Treatment Options for Feacal Sludge

Brief Note on Technology Options **2017**

PREFACE

Faecal sludge management is a widely discussed topic in Urban Sanitation today, there are developments in various fronts of this topic especially related to policies, behaviour change and operative guidelines. However very little information has been clarified for the decision maker as to what infrastructure options exist to treat faecal sludge. A question that ponders many engineers working with Urban local body is; what can we do with the faecal sludge that is being collected? Though many publications and materials are available online to educate on the treatment technology options, these are voluminous, flooded with information and data which makes it difficult for a decision maker who is limited by time as a resource, to read at ease and understand these solutions. It hence becomes neccesary that a step be made towards concising the vast amounts of theoretical and practical knowl-

edge into content which can be easily read and well understood. And also be able to provide a structure for the decision maker to appreciate or compare these technologies with one another.

This document, is a step towards such an effort. The techology options chosen for discussion are contextualised for Indian conditions, especially for cities in delta regions and river basins. The document is punctuated with various case studies for the reader to gain confidence and be able to relate to the factors contributing to the success of the case.

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Consortium for DEWATS Dissemination **Society**

INTRODUCTION

Faecal sludge treatment shares a lot in common with well-established theories and knowledge base for sewage treatment and wastewater engineering. It however differs in contextualising these concepts for treating varied and inconsistent charactestics of faecal sludge. Faecal sludge treatment has been practised in developing countries for more than a decade now, and hence there exists many experiences and anecdotes to share the success and failure of each approach. However, not all of these technology options find suitability in the current context of India, where problems such as negligent maintenance, constrain of land availability, inaccess to CAPEX by small and medium towns and etc. exists. It hence becomes necessary to screen the various options available and choose for discussion technologies which might fit the current needs of faecal sludge management.

The following technologies were screened for discussion:

1. Anaerobic digestion and drying – Devanahalli model
2. Planted drying bed
3. Thickening tank
4. Co-treatment in sewage treatment plants
5. Mechanical dewatering and filtrate treatment
6. Sludge dewatering and treatment through geobags

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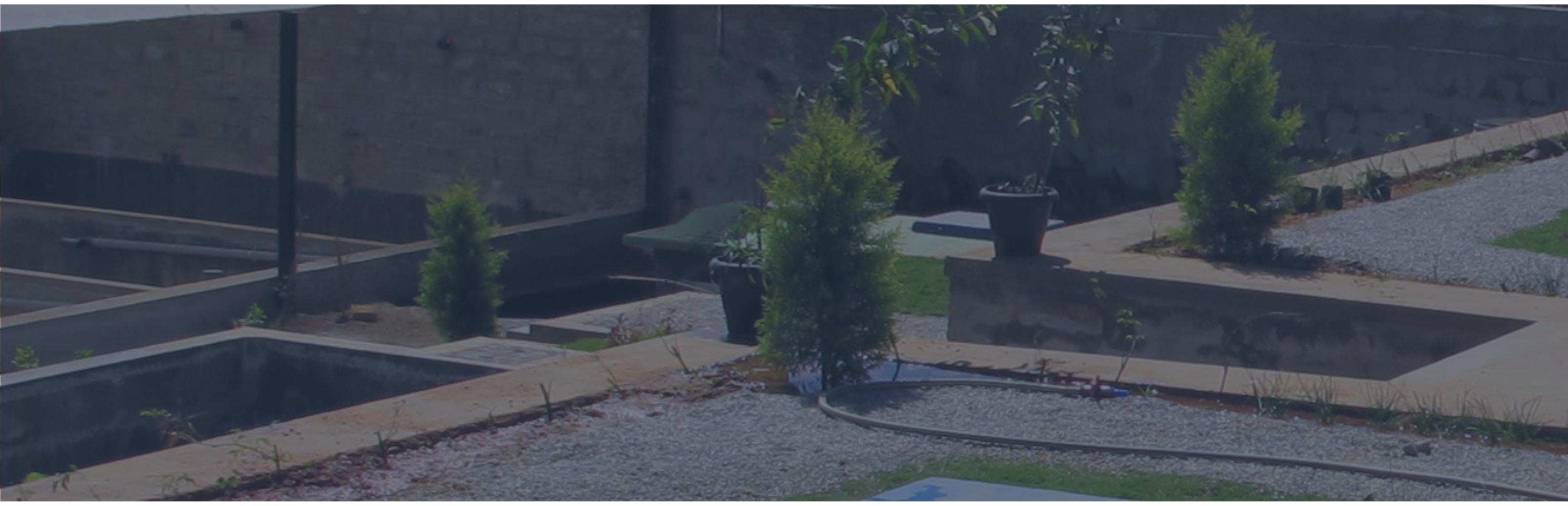


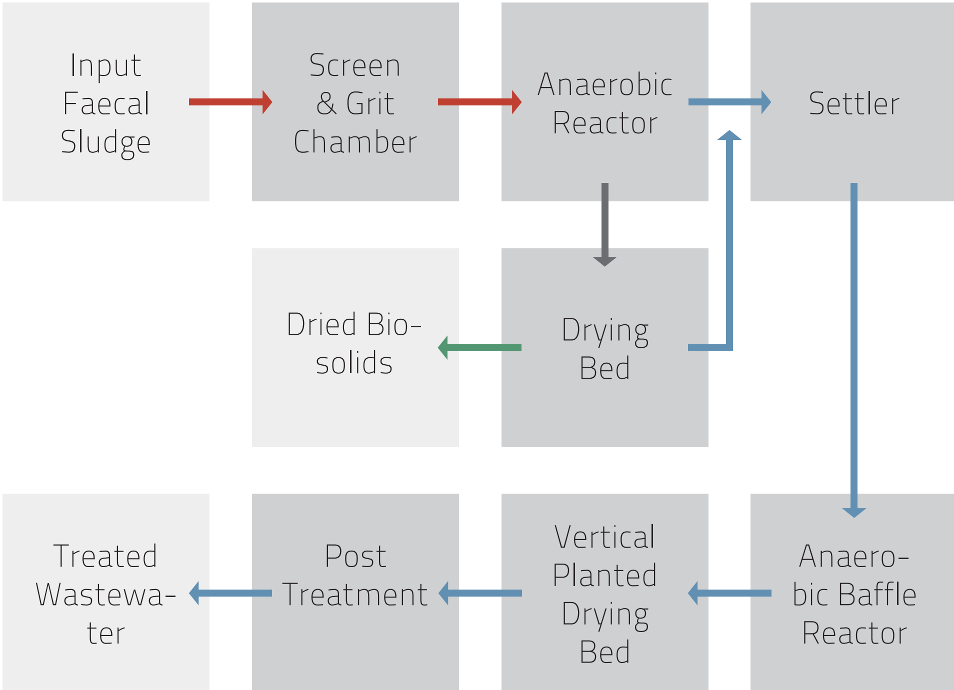

STABILISATION TANK

1 TECHNOLOGY OPTION
ANAEROBIC TREATMENT

ANAEROBIC TREATMENT

Anaerobic treatment is used for stabilizing partially digested sludge from on-site containment units. Faecal sludge with high volatile solids has potential for digestion and release of biogas before undergoing drying. It is also essential that such sludge be digested before application into farmlands as un-stabilized bio solids can leach organics when in contact with water. Anaerobic digestion combined with sludge drying beds can convert faecal sludge into treated water and dried bio-solids and additionally produce biogas as a byproduct.

TREATMENT CONCEPT



The desludging truck carrying faecal sludge will be directed to a receiving point inside the treatment facility. The faecal sludge received at the treatment facility will be discharged into the screen and grit chamber by means of gravity where large inert solids are trapped in this using bar screens and Grit chamber.

The liquid sludge (mixture of liquid and solids in slurry form) from the screen and grit chamber is further conveyed to a sludge stabilization (anaerobic) reactor through gravity for treatment. The objective is removal of degradable organic substance and generation of biogas. The stabilisation tank can be designed in various forms and shapes depending on the objective, chambers can be designed as biogas digestors (fixed and floating) or baffle reactors. Mixing velocities and retention times are two important design criteria. Retention time is dependent on the organic load of the input sludge and ranges between 6 -20 days. Other than sludge digestion, these modules can also be used for solid-liquid seperation. The sludge from stabilisation reactor is desludged onto the drying beds. Sludge drying beds are open structures with sloped base for holding graded filter media. The sludge undergoes liquid-solid separation and also drying. The percolate from the sludge drying bed is collected and conveyed to a collection tank by gravity. The dried sludge from the beds are removed periodically and transferred to the sludge storage shed located within the premises.

TREATMENT GOALS

1. *Stabilized bio solids*
2. *Treated water as per CPCB standards*
3. *Minimal operational requirement*
4. *Biogas generation – Energy recovery*

TREATMENT METHODOLOGY

1. *trash and grit removal*
2. *Sludge stabilization*
3. *Dewatering and drying*
4. *Percolate treatment*

The percolate water and supernatant from stabilisation reactor is collected in a settler providing time for initial sedimentation of solids. The settler overflows into an anaerobic baffle reactor and filter, where anaerobic conditions for the treatment of percolate are enabled.
The treated wastewater from the anaerobic filter is further treated using a vertical Planted Gravel Filter. Vertical gravel filter helps in infusion of air into the passing wastewater, thereby degrading organic matter, removal of nutrients, odour and colour.
Tertiary treatment module- sand carbon filter and UV treatment can be intergrated to meet the statutory requirements for treated water discharge.

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EFFLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100-150 mg/litre	< 100 mg/litre
Total solids	20 – 50 g/litre	300 – 500 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

SUITABILITY

Anaerobic treatment as a treatment option for faecal sludge is suitable (and not restricted to) for following conditions:

- *Input is partially digested or fresh faecal sludge*
- *Ambient temperatures are greater than 20 degree Celsius*
- *Reuse options of biogas digestor exists*
- *Treatment plant to be located in close proximity to habitation*

CASE STUDY

Faecal Sludge Treatment Plant Devanahalli, India

Constructed inIn 2015, the 2015, the pilot treatment facility was built in Devanahalli town, 50km away from Bangalore. It serves a population of 30.000 people, treating 6 m^3 of faecal sludge every day.

The treatment consists of five stages

1. Pre-treatment – retention of coarse materials
2. solid liquid separation
3. stabilisation through biogas and a stabilisation tank
4. sludge drying
5. Wastewater treatment - Settler, anaerobic filter and constructed wetland for separated liquid and percolate treatment. The cost of the treatment plant is around Rs. 55,00,000, while the operational expenses per annum is documented to be in the range of Rs.2,50,000 to Rs. 3,00,000.

Figure x: Sludge Drying Beds in Devanahalli

Pre-treatment	Screen and Grit chamber	Faecal sludge contains trash and grit such as plastics, soil, paper and fibre. Those solids reduce the treatment efficacy and value of end products. This is why they need to be removed before sludge undergoes any further treatment. Bar screens with vertical mesh usually separate the trash. The grit will settle through gravity. Appropriate arrangement for their collection and removal needs to be designed in the pre-treatment process.The separated trash and grit can be disposed along with municipal solid waste arrangement.
Sludge stabilisation and	Stabilisation reactor	The main objective of the stabilization reactor is to allow the sludge to digest anaerobically which leads to reduced organic load and better dewater-ability. Stabilisation reactors can be designed as biogas digestors, i.e having fixed or floating dome structures. These biogas digestors have a retention time of 5 – 15 days depending on the organic load input. The gas collected in the dome is to be utilised regularly to keep the biogas digestor operational. Sludge from the biogas digestor can be pumped or discharged through gravity into subsequent modules. An alternative to biogas digestors are baffle reactors. They provide a retention times of 8-20 days. In baffle reactors there is no dedicated gas collection point and hence recovery of biogas is minimal. Whenever the skillset for biogas construction is not available or when there is no reuse application for biogas, baffle reactors are an option. Baffled stabilisation tanks can also be provided with liquid and solid seperation units, which happens primarily through gravity based settling. The supernatant from such a seperation is sent into a settler and subsequent treatment modules.
Dewatering and drying	unplanted drying beds/ sludge drying bed	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 20 - 30 centimetres. The depth depends on the varying solids content in faecal sludge (3 - 5%). The majority of these solids with little moisture get retained at the top of the drying beds. The percolate from the sludge flows through these filter materials, undergoing treatment by filtration and biological digestion. The solids get retained in the top layers of the drying bed. Over a period of 12 - 30 days, the solids undergo dewatering and drying. The end product from the drying bed are bio-solids which can be further processed for value addition or used for land applications. A drainage mechanism is provided at the bottom of the drying bed to collect percolate, which still contains organic load and hence needs to be further treated.

Percolate treatment	Settler	Percolate from drying beds and supernatant from the stabilisation reactor is retained in a settler, typical with 3-4 hour retention time. This allows the settleable solids to settle.
	Anaerobic filter	Further treatment occurs at the anaerobic filter which has a retention time of 12-24 hours. The filter material provides surface for the growth of microorganism. The organisms aid in digestion and absorption of organic matter present in percolate.
	Planted gravel filter	Post anaerobic treatment modules, the partially treated wastewater is introduced into aerobic modules, such as horizontal/ vertical subsurface flow constructed wetlands. Flowing through this, the percolate comes in contact with natural air, which aid in nutrient and organic removal. In addition the plantation in these modules also absorb essential nutrients from the percolate.
Post treatment	Sand and carbon filter and UV treatment	The final treated wastewater is stored in an open tank, where filtration through sand - carbon filter and UV radiation together reduce the odour and disinfect the treated wastewater.

REUSE

Biosolids:
Stabilised biosolids can be used as a soil conditioner. They are enhancing the physical and nutrient properties of soil. Alternatively these can also be further processed along with municipal organic waste to yeildyield compost. At places of no reuse application, biosolids can be dried to act as a source of fuel or can be filled in land fill sites.

Treated wastewater:
Treated percolate can be used for irrigating farmlands or a, green belt within the treatment facility. Also they or can also be discharged into percolation pits to recharge ground water (when favourable conditions exist).

	END PRODUCT QUALITY	
	10 KLD	20 KLD
Biogas generation per day	*45 m^3*	*90 m^3*
Biosolids per annum	*50 – 55 tons*	*100 – 110 tons per day*
Nutrient rich water per day	*4 - 5 m^3*	*8– 10m^3*

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Generally used where the sludge is partially / unstabilized.
- They consume extensive area for treatment, a limited resource in Indian cities and towns.
- Stabilisation reactors require skilled operations as they are sensitive to input and external environment.

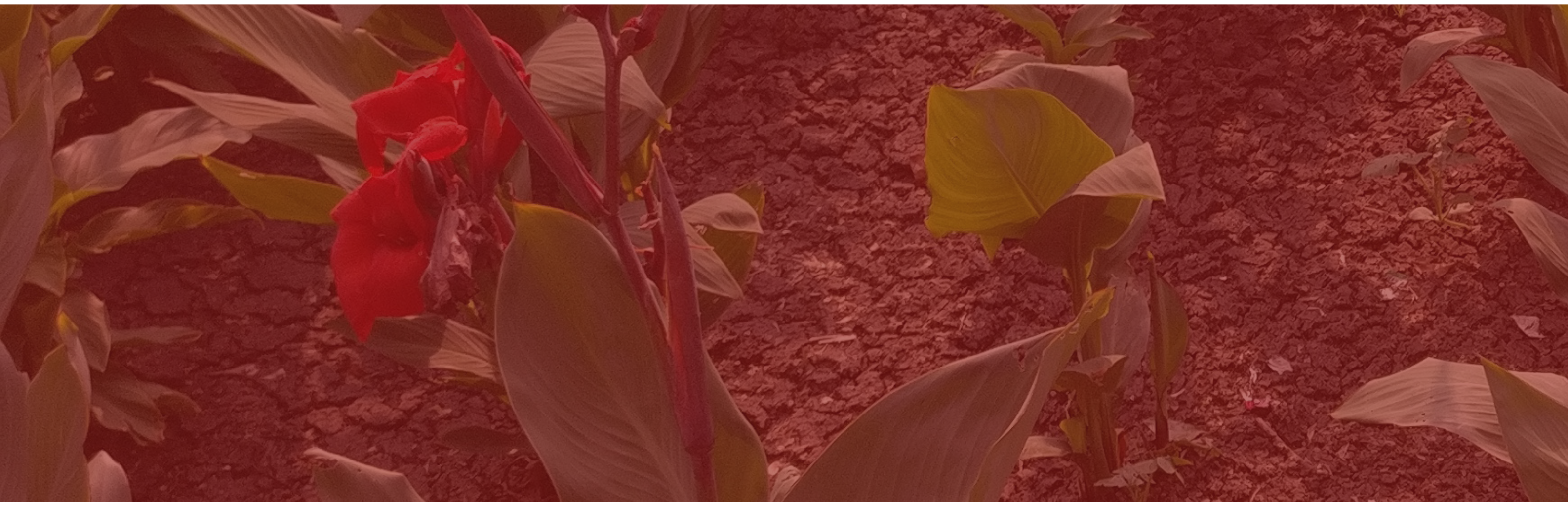
CHARACTERISTICS	END PRODUCT QUALITY			
	10 KLD	Per KLD	20 KLD	Per KLD
Area requirement – treatment module	*1300 m^2*	*130 m^2*	*2200 m^2*	*110 m^2*
Area for non-treatment facilities (road, greenbelt, operator room, etc)	*1300 m^2*	*130 m^2*	*1600 m^2*	*80 m^2*
Total Area	*2600 m^2*	*260 m^2*	*3800 m^2*	*190 m^2*
CAPEX	*Rs. 1,25,65,000*	*Rs. 13,57,500*	*Rs. 20,552,500*	*Rs. 10,27,625*
OPEX per annum	*Rs. 9,00,000*	*Rs. 90000*	*Rs. 13,25,500*	*Rs. 66,250*

CAPEX

S.no	PARTICULARS	AMOUNT 10 KLD	AMOUNT 20 KLD
1	Screen and grit chamber	1,00,000	2,00,000
2	Stabilisation Reactor	12,00,000	24,00,000
3	Sludge drying beds	35,00,000	63,00,000
4	Settler+ AF	5,00,000	8,00,000
5	Planted Gravel filter	5,00,000	8,50,000
6	Sand carbon filter	1,25,000	2,50,000
7	UV treatment	1,25,000	2,50,000
8	Collection tanks- 2 nos	5,00,000	7,00,000
8	Operator room	3,80,000	3,80,000
9	Flexible and rigid pavement	10,00,000	18,00,000
10	Electrical equipments	3,00,000	5,90,000
11	sludge storage house	6,90,000	11,50,000
12	Storm water drain	2,40,000	4,00,000
13	Roof of unplanted drying bed	12,50,000	25,00,000
14	Additional / Misc. works	2,50,000	5,00,000
15	compound wall	8,90,000	11,75,000
16	Plumbing and Registers	4,90,000	7,00,000
	Total	**1,20,40,000**	**2,09,45,000**

OPEX

S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	*20 KLD*	*10 KLD*	*20 KLD*
1	Manpower - Low skilled	per month	Every month	12	15,000	15,000	1,80,000	15,000
2	Electricity	per month	Every month	600 per 10 KLD	8	8	4,800	8
3	Consumables - operations	per month	Every month	12	1,000	2,000	12,000	2,000
4	Consumables - safety	per month	Every month	12	1,500	1,500	18,000	1,500
5	DEWATS & stabilisation tank-desludging	per service	once in 2 years	0.5	10,000	17,500	5,000	17,500
6	DEWATS - filter material replacement	per service	once in 5 years	0.2	50,000	75,000	10,000	75,000
7	Moving equipment service and replacements	per service	once in 2 years	0.5	10,000	15,000	5,000	15,000
8	Sand replacement in drying beds	per service	once in 2 years	0.5	1,30,000	2,50,000	65,000	2,50,000
9	Drying bed - maintenance	per service	once in 2 years	0.5	80,000	1,50,000	40,000	1,50,000
10	Misc. and contingency expenses	5% of O&M cost					16,990	23,143
	Total						3,39,800	4,62,850

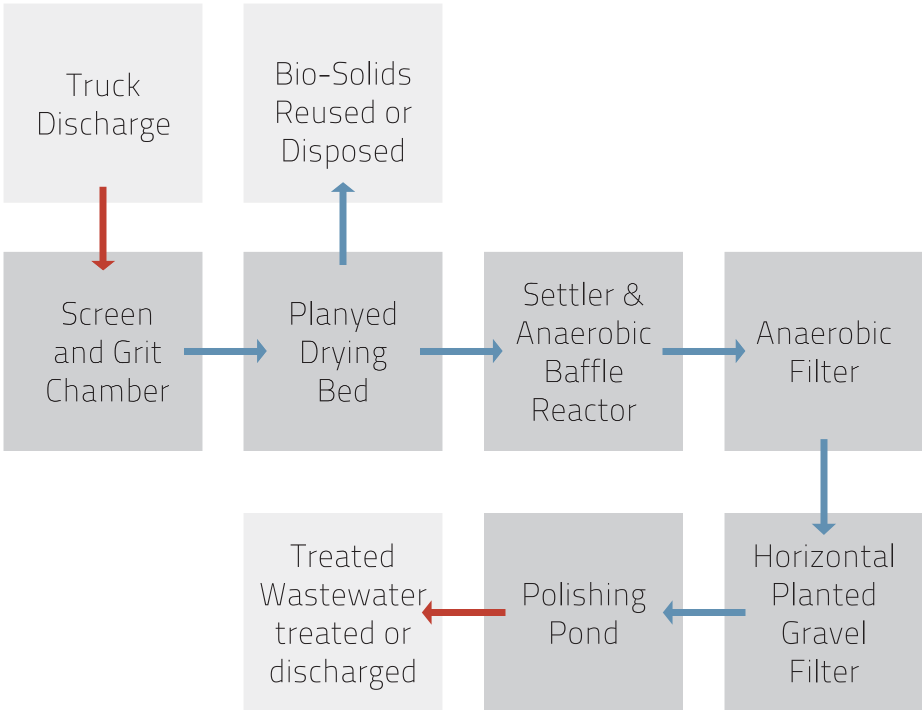

2 TECHNOLOGY OPTION

PLANTED DRYING BED

PLANTED DRYING BED

Planted drying beds are a safe disposal and treatment option especially when regular operation and intensive monitoring can be a concern. It uses a natural and non-mechanized way to treat sludge into end products such as stabilized bio-solids and treated wastewater. Sludge is treated due to dewatering and microbial digestion, while the liquid percolate is treated through a series of anaerobic digestion followed by constructed wetland.

TREATMENT CONCEPT



Faecal sludge and Septage emptied from pits and septic tanks is discharged into screen and grit chamber, where inert materials such as plastics, paper, fabric, soil and silt are removed using bar screen and gravity settling. The screened sludge is disposed into planted drying bed, which is filled with sand andgravel to support vegetation and to act as a filter media. The filtrate flows down through the media and is collected in drains, while the solids remains on the filter surface and is dewatered through gravity and evapotranspiration.The main advantage of the planted bed is that the filters do not need to be de-sludged after each drying cycle. Therefore fresh sludge can be directly applied over the previous layer with interval between subsequent applications. The plants and their root systems maintain the porosity of the filter and hence the beds require de-sludging only once every 2-3 years. The end product from drying bed is the bio-solids, which is stabilized and rich in nutrients, which can be used directly as a soil conditioner or co-composted with municipal organic waste to produce compost.
The percolate collected from the bottom of the drying bed is treated through a series of treatment modules such as settling tank, anaerobic baffle reactor, anaerobic filter, constructed wetland and polishing pond to achieve the desired effluent standard.

TREATMENT GOALS

1. *Stabilized bio solids*
2. *Treated water as per CPCB standards*
3. *Minimal operational requirement*
4. *Robust performance*

TREATMENT METHODOLOGY

1. *Trash and grit removal*
2. *Sludge dewatering*
3. *Percolate treatment*
4. *Sludge stabilization*

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EFFLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100-150 mg/litre	< 100 mg/litre
Total solids	20 – 50 g/litre	300 – 500 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

SUITABILITY

Planted drying bed as a treatment option for faecal sludge is suitable (and not restricted to) for following conditions:

- High variation in quantity of faecal sludge to be treated at the facility
- Moderate variation in the characterestics of faecal sludge
- Limited or no reuse option
- Ambient temperatures of less than 20 degree Celsius
- Wide fluctuation in temperatures across seasons
- Minimal operational requirement

TREATMENT MODULES

Pre-treatment	Screen and Grit chamber	Faecal sludge contains trash and grit such as plastics, soil, paper and fibre which reduce the treatment efficacy and value of end products, hence these need to be removed before sludge undergoes any further treatment. Bar screens with vertical mesh is preffered for trash seperation. Removal of grit usually happens through gravity settling. Appropriate arrangement for their collection and removal need to be designed in the pretreatment process. The seperated trash and grit can be disposed along with municipal solid waste arrangement.
Sludge stabilisation and dewatering	Planted drying beds	Planted drying beds consists of graded filter media such as gravel and sand. Pre-treated sludge is applied over these filter materials having macrophyte plantation. The percolate from the sludge flows through these filter materials, undergoing treatment by filtration and bilogical digestion. The solids get retained in the top layers of the drying bed, which over a period of 2-3 years undergo digestion and stabilisation. Planted drying beds are designed to treat a solid loading rate of 150-250 kg total solids/m2 per annum. The macrophytes help in stabilisation and dewatering, the roots of these plants enable growth of certain type of bacteria which also aid in nutrient removal. After 2-3 years of loading, the beds are left unused for 6 months where further dehydration and stabilisation of the solids occur. The end product from the drying bed is stabilised bio-solids which can be further processed for value addition or used for land applications. A drainage mechanism is provided at the bottom of the drying bed to collect percolate, which still contains organic load and hence needs to be further treated.

Percolate treatment	Settler	Percolate from drying beds is retained in a settler, typical with 3-4 hour retention time, this provides for settling of the settleable solids.
	Anaerobic baffle reactor (ABR)	Percolate from settler is further treated in anaerobic baffle reactor providing for an upflow movement of sludge through a sludge blanket. The retention time provided in the ABR is about 24-26 hours, with an upflow velocity of 0.9-1.2 m/hr
	Anaerobic filter	Further treatment occurs at the anaerobic filter provided with a retention time of 12-24 hours. The filter material provide surface for the growth of microorganism which aid in digestion and absorbsion of organic matter present in percolate.
	Planted gravel filter	Post anaerobic treatment modules, the partially treated wastewater is introduced into aerobic modules, such as horizontal subsurface flow constructed wetlands. Flowing through this, the percolate comes in contact with natural air, which aid in nutrient and organic removal. In addition the plantation in these modules also absorb essential nutrients from the percolate.
	Polishing Pond	The final treated wastewater is stored in an open tank where, surface aeration and UV radiation together reduce the organic and microbial load of the treated wastewater.

	END PRODUCT QUANTITY	
	10 KLD	20 KLD
Biosolids per annum	*50 – 55 tons*	*100 – 110 tons per day*
Nutrient rich water per day	*4 - 5 m^3*	*8– 10m^3*

REUSE

Biosolids:

Stabilised biosolids can be used as a soil conditioner enhancing the physical and nutrient properties of soil. Alternatively these can also be further processed along with municipal organic waste to yield compost. At places of no reuse application, biosolids can be dried to act as a source of fuel or can be filled in land fill sites.

Treated wastewater:

Treated percolate can be used for irrigating farmlands, green belt within the treatment facility or can also be discharged into percolation pits to recharge ground water (when favaourable conditions exist).

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Planted drying beds receive partially stabilised sludge, and might pose a threat of odour and nuisance due to insects.
- They consume extensive area for treatment, a limited resource in Indian cities and towns.
- Due to its low operational requirement, the treatment unit is often neglected which can lead to its failure.
- Macrophytes in the drying bed need to be acclimatized to faecal sludge by application of low strength faecal sludge or wastewater for a period of 3-4 months prior to commissioning of the system.

	END PRODUCT QUALITY				
		10 KLD	Per KLD	20 KLD	Per KLD
CHARACTERISTICS	Area requirement – treatment module	*1250 m²*	*125 m²*	*2400 m²*	*120 m²*
	Area for non-treatment facilities (road, greenbelt, operator room, etc)	*1250 m²*	*125 m²*	*2000 m²*	*105m²*
	Total Area	*2500 m²*	*250 m²*	*4500 m²*	*225m²*
	CAPEX	*Rs. 1,35,75,000*	*Rs. 13,57,500*	*Rs. 2,60,00,000*	*Rs. 13,00,000*
	OPEX per annum	*Rs. 2,50,000*	*Rs. 25000*	*Rs. 3,50,000*	*Rs. 17,500*

CASE STUDY

Thailand

Constructed in 1996, the pilot treatment facility was built in AIT campus in Thailand for conducting research on planted drying beds. The treatment consists of three stages: a. Pre-treatment – retention of coarse materials, b. balancing and mixing tank – to achieve certain homogenisation, c. planted drying beds along with waste stabilisation pond and vertical flow constructed wetland for percolate treatment. Three planted drying beds are designed with a sludge loading rate of 250 kg TS/m^2 annum.

Figure x: Planted drying bed in Thailand; Photo credits: SSWM

Figure x: PDB is Dakar, Senagal. Photo credits: EAWAG

Senegal

Implemented in 2008 under the guidance of EAWAG, planted drying beds were used as a treatment option for a full scale faecal sludge treatment plant in Dakar, Senegal.

CAPEX

S.no	PARTICULARS	AMOUNT	
		10 KLD	20 KLD
1	Screen + Planted drying bed	75,00,000	1,35,00,000
2	Settler+ ABR+AF	4,00,000	7,80,000
3	Planted Gravel filter	4,50,000	9,00,000
4	Collection tank	5,00,000	9,00,000
5	Polishing pond	1,25,000	2,50,000
6	Operator room	3,80,000	3,80,000
7	Flexible and rigid pavement	10,00,000	18,00,000
8	Electrical equipments	1,00,000	2,50,000
9	landscaping	2,00,000	4,00,000
10	Additional / Misc. works	2,50,000	5,00,000
11	compound wall	10,00,000	17,50,000
12	Plumbing and Registers	5,50,000	6,87,500
	Total	**1,24,55,000**	**2,20,97,500**

OPERATION AND MAINTENANCE COST

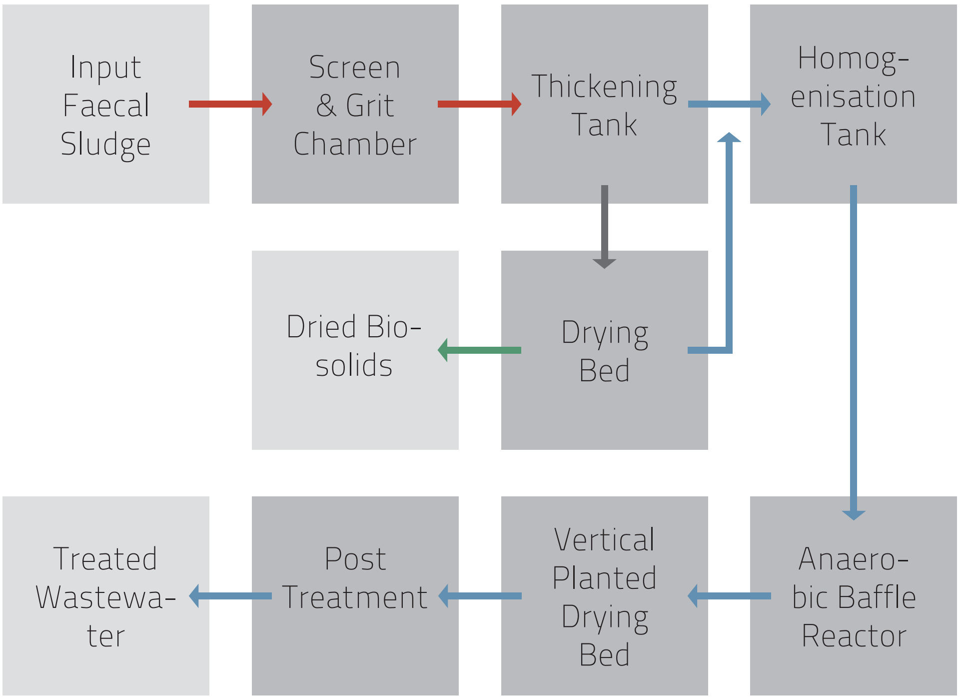
S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	20 KLD	10 KLD	20 KLD
1	Manpower - Low skilled	per month	Every month	12	12,000	12,000	1,44,000	1,44,000
2	Electricity	per month	Every month	750 / 1000	8	8	6,000	8,000
3	Consumables - operations	per month	Every month	12	2,000	3,000	24,000	36,000
4	Consumables - safety	per month	Every month	12	1,000	1,500	12,000	18,000
5	DEWATS - desludging	per service	once in 2 years	0.5	10,000	20,000	5,000	10,000
6	DEWATS - filter material replacement	per service	once in 5 years	0.2	50,000	80,000	10,000	16,000
7	Moving equipment service and replacements	per service	once in 2 years	0.5	10,000	12,000	5,000	6,000
8	Sand replacement in drying beds	per service	once in 5 years	0.2	1,20,000	3,00,000	24,000	60,000
9	Drying bed - maintenance	per service	once in 5 years	0.2	80,000	2,00,000	16,000	40,000
10	Misc. and contingency expenses	5% of O&M cost					12,300	16,900
	Total						2,58,300	3,54,900

3 TECHNOLOGY OPTION THICKENING TANK

THICKENING TANK

Thickening tanks are sedimentation tanks used in faecal sludge treatment for sludge dewatering. It uses gravity settling for liquid solid separation. Sludge removed from thickening tanks are further dewatered using drying beds to yield reusable bio-solids. The percolate undergoes anaerobic and aerobic treatment to achieve disposal standards.

TREATMENT CONCEPT



TREATMENT GOALS

1. *Dried bio solids*
2. *Treated water as per CPCB standards*

TREATMENT METHODOLOGY

1. *Trash and Grit removal*
2. *Sludge thickening*
3. *Sludge drying*
4. *Percolate treatment*

Faecal sludge and Septage emptied from pits and septic tanks is discharged into screen and grit chamber, where inert materials such as plastics, paper, fabric, soil and silt are removed using bar screen and gravity settling. The screened sludge is disposed in thickening tank where the heavy solids settle down due to gravity, over a period of 6-10 days, these solids undergo further dewatering due to weight of the liquid column above. The thickened sludge is removed from the bottom of the tank through pump or gravity and discharged into a sand drying bed. The supernatant in the thickening tank flows out into a homogenization tank and later into a series of wastewater treatment units. Scum accumulated in the top layers of the thickening tank is removed using a scrapping arrangement or manually as and when required. The end product from drying bed is bio-solids, which is rich in nutrients and can be used directly as a soil conditioner or co-composted with municipal organic waste to produce compost.

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EF-FLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100 mg/litre	<100 mg/litre
Total solids	20 – 50 g/litre	300 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

Suitability

The proposed treatment option for faecal sludge is suitable for following conditions:

- Fluctuating input faecal sludge characterestics
- Treating faecal sludge generated from non residential units such as hotels, restaurants, etc which have considerable quanitites of oil and grease
- Availability of electricity for treatment
- Skill set is available for operating and maintaining mechanised equipment – pumps
- Reuse option for dried sludge
- Suitable Climatic conditions for sludge drying – Hot and dry

TREATMENT MODULES

Pre-treatment	Screen and Grit chamber	Faecal sludge contains trash and grit such as plastics, soil, paper and fibre which reduce the treatment efficacy and value of end products, hence these need to be removed before sludge undergoes any further treatment. Bar screens with vertical mesh is preffered for trash seperation. Removal of grit usually happens through gravity settling. Appropriate arrangement for their collection and removal need to be designed in the pretreatment process. The seperated trash and grit can be disposed along with municipal solid waste arrangement.
Sludge Thickening	Thickening tank	Thickening tanks are sedimentation tanks which aid in gravity settling of heavy sludge particles. The length, depth and width is designed to enable this settling and to permit a sludge retention time of 10 days. During the 10 days of retention, the sludge undergoes further thickening due to the weight of liquid column above. Anaerobic digestion also occurs in the sludge accumulation layer. A bottom slope of 20 % is provided in the thickening tank to collect the sludge for pumping. The thickened sludge is usually between 6 – 10 % total solids offering resistance to natural flow,hence these need to be pumped to drying beds. Percolate with suspended and disolved solids spend close to 48 hours in the thickening tank, undergoing primary treatment. The scum layer formed due to oil and fats float to the top, which is removed periodically.

Dewatering and drying	Sand drying beds	Sludge from thickening tanks is pumped into drying beds, which have graded gravel and sand as a filtration media. The percolate from sludge pass vertically through the filter media and get collected through a drainage arrangement provided at the bottom part of the bed. The solids get retained on top of the sand layer and lose additional mositure due to evaporation. Typical drying periods vary between 6-15 days, after which, the dried sludge is removed from the bed and fresh sludge is loaded. Loading rate into a drying bed varies based on the local climatic condition such as humidity, temperature, wind flow etc, which aid in evaporation. It is also advisable to provide for a transparent shed above the beds to retain heat and enhance evaporation, but such designs must consider air draft. These sheds can also act as a barrier during rains. The dried biosolids can be stored or reused for various applications.
Percolate treatment	Homogenisation tank	Percolate from drying beds and supernatant from the thickening tank is collected into a homogenisation tank, where the variations in characterestics of wastewater are reduced. The tank also aids retaining excess of solids overflowing from thickening tank due to variation in input faecal sludge characterestics. The design consideration include providing a retention time of 24- 36 hours and depths greater than 1.2 metre for enabling septic conditions.
	Anaerobic baffle reactor (ABR)	Supernatant from homogenisation tank is further treated in anaerobic baffle reactor providing for an upflow movement of sludge through a sludge blanket. The retention time provided in the ABR is about 24-26 hours, with an upflow velocity of 0.9-1.2 m/hr.
	Anaerobic filter	Further treatment occurs at the anaerobic filter provided with a retention time of 12-24 hours. The filter material provide surface for the growth of microorganism which aid in digestion and absorbsion of organic matter present in percolate.
	Vertical flow constructed wetlands (VFCW)	Post anaerobic treatment modules, the partially treated wastewater is introduced into aerobic module- vertical flow constructed wetlands throigh siphon or a pump. Flowing through this module, the percolate comes in contact with natural air, which aid in nutrient and organic removal. In addition the plantation in these modules also absorb essential nutrients from the percolate.
	Post treatment modules	The percolate from VFCW is further treated through a series of sand-carbon filter and ultraviolet (UV) radiation. Presurrised sand and carbon filter reduce the solid content in the wastewater by straining and adsorbsion while UV raditation helps in disinfection.

REUSE

Biosolids:

Dried biosolids can be further processed to reduce microbial count. Options such as co-composting with municipal solid waste can aid in pasterisation from heat generated in the composting process. Alternately, biosolids can also be packed and stored in hot and dry condiion to enable inactivation of microorganism, especially helminth and ascaris eggs. Dried and pasterised biosolids can be used for land applications to enhance soil properties. Application of biosolids as fuel does not require pasterisation and hence can be further processed through dehydrating in solar driers or carbonization for enhancing fuel properties.

Treated wastewater:
Treated percolate can be used for non potable purposes such as irrigation, gardening or even disposal into water bodies. Percolation pits can also be considered to recharge groundwater aquifiers.

END PRODUCT QUALITY	10 KLD	20 KLD
Biogas generation per day	*45 m³*	*90 m³*
Biosolids per annum	*1 – 1.2 tons*	*2 – 2.5 tons per day*
Nutrient rich water per day	*5 - 6 m³*	*¹1 – 12 m³*

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Thickening tanks are usually open tanks with risks of odour and insects, hence sufficient buffer and green belt need to be provided.
- Availability of electricity is vital for the treatment process.
- Grit and trash removal mechanism if not operated or maintained can hinder thickening process.
- Option for reuse before deciding on further process of biosolid treatment.

CHARACTERISTICS	END PRODUCT QUALITY			
	10 KLD	Per KLD	20 KLD	Per KLD
Area requirement – treatment module	*1000 m²*	*100 m²*	*1800 m²*	*90 m²*
Area for non-treatment facilities (road, greenbelt, operator room, etc)	*1250 m²*	*125 m²*	*2000 m²*	*100 m²*
Total Area	*2250 m²*	*225 m²*	*3800 m²*	*190 m²*
CAPEX	*Rs. 1,05,00,000*	*Rs. 10,50,000*	*Rs. 1,80,00,000*	*Rs. 9,00,000*
OPEX per annum	*Rs. 4,00,000*	*Rs. 40000*	*Rs. 5,50,000*	*Rs. 27,500*

Figure x: Thickening tank being built for a faecal sludge treatment plant in Senegal

CASE STUDY

Dakar, Senegal

A treatment plant of capacity 100 m3 per day designed to treat faecal sludge from nearby areas. The treatment plant consists of two parallel thickening tanks followed by sludge drying beds and a homogenisation tank for liquid pre-treatment. The percolate from homogenisation tank is co-treated in a ASP based sewage treatment plant co-located within the same facility.

CAPEX

S.no	PARTICULARS	AMOUNT	
		10 KLD	20 KLD
1	Screen and grit chamber	1,00,000	2,00,000
2	Thickening tank	6,00,000	12,00,000
3	Homogenization tank	4,00,000	7,00,000
4	Sludge drying beds	23,00,000	45,00,000
5	ABR+ AF	5,00,000	8,00,000
6	Planted Gravel filter	5,00,000	8,50,000
7	Sand carbon filter	1,25,000	2,50,000
8	UV treatment	1,25,000	2,50,000
9	Collection tanks- 2 nos	5,00,000	7,00,000
10	Operator room	3,80,000	3,80,000
11	Flexible and rigid pavement	10,00,000	18,00,000
12	Electrical equipments	3,00,000	5,90,000
13	sludge storage house	6,90,000	11,50,000
14	Storm water drain	2,40,000	4,00,000
15	Roof of unplanted drying bed	12,50,000	25,00,000
16	Additional /Mischaleneous works	2,50,000	5,00,000
17	compound wall	8,90,000	11,75,000
18	Plumbing and Registers	4,90,000	7,00,000
	Total	**1,06,40,000**	**1,86,45,000**

OPEX

S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	*20 KLD*	*10 KLD*	*20 KLD*
1	Manpower - Low skilled	per month	Every month	12	15,000	15,000	1,80,000	1,80,000
2	Electricity	per month	Every month	3000 /4500	8	8	24,000	36,000
3	Consumables - operations	per month	Every month	12	5,000	10,000	60,000	1,20,000
4	Consumables - safety	per month	Every month	12	1,500	1,500	18,000	18,000
5	DEWATS & thickening tank- desludging	per service	once in 2 years	0.5	10,000	17,500	5,000	8,750
6	DEWATS - filter material replacement	per service	once in 5 years	0.2	50,000	75,000	10,000	15,000
7	Moving equipment service and replacements	per service	once in 2 years	0.5	10,000	15,000	5,000	7,500
8	Sand replacement in drying beds	per service	once in 2 years	0.5	1,30,000	2,50,000	65,000	1,25,000
9	Drying bed - maintenance	per service	once in 2 years	0.5	80,000	1,50,000	40,000	75,000
10	Misc. and contingency expenses	5% of O&M cost					20,350	29,263
	Total						4,27,350	4,62,850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4 TECHNOLOGY OPTION

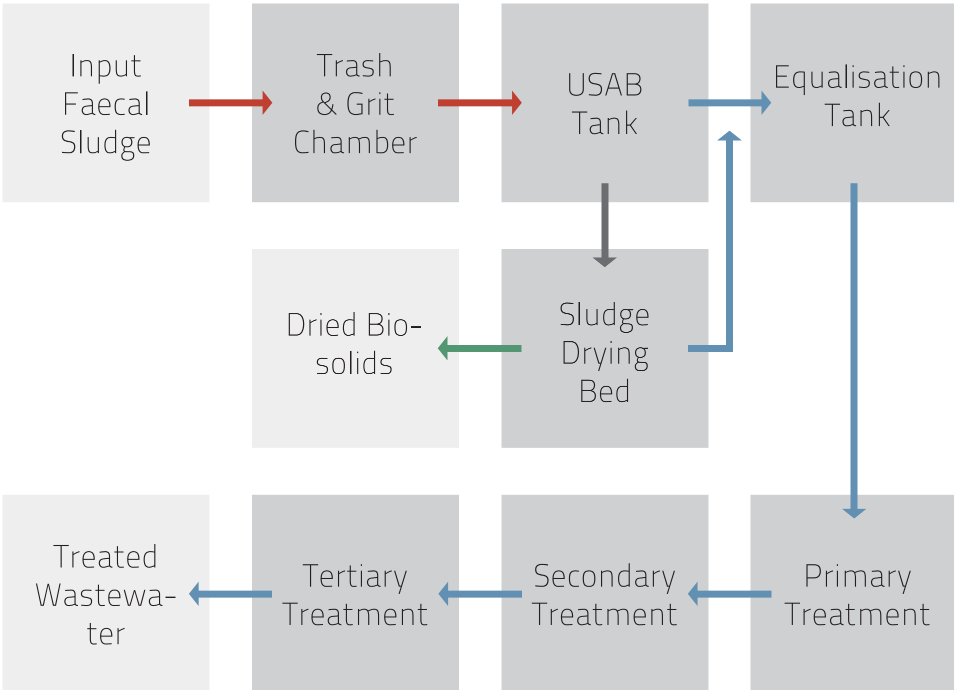
CO-TREATMENT

CO-TREATMENT

Sewage treatment plants are common in well establised urban areas and in new areas proposals are being developed for establishing STPs or interception and diversion treatment systems. As these systems are built with long and futuristic timelines, there remains extra capacities in the present situation, which can be harneses to treat faecal sludge from nearby areas which still use onsite sanitation systems for containment of domestic wastewater.

Faecal sludge is characterestically different from sewage as it contains higher concentration of solids and organic loads, hence treatment of faecal sludge in sewage treatment plants requires incorporating additional modules within the STP facility.

TREATMENT CONCEPT



Faecal sludge and Septage emptied from pits and septic tanks have characteristics much higher than normal sewage in terms of total solids, nutrients and biochemical oxygen demand. Introducing them directly into sewage treatment can affect the existing system and render the process ineffective; it is hence required to pre-treat faecal sludge. Pretreatment includes reducing the organic load and total solids entering into the STP, modules such as Up-flow anaerobic sludge blanket (UASB) tank and sludge drying beds can aid the reduction. Prior to these, the sludge has to be screened for trash and grit. The settled sludge from the UASB tank is dried in sludge drying beds while the supernatant is allowed to flow into the STP through an equalization tank. The percolate from the drying beds also combines with the supernatant in the equalization tank. The equalization tank provides for a control over flow and wastewater characteristic. The dried bio-solids from drying beds can be reused for land applications along with sewage sludge. It is however necessary to assess the existing performance and capacity utilization of the STP before designing for co-treatment. Such data provides a basis for estimating the faecal sludge treatment capacity.

TREATMENT GOALS

1. *Dewatered bio solids*
2. *Treated water as per CPCB standards*

TREATMENT METHODOLOGY

1. *Trash and grit removal*
2. *Sludge digestion*
3. *Sluge drying*
4. *Percolate treatment*

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EFFLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100 mg/litre	<100 mg/litre
Total solids	40 – 50 g/litre	300 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

Suitability

The proposed treatment option for faecal sludge is suitable for following conditions:

- Availability of sewage treatment plants with excess capacities
- Availability of land in existing STP facility for setting up pre-treatment of sludge
- Online monitoring of STP through SCADA for process corrections
- Availability of electricity and skilled manpower for operations and maintenance

TREATMENT MODULES

Pre-treatment	Screen and Grit chamber	Faecal sludge contains trash and grit such as plastics, soil, paper and fibre which reduce the treatment efficacy and value of end products, hence these need to be removed before sludge undergoes any further treatment. Bar screens with vertical mesh is preffered for trash seperation. Removal of grit usually happens through gravity settling. Appropriate arrangement for their collection and removal need to be designed in the pretreatment process The seperated trash and grit can be disposed along with municipal solid waste arrangement.
Sludge sDigestion	USAB Tank	Screened faecal sludge is discharged into an UASB tank consisting of a sludge blanket. Faecal sludge is introduced into the UASB tank in an upflow movement passing through the sludge blanket which aids in anaerobic digestion and filtration. The retention time for the percolate is between 2-5 hours, while the designed upflow velocity is between 0.9-1.2 m/hour. The heavy partcles of the sludge settle and form a part of the sludge blanket, which is periodically desludged into the drying beds.

Sludge drying	Drying bed	Sludge from UASB tanks is pumped into drying beds, which have graded gravel and sand as a filtration media. The percolate from sludge pass vertically through the filter media and get collected through a drainage arrangement provided at the bottom part of the bed. The solids get retained on top of the sand layer and lose additional mositure due to evaporation. Typical drying periods vary between 6-15 days, after which, the dried sludge is removed from the bed and fresh sludge is loaded. Loading rate into a drying bed varies based on the local climatic condition such as humidity, temperature, wind flow etc, which aid in evaporation. It is also advisable to provide for a transparent shed above the beds to retain heat and enhance evaporation, but such designs must consider air draft. These sheds can also act as a barrier during rains. The dried biosolids can be stored or reused for various applications.
Percolate treatment	Equalisation Tank	Equalisation tank receives both supernatant from UASB tank and percolate from drying beds. It is designed with a retention time of 24 hours and performs the function of reducing the variation in flow and characterstics of wastewater (supernatant and percolate) flowing into the STP.
	STP	Sewage treatment plants can be of any process, it is however advisable to assess the excess capacity and thereby plan for treatment of faecal sludge. It is also neccesary to continiously monitor the input parameters from equalisation tank into the STP and make neccesary process corrections for enabling the required output standards.

REUSE

Biosolids:
Dried biosolids can be packed and stored in hot and dry condiion to enable inactivation of microorganism, especially helminth and ascaris eggs. Dried and pasterised biosolids can be used for land applications to enhance soil properties. Application of biosolids as fuel does not require pasterisation and hence can be further processed by carbonization for enhancing fuel properties. Also, these biosolids can be sold/disposed along with sewage sludge.

Treated wastewater:
Treated percolate can be used for non portable purposes such as irrigation, gardening or even disposal into water bodies. Percolation pits can also be considered to recharge groundwater aquifiers

END PRODUCT QUALITY	10 KLD	20 KLD
Biogas generation per day	*45 m^3*	*90 m^3*
Biosolids per annum	*1 – 1.2 tons*	*2 – 2.5 tons per day*
Nutrient rich water per day	*5 - 6 m^3*	*^{1}1 – 12 m^3*

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Dried sludge is not completely stabilised and hence needs further processing before application for farming. Post processing such as co-composting, infrared heating can be considered to reduce microbial count.
- STP requires online monitoring and control of parameters to adjust the process based on inputs from faecal sludge pretreatment.
- If existing sewage sludge drying facility is underutilised, these can be used for faecal sludge drying.

CASE STUDY

Faecal sludge treatment plant in Kochi, Kerala

Treatment capacity: 100 m3 faecal sludge treatment in Cochin, India designed by ABG Engineering (India). A upflow anaerobic sludge blanket cone arrangement is provided to digest the organics in faecal sludge, while the supernatant is treated through a Sequential batch reaction process.

END PRODUCT QUALITY					
CHARACTERISTICS		10 KLD	Per KLD	20 KLD	Per KLD
	Area requirement – treatment module	*800 m^2*	*80 m^2*	*1400 m^2*	*70 m^2*
	Area for non-treat-ment facilities (road, greenbelt, operator room, etc)	*300 m^2*	*30 m^2*	*300 m^2*	*15 m^2*
	Total Area	*1100 m^2*	*110 m^2*	*1700 m^2*	*85 m^2*
	CAPEX	*Rs. 65,00,000*	*Rs.6,50,000*	*Rs. 1,04,00,000*	*Rs. 5,20,000*
	OPEX per annum	*Rs. 11,00,000*	*Rs.1,10,000*	*Rs. 16,00,000*	*Rs. 80,000*

CAPEX

S.no	PARTICULARS	AMOUNT 10 KLD	AMOUNT 20 KLD
1	Screen and grit chamber	1,00,000	2,00,000
2	UASB tank	6,00,000	12,00,000
3	Equalisation tank	4,00,000	7,00,000
4	Sludge drying beds	23,00,000	45,00,000
5	Electrical equipments	3,00,000	5,90,000
6	sludge storage house	6,90,000	11,50,000
7	Roof of unplanted drying bed	12,50,000	25,00,000
8	Additional / Mischaleneous works	2,50,000	5,00,000
9	Plumbing and Registers	4,90,000	7,00,000
10	Representative cost for STP -SBR	5,00,000	12,00,000
	Total	**68,80,000**	**1,32,40,000**

OPEX

S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	*20 KLD*	*10 KLD*	*20 KLD*
1	Manpower - low skilled	per month	Every month	12	15,000	15,000	1,80,000	1,80,000
2	Electricity	per month	Every month	1500 / 3000	8	8	12,000	24,000
3	Consumables - operations	per month	Every month	12	10,000	15,000	1,20,000	1,80,000
4	Consumables - safety	per month	Every month	12	2,000	2,000	24,000	24,000
5	Moving equipment service and replacements	per service	once in 2 years	0.5	20,000	40,000	10,000	20,000
6	Sand replacement in drying beds	per service	once in 2 years	0.5	1,30,000	2,50,000	65,000	1,25,000
7	Drying bed - maintenance	per service	once in 2 years	0.5	80,000	1,50,000	40,000	75,000
8	Delsudging of equalisation tank	per service	Every year	1	25,000	50,000	25,000	50,000
9	Electricity cost of STP	per month	Every month	2500	8	8	20,000	30,000
10	consumables for STP (includes disinfection)	per month	Every month	12	10,000	15,000	1,20,000	1,80,000
11	Manpower - STP	FTE	Every day	150	2,000	2,000	3,00,000	4,00,000
12	Maintenance cost of STP equipments	per service	every month	12	15,000	20,000	1,80,000	2,40,000
13	Misc. and contingency expenses	5% of O&M cost					54,800	76,400
	Total						11,50,800	16,04,400


VIAR

5 TECHNOLOGY OPTION MECHANICAL DEWATERING

MECHANICAL DEWATERING

Mechanical dewatering equipment such as screw press, filter press, belt press etc. is used to separate solids and liquids from faecal sludge. The dewatered sludge is dried in solar drying beds or disposed in landfills, while the liquid is treated using anaerobic treatment and aerobic filtration.

TREATMENT GOALS

1. *Dewatered bio solids*
2. *Treated water as per CPCB standards*

TREATMENT METHODOLOGY

1. *Trash and Grit removal*
2. *Sludge dewatering*
3. *Sludge drying*
4. *Filtrate treatment*

TREATMENT CONCEPT

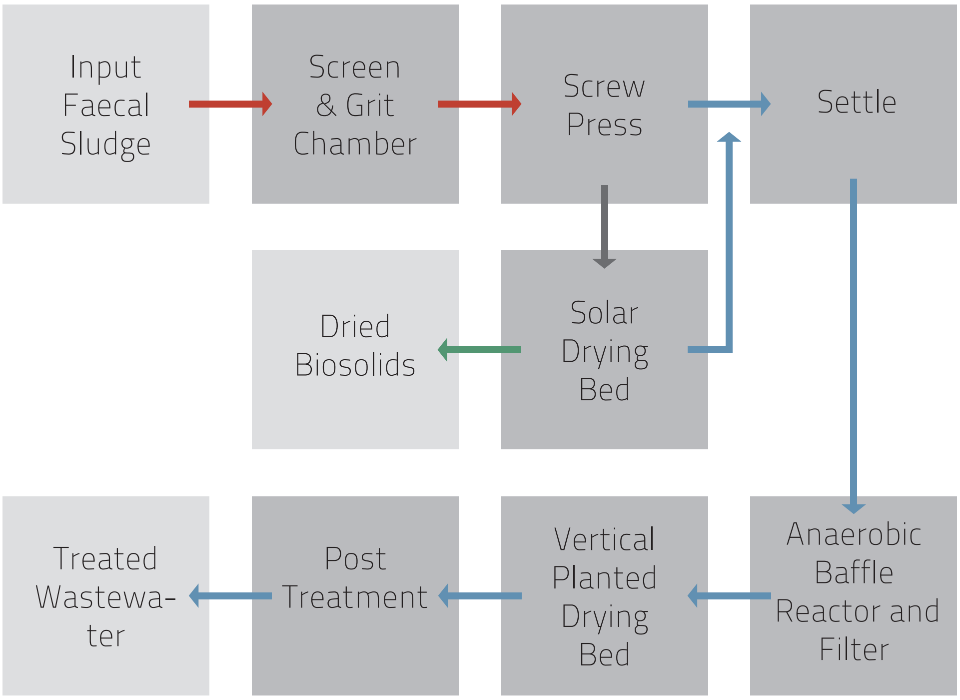


Figure x: Decanter with sludge handling facility and drying beds, Photo credits: Dav Robbins

Faecal sludge and Septage emptied from pits and septic tanks is discharged into screen and grit chamber, where inert materials such as plastics, paper, fabric, soil and silt are removed using bar screen and gravity settling. The sludge is mixed with flocculants using a dosing pump and then introduced into a Screw press. The screw press separates the solids and liquid in faecal sludge, the solids are collected separately, while the liquid filtrate flows into a settling tank. The de-cantered sludge is dried in solar drying beds, post which these bio-solids can be reused for land applications or as a source of fuel.

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EFFLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100 mg/litre	<100 mg/litre
Total solids	40 – 50 g/litre	300 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

Suitability

The proposed treatment option for faecal sludge is suitable for following conditions:

- Availability of electricity for treatment
- Skill set is available for operating and maintaining mechanised equipment – pumps, decanters, screw conveyors, etc.
- Low trash and grit content in input faecal sludge
- Availability of flocculants and disinfection chemicals
- Less land available for FS treatment

CASE STUDY

Faecal Sludge Treatment Plant in Cebu, Philippines

Treatment capacity: 150 m3 per day of faecal sludge. The input faecal sludge is pre-treated to remove grit and trash and is later decanted using screw press. The seperated sludge is dried and disposed in land fill sites, while the liquid is treated using extended aeration.

Pre-treatment	Screen and Grit chamber	Faecal sludge contains trash and grit such as plastics, soil, paper and fibre which can affect the performane of decanter. Bar screens with vertical mesh is preffered for trash seperation. Removal of grit usually happens through gravity settling. Appropriate arrangement for their collection and removal need to be designed in the pretreatment process. The seperated trash and grit can be disposed along with municipal solid waste arrangement.
Sludge Dewatering	Centrifuge Decanter	Once the heavy and inert particles such as trash and grit are removed, the sludge is dozed with flocculants with appropriate quanitites, these chemicals enhance the liquid solid seperation. The sludge is then introduced into a decanter and pressed against a filter media to separate the solids and liquid. The seperated solids, typically having 15-20% solids are collected using a bin or container. The liquid from the decanter is dicharged into a settling tank for further treatment.
Sludge drying	Solar drying beds	The sludge collected from decanter is spread over a paved floor with thickness not exceeding 10 cms. The sludge is sun dried, losing moisture to evaporation. A raking arrangement can enhance the sludge drying process and thereby reduce the net area required for drying. A poly house can be erected above the bed to capture and retain solar heat, but designing such a system needs to consider air draft throughout the beds. The dried sludge can be considered for land applications or as sources of fuel.
Filtrate treatment	Settler	Liquid from the decanter is retained in a settler, typical with 3-4 hour retention time, this provides for settling of the settleable solids.
	Anaerobic baffle reac-tor (ABR)	Supernatant from settler is further treated in anaerobic baffle reactor providing for an upflow movement of sludge through a sludge blanket. The retention time provided in the ABR is about 36 - 48 hours, with an upflow velocity of 0.9-1.2 m/hr.
	Anaerobic filter	Further treatment occurs at the anaerobic filter provided with a retention time of 24 - 36 hours. The filter material provide surface for the growth of microorganism which aid in digestion and absorption of organic matter present in filtrate.
	Vertical flow constructed wetlands (VFCW)	Post anaerobic treatment modules, the partially treated wastewater is introduced into aerobic module- vertical flow constructed wetlands through siphon or a pump. Flowing through this module, the filtrate comes in contact with natural air, which aid in nutrient and organic removal. In addition the plantation in these modules also absorb essential nutrients from the filtrate.
	Post treatment modules	The filtrate from VFCW is further treated through a series of sand-carbon filter and ultraviolet (UV) radiation. Pressurised sand and carbon filter reduce the solid content in the wastewater by straining and adsorption while UV radiation helps in disinfection.

REUSE

Biosolids:
Dried biosolids can be packed and stored in hot and dry condition to enable inactivation of microorganism, especially helminth and ascaris eggs. Dried and pasterised biosolids can be used for land applications to enhance soil properties. Application of biosolids as fuel does not require pasterisation and hence can be further processed by carbonization for enhancing fuel properties.

Treated wastewater:
Treated filtrate can be used for non potable purposes such as irrigation, gardening or even disposal into water bodies. Percolation pits can also be considered to recharge groundwater aquifiers.

END PRODUCT QUALITY	10 KLD	20 KLD
Biogas generation per day	*45 m^3*	*90 m^3*
Biosolids per annum	*1 -1.2 tons*	*2 – 2.5 tons per day*
Nutrient rich water per day	*5 - 6 m^3*	*11 – 12 m^3*

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Dried sludge is not completely stabilised and hence needs further processing before application for farming. Post processing such as co-composting, infrared heating can be considered to reduce microbial count.
- Operating a decanter requires skilled manpower and hence their availability is crucial in selection of such technologies.
- Easy availability of spare parts of the decanter and cost of O&M is to be considered vis a vis other available options.
- Unlined containment systems as a source of faecal sludge can generate lot of grit which can affect decanter function.

CHARACTERISTICS	END PRODUCT QUALITY				
		10 KLD	Per KLD	20 KLD	Per KLD
	Area requirement – treatment module	*600 m^2*	*60 m^2*	*1100 m^2*	*55 m^2*
	Area for non-treatment facilities (road, greenbelt, operator room, etc)	*300 m^2*	*30 m^2*	*300 m^2*	*15 m^2*
	Total Area	*900 m^2*	*90 m^2*	*1400 m^2*	*70 m^2*
	CAPEX	*Rs. 98,00,000*	*Rs.9,80,000*	*Rs. 1,60,00,000*	*Rs. 8,00,000*
	OPEX per annum	*Rs. 18,00,000*	*Rs. 1,80,000*	*Rs. 27,00,000*	*Rs. 1,35,000*

CAPEX

S.no	PARTICULARS	AMOUNT	
		10 KLD	20 KLD
1	Screen and grit chamber	1,00,000	2,00,000
2	Screw press	6,00,000	12,00,000
3	Solar drying beds	23,00,000	45,00,000
4	Settler+ ABR+ AF	5,00,000	8,00,000
5	Planted Gravel filter	5,00,000	8,50,000
6	Sand carbon filter	1,25,000	2,50,000
7	UV treatment	1,25,000	2,50,000
8	Collection tanks- 2 nos	5,00,000	7,00,000
9	Operator room	3,80,000	3,80,000
10	Flexible and rigid pavement	10,00,000	18,00,000
11	Electrical equipments	3,00,000	5,90,000
12	sludge storage house	6,90,000	11,50,000
13	Storm water drain	2,40,000	4,00,000
14	Roof of unplanted drying bed	12,50,000	25,00,000
15	Additional / Mischaleneous works	2,50,000	5,00,000
16	compound wall	8,90,000	11,75,000
17	Plumbing and Registers	4,90,000	7,00,000
18	Plumbing and Registers	4,90,000	7,00,000
	Total	**1,02,40,000**	**1,79,45,000**

OPERATION AND MAINTENANCE COST

S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	*20 KLD*	*10 KLD*	*20 KLD*
1	Manpower - low skilled	per month	Every month	12	15,000	15,000	1,80,000	1,80,000
2	Manpower - skilled	per month	Every month	12	30,000	30,000	3,60,000	3,60,000
3	Electricity	per month	Every month	7500 / 12000	8	8	60,000	96,000
4	Consumables - operations (includes polymers)	per month	Every month	12	80,000	1,50,000	9,60,000	18,00,000
5	Consumables - safety	per month	Every month	12	1,500	1,500	18,000	18,000
6	DEWATS - desludging	per service	once in 2 years	0.5	10,000	17,500	5,000	8,750
7	DEWATS - filter material replacement	per service	once in 5 years	0.2	50,000	75,000	10,000	15,000
8	Moving equipment service and replacements	per service	once in 2 years	0.5	50,000	1,00,000	25,000	50,000
9	Sand replacement in drying beds	per service	once in 2 years	0.5	1,30,000	2,50,000	65,000	1,25,000
10	Drying bed - maintenance	per service	once in 2 years	0.5	80,000	1,50,000	40,000	75,000
11	Misc. and contingency expenses	5% of O&M cost					86,150	1,36,388
	Total						18,09,150	28,64,138

6 TECHNOLOGY OPTION

GEOBAGS

GEOBAGS

Geobags are tubes made of permeable textiles used for dewatering which separate solids and liquids from faecal sludge. The dewatered sludge is dried in solar drying beds or disposed in landfills, while the liquid is treated using anaerobic treatment and aerobic filtration.

TREATMENT GOALS

1. *Dewatered bio solids*
2. *Treated water as per CPCB standards*

TREATMENT METHODOLOGY

1. *Trash and Grit removal*
2. *Sludge dewatering*
3. *Sludge drying*
4. *Filtrate treatment*

TREATMENT CONCEPT

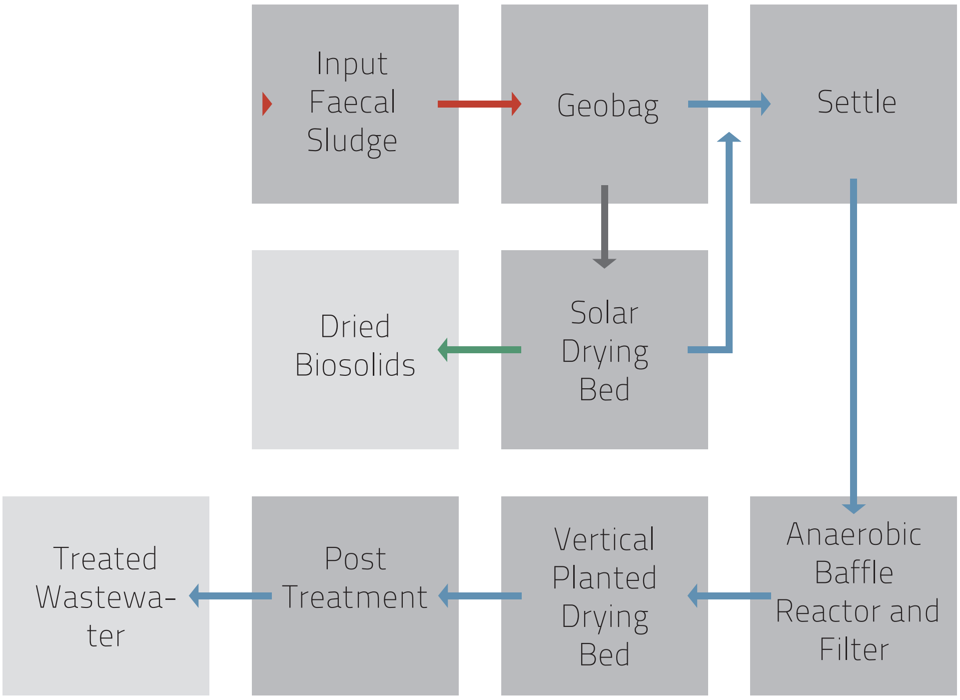


Figure x: Geobags in use. Photo credit: Tencate

Faecal sludge and Septage emptied from pits and septic tanks is discharged directly into the geo-bag, a certain amount of polymer is added inside the bag along with the sludge to improve its dewatering capability. The porous membrane of the bag allows the percolate to pass through, while holding back solids. The percolate is collected and treated using anaerobic and aerobic systems, while the dewatered sludge is dried in solar drying beds, post which these bio-solids can be reused for land applications or as a source of fuel.

DESIGN PARAMETERS

PARAMETERS	INPUT FAECAL SLUDGE	FINAL TREATED EFFLUENT	CPCB STANDARDS FOR DISCHARGE OF TREATED WATER
COD	20 – 50 g/litre	100 mg/litre	<100 mg/litre
Total solids	40 – 50 g/litre	300 mg/litre	< 300 mg/litre
TKN	3000 mg/litre	50 mg/litre	< 50 mg/litre

Suitability

The proposed treatment option for faecal sludge is suitable for following conditions:

- Geo bad is available or can be brought easily
- Huge fluctualtions in input faecal sludge quantity
- Space for treatment plant is limited
- Low trash and grit content in input faecal sludge
- Seasonal variations in faecal sludge quantity exist

CASE STUDY

Geobags were used in Eganville, Ontario (Canada) for treating septage received from a population of 3500 persons. A geotube measuring 22 feet by 22.5 feet was used for dewatering sludge throughout the winter season. Intial solid content of sludge from 3% was dewatered to achieve 40% TS. The following was the summary of operations:

Parameters	% reduction
Suspended solids	99.6%
Phosphorous captured	98.2%
Nitrogen captured	82.3%
E.coli reduction	99.9%

Sludge Dewatering	Geo bag	Faecal sludge is discharged into the geobag, bags of different capacities are available in the market, which determine the inour loading rate. Ideally, a bag can be loaded for 30 days, most water percolates out in 8-10 hour duration after each loading. After 30 days of loading the bag is left unattended for 10 -15 days, post which the bag is cut open and the sludge is raked out to be dried further in solar drying beds. The bag is made to rest on a concrete floor sloping with drainage arrangement to aid in collection of percolate.
Sludge drying	Solar drying beds	The sludge from geobags is spread over a paved floor, with thickness not exceeding 10 cms. The sludge is sun dried, losing most moisture to evaporation. A raking arrangement can enhance the sludge drying process and thereby reduce the net area required for drying. A poly house can be erected above the bed to capture and retain solar heat, but designing such a system needs to consider air draft throughout the beds. The dried sludge can be considered for land applications or as sources of fuel.
Filtrate treatment	Settler	Liquid from the geobag is conveyed in a settler, typical with 3-4 hour retention time, this provides for settling of the settleable solids.
	Anaerobic baffle reactor (ABR)	Supernatant from settler is further treated in anaerobic baffle reactor providing for an upflow movement of sludge through a sludge blanket. The retention time provided in the ABR is about 36 - 48 hours, with an upflow velocity of 0.9-1.2 m/hr.
	Anaerobic filter	Further treatment occurs at the anaerobic filter provided with a retention time of 24 - 36 hours. The filter material provide surface for the growth of microorganism which aid in digestion and absorption of organic matter present in filtrate.
	Vertical flow constructed wetlands (VFCW)	Post anaerobic treatment modules, the partially treated wastewater is introduced into aerobic module- vertical flow constructed wetlands through siphon or a pump. Flowing through this module, the filtrate comes in contact with natural air, which aid in nutrient and organic removal. In addition the plantation in these modules also absorb essential nutrients from the filtrate.
	Post treatment modules	The filtrate from VFCW is further treated through a series of sand-carbon filter and ultraviolet (UV) radiation. Pressurised sand and carbon filter reduce the solid content in the wastewater by straining and adsorption while UV radiation helps in disinfection.

REUSE

Biosolids:

Dried biosolids can be packed and stored in hot and dry condition to enable inactivation of microorganism, especially helminth and ascaris eggs. Dried and pasterised biosolids can be used for land applications to enhance soil properties. Application of biosolids as fuel does not require pasterisation and hence can be further processed by carbonization for enhancing fuel properties.

Treated wastewater:

Treated filtrate can be used for non potable purposes such as irrigation, gardening or even disposal into water bodies. Percolation pits can also be considered to recharge groundwater aquifiers.

END PRODUCT QUALITY	10 KLD	20 KLD
Biogas generation per day	*45 m^3*	*90 m^3*
Biosolids per annum	*1 -1.2 tons*	*2 – 2.5 tons per day*
Nutrient rich water per day	*4 -5 m^3*	*8 -10 m^3*

CONSIDERATION WHILE CHOOSING THE TREATMENT TECHNOLOGY

- Dried sludge is not completely stabilised and hence needs further processing before application for farming. Post processing such as co-composting, infrared heating can be considered to reduce microbial count.
- Geobag efficiency is linked with the use of polymers, skilled operation is required to estimate the correct quanitity of polymer usage for varying faecal sludge characterestics.

CHARACTERISTICS	END PRODUCT QUALITY			
	10 KLD	Per KLD	20 KLD	Per KLD
Area requirement – treatment module	*1200 m^2*	*120 m^2*	*2400 m^2*	*240 m^2*
Area for non-treatment facilities (road, greenbelt, operator room, etc)	*600 m^2*	*60 m^2*	*900 m^2*	*90 m^2*
Total Area	*1800 m^2*	*180 m^2*	*3300 m^2*	*330 m^2*
CAPEX	*Rs. 95,00,000*	*Rs.9,50,000*	*Rs. 1,60,00,000*	*Rs. 8,00,000*
OPEX per annum	*Rs. 20,00,000*	*Rs. 2,00,000*	*Rs. 36,00,000*	*Rs. 1,80,000*

CAPEX

S.no	PARTICULARS	AMOUNT	
		10 KLD	20 KLD
1	Geobag foundation	1,00,000	2,00,000
2	Geo bag - 1 year	5,40,000	10,80,000
3	Solar drying beds	23,00,000	45,00,000
4	Polymer dozing		
5	Settler+ ABR+ AF	5,00,000	8,00,000
6	Planted Gravel filter	5,00,000	8,50,000
7	Sand carbon filter	1,25,000	2,50,000
8	UV treatment	1,25,000	2,50,000
9	Collection tanks	5,00,000	7,00,000
10	Operator room	3,80,000	3,80,000
11	Flexible and rigid pavement	10,00,000	18,00,000
12	Electrical equipments	3,00,000	5,90,000
13	sludge storage house	6,90,000	11,50,000
14	Storm water drain	2,40,000	4,00,000
15	Roof of unplanted drying bed	12,50,000	25,00,000
16	Additional / Mischaleneous works	2,50,000	5,00,000
17	compound wall	8,90,000	11,75,000
18	Plumbing and Registers	4,90,000	7,00,000
	Total	**1,01,80,000**	**1,78,25,000**

OPERATION AND MAINTENANCE COST

S. no	Activity or resources	Unit	Frequency	No. of Units	Unit rate		Amount	
					10 KLD	*20 KLD*	*10 KLD*	*20 KLD*
1	Manpower - low skilled	per month	Every month	12	15,000	15,000	1,80,000	1,80,000
2	Geo bag replacement	per month	Every month	12	45,000	90,000	5,40,000	10,80,000
3	Electricity	per month	Every month	3000 / 12000	8	8	24,000	96,000
4	Consumables - operations (includes polymers)	per month	Every month	12	80,000	1,50,000	9,60,000	18,00,000
5	Consumables - safety	per month	Every month	12	1,500	1,500	18,000	18,000
6	DEWATS - desludging	per service	once in 2 years	0.5	10,000	17,500	5,000	8,750
7	DEWATS - filter material replacement	per service	once in 5 years	0.2	50,000	75,000	10,000	15,000
8	Moving equipment service and replacements	per service	once in 2 years	0.5	50,000	1,00,000	25,000	50,000
9	Sand replacement in drying beds	per service	once in 2 years	0.5	1,30,000	2,50,000	65,000	1,25,000
10	Drying bed - maintenance	per service	once in 2 years	0.5	80,000	1,50,000	40,000	75,000
11	Misc. and contingency expenses	5% of O&M cost					93,350	1,72,388
	Total						19,60,350	36,20,138