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Design of a Sewage Treatment Plant at Bearys Institute of Technology, Mangalore

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Abstract: *Wastewater generated in school and colleges have to take care as it may pollute the ground water if not treated properly. This paper focuses on the design of a STP unit in Bearys Institute of Technology (BIT), Mangalore for the treatment of boy's hostel wastewater of 160 students with 135 LPCD. Physical and chemical characteristics of the wastewater samples showed a low strength in pollutant concentrations. Treatment units were planned and designed based on the existing condition. Equalization tank was designed for flow balancing; however, flash mixer was designed to mix coagulants. Suspended particles can be removed with clariflocculator and generated floc can be sent to the sludge drying bed. Colloidal and finer particles can be removed in rapid gravity filter and disinfection unit was designed for destroying the pathogens and ensuring safe disposal of treated wastewater.*

Keywords: *Characteristics, Design, Dimension, Sewage, STP*

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I. Introduction

Sewage disposal in natural waters is a common practice among many nations. Large inputs of organic matter and nutrients from raw sewage to a weak hydrodynamic environment poses environmental and health problems from deterioration of water quality [1,2]. Shivaranjani and Thomas (2017) have presented the performance study for treatment of institutional wastewater by activated sludge process. The maximum BOD removal efficiency obtained was 93.7% and turbidity removal efficiency was 87.6% in the 8 hrs HRT [3]. Dhote et al. (2012) have undertaken a study of review on wastewater treatment technologies with chemical coagulation, adsorption and activated sludge to remove pollutants from wastewater [4]. Roy et al. (2016) have conducted studies on analysis and design of an institutional wastewater management scheme. They have pointed the recycling and recovering of wastewater with Sequencing Batch Reactor (SBR) [5]. Lognathan et al. (2012) have reported a batch mode SBR to treat domestic wastewater and the results showed that effective influent parameters were removed within 6 hr cycle time where an aeration rate was 6 L/min [6].

II. Methodology

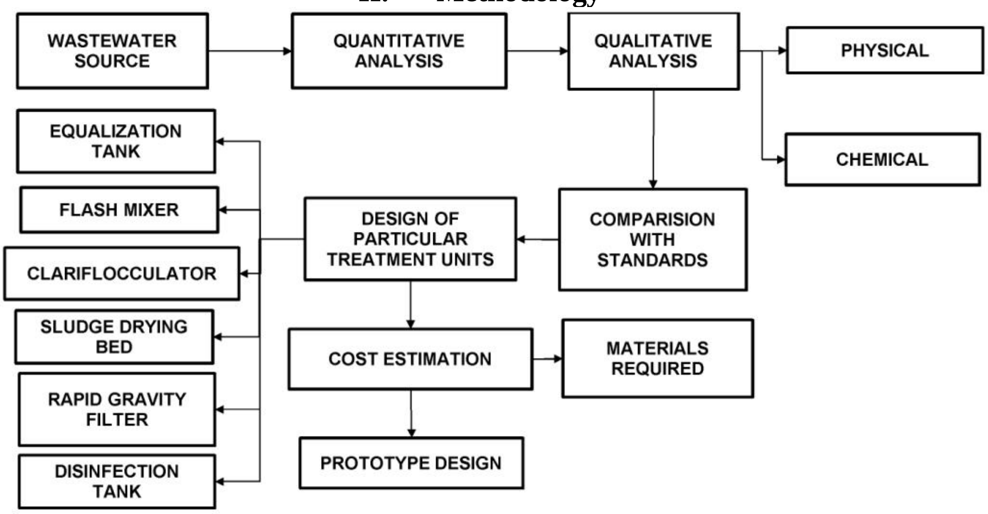


Fig. 1. Methodology adopted for the treatment of BIT boys hostel wastewater.

Methodology was developed based on the quantity and characteristics of wastewater generated in BIT boys' hostel. The treatment units were selected based on the functions and economy. Flow equalization tank was considered for balancing the generated wastewater. However, Flash mixer, Clariflocculator, and rapid gravity filters were taken into consideration for the removal of suspended and colloidal particles. Finally, disinfection unit was installed for killing the pathogens. The sludge generated in clariflocculator was sent to sludge drying bed.

III. Results and Discussion

3.1 Characteristics of collected wastewater sample

The collected wastewater (w/w) was characterized for physical and chemical parameters. Table 1 represents the characteristics of the collected sample. The pH of the wastewater sample was varying from 7.4 ± 0.7. However, BOD of the wastewater sample was observed varying from 55 ± 20 mg/l. On the other hand, COD of the wastewater sample was varying from 290 ± 60 mg/l. It was observed that BOD and COD were above the discharge standard as per IS-2012. Based on the characteristics of the sample it was concluded the wastewater was having low strength pollutant concentration.

Table 1: Physical and chemical characteristics of collected wastewater sample in BIT campus

Sl No.	Parameter	Unit	Concentration of wastewater sample	Discharge Standard (IS-2012)
Physical				
1	Temperature	°C	20 ± 40	> 5
2	Turbidity	NTU	2 ± 1	
3	Color	Hazens	Colorless	
Chemical				
4	pH		7.4 ± 0.7	5.5 - 9
5	Conductivity	µs/cm	190 ± 15	
6	TDS	mg/l	380 ± 40	
7	TSS	mg/l	130 ± 12	100
8	DO	mg/l	6.5 ± 2	> 4
9	BOD	mg/l	55 ± 20	30
10	COD	mg/l	290 ± 60	250
11	Chloride	mg/l	250 ± 20	
12	Sulfate (SO_4^{-2})	mg/l	95 ± 7	
13	Nitrate (NO_3^-)	mg/l	12 ± 2.2	10
14	Phosphate (PO_4)	mg/l	0.2 ± 0.14	5

3.2 Calculation of wastewater generated

INPUT			
No. of water tanks		2	nos
Each tank capacity		5000	liters
No. of times of filling		3	times
Population		160	Popln
Per capita demand		135	LPCD
CALCULATION			
Flow rate	Popln x LPCD	21600	L/d
		21.6	m^3/d
Quantity of water supplied		21.6	m^3/d
Quantity of wastewater generated	80% of water supply		
Quantity of wastewater generated	80% of water supply	17.28	m^3/d
Assume peak factor		1.3	times
Total quantity of ww generated	WW generated x 1.3	22.46	m^3/d
RESULT			
Quantity of wastewater generated		**22.46**	**m^3/d**
		22464	l/d
		0.022	MLD
		25	m^3/d
Consider future expansion and peak demand		2	times
	~	**50**	**m^3/d**

3.3 Design of Equalization tank

INPUT			
Average wastewater flow		50	m^3/d
		50000	l/d
Max Volm of WW in 1 hr		2100	L/hr
Max Vol of Eq Tank	from graph, 4000, say	5000	L
Detention period		1	hr
		3600	sec
Assume Depth		1.5	m
CALCULATION			
Volume of Equalization Tank	max vol * Dt	5000	L
		5.0	m^3
Surface area	Vol/depth	3.3	m^2
Assume	L:B	1.5	:1
Breadth of the tank	B	1.5	m
Length of tank	L	2.24	m
The velocity water in the Eq tank	v = Vol/SA	15	m/d
		62.5	cm/hr
Assume inlet and outlet pipe dia		0.15	m
RESULT			
Length	**L**	**2.24**	**m**
Width	**B**	**1.5**	**m**
Depth	**H**	**1.5**	**m**
Detention period	**Dt**	**1**	**hr**
Area of the equalization tank	**A**	**3.3**	$\mathbf{m^2}$
Calculated volume of Eq Tank	**Vol**	**5.0**	$\mathbf{m^3}$
Inlet and Outlet Pipe diameter	**d**	**0.15**	**m**

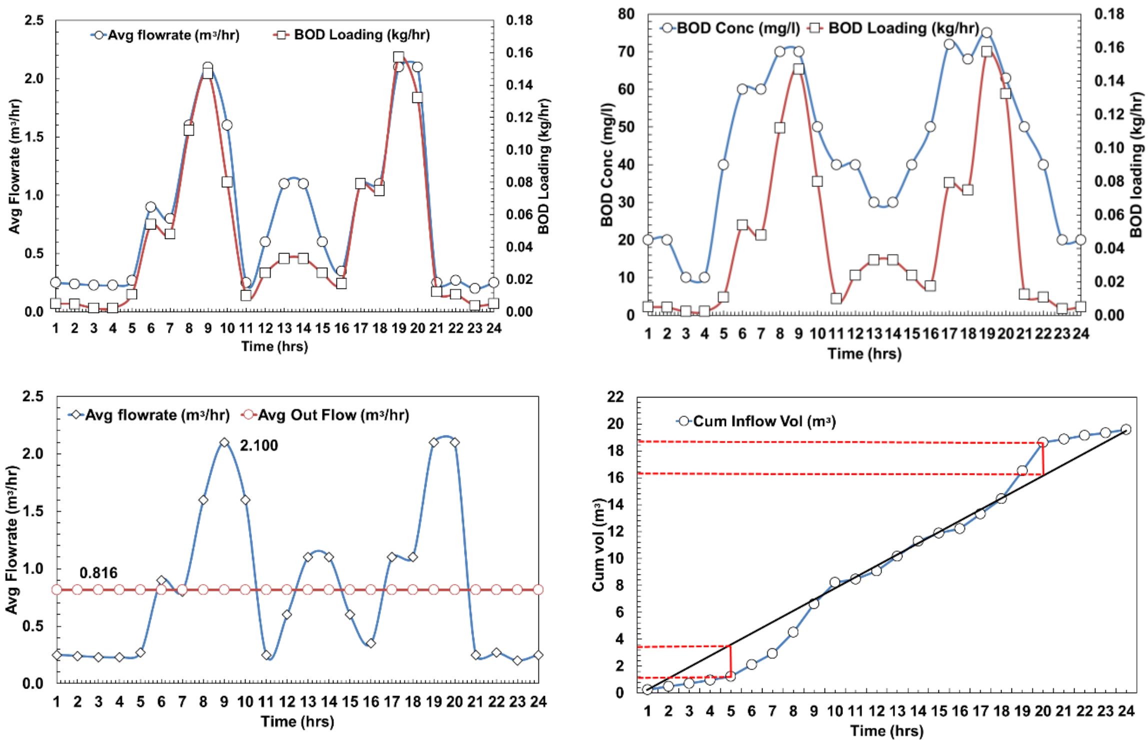
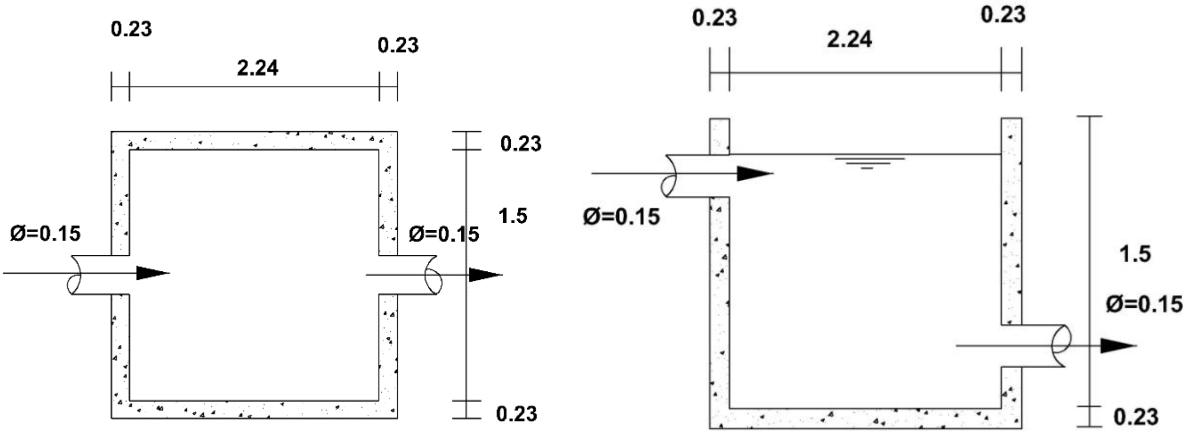


Fig. 2. Variation of BOD concentration, BOD loading, average flowrate, average outflow, cumulative volume of wastewater with time

Wastewater generated from BIT hostel was collected for 24 hrs. The concentration of the wastewater in terms of BOD was measured. The variation of average BOD concentration (mg/l) and BOD loading (kg/hr) was represented in Figure 2. However, a constant outflow was calculated as 0.816 m^3/hr. The cumulative maximum wastewater was calculated to design the maximum volume of equalization tank.



Plan Cross-section

Fig. 3. Plan and Cross-section of designed Equalization Tank (dimensions in m, not up to the scale)

3.4 Design of Flash Mixer

DESIGN CRITERIA

H : B	2	:1
Tangential velocity of impeller at tip	3	m/s
Impeller speed	100-130	rpm
Detention time	20-60	sec
For Dt, 10-60s, G	600-1000	1/sec
Dia of impeller to width	0.3-0.6	times
Distance of impeller blade from bottom to depth of tank	0.5-0.33	times
Liquid depth to tank dia/width	0.5-1.1	times

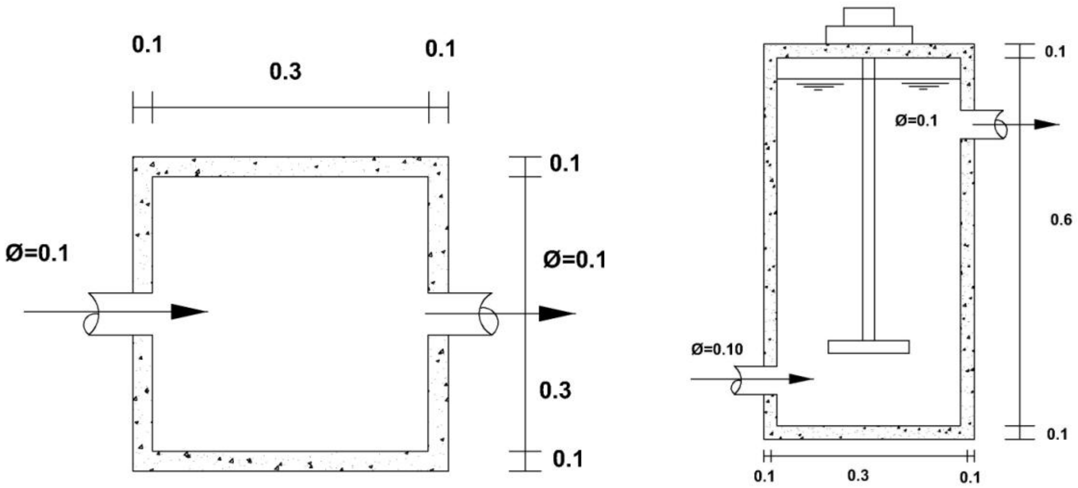
ASSUMPTIONS

Final alum conc	80	% of initial alum conc
G	700	1/sec
Detention time (Dt)	90	sec
water temp	18	°C
Impeller efficiency	80%	

CALCULATION

Given Q		50	m^3/d		
		0.000578704	m^3/s		
Dynamic viscosity μ @ 18˚ C				1063	kg/ms
				0.001063	Pa.sec
Vol of tank		flow x Dt		0.052	m^3
Provide JTQ1500 model double blade impeller with 130 rpm					
		n		2.17	
power				0.08	kW
power factor				1.8	
With 80% efficiency, final water power				0.064	kW
Calculation				64	W
$G = \sqrt{(P/\mu V)}$					
Volume capacity	$V=(P/G^2\mu)$			0.12	m^3
No of tanks				0.424	
	Say			1	nos
Tank dimensions = square type	H:W			2	:1
Vol L*W*H	2x*x*x			0.052	m^3
Width of tank	x=B			0.296	m
Length of tank	L			0.296	m
Depth of tank	H			0.593	m
Dia of impeller Di					
$Di=(P/(Kt*n^3*\rho))$^(1/5)	Di			0.263	m
Where, Kt=6.3, ρ=1000					

Pipe diameter					
Assume, Slope (S)		1 in		500	0.002
Assume, C value for Cement Concrete				140	
Apply Hazen Willium Eqn					
V=0.85 C*R^(0.63) * S^(0.54)	V=(Q/A)			A=πd^2/4	R=d/4
Dia of pipe					
d= ((4^1.63*Q)/(π*0.85*C*S^0.54))^(1/2.63)				0.0011	m
				1.1188	mm
		Say		10	cm
				0.05	m
Impeller shaft length	(2/3)*H			0.395	m
Concrete casting wall				0.13	m
Motor					
Power requirement		0.08	kW		
1HP		0.746	kW		
Required HP = Power required / 0.746 kW		0.11	HP		
Say		1	HP		
or					
Required		5	HP/4.5 m^3		
Volume		0.052	m3		
Required HP = 5HP*Vol/4.5 m^3		0.06	HP		
	Say	1	HP		
Result					
Flow rate		**Q**		**50**	**m^3/d**
Vol of tank		**Vol**		**0.052**	**m^3**
Width of tank		**B**		**0.30**	**m**
Length of tank		**L**		**0.30**	**m**
Depth of tank		**H**		**0.59**	**m**
Detention time		**Dt**		**90**	**sec**
Inlet and Outlet Pipe diameter		**d**		**0.10**	**m**



Plan   Cross-section

Fig. 4. Plan and Cross-section of designed Flash Mixer (dimensions in m, not up to the scale)

3.5 Design of Clariflocculator

Design Criteria for Flocculator

Depth of tank	2.5 to 5	m
Detention time (Dt)	10 to 40	min
Inlet velocity (v)	0.2 to 0.8	m/s
Velocity Gradient (G)	10 to 75	1/s
Total area of paddle	10 to 25% C/s	
RPM of the shaft	1 to 2	
Power Consumption	10 to 36	W/MLD

Peripheral velocity of blades	0.2 to 0.6	m/s
Outlet velocity to settling tank	0.3	m/s
Dimensionless factor (Gt)	10^4 to 10^5	

Design criteria for Clarifier and sludge hopper

Depth of the tank	2.5 to 5	m
Detention time	1.5 to 4	hr
Weir overflow rate	150 to 300	m^3/d/m
Dia of tank	30 to 60	m
Length of rectangular tank	30 to 100	m
Bottom slope	1%	for rectangular
	8%	for circular
Power	0.75	W/m^2
Scrapper Velocity	0.07	rpm
Tip velocity of scrapper	0.3	m/min
Sludge removal pipe dia	0.1 to 0.2	m
Slope of sludge hopper	1.2	:1

Given Data:

Water flowrate	50	m^3/d
	0.05	MLD
	2.083	m^3/hour
	0.035	m^3/min
	0.00058	m^3/sec
Detention time in flocculator	40	min
	2400	sec
	2400	sec
Inlet Velocity	0.25	m/s
Depth of flocculator (Hf)	2	m
Area of paddles	20%	of area of flocculator
No of paddles	2	
Clearance between paddle and flocculator wall	0.1	m
Tip velocity	0.2	m/s
Depth of clarifier (Hc)	3	m
Surface overflow rate	15	m^3/day/m^2
Detention time in Clarifier	2	hrs

CALCULATION

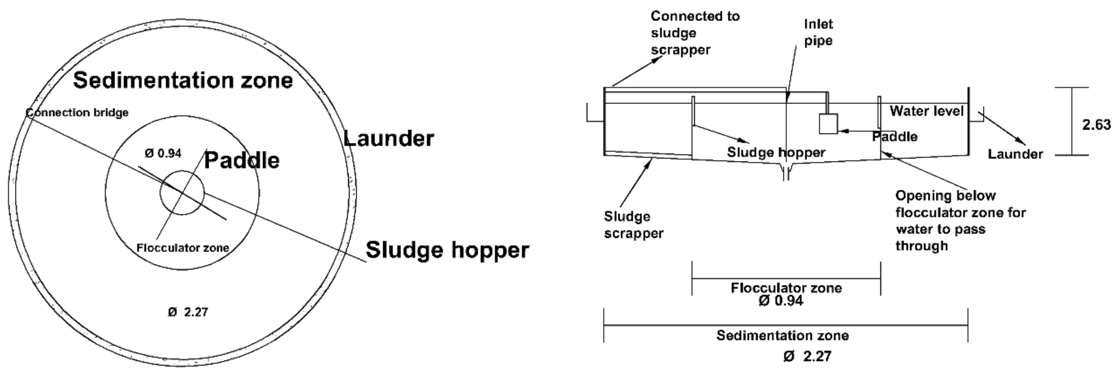
Volume required	Q * Dt	1.389	m^3
Inlet pipe velocity	v	0.25	m/s
Flow	Q	0.00058	m^3/sec
Area of inlet pipe (A1)	Q/v	0.0023	m^2
Diameter of inlet pipe (d1)	sqrt(4*SA/π)	0.054	m
Depth of flocculator		2	m
Volume of flocculator		1.389	m^3
Area of flocculator (A2)	Vol/depth	0.694	m^2
Total area of Flocculator	(A2+A1)	0.697	m^2
Diameter of Flocculator (d2)	sqrt(4*SA/π)	0.94	m
Area of paddles	20%*Df*depth	0.38	m^2
No of paddles		2	
Area of 1 paddle		0.19	m^2
Dimension of paddles	L=B= sqrt(SA)	0.43	m
	B	0.43	m
Tip velocity		0.2	m/s

Relative velocity	0.75* tip velocity	0.15	m/s
Radius of paddle revolution	(d2/2)-(d1-2)-clear distance	0.34	m
Rotation per minute of shaft	tip velocity/perimeter	0.093	rps
		5.6	rpm
		Can be controlled within 1 rpm	
Calculation of Power (P)			
Assume, Cd		1.8	
Density of water		1000	kg/ m^3
A= area of paddle		0.38	m^2
Vt = Relative velocity		0.15	m/s
Power (P)	0.5*Cd*ρ*A*Vt^3	1.14	W
Assume, μ = Dynamic viscosity		0.001008	
Velocity gradient	(P/μVol)^0.5	28.6	1/s
		b/w 10 to 75	1/s
Gt	G*Dt	68569	
	Should be b/w 10^4 to 10^5		
Power consumption	P/Q	22.86	W/MLD
	Should be b/w 10 to 36 W/MLD		
Surface overflow rate		15	m^3/day/m^2
Flow Rate		50	m^3/d
Area of Clarifier	Flow rate/SOR	3.33	m^2
Total area (A1+A2+A3)		4.0301	m^2
Total Diameter of Clarifier	sqrt(4*SA/π)	2.27	m
Detention time in Clarifier		2	hrs
Flow rate		2.083	m^3/hr
Surface overflow rate		15	m^3/day/m^2
Depth of clarifier	Q*Dt/SOR	0.278	m
Flow rate		0.035	m^3/min
Outflow to clarifier		0.3	m/min
Area of opening below flocculator	Q/outflow	0.116	m^2
Depth of opening	area/perimeter flocculator	0.039	m
Depth of clarifier	Opening H + Hf	2.04	m
Sludge hopper height		25%	Extra Clarifier height
		2.55	m
Assume, Diameter of sludge hopper		0.1	m
Assume, side slope		1.2	:1
Top diameter of sludge hopper		0.2	m
Bottom slope	adding 8%	0.0826	m
Total height at center of clariflocculator		2.632	m
Assume, Velocity in launder		0.3	m/s
Area	Q/v	0.0019	m^2
Assume depth		2	x width
Width		0.031	m
Depth		0.062	m
Wetted perimeter	2*depth + width	0.155	m
Hydraulic mean depth	R=A/P	0.0124	m
Using Manning's formula			
V= (1/N)*R^(2/3) * S^(1/2)			
N = Manning's constant		0.012	
V = Velocity		0.3	m/s
S	(N*V*R^(3/2))^2	3.7287E-08	
		1 in	26819149

Assume inlet pipe diameter		0.15	m

RESULT

Water flowrate	**Q**	**50**	**m^3/d**
Diameter of inlet pipe	**d1**	**0.054**	**m**
Diameter of Flocculator	**d2**	**0.94**	**m**
Total Diameter of Clarifier	**Dia**	**2.27**	**m**
Total height at center of CF	**H**	**2.632**	**m**
Dimension of paddles	**Dp**	**0.43**	**m**
Rotation per minute of shaft	**R**	**5.57**	**rpm**
Power	**P**	**1.14**	**W**
Power consumption	**Pc**	**22.86**	**W/MLD**
Inlet and Outlet Pipe diameter	**d**	**0.15**	**m**



Plan Cross-section

Fig. 5. Plan and Cross-section of designed Clariflocculator (dimensions in m, not up to the scale)

3.6 Design of Sludge drying bed

INPUT

Flow		50	m^3/d
Sludge applied	1 m^3/d	0.09	kg/d
For	50 m^3/d	4.5	kg/d
Assume specific gravity		1.015	
Solid content		1.50%	

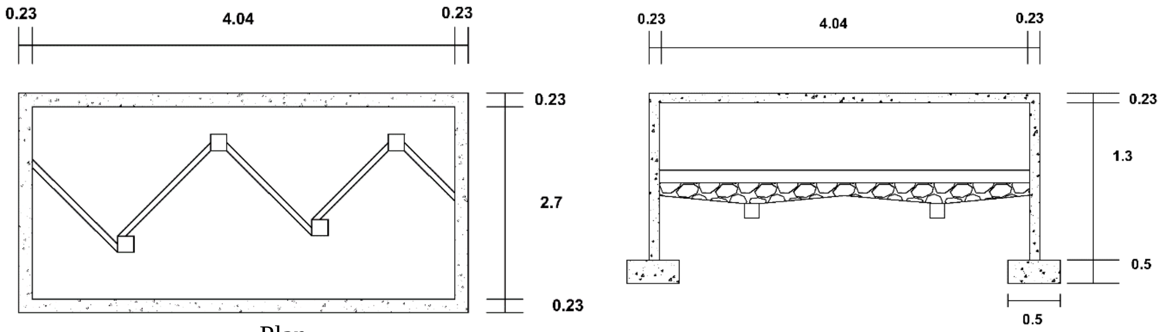
CALCULATION

Volume of sludge (sludge generated)/(1000*SG*solid content)		0.296	m^3/d
Assume total no of cycle in 1 year		33	nos
Period of each cycle	365/total nos	11.06	days
Total Volume of sludge to be handled	sludge Volume * days	3.269	m^3
Assume depth of spreading layer per cycle		0.3	m
Assume total depth of structure		1.3	m
Surface area	Vol/Depth	10.897	m^3
Assume L:B		1.5	: 1
	B	2.70	m
	L	4.04	m
Volume of bed	L*B*H	14.17	m^3
Assume Inlet and Outlet Pipe dia		0.15	m

RESULT

Flow	**Q**	**50**	**m^3/d**
Volume of sludge	**V(sludge)**	**0.296**	**m^3/d**

Period of each cycle	**Ct**	**11.06**	**d**
Total Vol of sludge handled	**Vol**	**3.269**	**m^3**
Length	**L**	**4.04**	**m**
Width	**B**	**2.70**	**m**
Depth	**H**	**1.3**	**m**
Volume of bed	**Vol**	**14.17**	**m^3**
Inlet and Outlet Pipe diameter	**d**	**0.15**	**m**



Plan

Cross-section

Fig. 6. Plan and Cross-section of designed Sludge Drying Bed (dimensions in m, not up to the scale)

3.7 Design of Rapid Gravity Filter

INPUT

Flow		50	m^3/d
Rate of filtration		0.075	$m^3/m^2/h$
No of bed		1	nos
Flow per bed		2.083	m^3/h

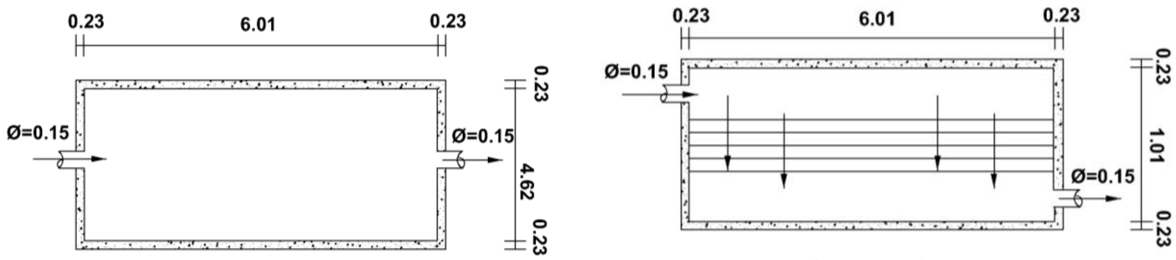
CALCULATION

Area of bed	Flow/Rate of Filtration	27.78	m^2
Assume, L:W	1.3 :1		
Width (W)	Sqrt(SA/ratio)	4.62	m
Length (L)		6.01	m
Ratio L:W		1.3	
	This is to the range of 1.11 to 1.66		
a) Sand			
Provide depth of sand as		3	cm
Effective size 0.5 mm		0.03	m
Uniformity coefficient 1.5			
d10 size		0.5	mm
d60 size		0.75	mm
b) Gravel			
Depth of gravel		0.45	m
Size of gravel at top		2 to 5	mm
size of gravel at bottom		50	mm
c) Depth of water			
Depth of water above sand surface		0.03	m
Free board		0.3	m
Provide extra depth		0.2	m
Total depth of filter box		1.01	m
d) Under drain system			
Provide 2 sections per filter bed			
Area of filter per bed		27.78	m^2
Under drain section		27.78	m^2

e) Backwashing of filters				
Rate of backwash			9	lit/m^2
Rate of air wash			12	lit/m^2
f) Inlet pipe for each filter bed				
Inlet flow per bed			50	m^3/day
For 20% overload (Q)		20%	60	m^3/day
For velocity of flow of			1	m/s
Surface area	Q/v		0.00069	m^2
Diameter of pipe (d)	sqrt(4*SA/3.14)		0.030	m
			29.74	mm
	Assume		15	cm
			0.15	m
g) Filter water outlet pipe per section of filter bed				
Outlet per section			50	m^3/day
For 20% overload (Q)		20%	60	m^3/day
For velocity of flow of			1	m/s
Surface area	Q/v		0.00069	m^2
Diameter of pipe (d)	sqrt(4*SA/3.14)		0.030	m
			29.74	mm
	Assume		15	cm
			0.15	m
Vol of bed	L*B*H		28.06	m^3

RESULT

Flow	**Q**	**50**	**m^3/d**
No of bed	**nos**	**1**	
Flow per bed	**Qnet**	**2.08**	**m^3/h**
Area of bed	**A(bed)**	**27.8**	**m^2**
Width	**B**	**4.62**	**m**
Length	**L**	**6.01**	**m**
Provide depth of sand as	**Hs**	**3**	**cm**
Depth of gravel	**Hg**	**0.45**	**m**
Depth of water above sand surface		**0.03**	**m**
Total depth of filter box	**H**	**1.01**	**m**
Vol of bed	**Vol**	**28.06**	**m^3**
Diameter of pipe	**d**	**0.15**	**m**



Plan   Cross-section

Fig. 7. Plan and Cross-section of designed Rapid Gravity Filter (dimensions in m, not up to the scale)

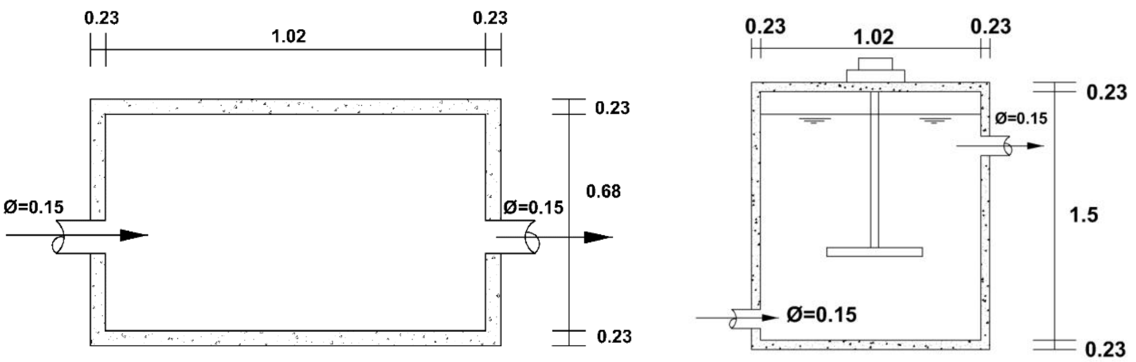
3.8 Design of Disinfection tank

INPUT

Flow		50	m^3/d
Assume depth		1.5	m
Assume detention time		30	min
CALCULATION		1800	sec
Therefore Volume	Flow * dt	1.042	m^3
Surface area	Q/H	0.694	m^2

Assume L:W		1.5 :1	
	W	0.68	
	L	1.02	
Assume dosage of Cl_2		5	mg/L
Quantity of Cl_2 required	Flow * Conc	250000	mg/d
		250	gm/d
		0.25	kg/d
Provide JTQ1500 model double blade impeller with 130 rpm			
power		0.2	kW
	n	2.17	
Diameter of impeller Di			
Di=(P/(Kt*n3*ρ))^(1/5)	Di	0.315	m
Where, Kt=6.3, ρ=1000			
Height of the shaft	Hs	1	m
Assume pipe dia		15	cm
		0.15	m
Vol of Tank	L*B*H	1.04	m^3

RESULT			
Flow	**Q**	**50**	**m^3/d**
Detention time	**Dt**	**30**	**min**
Length	**L**	**1.02**	**m**
Width	**B**	**0.68**	**m**
Depth	**Hs**	**1.5**	**m**
Vol of tank	**Vol**	**1.04**	**m^3**
Inlet and Outlet Pipe diameter	**d**	**0.15**	**m**



Plan Cross-section

Fig. 8. Plan and Cross-section of designed Disinfection Unit (dimensions in m, not up to the scale)

3.9 Summary of different designed treatment units

Table 2. Summary of the various treatment units in STP

Parameter	Unit	Eq tank	FM	CF	SDB	RGF	Dis
Flow rate (Q)	m^3/d	50	50	50	50	50	50
Detention time (Dt)	sec	3600	90	Dtf = 2400	11 d		1800
Volume (Vol)	m^3	5	0.052	Dtc = 7200	14.17	28.06	1.04
Length (L)	m	2.24	0.30		4.04	6.01	1.02
Width (B)	m	1.49	0.30		2.70	4.62	0.68
Depth (H)	m	1.50	0.59	2.63	1.30	1.01	1.5
Pipe dia (d)	m	0.3	0.05	0.15	0.15	0.15	0.15
Additional Info				df = 0.94 dc = 2.27	Vol(s) = 3.27	Rf = 0.075	Cl_2 = 0.25 kg/d

IV. Conclusion

The design of STP was considered for BIT hostel because a huge amount of wastewater was generating every day and the septic tank was unable to take the load. The design of the STP was considered for 160 students with 135 LPCD. Wastewater characteristics showed a lower concentration of pollutants. Hence, the designed was considered with equalization tank flowed by flash mixer, clariflocculator, rapid gravity filter with disinfection unit. Equalization tank will help to balance the flow, however, clariflocculator will help to form floc and removal of suspended particles. finer particles and colloidal particles will be removed in rapid gravity filter followed by disinfection unit to kill all pathogenic bacteria. However, planning has been done for the future expansion of the STP unit if requires. The designed STP is expected to handle 50 m^3 of water in a day.

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