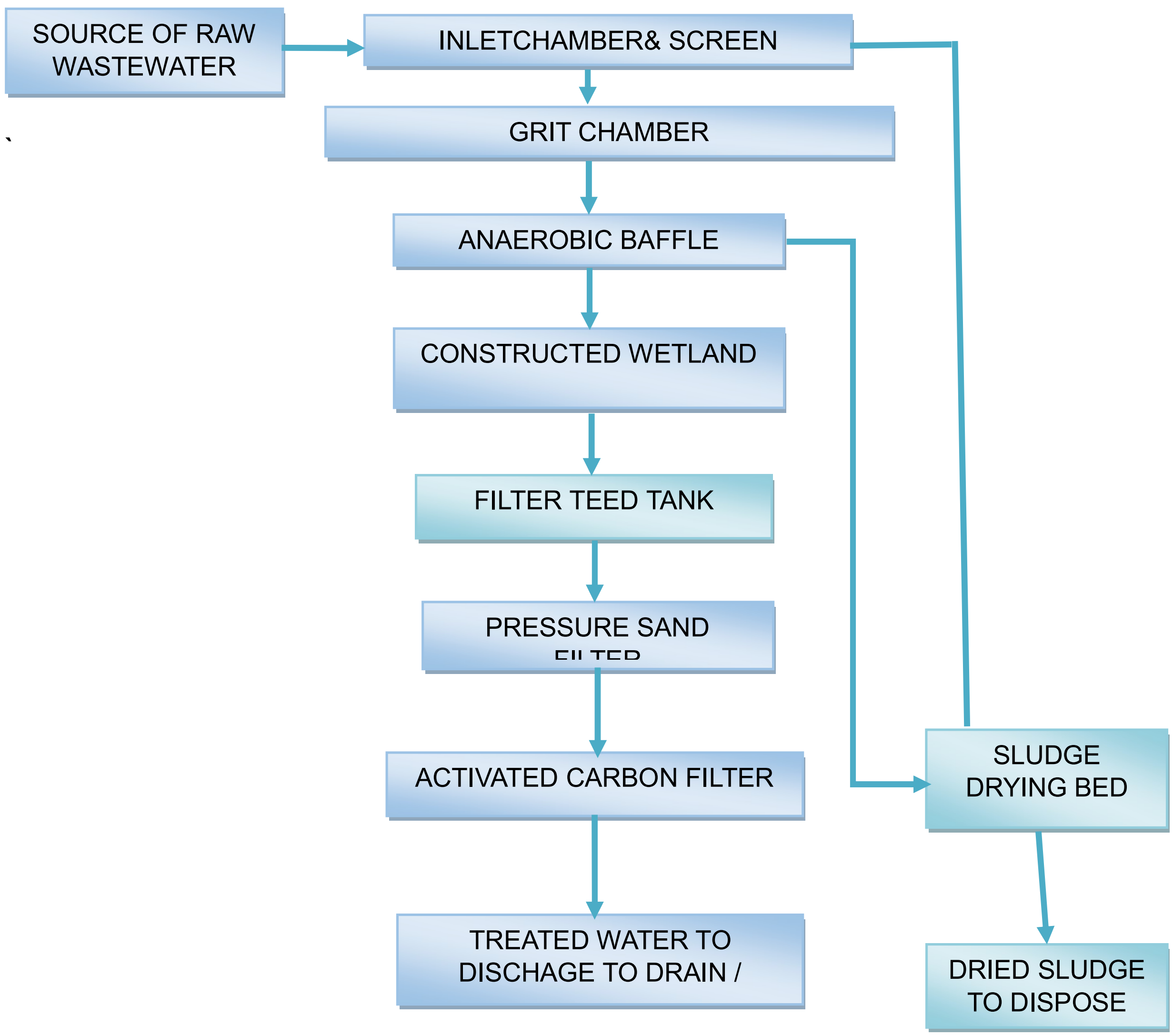
3 KLD FAECAL SLUDGE TREATMENT PLANT (FSTP) FOR ENGLISH BAZAR UNDER MALDA DISTRICT

TREATMENT SCHEME



Input Data

Sl. No.	Parameters	Design Data
1	Flow	3 cum/day
2	pH	6.5 to 8.5
3	Suspended Solids	750 mg/l
4	BOD	1600 mg/l
5	COD	5200 mg/l
6	TSS	1850 mg/l
6	Oil and Grease	50 mg/l

<u>Design of Grit Chamber cum scum removal unit</u>

a) ***Computation of settling velocity***

Grit Size to be removed (d) = 0.15 mm
= 0.15×10^{-3} m
Specific gravity of Grit (S_s) = 2.65

Kinematic Viscosity at 15deg C = 1.14×10^{-6} m^2/s (#) CPHEEO manual;

Settling Velocity (By Stoke's Law), (V_s) = $g \times d^2 \times (S_s-1) / (18 \times v)$
= $9.81 \times (0.15 \times 10^{-3})^2 \times (2.65 – 1) / (18 \times 1.14 \times 10^{-6})$
= 0.018 m/s

<u>Check for Reynold's Number</u>
Reynold's Number (R) = $V_s \times d / v$
= $0.018 \times (0.15 \times 10^{-3}) / (1.14 \times 10^{-6})$
= 2.37

As Reynold's Number (R) is greater than 0.5, Stoke's Law does not apply.
Applying Transitions Law for $0.5 < R < 10^3$
Settling Velocity, (V_s) = $[0.707 \times d^{1.6} \times (S_s-1) \times v^{-0.6}]^{0.714}$
= $[0.707 \times (0.15 \times 10^{-3})^{1.6} \times (2.65 – 1) \times (1.14 \times 10^{-6})^{-0.6}]^{0.714}$
= 0.0168 m/s

b) ***Computation of surface overflow rate, SOR***

The surface overflow rate for 100% removal efficiency in an ideal grit chamber = Settling velocity of the minimum size of particle to be removed
= 0.0168 m/s
= 1451.5 $m^3/m^2/d$

However, due to turbulence and short circuiting, due to several factors as eddy, wind and density currents, the actual value to be adopted has to be reduced taking into account the performance of the basin and the desired efficiency of the particles removal. To determine the actual overflow rate, the following formula is used.

Efficiency of removal of desired particles, (η) = $1- [1+ \{n \times V_s / (Q/A)\}]^{(-1/n)}$
Where,
n = Measure of settling basin performance

= 1/8 for very good performance
Q = Flow in m^3/d
A = Cross-sectional area perpendicular to the flow in m^2

Assuming,
η = 90%, n = 1/8 -- (*)

Surface Overloading Rate (Q/A) = $(V_s \times n) / [(1-\eta)^{-n} - 1]$
= $[1451.5 \times (1/8)] / [(1-0.75)^{-0.125} - 1]$
= 544 $m^3/m^2/d$

c) ***Determination of the dimensions of grit chamber***

Flow = 3*3 cum/day based on peak flow
Plan Area of grit Chamber = [Q / (Q /A)]
= (9) / 544
= 0.016 m^2
Width of Grit Chamber = 0.6 m
Length of Grit Chamber = (Plan Area / Width of Grit Chamber)
= (0.016/ 0.6)
= 0.027 m

Length of Grit Chamber provided = 1.5 m
Total length of Grit chamber = 1.5 m

The critical displacement velocity to initiate re-suspension of grit is given by
Critical Displacement Velocity, (V_c) = $[8 \times k \times g \times d \times (S_s-1) / f]^{0.5}$
For k = 0.04, f = 0.03, S_s = 2.65, d = 0.15 x 10^{-3} m ---------------------------------- (#)
Critical Displacement Velocity, (V_c) = $[8 \times 0.04 \times 9.81 \times (0.15 \times 10^{-3}) \times (2.65 - 1) / 0.03]^{0.5}$
= 0.161 m/s
The horizontal velocity of flow V_h should be kept less than critical displacement velocity V_c
Assuming a depth of 1.0 m
Horizontal Velocity of flow, (V_h) = [{(3 x 3) / (24 x 3600)}/ {0.6 x 1.5}]
= 0.00015 m/s
As $V_h < V_c$ hence the assumed depth is O.K.
The Detention time (HRT) =(Volume / Peak discharge)
(based on maximum flow) = (1.5 x 0.6 x 1.0) / {(3 x 3) / (24 x 3600)}
= 8640 sec = 2.4 hrs

As the detention time calculated (8640 sec) is more than the stipulated detention time (60 sec) hence the dimensions of the Grit Chamber is O.K.

Dimensions of Grit Chamber including scum removal unit, m
= 1.5 (L) x 1.5 (W) x 1.0 (Ht) ,

Design of Anaerobic Baffle Reactor

Assumption:

Sl. No.	Parameters	Input Data
1	Flow	3 cum/day
2	Peak factor	3
3	pH	6.5 to 8.5
4	Influent COD (S_o)	5200 mg/l
5	Influent BOD	1600 mg/l
6	Effluent TSS concentration	350 g / m³
7	Factor of safety for design SRT	1.5
8	VSS/TSS *[1]	0.85
9	f_d*[1]	0.15 g VSS cell debris/g VSS biomass decay
10	COD reduction *[1]	70%
11	COD / TSS ratio *[1]	1.8

*[1] As per Metcalf Eddy 4th Edition, Table 10-17

BOD in = 1600 mg/l

COD in = 5200 mg/l

1. Determine max flow at peak hour

Max$flowatpeakhours$ (m3/ h)

= $volumeofwastewater$ (m3) x 3/ 24(h)

= 3 x 3 / 24

= 0.375 cum/hr

Consider Max flow = 1.25 cum /hr

Determine the required reactor volume considering the volumetric organic loading

a. The nominal liquid volume of reactor based on using an acceptable organic loading is given by

$$V_n = \frac{QS_o}{L_{org}}$$

= $\frac{1.25 \ x\ 24\ x\ 5.2}{8}$

= 19.5m³

Where V_n= liquid volume of reactor, m³

Q = influent flowrate, m³/h = 2.5 m³/h

S_0 = influent COD, kg COD/m³ = 5.2 kg/ m³

L_{org} = Volumetric organic loading rate, kg COD/m³. d

= 8 kg COD/m³.d *

* Note: Recommended volumetric organic loading as per table 10-12, Anaerobic sludge Blanket Processes, Metcalf Eddy 4thEdition

b. Determine the total reactor liquid volume using equation

$V_L = \frac{V_n}{E} = \frac{19.5 \text{ m}^3}{0.8} = 24\text{m}^3$

Where V_n= liquid volume of reactor, m³
V_L= Total reactor volume of reactor, m³
E = Effectiveness factor, 80% considered (Ref: Metcalf Eddy 4th Edition)
Provided Anaerobic reactor volume = 24 m³

c. Hydraulic retention time = 24 m³ / 3 m³/day
= 8 day

Determine Solid retention time (SRT)

We consider the COD removal at the anaerobic reactor = 70%
* Ref: table 10-17, Metcalf Eddy 4th Edition

The effluent COD = (1.0-0.7) *5200 = 1560 mg/l = 1560 g / m³
The assumed effluent TSS concentration = 250 g / m³
Effluent COD from TSS = (250 g / m³) * 1.8 g COD / g TSS = 450 g / m³
Allowable effluent soluble COD = (1560 – 450) = 1110 g / m³
To determine SRT

$SRT = \left(\frac{\mu_m S_e}{K_s + S_e} - k_d\right)^{-1}$

Kinetic Coefficients are as per Table:10-10, Metcalf Eddy, 4th edition
Maximum specific growth rate μ_m = 0.20 g/g.d
Half velocity constant K_s = 900 mg/l
Decay coefficient k_d = 0.04 g/g.d

SRT = $\left(\frac{(0.20 \text{ g/g.d}) \ (1110 \text{ g / m}^3)}{(900+1110)\text{g / m}^3} - 0.04 \text{ g/g.d}\right)^{-1}$ = 14 d

SRT = 14 d
Suggested design Solid retention time (SRT) as per CPHEEO manual = 20 d at @24°*C*
So, we consider the designed SRT = 20 d

Determine the Sludge Production considering suggested SRT

Influent COD (S_o) = 5200 g/ m³

Effluent COD (*S*) = 1560 g/ m³

Particulate COD = 0.3 * S_o (Fraction of particulate COD consider 0.1 to 0.3)

= 0.3*5200 = 1560g/ m³

Determine the non-soluble COD as TSS using 1.8 g COD / g TSS (assume)

Non-soluble COD = 1560/1.8 = 867g/ m³

Degradable fraction of TSS = 0.8 (assume)

Nondegradable TSS = 0.2*(867) = 173g/ m³

$$P_{X,TSS} = \frac{QY(S_o - S)}{[1 + (k_d)SRT](0.85)} + \frac{f_d(k_d)QY(S_o - S)SRT}{[1 + (k_d)SRT](0.85)} + Q(nondegradable\ TSS)$$

Q = 3 m³/day
Y = Combined Yield = 0.08 g VSS / g COD
Decay coefficient k_d = 0.03 g/g.d
f_d= 0.15 g VSS cell debris / g VSS biomass decay
$(S_o - S)$ = Influent COD – effluent COD
= (5200 – 1560) = 3640 g/ m³

$$P_{X,TSS} = \frac{(3)(0.08)(3640)}{[1+(0.03)20](0.85)} + \frac{0.15(0.03)3(0.08)(3640)20}{[1+(0.03)20](0.85)} + 3(173)$$

= 642 g/d + 58 g/d +519 g/d

= 1219 g/d

Check reactor volume considering sludge production and SRT

Determine reactor Volume using Equation

$$Volume\ x\ X_{TSS} = (P_{X,TSS})(SRT)$$

Consider microbial mass (X_{TSS}) in the reactor = 2500 g/ m³

$$Volume = \frac{(P_{X,TSS})(SRT)}{X_{TSS}}$$

$$= \frac{(1219)(3)}{2500}$$

= 1.5m³

As pervolume organic loading kg COD/m³. d, Reactor volume = 1.5 m³

However, we consider additional space considering non degradable factor

Provided volume of anaerobic tank = 28 m³

Actual Hydraulic retention time = 28 m³ / 3 m³/day
= 9.3 day (Range: HRT in day 0.5 – 5 , Metcalf Eddy 4th Edition)

Check The up-flow velocity

Additional space considering storage
Volume the anaerobic reactor = 28 m³
No. of chamber consider = 8
Volume of each chamber = 28/8 m³ = 3.5 m³
Liquid depth consider = 2.5 m
Area of each chamber = 3.5/2.5 = 1.4 sqm
Upflow velocity at average flow = (3 / 24) / 1.4) = 0.08 m/h
Upflow velocity at peak flow = 1.25 / 1.4 = 0.89 m/h
Hence up-flow velocity is ok

Check BOD reduction

a. BOD removal based on detention time

Typical performance data for the removal of BOD as a function of the detention time using following formula

$R = \frac{t}{a+bt}$ where t= detention time

a, b = empirical constant

R = Removal efficiency

$R = \frac{(9.3)*24}{0.018+(0.02)(9.3)*24}$ Where, a= 0.018, b= 0.02; (ref: Metcalf & Eddy)

= 50%

BOD after anaerobic tank = 1600 x (1 – 0.50)

= 800 mg / l

b. Interrelation between BOD, COD after primary treatment

BOD/COD ratio range after primary treatment = 0.4 – 0.6

Consider BOD/COD ratio = 0.5

BOD after anaerobic tank = 0.5 x COD

= 0.5 x 1600 = 800 mg / lit

So, consider BOD after anaerobic tank = 800 mg/lit

Design of Constructed Wetland

Design Consideration of Constructed Wetland

Sl. No.	Parameters	Value
1	S0 (influent BOD) at inlet of wetland	800 mg/l
2	Se (effluent BOD) at outlet of wetland	30 mg/l
3	K_{BOD}(rate constant (m/d))	0.15m/d
4	Kf, hydraulic conductivity of the fully developed bed (m/s)	2 x 10^{-3} m/s
5	dH/ds = slope of bottom of the bed (m/m)	0.01

Th e wetland sized based on the equation proposed by Kickuth:

$$A = \left(\frac{Q_d(\ln BOD_{in} - \ln BOD_{out})}{K_{BOD}}\right)$$

· A = Surface area of bed (m2)

· Qd = average daily flow rate of sewage (m3/d)

· BOD_{in} = infl uent BOD5 concentration (mg/l)

· BOD_{out} = effl uent BOD5 concentration (mg/l)

· K_{BOD} = rate constant (m/d)

Qd = 3 m³/day

BOD_{in} = 800 mg/l

BOD_{out} = 30 mg/l

K_{BOD} = 0.15 m/d for Horizontal flow wetland

Substituting the values in the equation below:

$$A = \left(\frac{Q_d(\ln BOD_{in} - \ln BOD_{out})}{K_{BOD}}\right)$$

Area for Horizontal flow wetland = 65m^2

Dimensioning of the bed cross-section is derived from Darcy's law

Th e equation is:

Ac = Qs / Kf (dH/ds)

- · Ac = Cross sectional area of the bed (m2)
- · Qs = average fl ow (m3/s)
- · Kf = hydraulic conductivity of the fully developed bed (m/s)
- · dH/ds = slope of bottom of the bed (m/m)

Let us find the bed cross sectional area required for the Horizontal Flow wetland that was calculated as below

Qs = 3 m^3/day = 0.0000347 m^3/s

Kf = 2 x 10^{-3} m/s

dH/ds = 0.01

Substituting the values in the above equation,

Cross-sectional area (Ac) = 1.75 m^2

Effective Depth of wetland = 1.50 m

Free Board = 0.5 m

Width of wetland = 1.75 m^2/ 1.50 m
= 1.16 m

Provided width of wetland = 2.0 m

Length of wetland = 65 / 2.0 m
= 32.5 m

Size of wetland

Provided Length of wetland = 34.0 m

Provided Width of wetland = 2.0 m

Total depth of wetland including freeboard = 2.0 m

Filter feed tank

Peak Flow	= 1.25 cum/hr
Detention time	= 2.0 hr.
Capacity of tank	= (1.25*2) = 2.5 cum
Liquid depth of tank	= 1.2 m
Surface area of tank	= 2.1 sqm
Dimension of the tank	= 1.50 m x 1.50 m
Provided tank Provided free board of tank	= 0.30 m
Total height of tank including free board	= (1.2 +0.30) m = 1.50 m

Dimensions of Filter Feed tank including free board, m = 1.50 m x 1.50 mx 1.50 m (Height)

Pressure sand filter

Design Consideration for PSF

Capacity of Filter (Q)	= 1.0 cum / hr
Loading rate (LR)	= 6 cum / sqm / hr
Calculated diameter	= Sqrt(1.0*4/6*π) = 0.460 m
Diameter provided	= 0.600 m
Total Height of Filter	= 1.550 m
MOC of Filter	= FRP
Type of Valve and size	= Multiport valve and 25 NB
Velocity through pipe	= 1.8 m/s
MOC of Pipe	= uPVC,
Media	= Graded gravels and coarse sand

Activated Carbon filter

Design Consideration for ACF

Capacity of Filter (Q)	= 1.0 cum / hr
Loading rate (LR)	= 6 cum / sqm / hr
Calculated diameter	= Sqrt(1.0*4/6*π) = 0.460 m
Diameter provided	= 0.60 m
Total Height of Filter	= 1.550 m
MOC of Filter	= FRP
Type of Valve and size	= Multiport valve and 25 NB
Velocity through pipe	= 1.8 m/s
MOC of Pipe	= uPVC,
Media	= Graded gravels and activated carbon

K. Sludge Drying Bed

Flow = 3 cum/day

Sludge generated = 1219 g/day = 1.2 kg/day

Total Sludge wasted (25 % of total treated BOD)= 0.3 kg /day

Calculation of Area required based on Sludge Volume

No. of Cycles	= 60 days
Concentration of sludge	= 0.9%
Volume of sludge generated	= 0.3 / (0.9 x 10)
	= 0.033 cum/day
Depth of sludge in Sludge Drying Beds	= 0.2 m
Area of drying required	=0.033 x 60 / 0.2 = 10 sq.m
No. of drying beds	= 2 nos.
Area of each Drying Bed	= 10/2 = 5 sq.m
Length of each Bed	= 4.5 m
Width of each Bed	= 5/4.5 m = 1.1 m
Provided Width of each bed	= 1.4 m

Provided Dimensions of Sludge Drying Beds, m = 4.5 (L) x 1.4 (W) x 0.8m +0.5m FB (ht), 2Nos