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Planning and Working Analysis of Faecal Sludge Treatment Plant

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Abstract-The problems posed by fecal sludge (FS) are multidimensional because most cities rapidly urbanize, which results in the increase in population, urban settlement, and waste generation. Issues concerning health and waste treatment have continued to create alarming situations. These issues had indeed interfered with the proper steps in managing FS, which contaminates the environment. FS can be used in agriculture as fertilizer because it is an excellent source of nutrients. The recent decline in crop production due to loss of soil organic component, erosion, and nutrient runoff has generated interest in the recycling of FS into soil nutrients through stabilization and composting. However, human feces are considerably liable to spread microorganisms to other persons. Thus, sanitation, stabilization, and composting should be the main objectives of FS treatment to minimize the risk to public and environmental health. This review presents an improved FS management (FSM) and technology option for soil amendment that is grouped into three headings, namely, (1) collection, (2) treatment, and (3) composting. The main problems associated with the collection and treatment of FS, such as inadequate tools and improper treatment processes, are summarized, and the trends and challenges that concern the applicability of each of the technologies in developing urban centers are critically reviewed. Stabilization during pretreatment before composting is suggested as the best method to reduce pathogens in FS. Results are precisely intended to be used as a support for decisions on policies and strategies for FSM and investments for improved treatment facilities. Treated water can be used for irrigation purpose which enhances the crop growth or end product water can be released into the river or lake or pond.

Keywords- Faecal sludge, screening, sludge drying, stabilization, composting.

I. INTRODUCTION

The main objective of Faecal Sludge (FS) treatment is to ensure the protection of human health and environment.The characteristics of FS such as Total Solids (TS) content, higher by a factor of ten to hundred when compared with wastewater.However, the characteristics can vary significantly from place to place. Typically the fs contain high concentration of total solids and may have high levels of BOD/COD and pathogens.

In India currently there are no standards for the treated solids from faecal sludge treatment plants. The standards specified for sewage treatment plants by the Tamilnadu pollution control board are for the discharge of treated effluents, and are applicable for the wastewater (liquid component of FS) from the FSTP. The treatment facility is proposed to be located in the urban local body. It would have the capacity to treat 20KLD of faecal sludge per day.

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1. Criteria Adopted For Design of Faecal Sludge Treatment System:

1.1Faecal sludge Characteristics:

Faecal Sludge characteristics vary widely from one location to another. This variation is due to several factors, which includes number of users of the septic tank at the household, kind of waste disposed in the septictank, size of the tank, dislodging frequency, climatic conditions and the construction specifications of the septic tank.

Knowledge of the faecal sludge characteristics and its variability is very important in designing the treatment facility. Based on the past experience and literature review, the faecal sludge characteristics considered for designing the facility are as follows:

Table 1. General Characteristics of Faecal Sludge.

Parameters	Concentration
Biochemical oxygen demand(BOD) mg/l (average)	20000
Chemical oxygen demand(COD),mg/l(average)	40000
Total solids(TS),mg/l(average)	30000
pH	7.8
Ammonium as N, mg/l	230-320
Settleable solids(SS),%,(average)	25

1.2 Faecal Sludge feeding into the tank (peak flow):

It is of utmost important to clearly define the rate at which the faecal sludge will be fed into the treatment system.The faecal sludge feeding into the treatment system during the day depends on the time of faecal sludge collected and delivered from the desludging trucks.

The treatment modules are designed considering a flow rate generated by discharging 8 Kilo litres of faecal sludge being discharged from the truck into the treatment plant in 8-10 minutes time.

1.3 Hydraulic Retention Time:

In order to ensure the effective treatment of sludge as well as sludge water, it is necessary to provide adequate sludge and hydraulic retention time for each of the treatment module proposed.

The proposed Solids and Hydraulic Retention Time for each of the treatment modules are explained in the subsequent sections.

II. TREATMENT CONCEPT

The treatment concept proposed for faecal sludge treatment in ULB has been developed considering mainly;

- Maximum treatment efficiency
- Safe operation
- Minimum operation and maintenance requirements and
- Meeting environmental standards as prescribed by PCB

1. Treatment Stages and Modules adopted:

The treatment modules proposed are combined in a particular sequence for the complete treatment of the faecal sludge. The treatment process listed in table 2 (Part 1) will ensure removal of grit and debris, homogenization, solids-liquid separation and stabilization of the FS prior to dewatering.

The Part 1 includes a screen chamber as a preliminary treatment unit, followed by Stabilization Reactor (anaerobic digestion of FS).

The stabilization reactor reduces the load on the dewatering unit, by acting as a solid-liquid separator. The Part 2of the treatment process includes dewatering, which is a gravity-based system.

Table 2. Process of FSTP.

No.	Treatment steps	category
1	screening	Part 1
2	Homogenization	
3	Solid liquid separation	
4	Solid stabilization	
5	Solid dewatering	Part 2
6	Primary treatment of liquid for BOD reduction	Part 3
7	Secondary treatment of liquid for nutrient reduction	
8	Tertiary treatment of liquid for pathogen reduction	

Part 3 processes are for the liquid treatment including, a Settler and Anaerobic Filter, Horizontal Planted Gravel Filter (HPGF) and Maturation Pond (MP).

Table 3.Different Faecal Sludge Treatment Stages and Modules.

No	Treatment stages	Treatment modules
1	Pre treatment	Screen chamber
2	Sludge stabilization	Stabilization reactor
3	Sludge drying	Sludge drying beds
4	Percolate treatment	
		Integrated settler and anaerobic filter
		Horizontal planted gravel filter
		Maturation pond

2. Process Flow Diagram:

The FS is received at the Screen chamber. Further it flows to the stabilization reactor where it is retained for 13 days. From the SR the liquid stream flows to ISAF. The liquid stream subsequently gets treated as it flows through HPGF and maturation pond. The solids part is pumped to SDB from the SR. The leach ate from SDB moves to ISAF whereas the solids are removed and stored after it acquires sufficient drying. Solids may be co-composted and used as fertilizer.

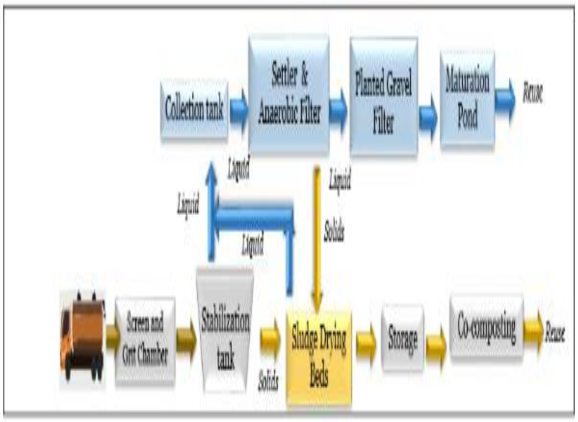

Fig 1. Overall process flow diagram.

3. Design Description of the Proposed Treatment:

3.1 Modules:

The Treatment plant is subdivided into 2 decentralized units of 10 cum each within the FSTP site. There are 2 Screen chambers, 2 Stabilization reactors and 24 sludge drying beds (12 for each stabilization tank).

However, there is a common percolate treatment facility for 20 KLD; DEWATS- 1 Integrated Settler Anaerobic Filter, 3Horizontal Planted gravel filter; 1 Maturation Pond and a final collection tank.

3.2 Screen Chamber:

It is a physical method of separation solid waste and inorganic solids like plastic, cloths, sand, slits etc. from faecal sludge to prevent the clogging subsequent treatment modules and also enhance the values of treatment end products. This is used to remove larger particles of floating and suspended matter by coarse screening. This is accomplished by a set of inclined parallel bars having opening.

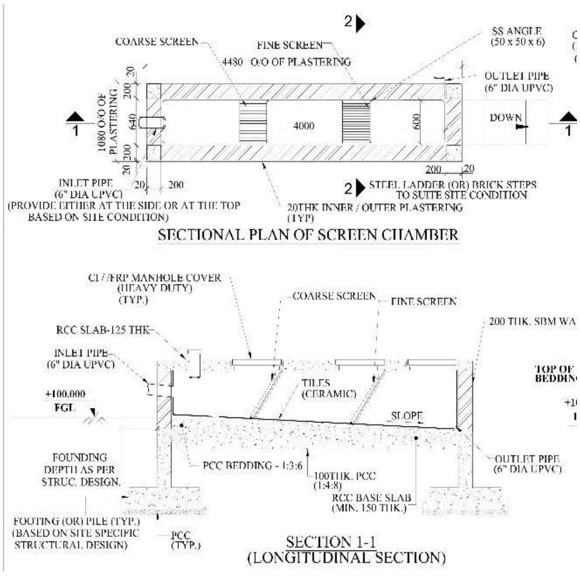

Fig 2. 2 screen chamber plan.

The velocity should neither be too low as to cause the settling of lighter organic matter, nor should it be too high as to preclude the settlement of the silt and grit present in the sewage. A horizontal velocity of flow of 15 to 30 cm /sec is used at peak flows. The detention time proposed in the grit chamber varies between 30 to 60 seconds.

Table 4. Specifications for Screen and Grit chamber.

Parameters	unit	Values
Area required	m^2	10(2sc requiring 5 sq.m each)
Retention time	seconds	30-60
Number of screens andgrit chambers		2 nos

4. Stabilization Reactor:

The main objective of the stabilization reactor is to allow the sludge to digest an aerobically which leads to reduced BOD and better dewater ability. During the anaerobic treatment process, there is also removal of degradable organic matter present in the faecal sludge. The stabilization process also helps in improving the sludge dewater ability and subsequent drying of solids.

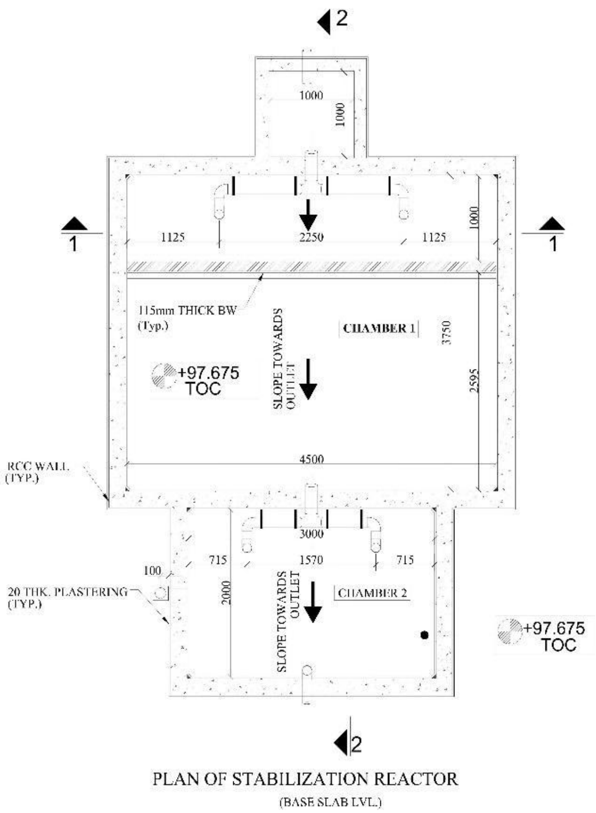

Fig 3. Plan of stabilization reactor.

The stabilization reactor has 3 chambers. The first chamber has a retention time of 2 days and assists in homogenization of sludge. The turbulence in the chamber is created by maintaining an up-flow velocity of 4-5 m/hr using the energy produced during discharge of sludge from the desludging vehicle into the module.

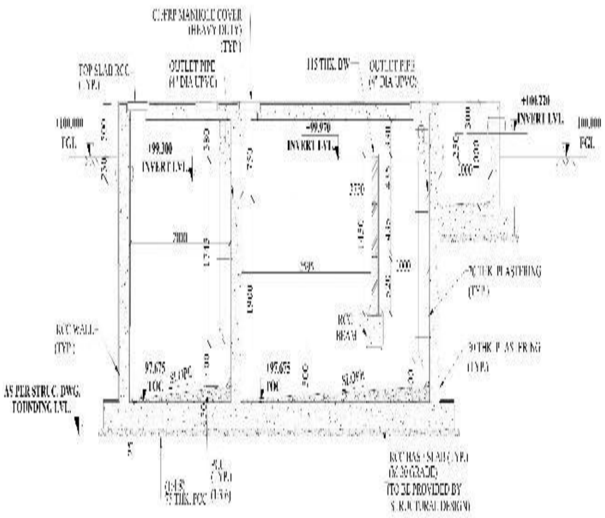

Fig 4. Sectional Diagram of Stabilization Reactor.

The second chamber has a retention time of 10 days and is designed to stabilize sludge through aiding the process of anaerobic digestion. The length of the chamber is kept low to prevent dead zones and liquid funnels that may be created at the outlet. A baffle wall is also designed for similar purpose.

The up-flow velocity in this chamber is kept at 1.5 -2 m/hr, this is to disturb the sludge and help entrapped bio-gas to escape, thereby aiding liquid solid separation.The third chamber retains the sludge for 1 day, this is used as an intermediate collection tank to empty the contents into the drying bed every day.

Table 5. Specifications of Stabilization Reactor.

Parameters	Unit	Values
No of chamber	no	3
Sludge treatment capacity per day per reactor	m^3	10
Total volume of tank	m^3	130
Retention tank	day	13
Slurry disposal into the drying bed	day	every day :10 m^3
Bod outlet	mg/l	8000-10000
Cod outlet	mg/l	15000-20000

5. Sludge Drying Bed:

The liquid sludge retained at the bottom of the stabilization reactor is desludged and transferred to unplanted sludge drying beds. Sludge drying beds are open tanks filled with graded filter media. Each sludge drying bed can accommodate 8 m^3 of digested faecal sludge. The drying time provided in the beds is 12 days.

The slurry from the stabilization reactor is fed into the sludge drying beds every day. The Maximum feed depth into each of the sludge drying bed is 25 centimetres considering that solids content in faecal sludge vary between 3 - 5%.

The remaining quantity which is known as percolate would be conveyed from the bottom of the bed into the Integrated Settler and Anaerobic Filter for further treatment before being further treated. The sludge drying bed consists of different filter media placed at different depths.

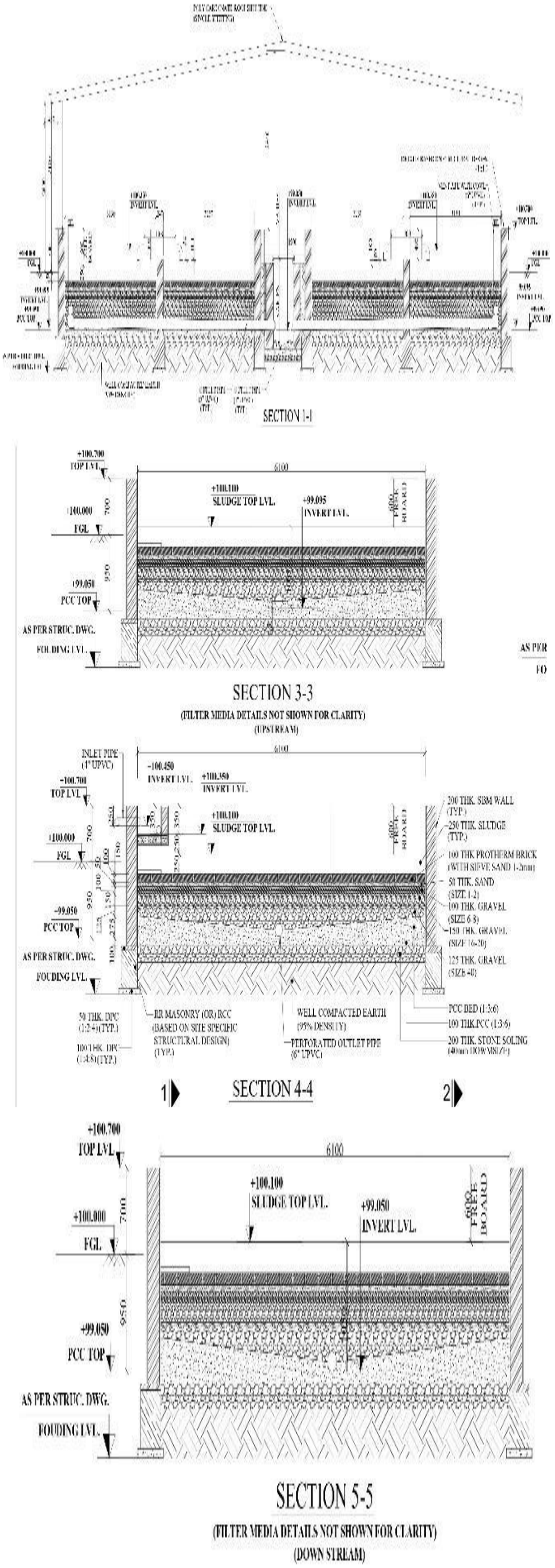

Fig 5. Section of Sludge Drying Bed.

Table 6. Specifications for Sludge Drying Bed.

Parameters	Unit	Values
Total number of beds	-	24
Treatment volume of each bed	m^3	10
Estimated volume of solid retained	%	30
Area required	m^2	39.65m^2 per bed
Slurry feeding frequency	days	12
Slurry drying period	days	13
Bod outlet(percolate)	mg/l	300
Cod outlet (percolate)	mg/l	800

6. Integrated settler and Anaerobic Filter (ISAF):

The percolate from the Sludge Drying Bed is further subjected to treatment in ISAF (Figure 5). The incoming faecal sludge load has pretty high solids content. Therefore, it is proposed to provide a settler for sedimentation before it enters into the anaerobic filter. The anaerobic filter is provided with 3 numbers of anaerobic fixed bed filter chambers. As the wastewater flows through the filter, particles are trapped and organic matter degraded by the biomass that is attached to the filter material.

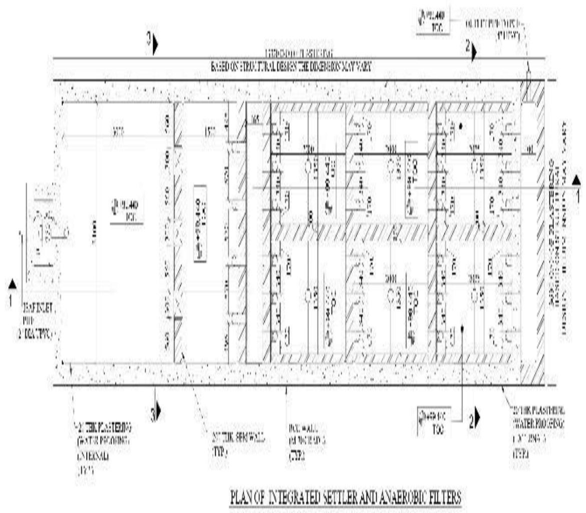

Fig 6. Plan of Integrated Settler And Anaerobic Filter.

Table 7. Specifications of Integrated Settler and Anaerobic Filter (ISAF)

Parameters	Unit	Values
Faecal sludge quantity	m^3	9.80
Total number of chambers	-	2+3
Hydraulic retention time	hrs	36
Area required	m^2	48
Cod outlet	mg/l	200
Bod outlet	mg/l	<30

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7. Horizontal Planted Gravel filters (HPGF):

Organic load entering into the HPGF is already within the required effluent BOD (<30mg/L) requirement. In order to remove the odour and colour and to enrich the wastewater with oxygen it is necessary to allow the wastewater to pass through aerobic treatment.

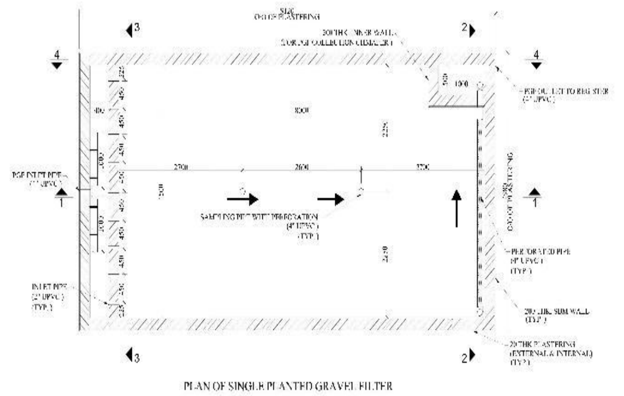

Fig 7. Plan And Sectional Diagram of HPGF.

HPGF is made of planted filter materials consisting of graded gravel. The bottom slope is 1% and the flow direction is vertical. The main plants used in this filter bed are Canna indica, Reed juncus, Papyrus and Phragmites. The plant selection is mainly based on their ability to grow in wastewater and have their roots spread wide. The vertical planted drying beds also aid in reducing the nutrients such as N, P and K present in wastewater.

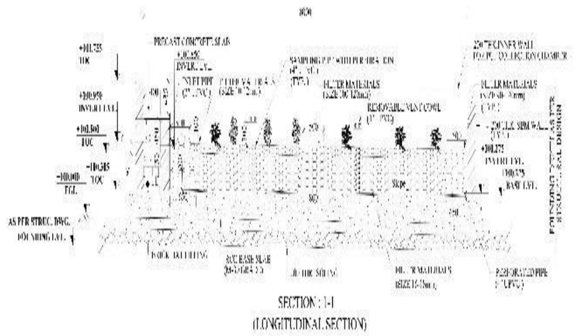

Fig 8. Longitudinal Section of HPGF.

Table 8. Specifications Of HPGF

Parameters	Unit	Values
Percolate treatment quantity	m^3	9.74
Total number time per HPGF	-	3
Hydraulic retention time per HPGF	min	1.5 days
Area required per HPGF	m^2	47.5
BOD outlet	mg/l	<20
COD outlet	mg/l	<50

8. Maturation Pond:

The 9.74m3 volume (reduction of 5% of volume) of effluent collected from the Horizontal Planted Gravel Filter is treated in the Maturation pond.

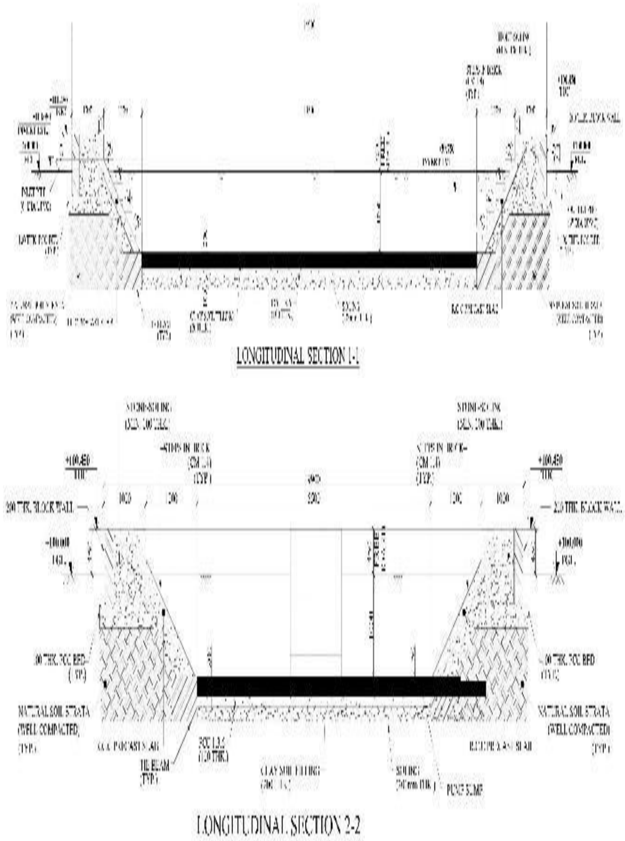

Fig 9. Longitudinal Section of Maturation Pond.

The retention time assumed for the treatment of effluent is 5 days. The depth of retention proposed is 1.00m. The area required for the treatment is 295.82m2. The proposed size of the unit is 21.1m x14.02m.

The treated effluent is proposed to be collected in the Collection Tank. Maturations ponds are shallow ponds of depth. The primary function of maturation ponds is the removal of excreted pathogens. The ponds are well oxygenated through the day by natural means. A small reduction in the BOD also occurs. The retention time is calculated for 96% removal of faecal coli form.

III. CONCLUSION

The treatment system generates treated water as the end product. The specifications of the treated water are listed ahead.

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1. Treated Water:

Water from liquid treatment modules are stored in a collection tank from where it can be reused for irrigating plantations within the premises or in nearby buffer zones next to the proposed FSTP. The characteristics of the treated water are as follows:

Table 9. Treated Water Characteristics.

Parameters	Characteristics of treated water
pH	6.5-9
Temperature	25-35^{0}c
Bod at 5 days mg/l	less than 30
Total suspended solids mg/l	less than 100
Faecal coliform per 100ml	less than 1000
Total nitrogen mg/l	less than 10

Table 10. Mass Balance of FSTP.

No	Accumulation in screen chamber	Values
1	TS per day, kg	0.27
2	volume per day , m^3	0.025
3	total liquid content, kg	8.73
4	trash content, kg/m^3	1.5
5	total trash kg	30
6	%of sludge by weight lost through trash	30
7	specific gravity of trash	1.2
No	Inlet To StabilisationReactor	Values
1	Total Solids, kg/m^3	30
2	volume per day, m^3	19.98
3	TS per day , kg	599.73
4	total liquid content, kg	19391.27
No	Outlet Of Stabilization Tank/SDB inlet	Values
1	total solids, kg/m^3	29.07
2	volume per day, m^3	19.62
3	TS per day , kg	570.29
4	total liquid content, kg	19056.89
No	Accumulation in Stabilisation Reactor	Values
1	TS per day, kg	25.17
2	Total Liquid	334.38
3	Total Solids concentration per volume of inlet sludge(%)	7
4	Accumulation rate m^3/m^3 of inlet	0.018
5	Accumulation(kg)	359.550
6	Biogas Density, kg/m^3	0930
7	Gas Production m^3/m^3 of FS	0.0230
8	Biogas Generation, kg	4.273
No	SDB after 12days of drying	Values
1	Total Solids after 12 days of retention, kg	553.8
2	Total moisture left in the cake after 12days drying, kg	553.8
No	Leachate(inlet to settler from SDB)	Values
1	TS per day, kg	16.477
2	% of total volume passing through the filter media	70%
3	Total Solids kg/m^3	1.2
4	Density of leachate kg/m^3	1000
5	Total liquid content, kg	13714
6	Total volume passing the filter media	13.731
7	Evaporation moisture loss in 12 days in ml/day	4788.74
No	Settler outlet/AF inlet	Values
1	Volume per day m3	13.724
2	TS per day, Kg	9.612
3	Total liquid content(1000kg)	13.714
No	Accumulation in Settler	Values
1	Accumulation rate, kg/m^3	0.500
2	Accumulated sludge, kg/day	6.865
3	Volation rate	80%
4	Long term sludge accumulation, kg/day	1.37308
No	AF Outlet/ PGF inlet	Values
1	volume per day m^3	13.720
2	TS per day , kg	5.494
3	total liquid content, kg	13.7143
No	Accumulation in AF	Values
1	Accumulation rate, kg/m^3	0.300
2	Accumulated sludge, kg/day	4.1172
3	Volation rate	80%
4	Long term sludge accumulation, kg/day	0.82344
No	PGF outlet	Values
1	Volume per day m^3	10.974
2	TS per day , kg	2.75
3	Total Liquid Content,(1000 kg)	10.971
No	Accumulation in PGF	Values
1	Accumulation rate, kg/m^3	0.20
2	Accumulated sludge, kg/day	2.74
3	Volation rate	80%
4	Long term sludge accumulation, kg/day	0.54879
5	Evaporation Moisture loss 20% of volume	2.74
No	Maturation Pond Outlet	Values
1	Volume per day m^3	10.907

2	TS per day , kg	1.65
3	Total Liquid Content,(1000 kg)	10.90563
No	Accumulation Maturation Pond	Values
1	Accumulation rate, kg/m^3	0.10
2	Accumulated sludge, kg/day	1.10
3	Volation rate	50%
4	Long term sludge accumulation, kg/day	0.54871
No	Evaporation	Values
1	Moisture Loss ,ml/day	3
2	Area of pond	21.95
3	Evaporation loss in m^3	0.0658

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