$$\frac{\textit{Volume of wastewater } (m^3) * \textit{COD in } (mg/l)}{\textit{Net volume of filter chamber} * (1/1000 \ (g/kg))}$$

Check!!! Organic load < 4 kg COD/ m^3/day!!!

9. Determine ***factor temperature***.



temp < 20 °C:
*factor = (temp-10)*0.39/20+0.47*

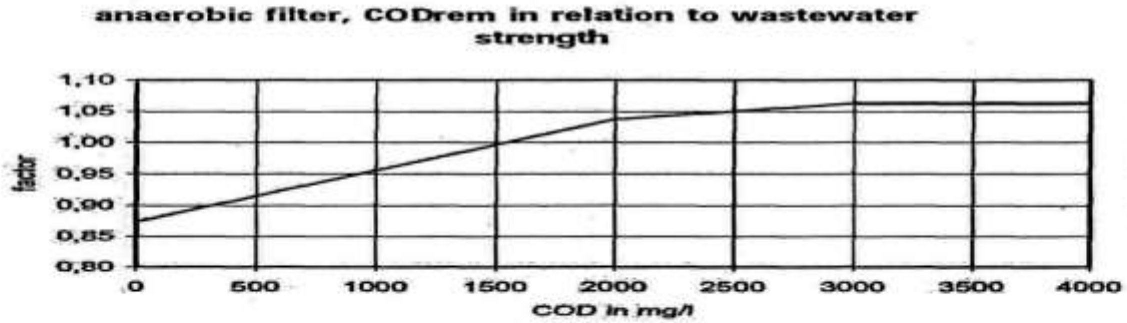
temp < 25 °C:
*factor = (temp-20)*0.14/5+0.86*

temp < 30 °C:
*factor = (temp-25)*0.08/5+1*

temp ≥ 30 °C:
factor = 1.10

10. Determine ***factor strength***.

Design Calculations (AF)

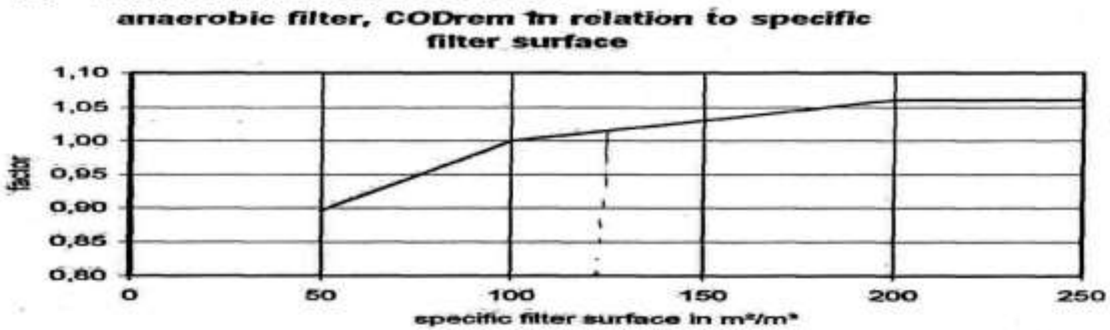


COD_{in} < 2000 mg/L:
factor = COD_{in}*0.17/2000+0.87

COD_{in} < 3000 mg/L:
factor = (COD_{in} -2000)*0.02/1000+1.04

$COD_{in} \geq$ 3000 mg/L:
factor = *1.06*

11. Determine *factor surface*.



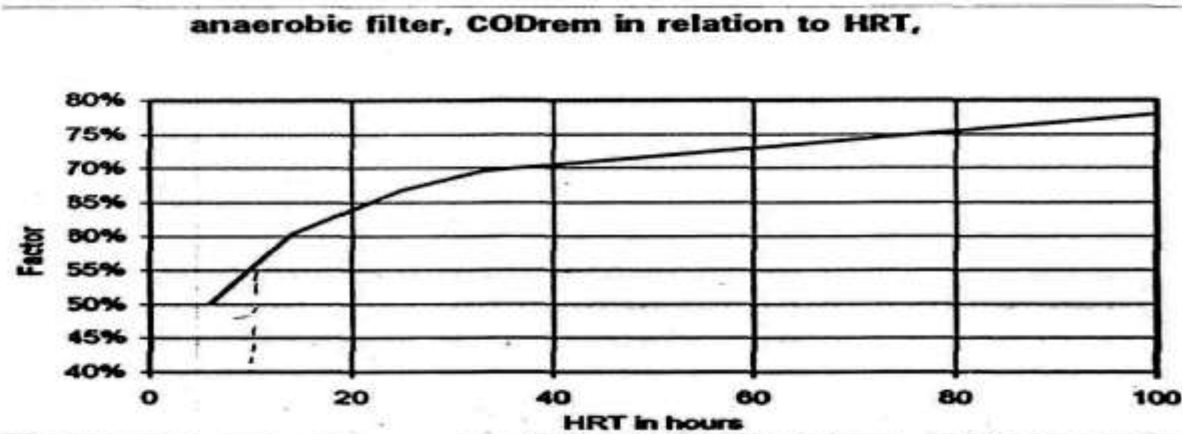
surface < 100 m^2/m^3:
factor = (surface-50)*0.1/50+0.9

surface < 200 m^2/m^3:
factor = (surface-100)*0.06/100+1

surface $\geq$ 200 m^2/m^3:
factor = 1.06

12. Determine *factor HRT*.

12. Determine factor HRT.



HRT < 12h:
factor = HRT*0.16/12+0.44

HRT < 24h:
factor = (HRT-12)*0.07/12+0.6

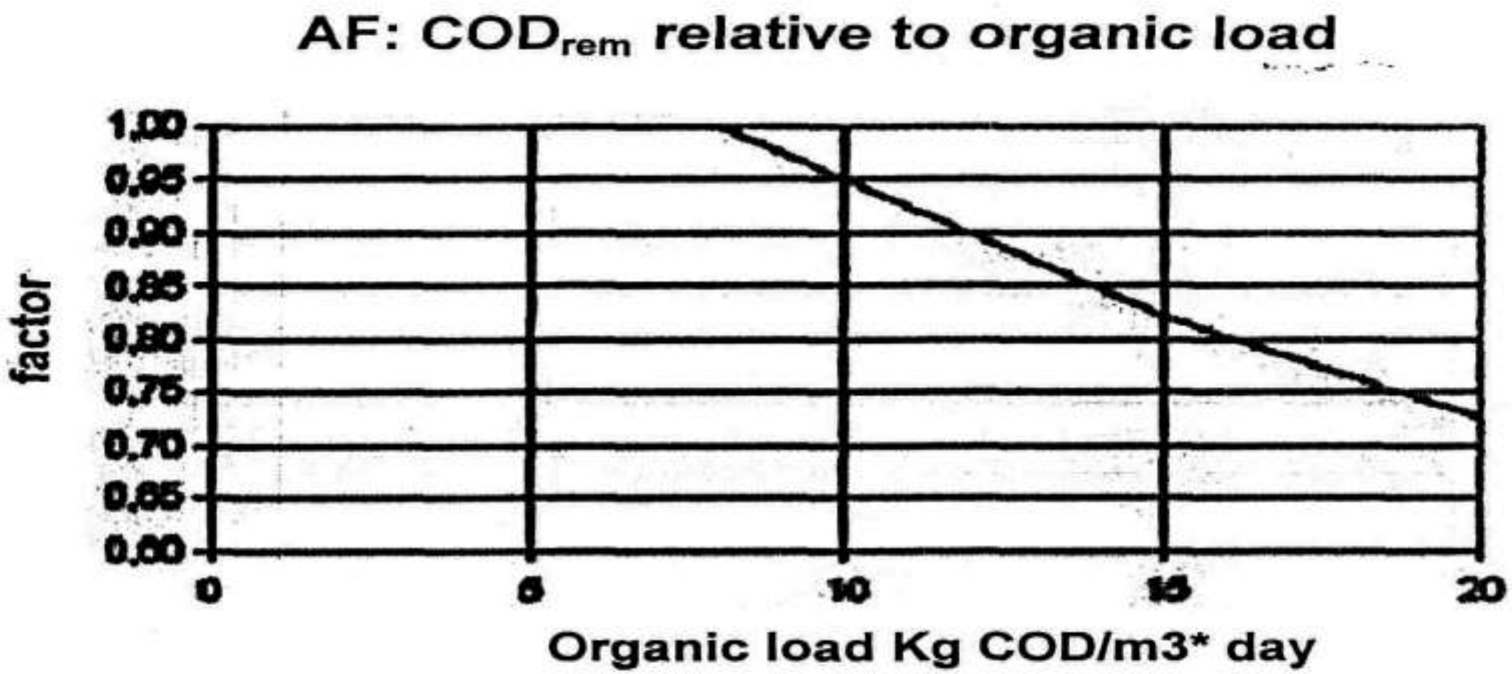
HRT < 33h:
factor = (HRT-24)*0.03/9+0.67

HRT < 100h:
factor = (HRT-33)*0.09/67+0.7

HRT $\geq$ 100h:
factor = *0.78*

Design Calculations (AF)

13. Determine ***factor organic load.***



14. Determine ***factor chamber.***

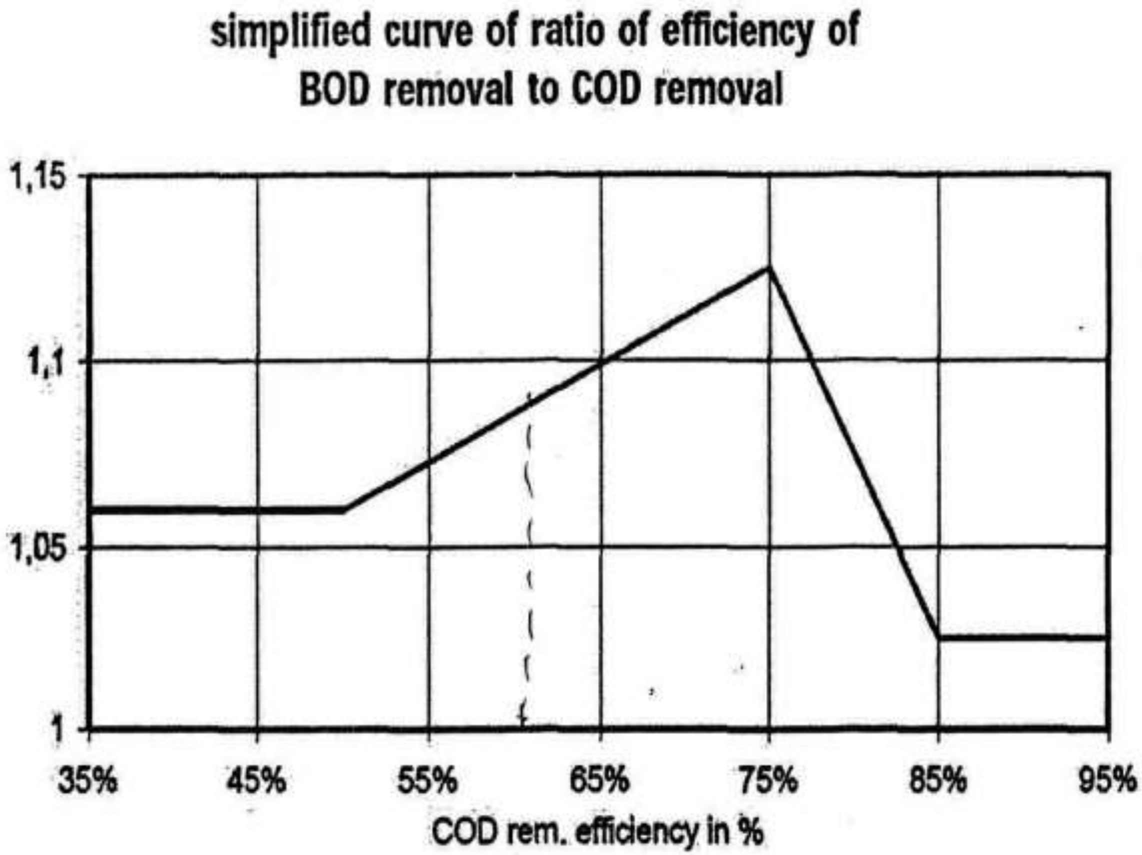
- Factor COD_{rem} related to number of up-flow chambers (f-chamber)
    - factor = 1 + (no of chambers * 0.04)

15. Determine ***COD removal rate*** = (*factor temperature * factor strength * factor surface * factor HRT * factor organic load * factor chamber*)

16. Determine ***COD outlet*** (mg/l) = ((*1 - COD removal rate) * COD in* (mg/l)).

17. Determine ***factor efficiency BOD removal to COD removal.***

Design Calculations (AF)



$COD_{rem} < 0.5$:
factor = *1.06*

$COD_{rem} < 0.75$:
factor = $(COD_{rem}-0.5)*0.065/0.25+1.06$

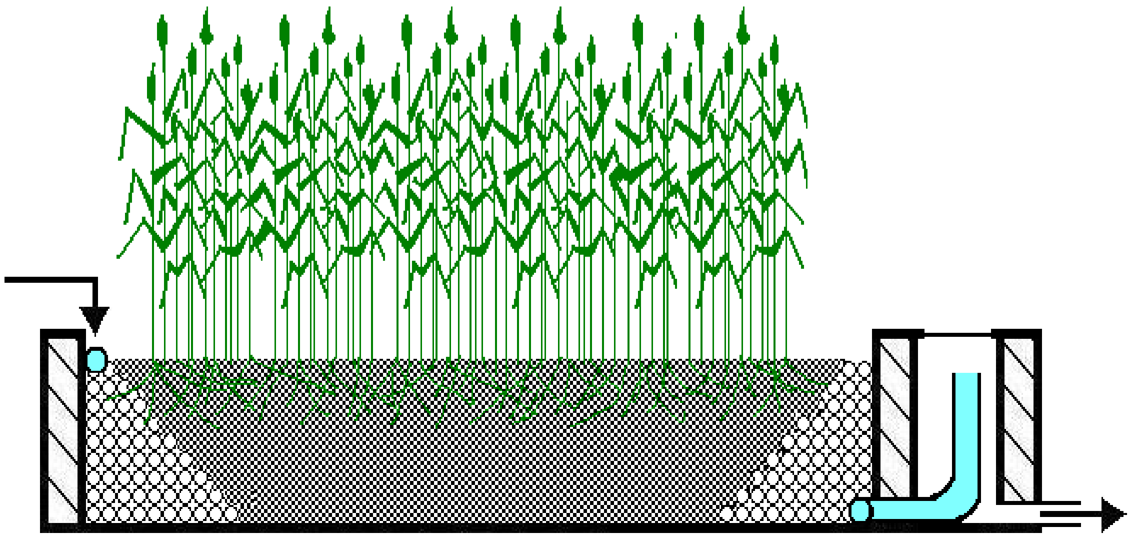
$COD_{rem} < 0.85$:
factor = $1.125-(COD_{rem}-0.75)*0.1/0.1$

$COD_{rem} \geq 0.85$:
factor = *1.025*

$$BOD_{rem} = COD_{rem} * \text{factor}$$

18. Determine ***BOD removal rate*** = (*COD removal rate * factor efficiency BOD removal to COD removal*)
19. Determine ***BOD outlet*** = ((1 – *BOD removal rate*) * *BOD in* (mg/l)).

Horizontal Planted Gravel Filter (HPGF)



Horizontal planted gravel filter (HPGF)

Kind of Treatment:
- aerobic-facultative-anaerobic degradation of dissolved & fine suspended solids
- pathogen removal

Wastewater Type:
- domestic & weak industrial wastewater where settleable solids & most suspended solids are already removed by pre-treatment

Advantages:
- high treatment efficiency
- pleasant landscaping possible
- no wastewater above ground
- cheap in construction if filter material is easily available
- no nuisance of odour
- pathogen and nutrient removal

Disadvantages:
- high space requirement
- costly if right quality of gravel is not available
- great knowledge and care are required during construction
- intensive maintenance & super-vision during first 1 – 2 years

Design Calculations (HGFP)
Horizontal Gravel Filter plant

Thumb Rules

1. Void of gravel – 35%- 45%
2. Max BOD on X sectional area- 150 g/m^3 s
3. Max organic on chosen surface (Organic load limit) – 10 $g//m^2$ BOD
4. Gravel size– 5-7mm, 10-12mm, 50-70mm dia., bigger size at inlet & outlet
5. Slope 1%
6. Height of filter 50 - 60 cm
7. Construction – Swivel at inlet & outlet to adjust water level

G – effi: ratio BOD_{rem}/COD_{rem}

G – 35% pore space & BOD_{rem}

G – 90% BODrem –HRT & Tem;

Note: Calculation 23 Steps

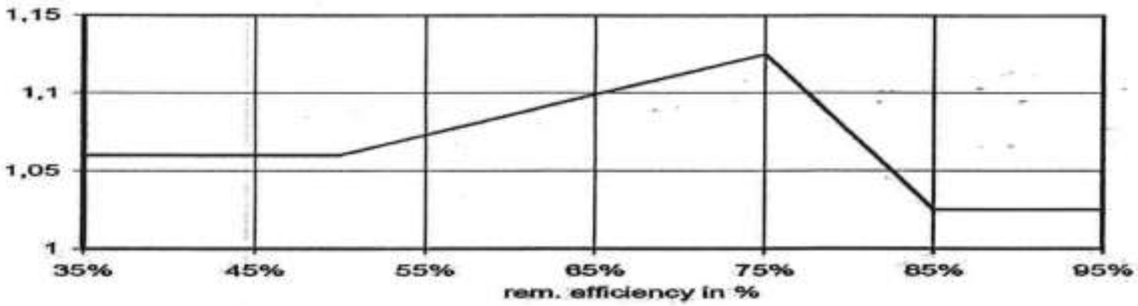
Design Calculations (HGFP)

E. Calculation

a. *Removal of Organic pollutants (BOD and COD removal)*

1. Determine ***COD/BOD ratio*** = (*COD in* (mg/l) / *BOD in* (mg/l))
2. Determine ***BOD removal rate*** = *BOD in* (mg/l) – *expected BOD out* (mg/l) / *BOD in* (mg/l))
3. Determine ***factor efficiency ratio of BOD removal to COD removal.***

simplified curve of ratio of efficiency of BOD removal to COD removal



Removal < 0.5:
factor = *1.06*

Removal < 0.75:
factor = $(BOD_{rem}-0.5)*0.065/0.25+1.06$

Removal < 0.85:
factor = $1.125-(BOD_{rem}-0.75)*0.1/0.1$

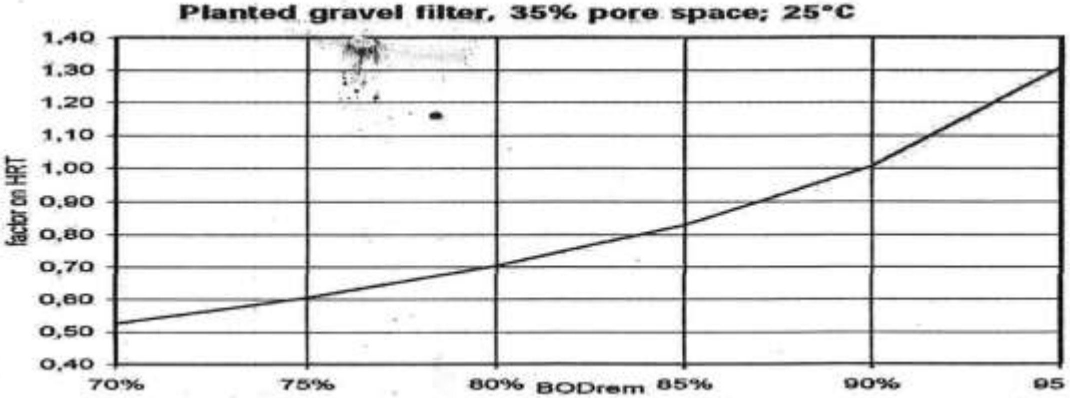
Removal ≥ 0.85:
factor = *1.025*

4. Determine ***COD removal rate*** = *BOD removal rate* / *Factor efficiency ratio of BOD removal to COD removal*
5. Determine ***COD out*** (mg/l) = [COD in (mg/l) * (1- *COD removal rate*)]

b. *Hydraulic design requirements*

6. Determine ***Hydraulic Conductivity*** (m/d)
7. Determine ***factor HRT – BOD removal.***

Planted gravel filter, 35% pore space; 25°C



BOD_{rem} < 40%:
factor = $BOD_{rem} * 0.22/0.4$

BOD_{rem} < 75%:
factor = $(BOD_{rem} - 0.4) * 31/35 + 0.22$

BOD_{rem} < 80%:
factor = $(BOD_{rem} - 0.75) * 9.5/5 + 0.605$

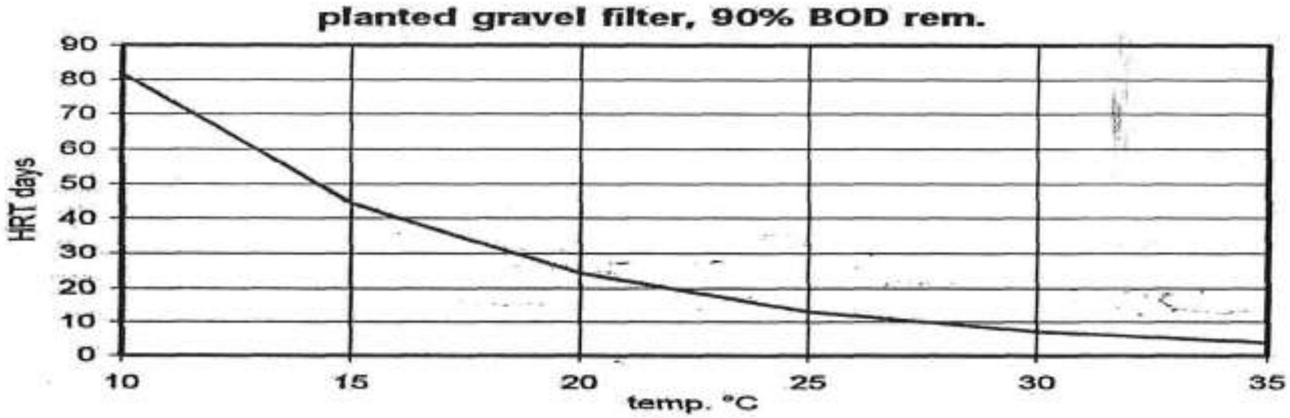
BOD_{rem} < 85%:
factor = $(BOD_{rem} - 0.8) * 12.5/5 + 0.7$

BOD_{rem} < 90%:
factor = $(BOD_{rem} - 0.85) * 17.5/5 + 0.825$

BOD_{rem} ≥ 90%:
factor = $(BOD_{rem} - 0.9) * 30/5 + 1$

Design Calculations (HGFP)

8. Determine ***factor HRT – temperature***.



temp < 15°C:
*factor = 82-(temp-10) *37/5*

temp < 20°C:
*factor = 45-(temp-15) *31/5*

temp < 25°C:
*factor = 24-(temp-20) *11/5*

temp < 30°C:
*factor = 13-(temp-25) *6/5*

temp ≥ 30°C:
factor = 7

9. Determine ***HRT*** (d) = ((*factor HRT to BOD removal*) * (*factor HRT to temperature*))

10. Determine ***HRT in 35% pore space*** (d) = (35% * *HRT*)

c. *Determination of Chamber sizes*

11. Determine ***cross section area 1*** (m^2) = $\frac{\text{daily wastewater flow } (m^3)}{\text{Conductivity (m/d) * elevation (\%)}}$

12. Determine ***cross section area 2*** (m^2) =

$$\frac{\text{Daily wastewater flow } (m^3) * \text{BOD in (mg/l)}}{\text{Max BOD5 on cross section area}}$$

13. Determine chosen ***cross section area***.

If cross section area 1 > cross section area 2, then 1. If cross section area 1 < cross section area 2, then 2!!!

14. Determine ***required width of filter basin*** (m) = $\frac{\text{cross section area } (m^2)}{\text{Depth (m)}}$

15. Determine ***chosen width of filter basin*** (m).

16. Determine ***required surface area 1*** (m^2) =

$$\frac{\text{Daily flow } (m^3) * [\text{BOD in (mg/l)} - \text{expected BOD out (mg/l)}]}{\text{Max organic load}}$$

17. Determine ***required surface area 2*** (m^2) = $\frac{\text{daily flow } (m^3) * \text{HRT (d)}}{\text{Depth of filter (m)}}$

18. Determine chosen ***required surface area*** (m^2).

Design Calculations (HGFP)

If required surface area 1 > required surface area 2, then 1. If required surface area 1 < required surface area 2, then 2!!!

19. Determine ***required length of filter basin*** (m) = $\frac{\textit{chosen surface area } (m^2)}{\textit{width of filter basin } (m)}$

20. Determine ***chosen length of filter basin*** (m).

21. Determine ***actual surface area*** (m) = (*chosen length* (m) * *chosen width* (m))

Check!!! Actual surface area > chosen required surface area.

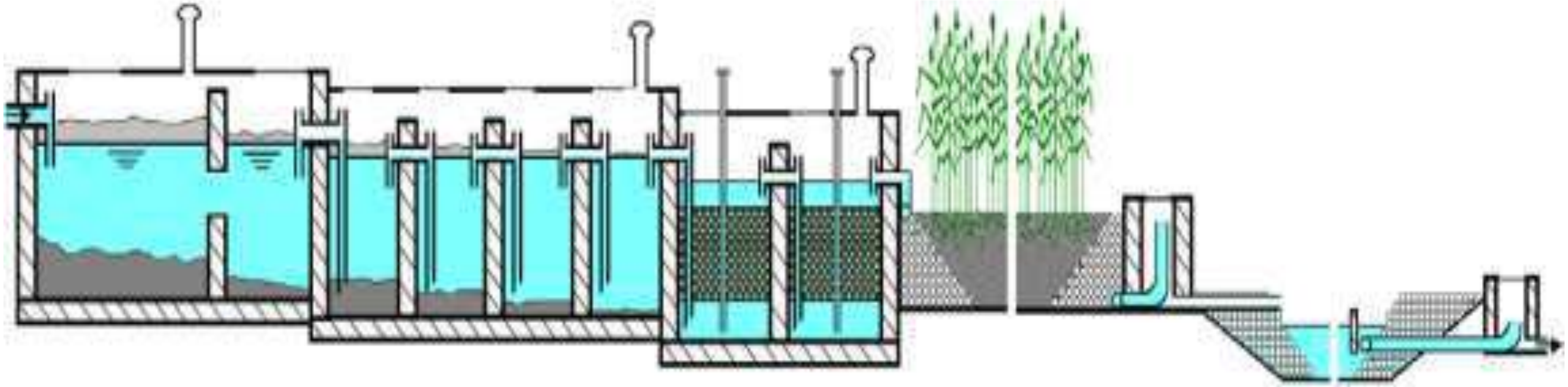
22. Determine ***hydraulic load on chosen surface*** (m/d) = $\frac{\textit{daily flow } (m^3)}{\textit{Actual surface area } (m^3)}$

Check!!! Should be less than 0.1 m/d – 0.3 m/d depending on the type of filter media chosen

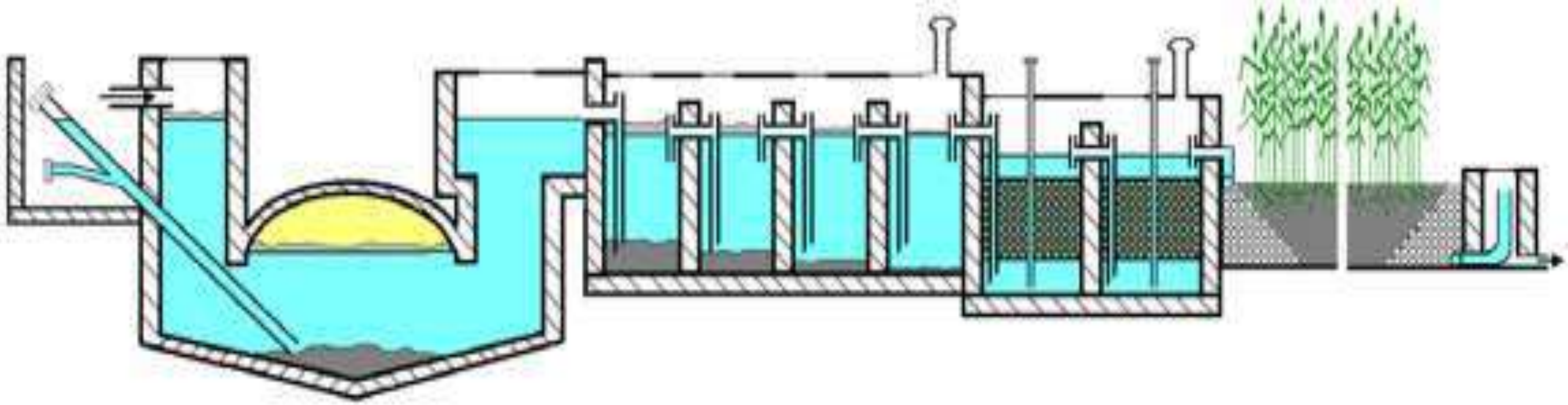
23. Determine ***organic load on chosen surface*** (g/m^2 BOD) = (*hydraulic load* (m/d) * *BOD in* (mg/l))

CDD- Consortium DEWATS Disemination

Decentralized Wastewater Treatment System



settler – ABR – AF – PGF – polishing pond (not true to scale)



fixed dome biogas settler – ABR – AF – PGF (not true to scale)

Engineer’s Manipulation for Space

Reutilizing Wastewater for Plants





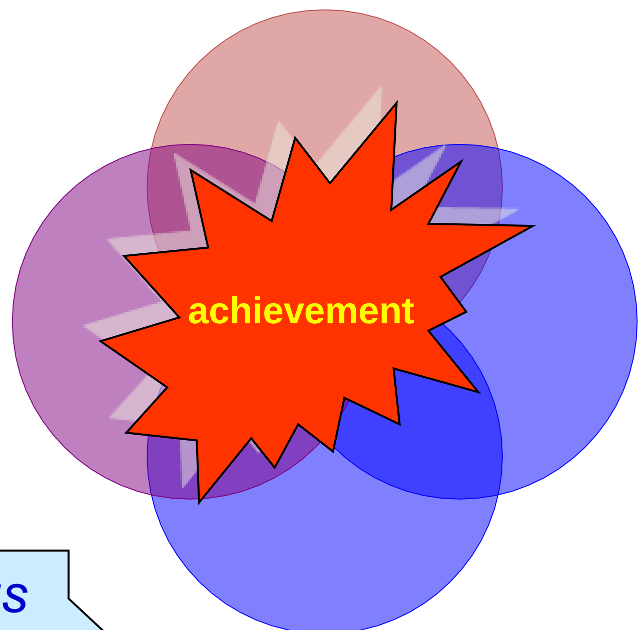

COCA

"If you think you can and if you think you can't, you're right."

CAPABILITIES

"Practice is the best of all instructions."

ACTION



"An optimist sees an opportunity in every difficultly."

OPPORTUNITIES

"The future belongs to the common man with uncommon determination."

COMMITMENT

THANK YOU