GUIDANCE DOCUMENT

FOR DESIGN OF FSTP BASED ON

DRYING BED TECHNOLOGIES

Guidance Document for Design of FSTP based on Drying Bed Technologies
Publication by - Consortium for DEWATS™ Dissemination (CDD) Society, Bengaluru

This is a reference document only and the designs presented in the document need to be contextualized through expert support.

Photographs
All photographs are courtesy of Consortium for DEWATS™ Dissemination Society, Bengaluru unless indicated otherwise.
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Abbreviations

ASR	Anaerobic Stabilization Reactor
BOD	Biological Oxygen Demand
BT	Balancing Tank
BORDA	Bremen Overseas Research and Development Association
CDD	Consortium for DEWATS Dissemination Society
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environmental Engineering Organisation
Cum	Cubic Meter
DEWATS	Decentralized wastewater Treatment System
EGL	Existing Ground Level
FGL	Finished Ground Level
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
HRT	Hydraulic Retention Time
ISAF	Integrated Settler and Anaerobic Filter
KLD	Kilo litre day
MPN	Most Probable Number
NGT	National Green Tribunal
NH_3-N	Ammonia
NH_4-N	Ammonium ion
O&M	Operation and Maintenance
ODF	Open Defecation Free
OSS	Onsite Sanitation system
PBM	Permanent Bench Mark
PDB	Planted Drying Bed
PGF	Planted Gravel Filter
PH_4	Phosphate
PP	Polishing Pond
SBM	Solid Block Masonry
SC	Screen Chamber
SCF	Sand Carbon Filter
SDB	Sludge Drying Bed
STP	Sewage Treatment Plant
TBM	Temporary Bench Mark
TKN	Total Kjeldahl Nitrogen
TP	Triose Phosphate
TS	Total Solid
TSS	Total Suspended Solid
ULB	Urban Local Body
UoI	Union of India
UPDB	Unplanted Drying Bed
USEPA	United States Environment Protection Agency
VS	Volatile Solid
WHO	World Health Organisation

Dhenkanal FSTP

Preface

Post the launch of the Swacch Bharat Mission in 2014 which focused on making India Open Defecation Free (ODF) through provision of toilets – there has been relentless **focus on the question "Toilet ke Baad Kya" (What happens after you flush the toilet).**

Given that only 40% of the households in Urban India are connected to sewer networks, pertinent and important conversations began around how to handle the **waste** generated by the remaining **60% of the households which is contained in Onsite Sanitation Systems (OSS)** like **septic tanks,** twin **pits** and single pits. In order to handle the waste contained in these OSS (Faecal Sludge), the common practise among households is to reach out to a septic tank cleaning operator who would desludge the Septic tank/pit and eventually **dispose** off Faecal Sludge (FS) in the environment – mostly into **surface water bodies, fields or vacant lands**– leading to **contamination** of these invaluable resources. To avoid this, **FS needs to be safely treated.** In the last five years, the country has taken rapid strides in the area of FS treatment and management.

At the time of writing this document, more than 130 FSTPs are operational and at least 300 more are under various stages of construction in India. These **FSTPs have been designed** using various approaches – **Anaerobic, Electromechanical, Thermal** to name a few. Over the next half a decade, FSTPs are expected to be setup in all the towns in India (7,935 according to Census 2011). As more and more states in the country expect to scale up Faecal Sludge Management (FSM), it should be possible for both the **Government and Private Sector** to have access to and understand existing designs and technologies in an easy manner which will help them make an **informed decision on choice of technology for Faecal Sludge Treatment Plant (FSTP) implementation.**

At CDD, over the past five years, we have developed **designs for more than 50 FSTPs** across the country– **built on our legacy of Nature Based Solutions.** These designs based on Anaerobic Stabilization with Unplanted Sludge Drying Bed **(ASR + UPDB)** and Planted Drying Bed **(PDB)** have been developed through a process of **intensive applied research,** continuous improvement and iteration. These designs can be **built using locally available materials,** are **easy and cheaper to operate & maintain** and **have very low energy consumption.**

As on 1st December 2020, more than 10 FSTPs designed by CDD using these technologies are running successfully. More importantly, there are a number of FSTPs designed and built by other organizations around the country based on **ASR + UPDB** that have **demonstrated desired results.**

Using this document

This document is an attempt to unpack the designs based on drying bed technologies. We believe that these are **designs** which can be easily understood by Civil and Environmental Engineers in **Government as well as Private Organizations** – who can then apply their skills in **contextualizing** the designs to specific sites that they encounter. This document – drawing from our vast experience - outlines the **process flows, functionalities** of the key modules, **key design assumptions**, dimensions of modules and for a specific capacity of FSTP – provides the **detailed drawings** as a reference. Further, to help contextualizing designs to specific sites – some of the critical elements of **Master Planning, Layouts** and detailed design are called out.

However, **this document is not to be treated as a design manual. Readers of the document are advised to seek expert support to contextualize the designs to specific sites.**

We hope this document is useful to the talented pool of Sanitation engineers around the country and anyone who is keen on gaining a deeper understanding of FSTP design.

Acknowledgments

The designs presented in this document are the result of efforts of a concerted pool of professionals that CDD has helped nurture over the last decade. We would like to acknowledge the key contributions of our colleagues – Nikhil Gampa, Ritesh Kumar and Krishna Swaroop who have helped compile the document, Susheel Sagar who has designed this document, Susmita Sinha, Sanjay Deu, GS Santhosh, Pavan Kumar Reddy and Sagar Patil for their review and many others in CDD and its network whose body of work has helped shape the ideas in this document.

While the current publication draws upon CDD's experience in the field of FSTP design – **we continue** to engage in **optimizing these designs** – in terms of **cost, area and efficiencies.** The designs covered in this document are thus, not to be construed as perfect designs but more as **work in progress.** We welcome feedback from readers and further insights and contributions.

We hope you find this document insightful and useful.

Happy reading!!!


CASS FSTP

1. Introduction

1.1 Need for FS Treatment

Faecal sludge (FS): is undigested or partially digested or digested slurry or solids containing mostly human excreta and water, in combination with sand, grit, metals, solid waste and/or various chemical compounds. FS is generated or formed from on-site sanitation systems, resulting from the collection and storage of excreta or black water, with or without greywater.

The physico-chemical characteristics of the faecal sludge will vary depending on factors such as the size and type of onsite sanitation system, design, desludging interval and the geo-climatic conditions of the place where the tank is located, the quantity and quality of water supplied and the type of wastewater originating from the household. Typically, **FS contains higher concentration of total solids, higher levels of BOD,COD and pathogens when compared to wastewater.**

The typical FS characteristics over 10 different parameters available from various authors, books and primary data are compiled in the table for reference.

Sl. No.	Parameter (mg/l)	USEPA	Linda Strande et.al (Public toilet)	Linda Strande et.al (Septic tank)	D' halli[3]	Siricilla[4]
1	TS	40,000	35,000	30,000	34,560	25,000
2	VS	25,000	22,000	19,500	19,965	17,000
3	TSS	15,000	-	-	16,700	15,700
4	BOD[1]	7,000	7,600	2,600	3,750	-
5	COD[2]	15,000	20,000-50,000	<10,000	23,900	32,000
6	TKN	700	3,400	1,000	-	-
7	NH_3- N	150			-	-
8	NH4-N		3,300	1,200	600	-
9	TP	250	450	150	-	-
10	PO4	-	-	-	830	-

Table 1 : Raw FS Characteristics

[1]Biological Oxygen Demand

[2]Chemical Oxygen Demand

[3]90 samples (average values) from Devanahalli FSTP have been considered

[4]46 samples (average values) from Sircilla, Telangana – collected from various vacuum truck operators have been considered

Given these characteristics, FS when not managed properly and disposed off unsafely - causes pollution of water sources including surface water and groundwater. **When safely treated, the treated faecal sludge can be a useful resource.** Faecal sludge contains plant nutrients such as nitrogen and phosphorous which is contributed by human urine and faeces. Treated faecal sludge can provide the required nutrients for crop production and hence can be used as a soil conditioner. Also, treated sludge can be used as biochar[5].

The main objective of faecal sludge (FS) treatment is to ensure that the FS is safely treated in accordance with standards so as to **prevent pollution of water sources & soil** leading to protection of human & environmental health. In India, there are standards specified for sewage treatment plants (STP) by the Central Pollution Control Board (CPCB) for the discharge of treated effluents and is applicable for the wastewater discharged from Faecal Sludge Treatment Plant (FSTP) which are presented in the table below (Table 2). The United States Environmental Protection Agency (USEPA) and the World Health Organization (WHO) standards are considered for biosolids (Table 3).

Sl No.	Parameters	Units	Mega and Metropolis Cities	Class I cities	Others	Deep Marine Outfalls
1	pH	Number	5.5 to 9	5.5 to 9	5.5 to 9	5.5 to 9
2	Biochemical Oxygen Demand (BOD)	mg/L	10	20	30	30
3	Total Suspended solids (TSS)	mg/L	20	30	50	50
4	Chemical Oxygen Demand (COD)	mg/L	50	100	150	150
5	Faecal Coliform	MPN/ 100mL	Desirable 100 – Permissible 230	Desirable 230 - Permissible 1000	Desirable 1000 - Permissible 10000	Desirable 1000 - Permissible 10000

Table 2 : Effluent discharge standards (applicable to all mode of disposal)[6]

[5]Biochar is formed from the heating of biomass (300–1000°C) in the absence of oxygen and is a coproduct of pyrolysis and gasification processes used to produce liquid and gaseous fuels

[6]NGT 1069-2018 Nitin Deshpande Vs UoI 30.04.2019

The main objective of faecal sludge (FS) treatment is to ensure protection of human and environmental health. In India, currently, there are no notified standards for use or disposal of the treated bio-solids from faecal sludge treatment plant (FSTP). The standards specified for sewage treatment plant (STP) by the Central Pollution Control Board (CPCB) are for the discharge of treated effluents and is applicable for the wastewater discharged from FSTP which are presented in the Table 2. The United States Environmental Protection Agency (USEPA) and the World Health Organization (WHO) standards are considered for biosolids (Table 3).

Parameters	Values	Remarks	Source
Faecal coliforms	< 1,000 MPN/g TS	Class A Biosolids	USEPA, 1993
	< 2,000,000 MPN/g TS	Class B Biosolids	USEPA, 1993
Salmonella spp	MPN/g TS < 2,000,000 CFU/g TS	Class A biosolids	USEPA, 1993
		Class B Biosolids	USEPA, 1993
Helminths	<1 no of egg/L	For treated effluent used for vegetable irrigation	WHO, 2006
	<1 no of egg/g TS	In Faecal Sludge post treatment	WHO, 2006
Class A: When prepared for sale or give away and passes on to the user for land application or producing other product Class B: Pathogen reduction for land application and surface disposal			

Table 3 : Biosolids standards

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1.2 FS Treatment Stages

For FS to be safe for reuse (both the solid and liquid component), certain treatment steps need to be followed; which are outlined in the table below .

Treatment Stage	Treatment Methods	Treatment Options
Solid -Liquid Separation	Screening	• Manually cleaned • Mechanically cleaned
	Settling/Sedimentation/Thickening	• Gravity-time based settling tank • Forced settling – Coagulation/Flocculation
Stabilization	Biological Stabilization	• Aerobic, Anaerobic Stabilization
	Chemical Stabilization	• Lime Stabilization
	Thermal Stabilization	• Using airtight sealed containers
Dewatering and Drying of Sludge	Filtration, Evaporation and evapotranspiration	• Planted Drying Beds • Unplanted Sludge Drying Beds
	Centrifugation / Pressure pressing	• Screw Press, Filter Press, Centrifuge
	Heat drying / Solar drying	• Solar Drying using greenhouse roofing
	Thermal drying	• Pyrolysis, Incineration
Liquid/Effluent Treatment	Based on the treatment methods adopted above, a suitable wastewater treatment system based on any of the standard STP technologies may be configured to treat the effluent to achieve required standards covering Primary, Secondary and Tertiary Treatment	
Disinfection	Solids	• Co-Composting • Desiccation – moisture removal from cell • Lime/Ammonia treatment • Pyrolysis / Sludge incineration (850 $^{\circ}$C)
	Liquid	• UV / Ozonation • Chlorination • Pasteurization (80 – 90°C)

Table 4 : FS Treatment Stages

1.3 Treatment Approaches

For the purpose of this document, the FS treatment methods are classified into active and passive approaches.

Passive approaches can be characterized as those that can operate on **gravity, biological treatment methods consuming less energy, no chemicals** and having very few moving/ mechanical parts. As a result, the skill level required to operate FS treatment plants using passive methods is low.

Active approaches on the other hand can be characterized by **higher energy requirements, chemical consumption, presence of multiple mechanical/electromechanical parts in the treatment process.** The skill level required to operate such FSTPs will be relatively higher when compared to FSTPs based on passive methods.

There will be systems where a combination of the above methods are applied to achieve the desired results of FS Treatment. Such systems can be defined as **Hybrid Systems.**

In **this document**, we have showcased guidance required for designing of FSTP based on UPDB & PDB which are passive approaches.

Devanahalli FSTP

1.4 Designing FSTPs to facilitate Gender Inclusivity

Lack of sanitation affects different genders disproportionately as it not only affects their ability to relieve themselves safely but also limits their opportunities to receive education and work. **Women and women led organizations have been at the forefront of significant milestones** in Solid Waste Management in India – enactment of Solid Waste Management rules, Swacha Bangalore, Ward Level Dry Waste Collection Centres in Bangalore to name a few.

While FSM is in its nascent stages, It is essential now to **consciously take into consideration the ergonomics of operations and occupational safety for all genders while designing future FSTPs.** Conscious efforts to increase the participation of women as service providers in sanitation has been made in the states of Odisha, Telangana, Andhra Pradesh, Maharashtra & Uttar Pradesh. In some of the states, the FSTP operations and maintenance is being outsourced to women self-help groups thereby providing them livelihood opportunities. There is an increasing possibility of more states following this pattern. It has, therefore become extremely **important to take into consideration the possibility of women as well as transgenders taking up O&M of FSTP** - while designing and constructing the treatment plant.

Some crucial aspects to be considered are as follows:

Concerning safety and dignity:

- The site has to be selected in such a way that it is safe and secure for the woman/transgender person operator(s) and worker(s) for carrying out their duties.
- The **site should be near to the city/town** with **good transportation/access facilities**. ULBs should take up the responsibility of providing the necessary facilities.
- There should be **facilities which are gender inclusive. For example** there can be ladies' toilets, changing rooms with adequate privacy. Interiors of such space should have hooks to hang purse, washroom hanger for clothes and shelves to keep toiletries and adequate lighting.
- **The toilets should be separate** for men and women but located sufficiently close to the operator room.
- The above facilities are to be ensured during FSTP construction also – as a lot of women are involved in construction activities. **ULBs need to take up this responsibility and contractors need to be made aware** of this basic and fundamental requirement to protect the dignity of women.It is recommended to station at least two or more women operators and workers to take care of the plant operation and maintenance.

- An alternate power source should be available to provide a 24x7 power supply. It should be designed based on peak load consumption and the expected number of hours of power blackouts and the switching mechanism must be located at/near the operator room.
- The site as well as the access road(s) shall be well lit with **street lights**.
- The **plants should have security provisions** such as guards, CCTV cameras (under the functioning of ULB administration), and emergency helpline numbers of the ULB, fire station, police station, and Ambulance displayed prominently at strategic locations.
- **Regular police patrolling** of the FSTP area shall be ensured by the ULB/local administration, throughout the day as well as night, if there is a provision for the FSTP operator to stay in the vicinity of the FSTP.
- If the FSTP accepts load in **odd hours, a security guard** shall be stationed at the plant.
- Along with **skill training, self defense training** could be included for the FSTP operators.

Concerning Ergonomics

- The **treatment modules should be made easily accessible.** For example, the maintenance chamber lids and valves should be easily accessible without needing to stretch or bend excessively. Typically, any valve should not be located at a height of more than 4m from an easily accessible platform.
- The **maintenance chamber lids should be constructed with lighter materials** such as mild steel(MS), Cast Iron(CI), Steel Fiber reinforced concrete(SFRC), Galvanized Iron(GI) and Fiber reinforced concrete(FRC) which can be lifted easily. The number of openings in the form of maintenance chamber lids should be kept to a minimum. The risks are that the cost might increase but they will eventually be balanced out due to reduced operational costs and less number of openings.
- **One can provide inspection hole of smaller diameter** (for eg: 300 mm dia) for inspection of modules having a lid of concrete so as to facilitate daily monitoring of the modules. This can be used for simple daily operations like sampling purposes etc. In case of major maintenance works, one has to use the main maintenance hole provided. This will avoid the need for the operator to regularly lift heavy maintenance hole covers.

Maintenance Chamber

- **Sign boards should be placed near pumps** and **other heavy equipment** that can be generally heavy, mentioning that at least two people should pull it up together and that the activity is not to be done alone.
- Operator(s) and helper(s) height[7] can be a constraint. Necessary care needs to be taken – for modules like PDB, Polishing Pond. **A staircase/ladder provision in design has to be included (if free board is more and the module is underground)**. Integrating modules with platforms to enable people with lesser height to undertake regular O&M has to be a design consideration.
- Adequate training should be provided to everyone working as an operator(s) and helper(s) – so that they can turn the **FSTP into a good co-working space.**
- A **reliable source of potable water, municipal piped water or on-site borewell, supply should be provided**, with adequate quantity of water, for drinking purposes (complying to drinking water standards) and for cleaning.

The engineering designs in the document have been prepared considering the above aspects to ensure that FSTPs are designed to facilitate easy O&M across genders.

Jhansi FSTP Polishing pond

Maintenance Chamber

[7] In India the average female height is about 5 feet.

Siricilla FSTP

2. Process Flow & Module Descriptions

The section below outlines the treatment concepts and describes the constituent treatment modules that form a part of two key treatment systems, namely

1) Unplanted Drying Beds with percolate treatment – **referred to as UPDBs**
2) Planted Sludge Drying Beds with percolate treatment – **referred to as PDBs**

Process Flow for UPDB based treatment system

The graphic below depicts the typical process flow for UPDBs

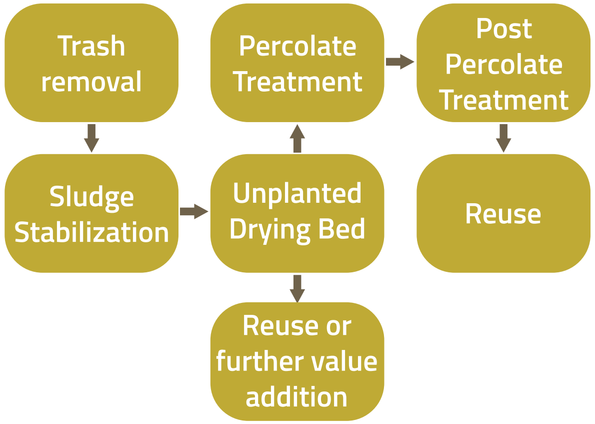


Table 5 provides the reduction in concentrations of key parameters of FS across different stages of treatment using UPDB based system.

Table 5 : UPDB Parameters

Module	COD		BOD	
	In	Out	In	Out
UPDB	<7,500 mg/l	1,500 - 1,650 mg/l	1,000 - 1,500 mg/l	400 - 550 mg/l
ISAF	<1,650 mg/l	<275 mg/l	<400 - 550 mg/l	<60 mg/l
PGF	<275 mg/l	<50 mg/l	<60 mg/l	<20 mg/l
SCF	<50 mg/l	<30 mg/l	<20 mg/l	<10 mg/l

These assumptions are based on observations from initial pilot implementations.

Phulera Sambhar FSTP

The dried sludge from the UPDB can be co-composted with municipal organic waste to produce nutrient-rich bio-solids that can be safely used by farmers. This process of co-composting will result in the inactivation of pathogens(helminth eggs).

The link below details the process for co-composting to comply with FCO[8] standards in India.

https://cddindia.org/wp-content/uploads/2020/10/co-composting-findings.pdf

Process Flow for PDB based treatment system

In PDB based treatment system, the FS is discharged into the PDB for upto 12-24 months (providing 6-8 days as an interval between every load).

This is called as **loading period** and after this, the PDB is provided with a **resting period about 4-6 months**(during which no disposal of FS will take place into the particular bed). After the resting period, the **accumulated sludge from the PDB** needs to be removed during **non-monsoon period** and **sun-dried** so that it is free of moisture.

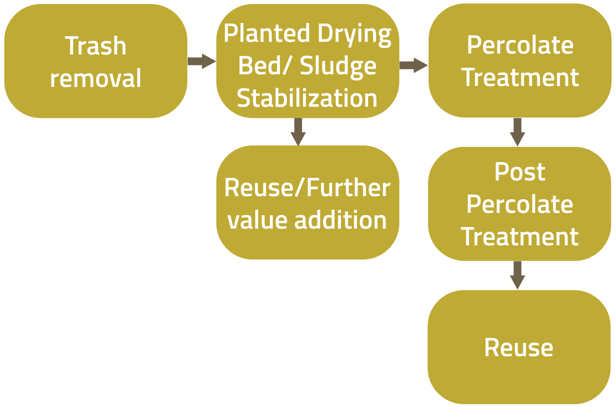
The dried sludge from the PDB can be directly applied to the soil as a conditioner with necessary precautions.

[8]FCO 1985 Specification on City Compost

Table 6 : PDB Parameters

Module	COD		BOD	
	In	Out	In	Out
PDB	<30,000 mg/l	<500 mg/l	7,500-10,000 mg/l	<200 mg/l
ISAF	<500 mg/l	<150 mg/l	150 - 200 mg/l	<50 mg/l
PGF	<150 mg/l	<60 mg/l	<50 mg/l	<15 mg/l
SCF	<60 mg/l	<30 mg/l	<15 mg/l	<10 mg/l

These assumptions are based on observations from initial pilot implementations.



The graphic above depicts the typical process flow for PDBs

Jhansi FSTP PDB view

2.1 Screen and Grit Chamber

Screen and Grit Chamber has two arrangements namely, Screen chamber (SC) and Grit chamber which is a **physical method for separation of solid waste** and grit (like sanitary napkins, plastic, cloth, sand, silt, etc.) from the faecal sludge to **prevent clogging** of subsequent treatment modules and ease operations. This will also enhance the value of treated end products.

The screen chamber consists of a series of **inclined screens** (45^{0} angle) made from mild steel or stainless steel and coated with anti-corrosive elements to ensure durability of the screens. The screen chamber has a inclined screen with 2.5 cm spacing between each bar. The trash can be collected by manually scraping the screen with a rake or similar arrangement. The **collected trash should be stored and disposed off** (or sometimes incinerated separately) along with other solid waste generated at the site and handed over to the appropriate solid waste collectors.

The grit chamber is used to trap sand and grit particles from entering the treatment modules. In Grit chamber, the flow velocity is a decisive design consideration. The velocity should be moderately managed so that lighter organic matter do not settle.

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.

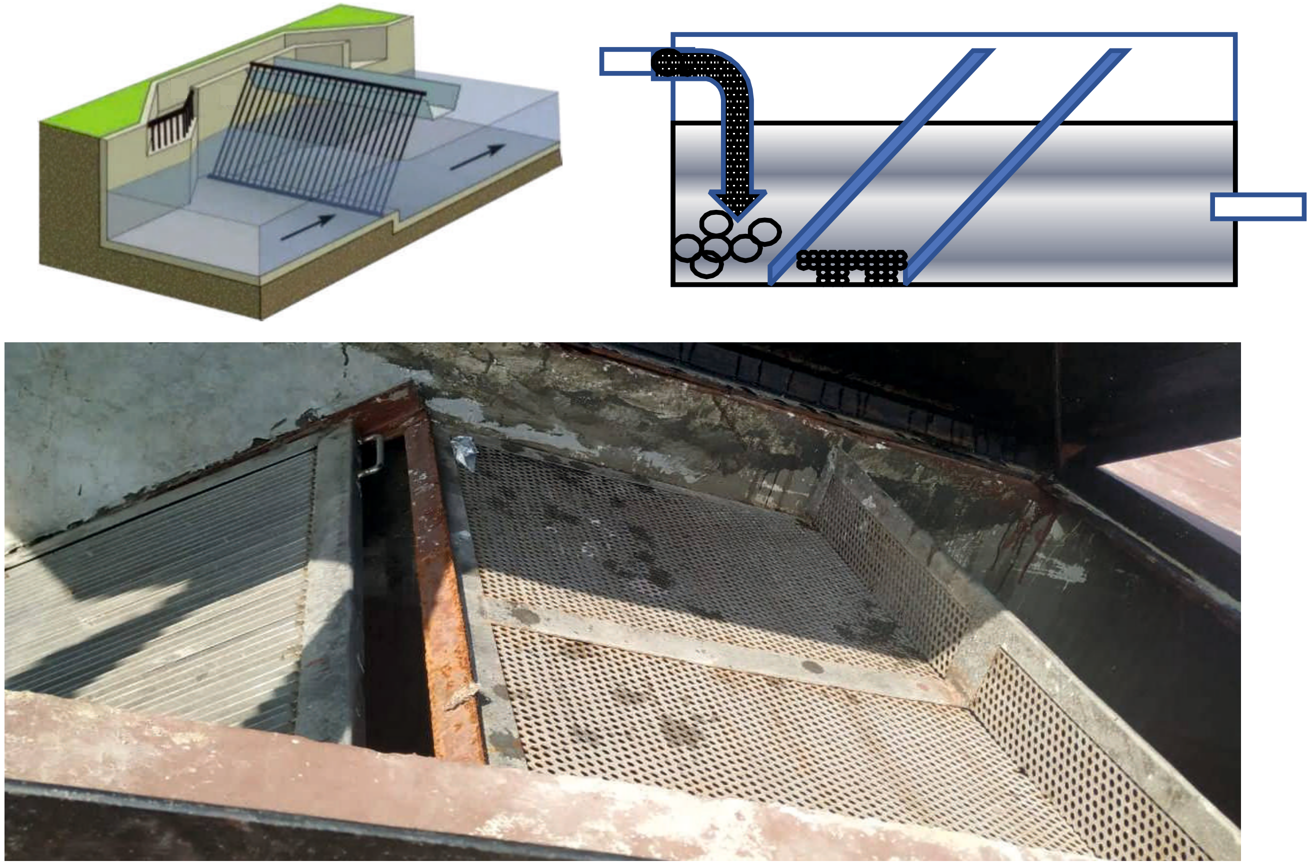


Figure 1 : Screen and Grit Chamber

2.2 Anaerobic Stabilisation Reactor (ASR)

The main objective of the anaerobic stabilization reactor is to **allow the sludge to further digest anaerobically,** which leads to reduced organic load and better dewater-ability. ASR is typically provided upstream of UPDB. Stabilized sludge has **improved dewaterability** and hence improves efficiency of the system.

This **module may also be used in conjunction with PDB**, in cases where there is more frequent desludging of **fresh sludge** – i.e. from public/ community toilets, from apartments/ hostels into the FSTP. This ensureshomogenisation and stabilisation of the FS.

The sludge retention time (SRT) of the ASR must be able to reduce the VS/TS ratio. Sludge should be mixed within the stabilization reactor to ensure optimal levels of anaerobic digestion.

A typical stabilization reactor has three chambers. The first chamber has a retention time of 2 days and assists in the homogenization of sludge. During the discharge of sludge from the desludging vehicle, high turbulence is created in the chamber with an up-flow velocity of 4-5 m/hr.

The second chamber assists in stabilisation of sludge. Retention time of 7 days is provided in this chamber. FS is stabilized in this chamber through the process of anaerobic digestion. This process reduces the VSS. 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 provided to maintain flow pattern between the chambers and prevent sludge accumulation. The chamber is designed to ensure an upflow velocity of 1.5-2 m/hr.

The third chamber has a retention time of one day. Sludge is further conveyed to drying beds either through gravity or through appropriate pumping arrangements.

In case of gravity flow - an overflow pipe is provided in the third chamber to allow FS to flow to the UPDB/PDB. The level for this overflow pipe is to be maintained higher than the inlet pipe.

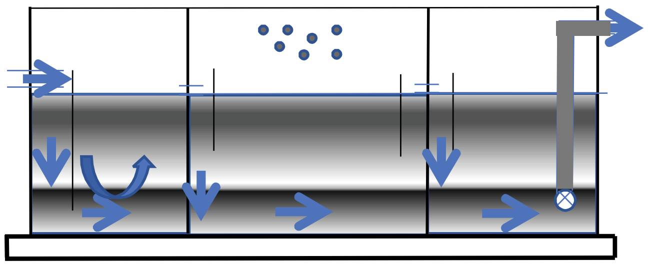


Figure 2 : Section of Sludge Stabilisation Reactor

2.3 Unplanted Drying Bed (UPDB)

Unplanted drying beds (UPDB) are **open tank structures filled with different graded filter media(sand and coarse aggregate).** UPDB is designed as multiple beds of the same size designed according to TS content of influent FS and drying period required.

Typically, the sludge accumulated at the bottom of the ASR flows by gravity/is pumped into each drying bed (based on the context). Considering the average climatic conditions in India, about **14 - 21 days of drying period** should be provided for adequate drying, and accordingly, the size of each drying bed and number of drying beds should be calculated.

The sludge from the ASR is fed into the sludge drying beds every day. The maximum feed depth into each of the sludge drying beds should be around 25-30 centimetres (based on our experience) considering that solids content in FS varies between 3-5%. Most of these solids along with 20-50% of incoming liquid is retained on the surface of filter material along with sludge cake in the UPDB. The remaining 50-80% of liquid, known as percolate, flows through the filter media and into the percolate treatment system.

It then gets conveyed to the percolate treatment system (for eg: integrated settler & anaerobic filter and planted gravel filter) for further treatment before being discharged or reused. A superstructure (roof) made of a transparent sheet is provided to prevent rainwater into the drying bed.

The dried sludge, once removed from the UPDB should be subjected to pathogen reduction treatment process. Hence it can be co-composted with municipal organic solid waste to obtain compost which can be used as a soil conditioner for agricultural purposes.

Figure 3 : Unplanted Drying Bed

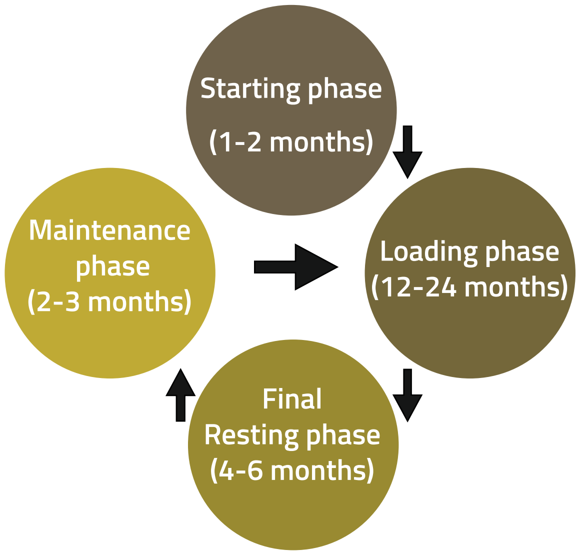
2.4 Planted Drying Bed (PDB)

Planted drying beds (PDBs) are sludge drying beds having filter media (e.g. sand and gravel) andhave plants with emergent macrophytes in it. Typically, FS can be applied to PDBs after screening. **PDBs are loaded with layers of sludge that are subsequently dewatered and stabilised through multiple physical and biological mechanisms.** The solid loading rate for planted drying beds in tropical climates should be in the range of **180–250 Kg TS/m2/ year.** FS is repeatedly loaded onto PDBs (loading phase), with up to 15-20 cm of FS per loading. The minimum time between two successive loadings in the PDB should be 6-8 days (varies based on the local evapotranspiration rates). Here, it accumulates for several years depending on the loading rate (loading period 12-24 months, resting period 4-6 months). The dimensions of the system are to be designed accordingly and the percolate from the PDB is treated separately in any wastewater treatment system.

The **volume of sludge on the PDB reduces continuously through moisture loss and degradation.** At the same time, the plants maintain the porosity in the sludge layer, thereby significantly reducing the need for sludge removal compared to unplanted drying beds (which require sludge removal every two to three weeks).

After the completion of loading phase, the accumulated sludge from the PDB needs to be removed and sun dried so that it is free of moisture and stored in safe place. It can then be directly applied to soil as a conditioner. **Unlike UPDBs, the removed sludge does not need to be treated further for pathogen inactivation – as the long retention period of 6-12 months ensures that pathogens are inactivated.** The plants that are uprooted from the PDB can also be converted into manure.

Operation Cycle of PDB



** Assumptions for PDB phases are on the basis of observations from PDB pilot implementations.*

Figure 4 : Planted Drying Bed

Figure 5 : PDB Under Construction - Plumbing, Plantation and Side Walls

2.5 Percolate Treatment - DEWATS™

The percolate from the UPDB/PDB is to be treated so that it can either be reused for secondary purposes or disposed off safely. As this document focuses on **passive approaches** for treatment, we have considered **DEWATS™ approach for percolate treatment.** However, any percolate treatment system which would meet the discharge standards mentioned in Table 2 can be considered for treatment.

DEWATS™ is a technical approach to decentralized wastewater treatment which uses physical and biological treatment mechanisms. It uses natural bacteria, plants and gravity instead of electricity and chemicals. While multiple modules can comprise a DEWATS™, for treatment of percolate in the FSTP specific modules are considered based on the quality that is expected from drying beds– they are Settler, Anaerobic Filter (AF) and Planted Gravel Filter (PGF).

It is ideal for a majority of settings where electricity is not reliably available and skilled human resource is hard to come by. It is also very easy to integrate aesthetically into treatment facility and is adaptable to a variety of organic wastewater characteristics – making it a **robust choice for effluent treatment in FSTPs.**

- **DEWATS™ is recognized as one of the technologies accredited by the Dr. Mashelkar Committee[9],** a committee set up by the Prime Minister's Office to recommend clean technologies in India.
- **DEWATS™ has been mentioned in the Central Public Health and Environmental Engineering Organization's (CPHEEO) manual** on Sewerage and Sewage Treatment.

This document will only cover the basic design elements of a DEWATS™ relevant to the extent of how they plugin to FSTPs and will not provide detailed designs of the DEWATS™ system. For understanding the detailed DEWATS™ design - a few important resources for DEWATS™ are included below which can be used for reference:

- **DEWATS™ in Developing Countries by Sasse, L - Bremen Overseas Research and Development Association (BORDA), Germany, 1998.**

https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/1933

- **Decentralized Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries – A Practical Guide**

https://sswm.info/sites/default/files/reference_attachments/DEWATS_Guidebook_small.pdf

Figure 6 : A DEWATS™ System

[9]DEWATS™ is a certified trademark of CDD under the Trade Marks Act, 1999 (Government of India).

2.5.1 Integrated Settler and Anaerobic filter

The percolate from the UPDB/PDB is subjected to treatment in the Integrated Settler and Anaerobic Filter (ISAF). "FS is characterized by higher solids content when compared to sewage." Although most of the solids will be retained in the drying beds. However in the long run, a small percentage of the solids may find their way into the percolate. Therefore, **a Settler is proposed for sedimentation before the percolate is treated in the Anaerobic Filters.** A settler is a primary treatment module for wastewater; it is designed to remove settleable solids by sedimentation.

The AF consists of three chambers (number of chambers will vary based on the strength of the wastewater) in series in which the wastewater flows through baffles. Here, the suspended and dissolved solids present in the wastewater undergo anaerobic degradation. The activated sludge settles down at the bottom of each chamber and bio-film formation is expected to occur that helps in treatment of the influent wastewater through where micro-organisms feed on the organic and nutrient content in wastewater for their metabolism. As wastewater flows through the filter, particles are trapped, and organic matter is degraded by the biomass that is attached to the filter material.

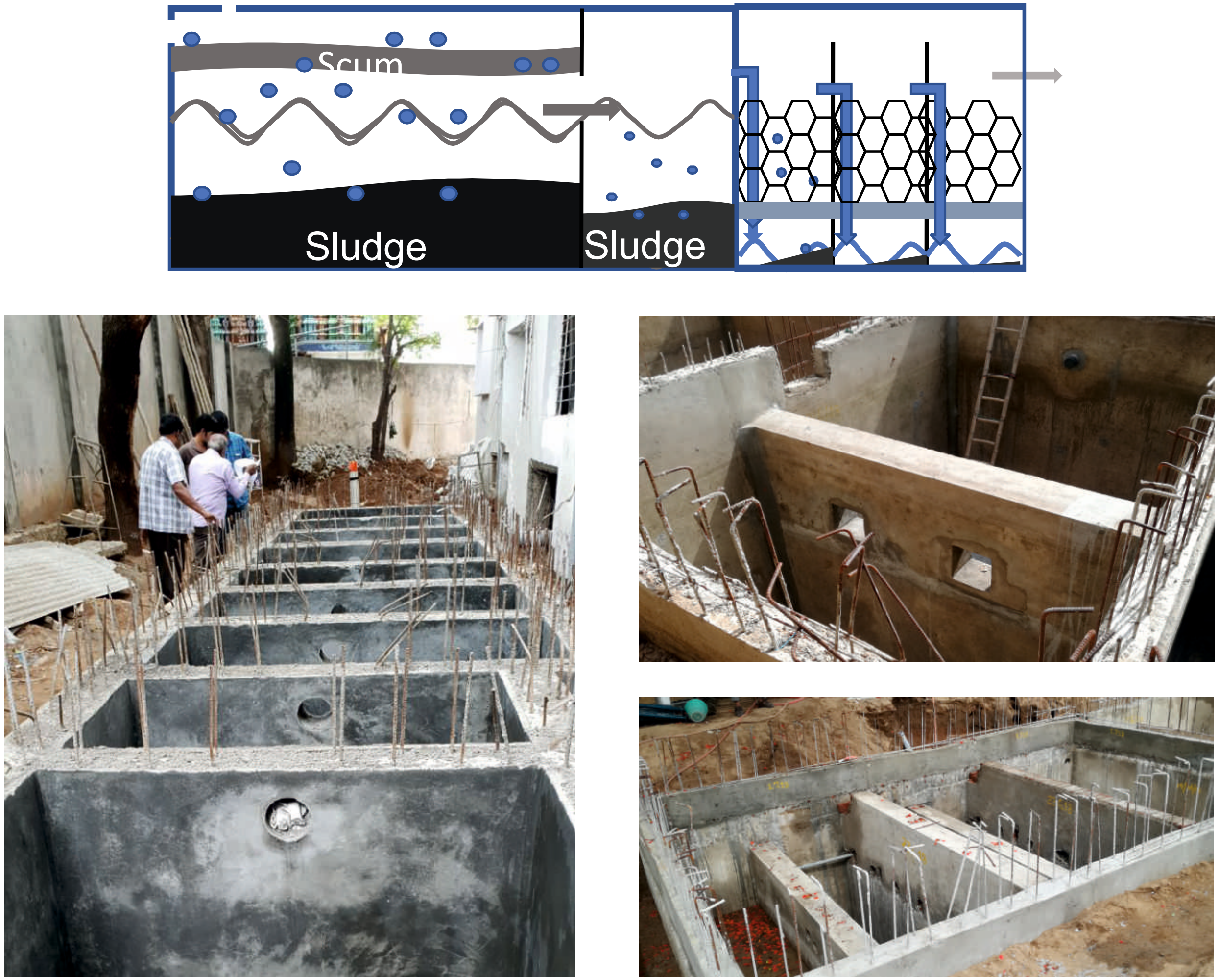


Figure 7 : Integrated Settler and Anaerobic filter

2.5.2 Planted Gravel Filter

The planted gravel filter (PGF) is used as an aerobic tertiary treatment module where the pollutants (mostly nutrients) present in the wastewater are degraded aerobically.

Odour and colour in wastewater is reduced through the process of oxygenation in PGF. PGF comprises of graded gravel as filter media and plants. The flow direction of wastewater is horizontal and the bottom slope is designed at a slope of 1%. Some of the plants used in this module 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 PGF also help in reducing the nutrients such as N, P and K present in wastewater

Figure 8 : Planted Gravel Filter

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2.6 Polishing Pond

Polishing ponds are shallow tanks of depth ranging from 1 to 1.5m. The primary function of polishing ponds is the removal of pathogens present in wastewater. The ponds are well oxygenated through the day by natural means. A small reduction in BOD also occurs. The retention time value(3-5 days) is calculated for 96% removal of faecal coliform.

Khandela FSTP Polishing Pond

Sircilla FSTP Polishing Pond

Sidippet FSTP Polishing Pond

Figure 9 : Polishing Pond

2.7 Co-Composting

Co-composting refers to the controlled passive aerobic degradation of organics, using more than one feedstock. **Co-composting involves combining the feed stock of high nitrogen content (faecal sludge) with the carbon rich organic waste (municipal wet waste)** to produce compost for crop production.

Windrow method of co-composting is one of the most practiced method of composting. Windrow method of co-composting FS with municipal wet waste will help in **reducing the pathogens** due to the heat generated during thermophilic phase of co-composting (to **65-70 °C for a period of 3-5 days**) inside each windrow.

Windrow heap is constructed by placing **FS and organic waste layer by layer in 1:2 ratio** respectively. Addition of carbon-rich organic material to faecal sludge will help in balancing the Carbon: Nitrogen (C:N ratio between 20:1 to 30:1) which is the required ratio for compost. While building the co-composting heap, a large enough windrow base area (e.g. 2.5 m x 1.5 m) and adequate pile height (1.5-1.8 m) should be ensured and the pile width should decrease towards the top. The windrow heap is turned at regular intervals (e.g. 10 days) to ensure aeration and uniform distribution of feedstock. The optimum composting period of 90 days is necessary to inactivate pathogens.

Figure 10 : Co-composting FS with Municipal Solid Waste through Windrow method

Source: Findings from Co-composting, Devanahalli FSTP, CDD Society; Cofie et al., 2016; Koné et al., 2007.

2.8 Sand and Carbon Filter with UV radiation System

Sand and carbon filters are vessels containing refined and cleaned sand in one and activated carbon in the other. **Pressure Sand filter helps to reduce the suspended solids** in the treated water to meet the levels as prescribed by the CPCB, while **carbon filter reduces any residual odour and colour** by the mechanism of adsorption. These filters are to be backflushed at regular intervals to prevent clogging and ensure efficient working of the system as per manufacturer's guidance.

Ultra violet radiation deactivates the pathogens and therefore reduces the harmful impact of pathogens while reusing or disposing of treated percolate.

The sand carbon filter works as a batch process and is designed for a capacity that is equivalent to wastewater quantity coming out of percolate treatment system during the operating hours of the sand carbon filter.

Figure 11: Final treatment of wastewater with Sand and Carbon Filter along with UV radiation method

Other post percolate treatment systems can also be used in place of sand and carbon filter with UV radiation to meet the requirements.

Leh FSTP

3. Preparation of Layout & Master Plan for FSTP

Master Plan preparation for the FSTP site forms an important part of the design process. A well designed master plan **can reduce costs of construction,** improve the **ease of construction** and most importantly improve **ease of operations and maintenance.** On the other hand, poor master planning can have adverse consequences for long term sustainability of the FSTP. Master planning should take into account the following:

- Movement of the desludging truck within the site
- Disposal/reuse of end products from treatment plant
- Discharge point of percolate is to be taken into consideration for placement of treatment modules
- Sludge removal from UPDB/PDB post treatment and storage
- Ease of access to various treatment modules for the operator
- Placing of the operator room such that the operator gets an unimpeded view of the FSTP from where the operator sits
- Optimum space utilization
- Positioning modules to best utilize the land gradient for a gravity flow
- Planning for occupational safety hazards specific to FSTP
- Planning for ergonomics of operators
- Aesthetics – through plantations, adequate spacing, choosing the right color schemes.
- Considering future expansion of FSTP and planning layout to accommodate this expansion

It should be noted that FSTPs typically have non-treatment components like Operator Room, Labs, Boundary Walls, Sludge Storage rooms – which can constitute a significant portion of the construction cost. Poor master planning can lead to unnecessary capital expenditure in the short run and increased operations and maintenance requirements in the long run. This section outlines guidance for master planning of an FSTP followed by master plans of specific capacities of FSTPs – depicting arrangement of the treatment modules within the FSTP, the dimensions of these treatment modules and also the arrangement of non treatment modules.

FSTP site layout and preparation

3.1 Guidance for preparing a layout and master plan

A. Locating Modules	
Marking	- Before making any master plan, topographical survey needs to be done. - Marking of the boundary wall of the FSTP site needs to be undertaken. - Once the disposal point in the master plan is located, the individual treatment module drawings have to be placed in the layout drawing as per the site conditions.
Screen and Grit Chamber	- Screen and grit chamber have to be very close to the approach road and easily accessible by desludging vehicle – without having to cover long distances within the plant. - The screen and grit chamber location is generally chosen considering the gradient of the site (generally on higher elevation), to support gravity flow through the modules with minimal excavation and filling done at the site
Anaerobic Stabilization Reactor	- The ASR needs to be placed close to the screen chamber, with access for desludging during maintenance. - ASR should not be placed at the lowest point or where chances of flooding are high. - The distance between stabilization reactor and drying beds should be optimized with little obstruction (road, structures etc.)
Drying Beds	- The dried sludge needs to be conveyed to sludge storage yard or for disposal, and hence it needs to be accessible by at least small vehicles. - Drying beds rely on evaporation for drying and hence this module needs to be away from shadow areas and away from areas where windflow is obstructed. - As a minimum requirement, a push cart needs to be able to access the Sludge drying beds – access road of 1.5 m will be required. - For a planted drying bed – access road will have to be a minimum of 3 metres – as it will require at least tractors to be able to access the beds to clear the PDB for the resting period.
Percolate Treatment	- The percolate treatment location should be preferably located near to the disposal/reuse point.
Sludge Storage Room/Yard	- The sludge storage room/yard must be accessible by push carts/tractor to enable easy transportation of treated sludge from the site
Operator Room	- Preferably at a location overlooking the entire plant - Must have road and pathway access to all parts of the plant

Reception	- To be placed close to the entry into the plant Can share common walls with the operator room to optimize on material cost and space.
Vehicular Movement	- The vehicle travel path should be visualized, from the entrance to emptying at screening chamber, turning or returning after emptying.
Road	- Internal roads should be designed for a minimum carriageway width of 3.5 m for single lane and 7 m for two lanes - The minimum turning radius for roads inside the FSTP should be 10 m for a capacity of 3.5-5 cum truck - Considering the trucks are loaded with FS and thus heavy, ramps in road should not exceed 1:15 slopes
Fire Safety	- Water buckets and fire extinguisher located close to the operator room and also at multiple locations as necessary. The operator or staff have to be trained in the fire safety operations. - First aid kits should be made available in the operator room
Offset, Flooding considerations	- While placing the modules, offset between the modules should be maintained, to avoid module foundation overlap. 1-2 meters of space should be provided between treatment modules. - Also, while placing the modules in the layout, the final disposal location should be identified and considered. Generally, liquid treatment modules are closer to the disposal location. - Prevention of flooding – Treatment modules should be at least 0.3 m to 0.45 m above ground to prevent rain water from entering the modules - Adequate considerations need to be made for drainage of storm water.
Toilets and Change Rooms	- Provisions for separate toilets and changing rooms for male & female staff need to be made. - The entry to women's toilets, changing rooms must be different from that of men's toilet/changing room entrance. The paths to toilets and changing rooms should be well lit.
B. Gradient requirements	
Completely Gravity Based system with no pumps	- In general, the hydraulic drop (difference in level from inlet of the screening chamber to the outlet of PGF) required for gravity based stabilization reactor and unplanted drying bed-based concept is about 5 m, - PDB based systems (without ASR) require a hydraulic drop of 4 m. - To enable gravity flow - filling and excavation of ground is carried out. It creates sudden change in RL. In those kinds of scenarios, retaining wall should be provided.

Where gradient is unavailable	- In the case of lands with naturally less slope/ tough terrain for excavation - which cannot accommodate the hydraulic drop needed, one may choose to introduce pumping at one or more stages. - In ASR+UPDB based concept – pumping of stabilized sludge is taken up from ASR to UPDB – which means ASRs may be located below FGL and UPDBs may be located above FGL – thereby offering the required hydraulic drop for percolate treatment in DEWATS™. - Where space is available, ramps may also be provided to ensure adequate hydraulic drop from inlet of the screening chamber to the outlet of PGF. - Where adequate hydraulic drop is not available for PGF, balancing tanks can be used to hold the percolate from UPDBs or PDBs – from where they can be pumped periodically to the DEWATS™.
C. Miscellaneous	
	- Fixing the levels and orientation of the modules should be seen as an iterative process between creating Master plan, hydraulic profile and module drawings - Adequate street lights to be considered in the layout - All the plumbing lines should be visualized for practicality and implementability while locating treatment modules in the layout - The slopes of road and ramp provided within the FSTP needs to be mentioned in the master plan - While creating the layout, EGL's[10] and FGL's[11] have to be finalized and marked on the master plan - Wherever the wastewater pipes cross the road, necessary precautions/care has to be taken so as to minimize the chances of pipe breakage. - Storm water drainage network with open drains/any relevant infrastructure should be considered as per the gradient of the site inorder to avoid any stagnation of water at the site. At starting point of storm water drain, depth should be minimum 0.3 m and should increase along the length of the drains at 1:300 slope till discharge point. - The inlet and outlet levels of all the treatment modules can be provided in the master plan. - A single gate for entry and exit of the FSTP site is to be considered wherever possible so as to minimize the effort for the operator in monitoring multiple gates apart from reducing cost for gate(s). - Tap water should be provided near the screen chamber so that spillage from the truck (if any) during desludging process can be cleaned

[10]Existing ground level [11]Finished ground level

Master plans

The next sections of this document contain layouts of two different capacities of FSTPs designed using UPDB and PDB approaches respectively.

- UPDB master plans cover FSTPs of 15 KLD and 20 KLD capacities respectively.
- PDB master plans cover FSTPs of 6 KLD and 16 KLD capacities respectively.

The purpose of sharing these master plans is to provide the reader with a sense of how the various elements of the master plan come together in these layouts.

The master plans provided in this document are only indicative and not exhaustive. Designers must take up master plans depending on the site conditions.


Angul FSTP

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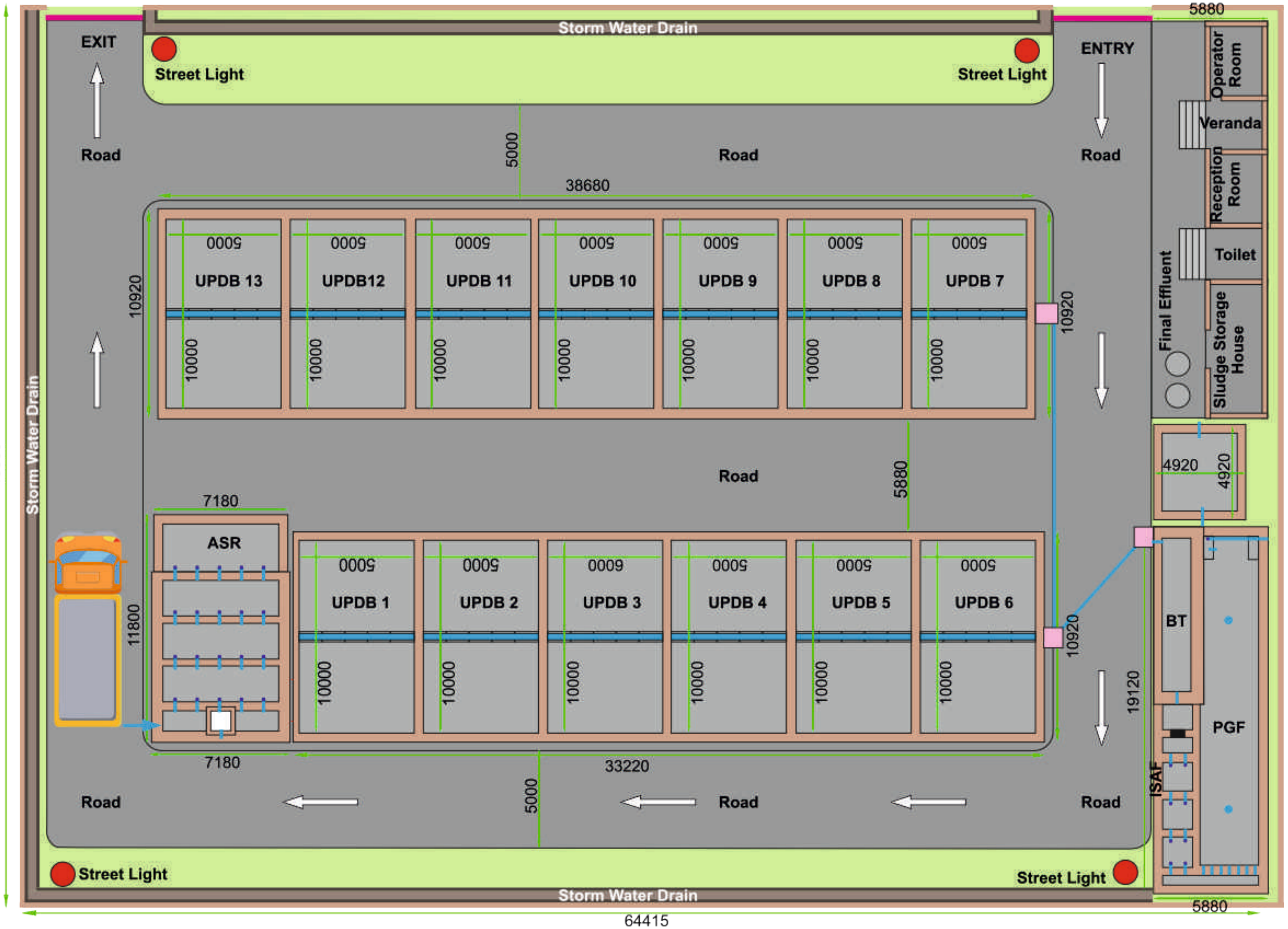
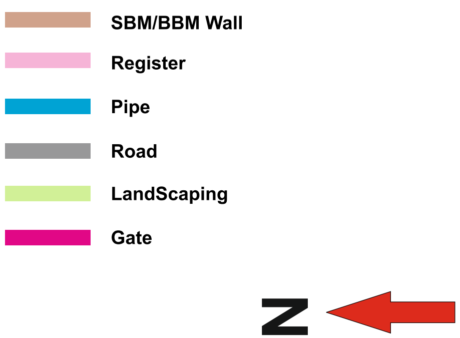
3.2 UPDB Master Plans

3.2.1 - UPDB Master Plan - 15 KLD

Figure 12: 15 KLD UPDB Master Plan





15 KLD UPDB Master Plan

Some of the salient aspects of the master plan are listed below.

- The topography of the site is assumed to be sloping from north towards the south (and towards the entry gate).
- The level difference available within the site is <0.5 m (flat land parcel) and hence there is a provision for pumping. This would reduce the cost of construction due to decrease in cost of excavation and filling as well as reduction in reinforcements/structural components.
- There is an entry at the south east corner of the site and exit at north-east corner. There is an access road covering all major modules/ most of the site.
- The UPDBs are located in the central portion of the site in a series - facing each other - with the ASR located at the top of one of the UPDB series
- The DEWATS™/module for percolate treatment is near to the UPDBs towards the entrance and SCF & polishing pond are near to the entrance gate. Locating DEWATS™ at the entrance gate will greatly add to the aesthetics of the FSTP as plants and flowers will be visible first up.
- The operator room, reception room, sludge storage house are located next to each other as a complex and located in the south-east corner. This gives the operator easy access to the road, a view of the entrance and also an unimpeded view of the entire plant.
- The toilet and the washroom provided within the site has a septic tank which is connected to the DEWATS™ system.
- All the treatment modules are easily accessible from the road.
- Between the drying beds and the DEWATS™ modules, paved blocks are provided so as to enable movement of the operator for regular operations and maintenance activities.
- The sludge storage house (located beside the polishing pond near to the entrance) has easy access to the main road which would make it easy to load/unload thetreated bio-solids and for the movement of the push carts from the UPDBs
- The street lights are located at 4 locations surrounding/outward corners of the UPDB modules, it would ensure that major portion of the site is under the light during the night time.
- Storm water drainage system is planned within the site considering the entire site premises as the catchment area and is laid along the site boundary. The drainage uses natural slope in the site-sloping towards the entrance gate.
- The treated wastewater is reused for landscaping or discharged to the near by drain or soak pit (incase of excess after reusing)

3.2.2 - UPDB Master Plan - 20 KLD

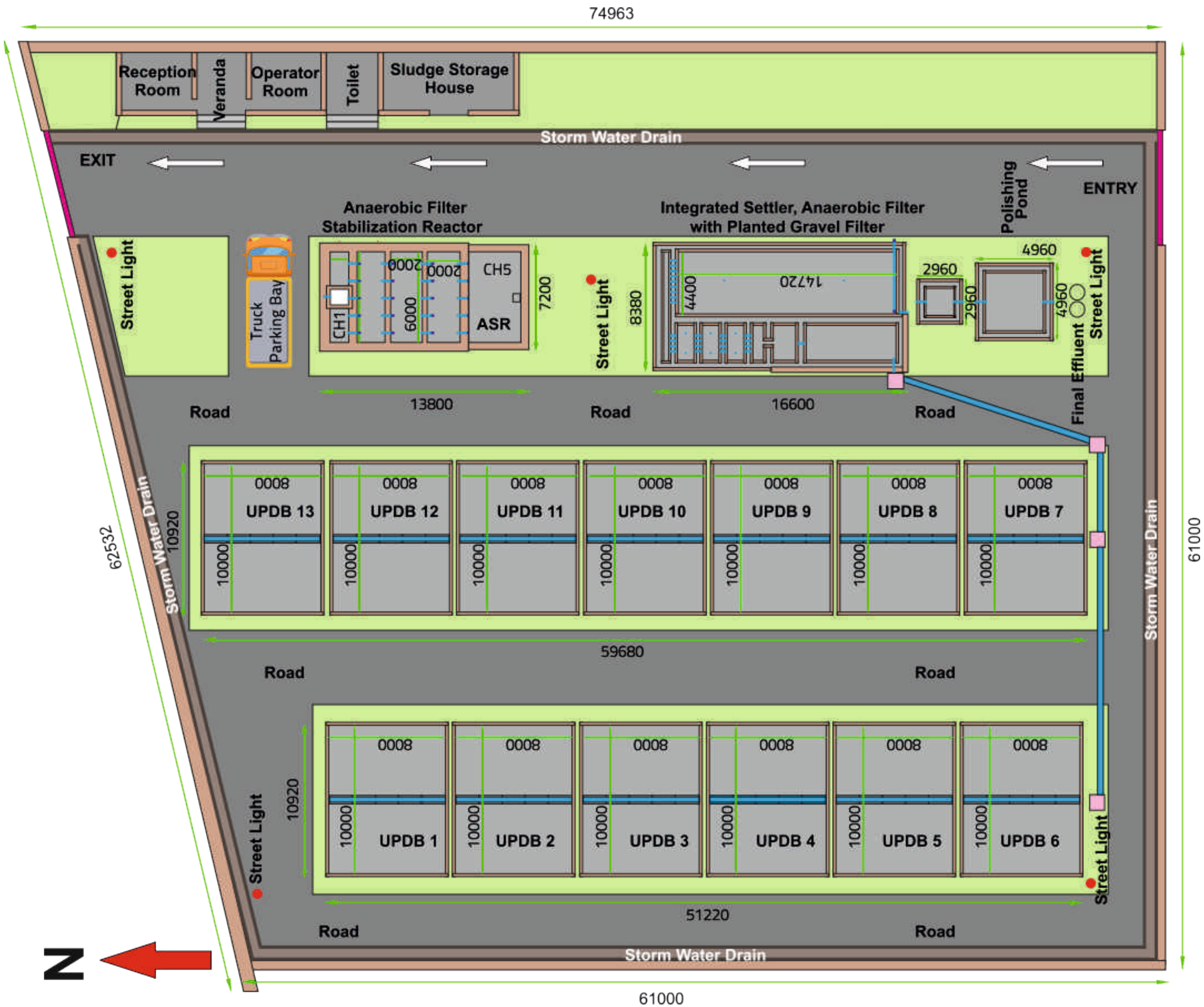


Figure 13 : 20 KLD UPDB Master Plan

20 KLD UPDB Master Plan

Some of the salient aspects of the master plan are listed below.

- The topography of the site is assumed to be flat through out the site.
- There is an entry at the south east corner of the site and exit at north-west corner. There is an access road covering all major modules/ most of the site.
- The UPDBs are placed in the left portion of the site in a series facing each and parallel to ASR.
- The DEWATS™/module for percolate treatment is near to the UPDBs towards the entrance and SCF & polishing pond are near to the entrance gate so as to create a good ambience visually.
- The operator room, reception room, sludge storage house as a complex is placed at south -west corner so that the operator will have more control over the treatment plant, trucks coming in & out and as well as have a sight of the entire plant for easy monitoring
- The toilet/washroom provided within the site has an OSS/septic tank which is connected with the DEWATS™ system/ISAF and hence the location is determined/maintained at less proximity
- The modules both treatment and non-treatment modules are placed in such a way that there is easy access from the road so as to enable easy operations and maintenance.
- In the middle of the modules, paved blocks platform is provided as to enable movement of the operator for any operations and maintenance activities.
- The sludge storage house (located to the west side of the site) has easy access to the main road system which would make it easy to load/unload the treated bio-solids and for the movement of the push carts from the UPDBs
- The street lights are provided at 4 locations surrounding/outward corners of the UPDB modules, it would ensure that major portion of the site is under the light during the night time.
- The drainage system is provided in the site covering the entire site premises as the catchment area and is laid as the outside border within the site and sloped towards one corner (exit gate towards operator room)
- The treated wastewater is reused for landscaping or discharged to the near by drain or soak pit (incase of excess after reusing)

3.3 PDB Master Plans

3.3.1 - PDB Master Plan - 6 KLD

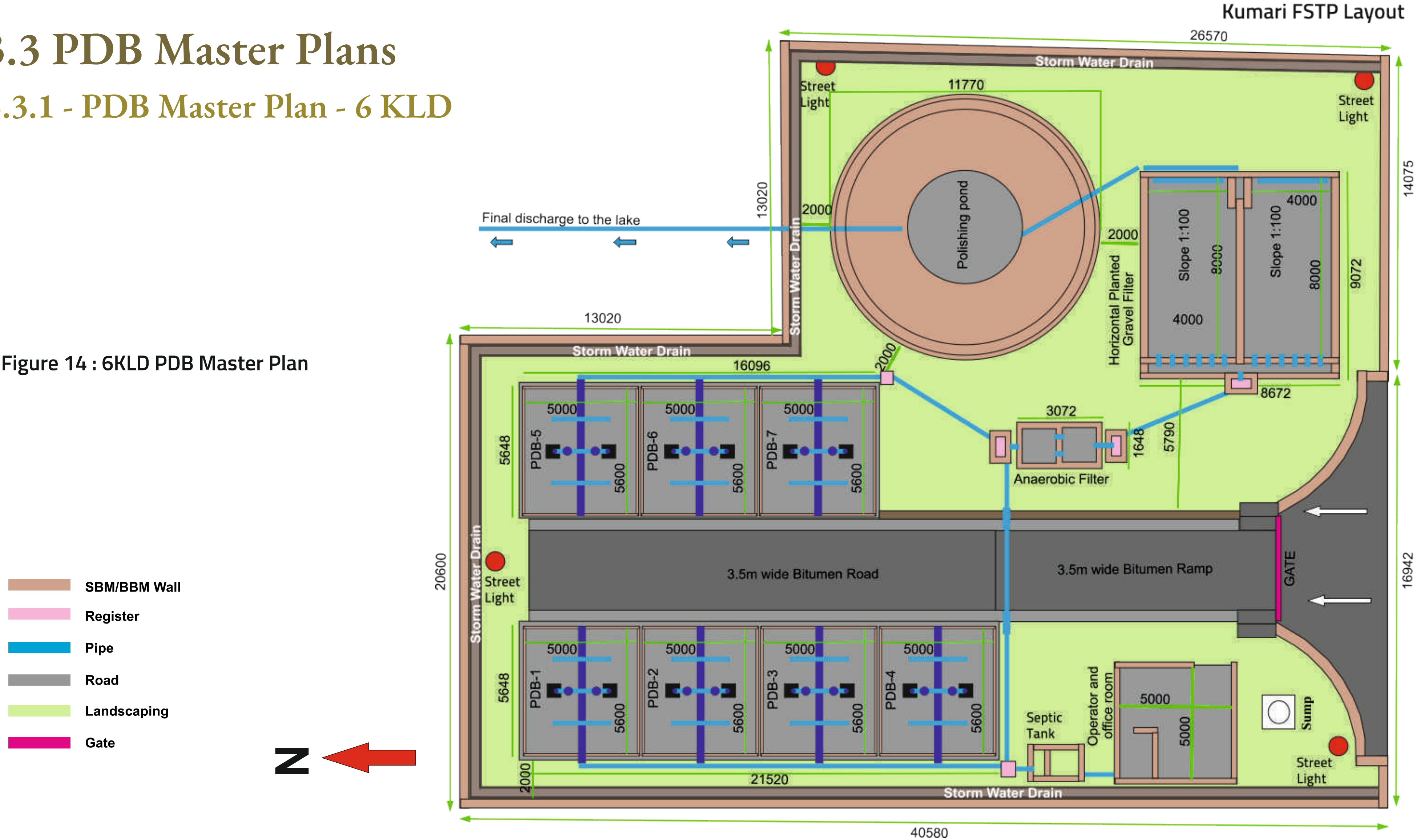


Figure 14 : 6KLD PDB Master Plan

For 6 KLD PDB Master Plan

Some of the salient aspects of the master plan are listed below.

- The topography of the site is assumed to be sloping from north towards the south.
- The entry and exit gates are the same. There is an access road covering all major modules/ most of the site.
- The PDBs are placed in the central portion of the site in a series facing each other at the top.
- The DEWATS™/module for percolate treatment is towards south east of the site, near to the entrance gate so as to create a good ambience visually.
- The operator room is placed at south-west corner so that the operator will have more control over the treatment plant, desludging operators and as well as have a sight of the entire plant for monitoring
- The toilet/washroom provided within the site has an OSS/septic tank which is connected with the DEWATS™ system/ISAF and hence the location is determined/maintained at less proximity
- The modules- both treatment and non-treatment are placed in such a way that there is easy access from the road so as to enable easy operations and maintenance.
- In the middle of the modules, pavered blocks platform is provided as to enable movement of the operator for any operations and maintenance activities.
- The street lights are provided at 3 to 4 locations surrounding/outward corners of the PDB modules, it would ensure that major portion of the site is under the light during the night time.
- The drainage system is provided in the site covering the entire site premises as the catchment area and is laid as the outside border within the site and sloped towards entry gate.
- The treated wastewater is reused for landscaping or discharged to the near by drain or soak pit (incase of excess after reusing)

3.3.2 - PDB Master Plan - 16 KLD

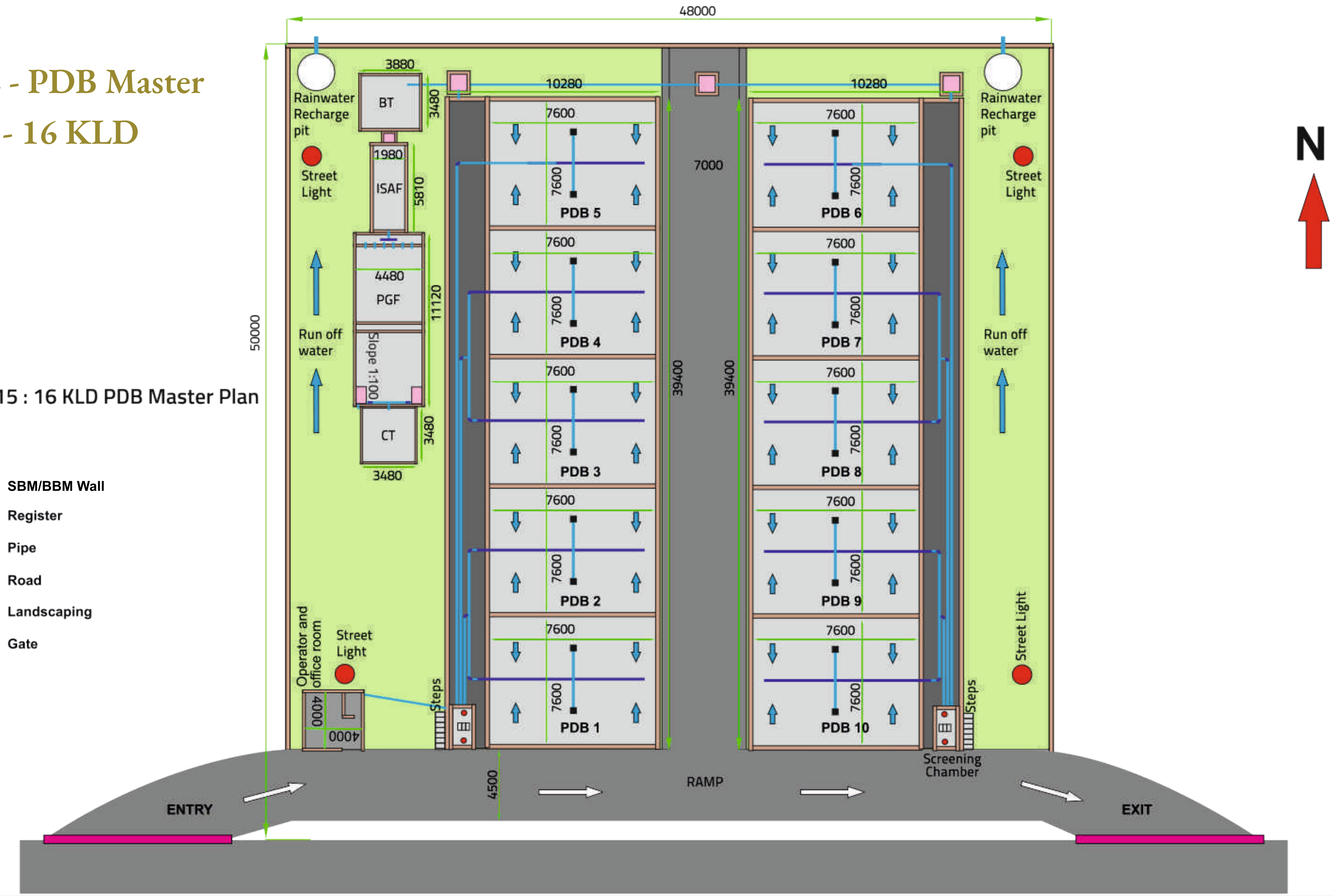


Figure 15 : 16 KLD PDB Master Plan

- SBM/BBM Wall
- Register
- Pipe
- Road
- Landscaping
- Gate

For 16 KLD PDB Master Plan

Some of the salient aspects of the above masterplan are listed below.

- The site has very little gradient – slightly sloping towards the north.
- A ramp is provided so that the desludging truck can discharge at the required height into the screening chamber from where the FS will flow to the PDBs through gravity. The truck discharges and exits the ramp, post which it can turn back onto the road right next to the ramp. The truck does not reverse on the ramp.
- The discharge from the screening chamber to the PDBs is controlled through valve arrangements to ensure FS flows to the relevant PDB.
- The percolate from the PDBs flows into a balancing tank which then pumps it into DEWATS™ from time to time as programmed by a level controller. A balancing tank is required here so as to avoid locating the planted gravel filter module more than 1m below the finished ground level. PGF needs to be accessible easily for regular O&M.
- It can be noticed that DEWATS™ has been located next to an existing plantation – so that the treated water can be reused for gardening.
- Steps are provided from the ramp to enable the operator to access the PDBs and DEWATS™ for regular O&M.
- This FSTP is being constructed in an existing solid waste management facility which already has office rooms, store rooms and toilets. Hence no separate non treatment infrastructure was planned.
- For undertaking maintenance of the PDBs, a road is provided from the ramp – splitting the PDBs. A tractor can easily move in to collect the treated FS from the PDB during PDB's resting period.
- As the site slopes towards the north, two rainwater harvesting pits are provided at the northwest corner and the northeast corner for recharge. Overflows are directed towards a drain which is located right next to the boundary wall towards the north of the site.
- The treated wastewater is reused for landscaping or discharged to the near by drain or soak pit (incase of excess after reuse)

Khandela FSTP Construction View

4. Standard Designs for Drying Bed based FSTPs

This section provides the details of the basis of design summarizing the design calculations, key design assumptions/ parameters followed to arrive at sizing the treatment modules of FSTPs (both UPDB and PDB based treatment systems).

It should be noted that the **design assumptions and calculations remain consistent for a module across FSTP sizes**. Only the dimensions of the modules vary. For the same capacity FSTP, **if the design assumptions are changed, the dimensions will also vary accordingly.**

For UPDBs with ASR; three different capacities of FSTP are chosen. These are

- 10 KLD
- 15 KLD
- 20 KLD

The module dimensions are provided for each of the above capacities. However, the detailed drawings are provided for a 10 KLD ASR+UPDB design with specific suggestions that should be taken into consideration when taking up detailed designs for any capacity in general.

For PDBs also three different capacities of FSTP are chosen. These are:

- 6 KLD
- 10 KLD
- 16 KLD

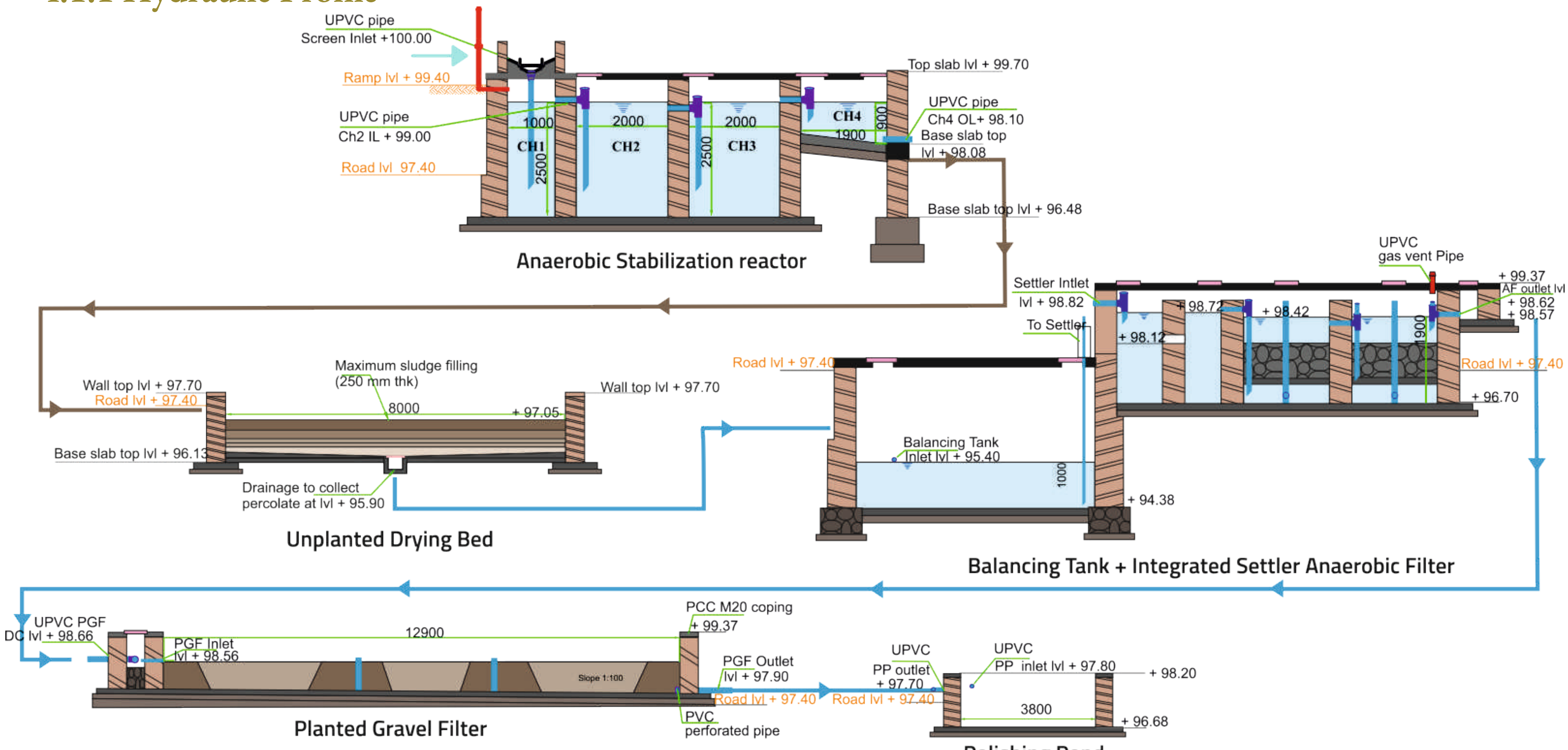
The module dimensions are provided for each of the above capacities. However, the detailed drawings are provided for a **10 KLD PDB design** with specific suggestions that should be taken into consideration when taking up detailed designs for any capacity in general.

The drawings in the subsequent sections do not make any structural recommendations - as these recommendations will vary from one place to another. Readers are advised to seek expert support for preparation of structural drawings to contextualize the designs.

Topography survey being carried out

4.1 ASR - Unplanted Drying Bed Designs

4.1.1 Hydraulic Profile



** The hydraulic profile is indicative. This needs to be contextualized for every site depending on site specific considerations.*

Understanding the Hydraulic Profile of UPDB

- The hydraulic profile is made to check and ensure that the critical levels (inlet and outlet) allows free flow of sludge and liquid from the inlet to the outlet.
- The inter modules connection pipe slope should be in between (1:50 to 1:100)
- Identifying the inlet level of the screen chamber is crucial
- In the drawing 4.1.1 - brown colour refers to piping connection for sludge, blue colour refers to pipe connection for percolate.
- Before detailing individual modules, a hydraulic profile that represents all the levels and EGL/ FGL in the drawing should be prepared
- The hydraulic profile also shows the level difference within the modules.

Phulera Sambhar FSTP

4.1.2 Screen Chamber[12]

Assumptions

Parameters	Assumptions
Desludging Truck Capacity	3,000-5,000 litres
Emptying	10 to 12 minutes
Horizontal Velocity	15 cm/sec to 30 cm/sec
Retention Time	30 - 60 Seconds

Dimensions*

Sl. No.	Module	No. of screen chamber	Internal Length (m)	Internal Width (m)	Internal Depth (m)
1	Screen chamber	1	2	1	0.8

Screen chamber remains the same for all capacities . The screen has been designed for 3000 liters truck that empties FS within 10-12 minutes. For larger or smaller truck capacities, the screening chamber will have to be resized accordingly - depending on the flow rate.

Screen Chamber

*Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions

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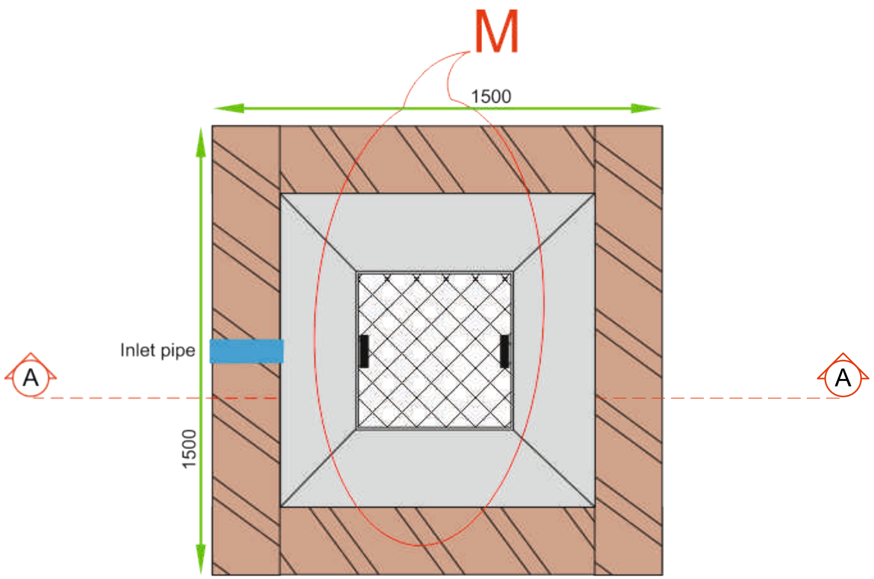
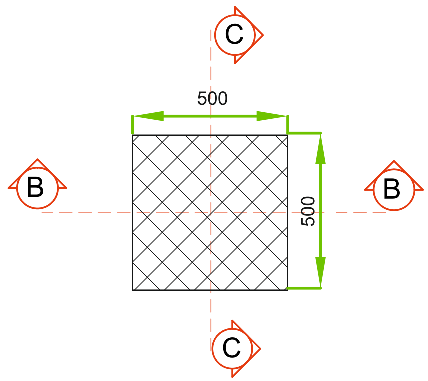
Screen Chamber (SC)

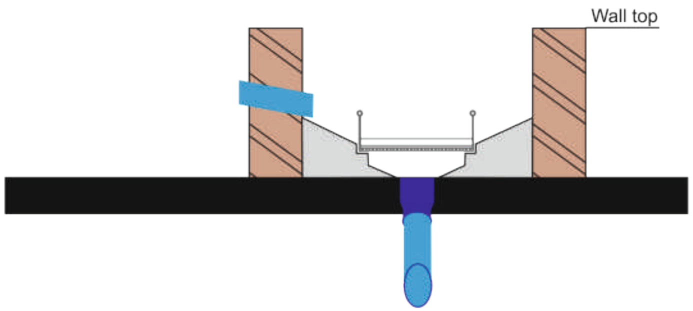


Sectional plan of Screen Chamber

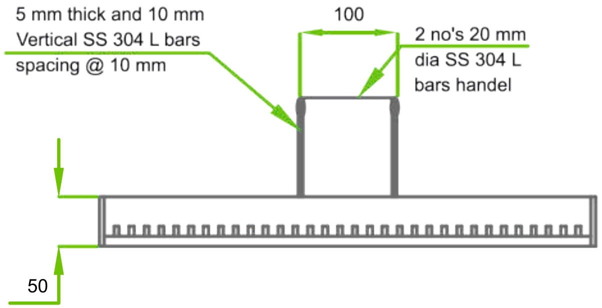


Detail of M

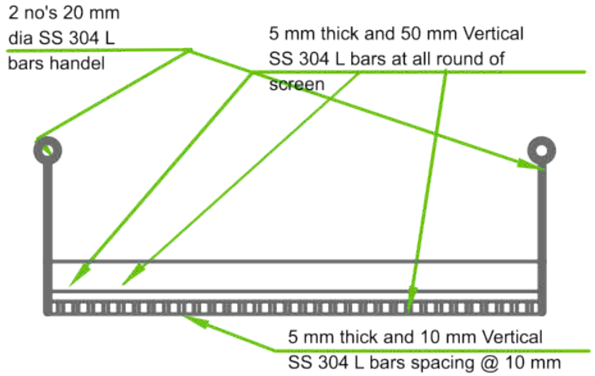
- The screen bar used in the screen chamber should be of stainless steel.
- Screen inlet is always taken with the reference of cesspool truck outlet level.
- The bottom screeding in the SC has to be given such that FS does not stagnate in the chamber. It shall be of hopper shape.
- The maintenance hole should be given right above the screens to enable lifting, removal of solids and screens for maintenance



Cross-Section A-A of Screen Chamber



Cross-Section C-C of Screen Chamber



Cross-Section B-B of Screen Chamber

[12]Drawing contains the details only for screen chamber and the details for the same are provided

4.1.3 Anaerobic Stabilization Reactor

Assumptions

Parameters	Assumptions
Upflow velocity in 1st chamber	4 to 5 m/hr
Upflow velocity in 2nd chamber	1.5 to 2 m/hr
Retention Time	7-10 days
Depth	2 to 2.5 m
VSS* reduction	Upto 60%

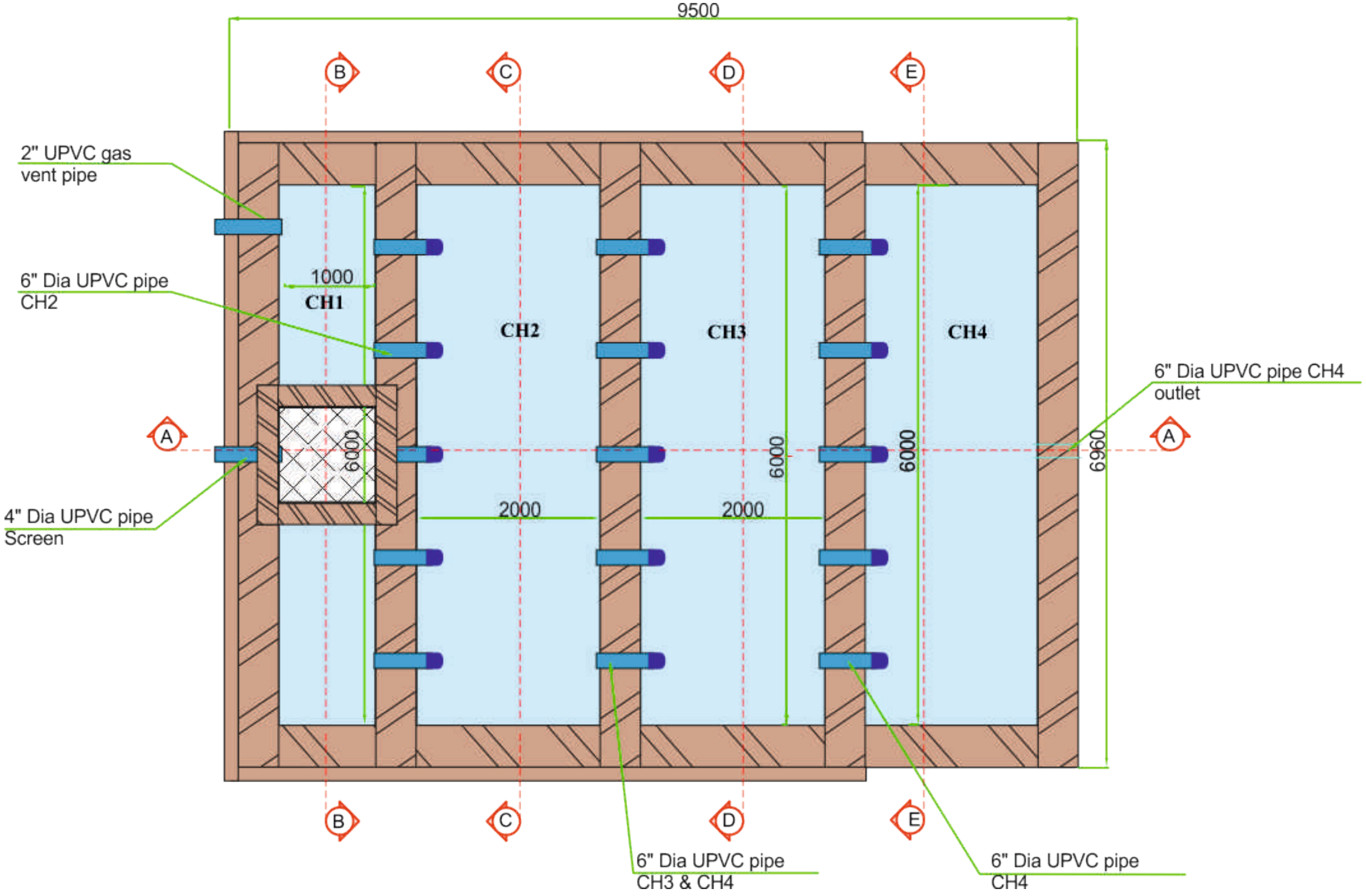
* VSS is 60-65% of TS

Dimensions*

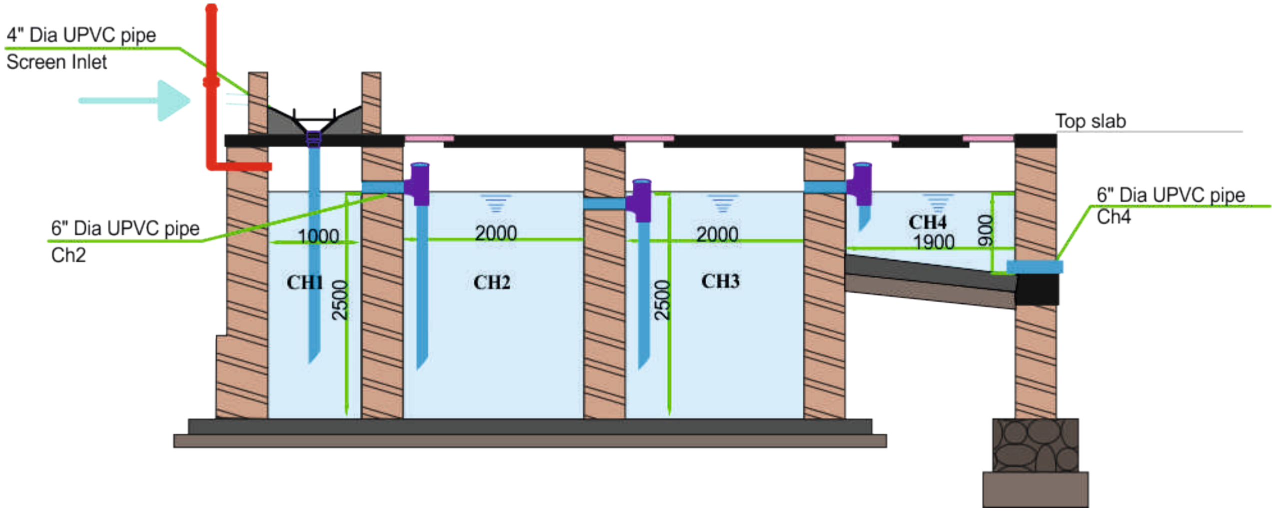
Sl. No.	ASR Chamber name	No. of chambers	Internal Length(m)	Internal Width (m)	Sludge Depth (m)	Volume (KL)
10 KLD						
1	Mixing	1	1.0	6.0	2.5	15.0
2	Digestion	2	2.0	6.0	2.5	60.0
3	Discharge	1	1.9	6.0	0.9	10.0
15 KLD						
1	Mixing	1	1.0	6.0	2.5	15.0
2	Digestion	3	1.8	6.0	2.5	81.0
3	Discharge	1	3.0	6.0	0.9	16.2
20 KLD						
1	Mixing	1	1.0	6.0	2.7	16.2
2	Digestion	3	2.0	6.0	2.7	97.2
3	Discharge	1	3.7	6.0	0.9	20.0

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

Sectional plan of Anaerobic Stablisation Reactor

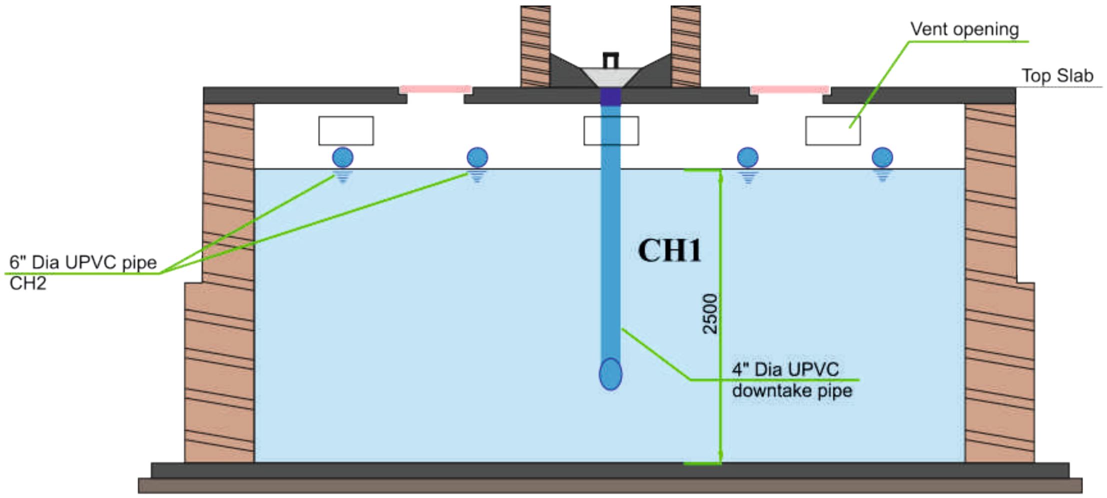


Longitudinal section A-A of Anaerobic Stabilisation Reactor

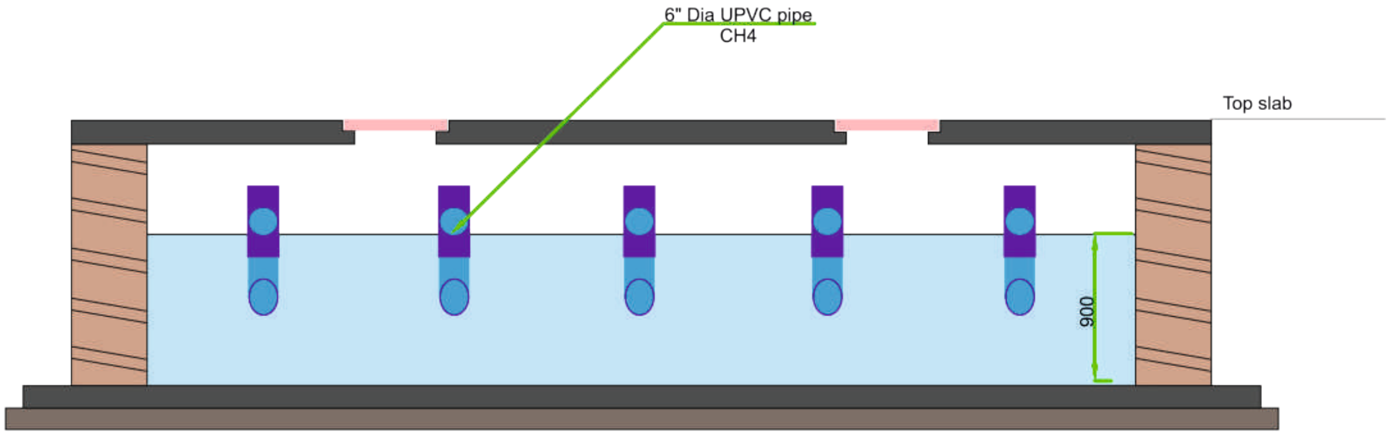


This subsection details the master plan and cross-section of ASR.

- The ASR has 4 chambers.
- Screening chamber can be mounted over the 1st chamber.
- The maintenance hole with covers has to be appropriately provided to enable desludging of the tanks for maintenance purposes and for access to internal pipes.

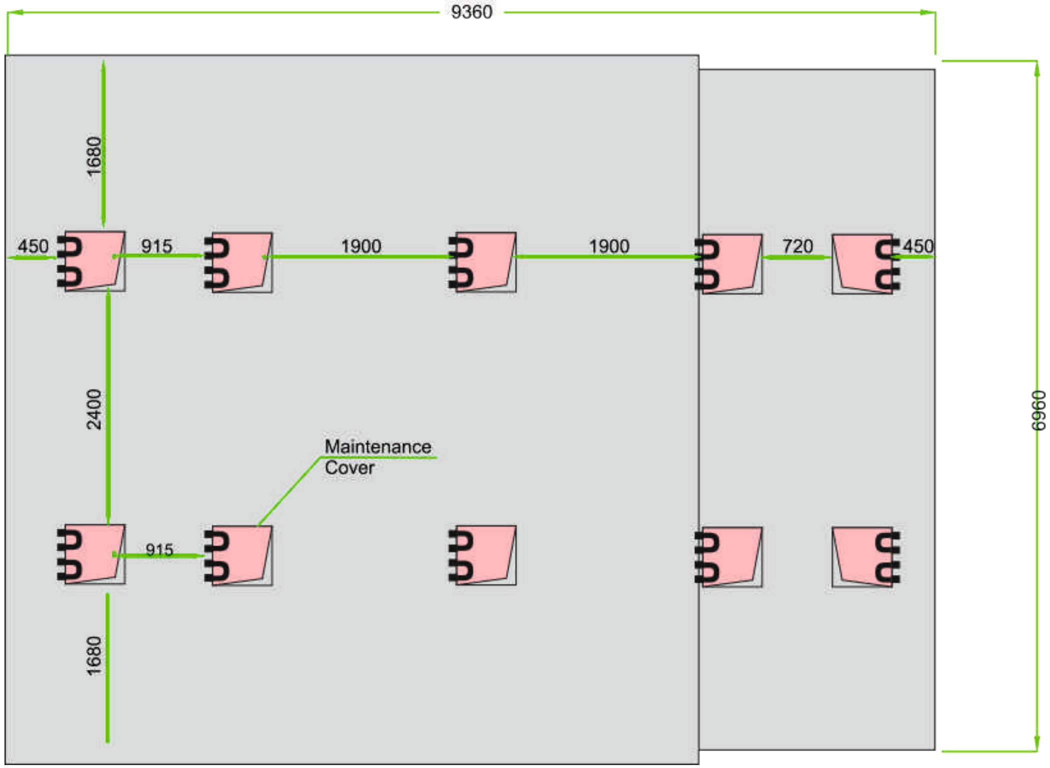


Cross section B-B of Anaerobic Stabilisation Reactor



Cross section E-E of Anaerobic Stabilisation Reactor

Maintenance hole of Anaerobic Stabilisation Reactor



This subsection details the maintenance hole of ASR Layout.

- The plan cross-section of the 1st chamber.
- The screen pipe has been kept till the bottom for better mixing of sludge.

4.1.4 Unplanted Drying Beds(UPDB)

Assumptions

Parameters	Assumptions
Drying period	14 - 21 days
No. of beds	13
Volume of percolate as % of FSTP capacity	50% to 80%
Total solids in influent	3% - 5%
COD out - percolate	<1500-1,650 mg/l
BOD out - percolate (1/3 of COD out)	<400-550 mg/l
Height of sludge layer	0.15 m - 0.25m
Dried sludge quantity per bed	~1% - 1.5% of the FSTP capacity
Solids loading rate	200-300kgTS/m^2/year

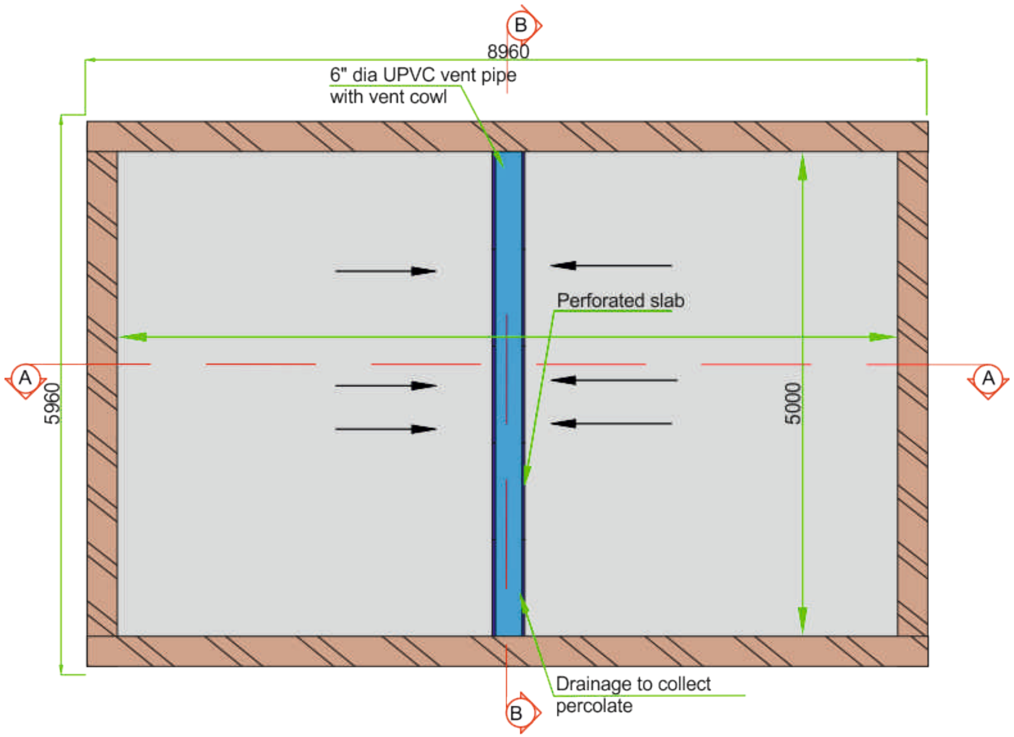
Generally, UPDBs are sized such that the volume of the last chamber of the ASR is equal to the volume of the sludge a UPDB can hold. This enables easy operation, since the operator is aware of how much to pump or let out into a drying bed. The number of UPDBs in this context has been assumed to be 13 days. It may vary as per context.

Also, the drying beds should be numbered so that the operator can keep a log of which drying bed was filled on respective date and hence track drying time.

Dimensions*

Capacity/KLD	No.of chambers/Beds	Internal Length (m)	Internal Width (m)	Sludge Depth (m)	Volume (KL) or Total KL
10	13	8	5	0.25	130
15	13	10	5	0.25	162.5
20	13	10	8	0.25	260

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

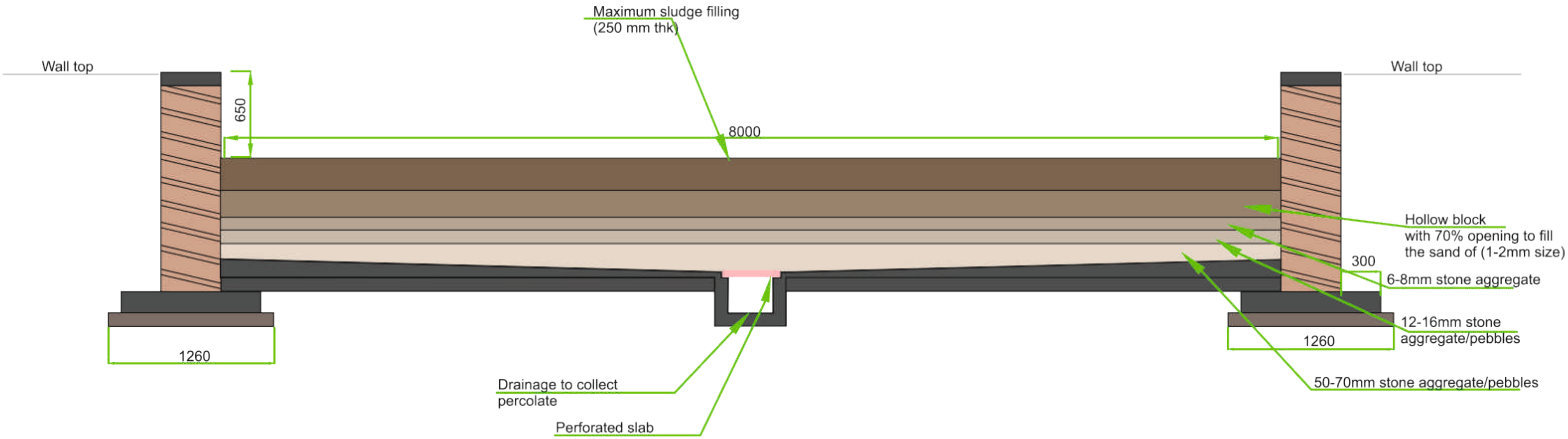


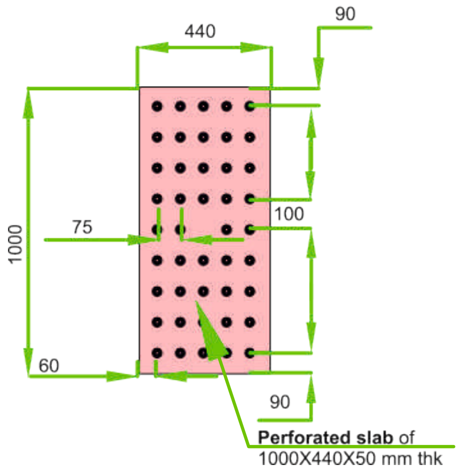
Sectional plan of Unplanted Drying bed

This subsection details the sludge drying bed and its cross-section.

- The beds should be designed to collect the percolate at the center of the bed.
- The bed is filled with different sizes of filter media in different layers.
- The bottom PCC slope is maintained at a ratio of 1:100.
- Typical aggregates used in the filter media are as follows:
  - First layer : 50-70 mm stone aggregate or pebbles (200mm thick)
  - Second layer : 12-16mm stone aggregate/pebbles (100 mm thick)
  - Third layers : 6 -8mm aggregate (100mm thick)
  - Fourth and top layer : 1-2 mm fine sand (200 mm thick)
- Before laying filter media in the bed, all the filter media should be washed properly so that the media is cleansed of mud and dust. This will ensure the system is not clogged during the treatment process.
- The purpose of the filter media is to retain solid particles on the top and filter the percolate part.
- A perforated slab is provided above the drainage.
- At every inlet point splash plate is to be used so that during the discharge of sludge, sand layer is not disturbed

Cross section A-A of Unplanted Drying bed

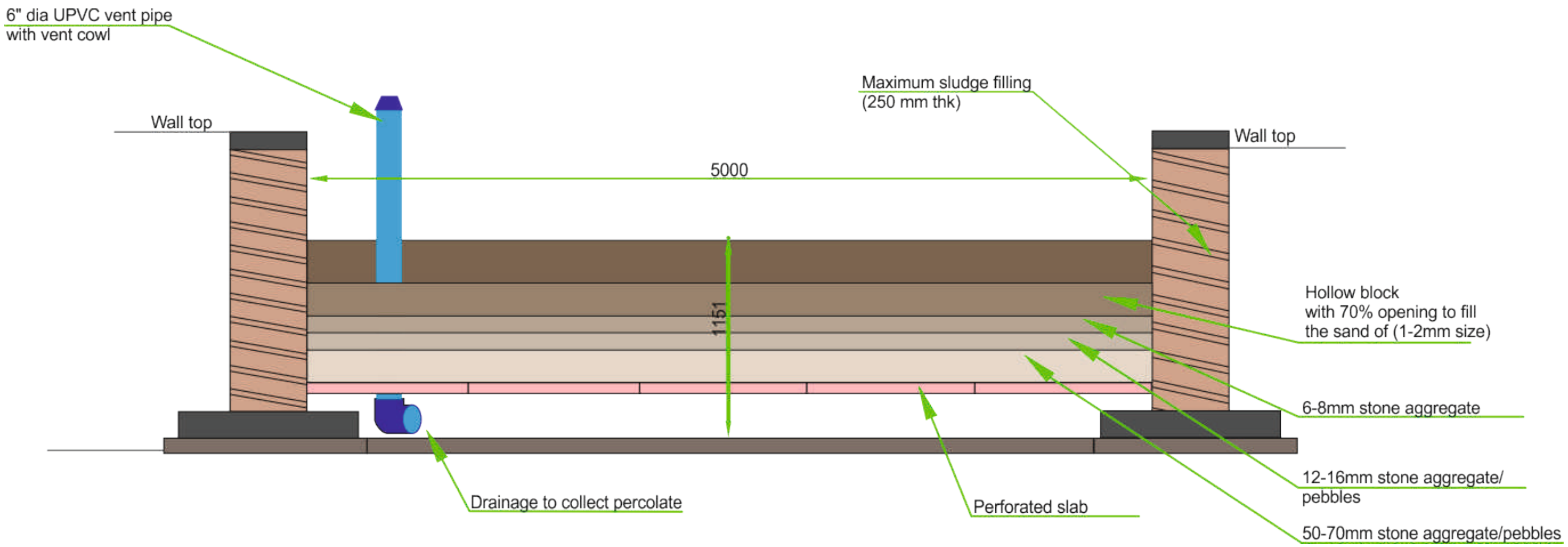




This subsection details the perforated drawing of UPDB.

- The screeding of the UPDB's base slab is to be taken care so that the percolate from all corners is directed towards the perforated pipe and the percolate flows freely without any stagnation.
- Vent pipes should be appropriately positioned as shown above.
- FGL and EGLs should be maintained consistent with the master plan.
- Minimum free board is to be maintained to enable maintenance of the UPDB.

Cross section B-B of Unplanted Drying bed



4.1.5 Integrated Settler and Anaerobic filter

Assumptions

Parameters	Assumptions
Discharge (Q daily)	50% - 80% of FSTP capacity
Time of peak flow (peak)	4 hrs
Max. Chemical Oxygen Demand (COD in)	1,650 mg/l
Max. Biological Oxygen Demand (BOD in)	550 mg/l
Effluent COD (CODout)	<275 mg/l
Effluent BOD (BODout)	<60 mg/l
Hydraulic Retention Time (HRT)	~1.5 hr
Depth	2 to 2.5 m

Dimensions*

Sl. No.	Module	No.of chamber	Internal Length (m)	Internal Width (m)	Internal Depth (m)	Volume (KL)
10 KLD						
1	Settler	2	1.8	1.5	2.0	5.4
2	Anaerobicfilter	2	1.9	1.5	1.9	8.4
15 KLD						
1	Settler	2	2.3	1.5	2.0	5.4
2	Anaerobicfilter	3	1.5	1.5	1.8	12.2
20 KLD						
1	Settler	2	2.6	2.6	2.0	13.5
2	Anaerobicfilter	3	1.2	2.6	1.8	16.9

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

4.1.6 Planted Gravel Filter

Assumptions

Parameters	Assumptions
Percolate treatment quantity	50% - 80%
Total number of PGF	1 No
Hydraulic Retention Time per PGF	2 days
COD outlet	<50 mg/l
BOD outlet	<20 mg/l
Hydraulic Conductivity	372 m/d

Dimensions*

Capacity of the FSTP	No.of chamber	Internal Length(m)	Internal Width (m)	Internal Depth (m)	Volume (KL)
10 KLD	1	12.9	2.5	0.6	19.35
15 KLD	1	21.5	2.15	0.6	27.8
20 KLD	1	13.7	4.0	0.6	32.9

The design of PGF is based on
· Nutrient change requirement
· Plant capacity sizes
· Gradient of site and Power supply
· HPGF Design

$$A_s = \frac{Q(\ln C_o - \ln C_e)}{K_T dn}$$

· Q is the influent flow (m3 /d);
· Co and Ce the mean influent and effluent BOD (mg/L)
· KT, the area-based first-order rate constant for BOD removal (temperature: 280C; K 20: 1.1)
· Depth of filter bed and n porosity in percentage.
· Assuming a filter bed depth of 60 cm, cross-sectional area of the filter bed is calculated with slope (1%) and permeability (3 x 10-3 m3/m2/d).

Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions

4.1.7 Polishing Pond

Assumptions

· Designed assuming a depth of 1m and retention time of 3-5 days

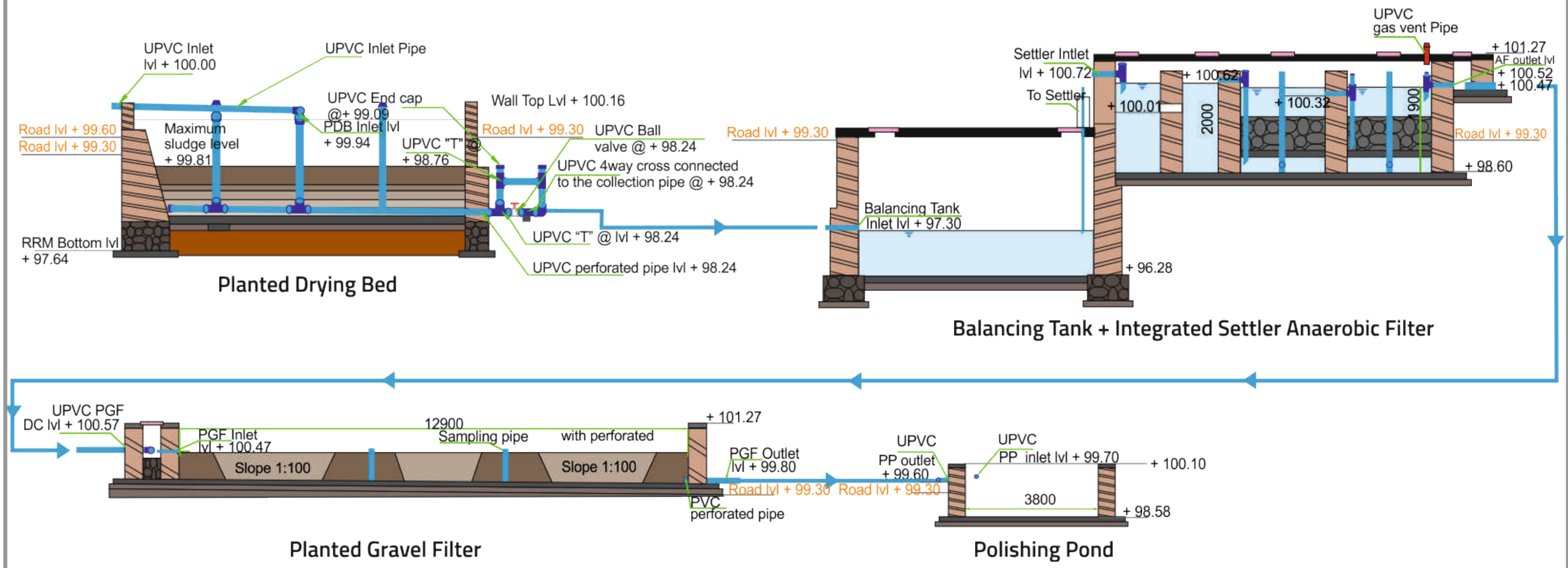
Dimensions*

Parameters	Unit	Values
Area of Pond	m^2	8
Depth of the water in pond	m	1.0
Pathogen inactivation	Natural solar disinfection	

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

4.2 Planted Drying Bed Designs

4.2.1 Hydraulic Profile of Planted Drying Bed



** The hydraulic profile is indicative. This needs to be contextualized for every site depending on site specific considerations.*

Understanding the Hydraulic profile of PDB

- The hydraulic profile is made to check and ensure that the critical levels (inlet and outlet) allows free flow of sludge and liquid from the inlet to the outlet.
- The inter modules connection pipe slope should be in between (1:50 to 1:100)
- Identifying the inlet level of the screen chamber is crucial
- In the drawing 4.2.1 - blue colour refers to pipe connection for percolate.
- Before detailing individual modules, a hydraulic profile that represents all the levels and EGL/ FGL in the drawing should be prepared
- The hydraulic profile also shows the level difference within the modules.

FS unloading at Phulera Sambhar FSTP

4.2.2 Screen and Grit Chamber

Assumptions

Parameters	Assumptions
Desludging Truck Capacity	3,000
Emptying	6 to 7 minutes
Settling velocity	15 cm/sec to 30 cm/sec
Retention Time	30 Seconds

Dimensions*

Sl. No.	Module	No. of screen chambers	Internal Length (m)	Internal Width (m)	Internal Depth (m)
1	Screen chamber	Equal to number of beds in PDB	2	1	0.8

Screen Chamber remains the same for all capacities. the screen has been designed for 3000liters truck that empties FS within 6-7 minutes. For larger or smaller truck capacities, the screening chamber will have to be resized accordingly - depending on the flow rate

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

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4.2.3 Planted Drying Beds

Assumptions

Parameter	Assumptions
Sludge loading rate	180-250 Kg/m²/year
Feeding frequency for PDB in Indian context	4 to 15 days[13]
Total Solids concentration in FS	20,000 – 30,000 mg/l[14]
Feeding Frequency	6-8 Days
Volume of percolate	50% - 70%
Influent BOD	7500- 10,000 mg/l
Influent COD	<30,000 mg/l
COD out - percolate	<500 mg/l
BOD out - percolate	<200 mg/l
COD reduction in leachate	77 to 99%[15]

During construction of PDBs, the plumbing arrangement and sloping within the PDBs are the most crucial elements to focus on. Specific details to be considered for plumbing and sloping are mentioned next to the drawings in the next few sections.

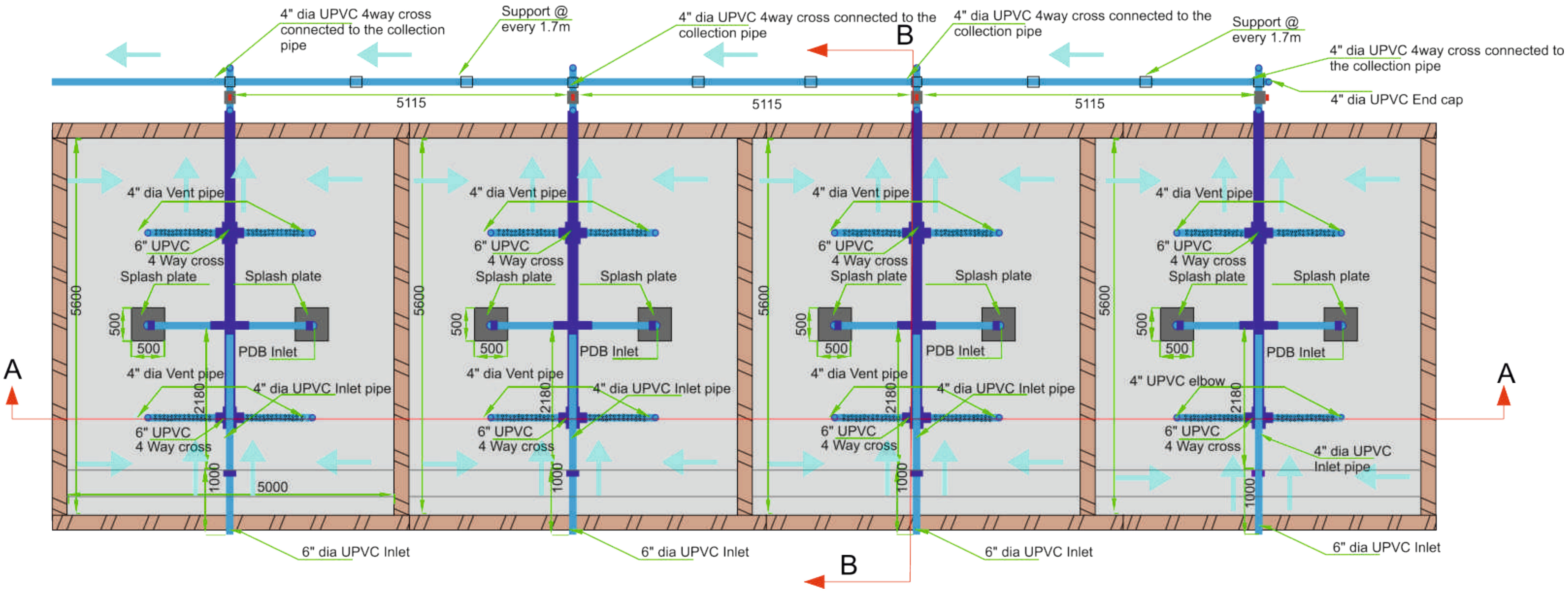
Dimensions*

Parameter/Assumption	For 6 KLD	For 10 KLD	For 16 KLD
Total number of beds	7 No's	10 No's	8 No's
Dimensions (L × B)	5 X 5 m	5.6 x 5 m	7.6 x 7.6 m
Total area required	175 m^2	280 m^2	464 m^2
Area of each Planted Drying bed	25 m^2	28 m^2	58 m^2

Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions

[13] FSM Manual, IWA Publication
[14] Total Solids in FS < 3 % (Source: CPHEEO, 2013) & CDD's internal research
[15] Case Study on Loading rate experiments in Cameroon (Adapted from Kengne et al., 2011), FSM, IWA.

4.2.4 Detailed Drawings of Planted Drying Beds

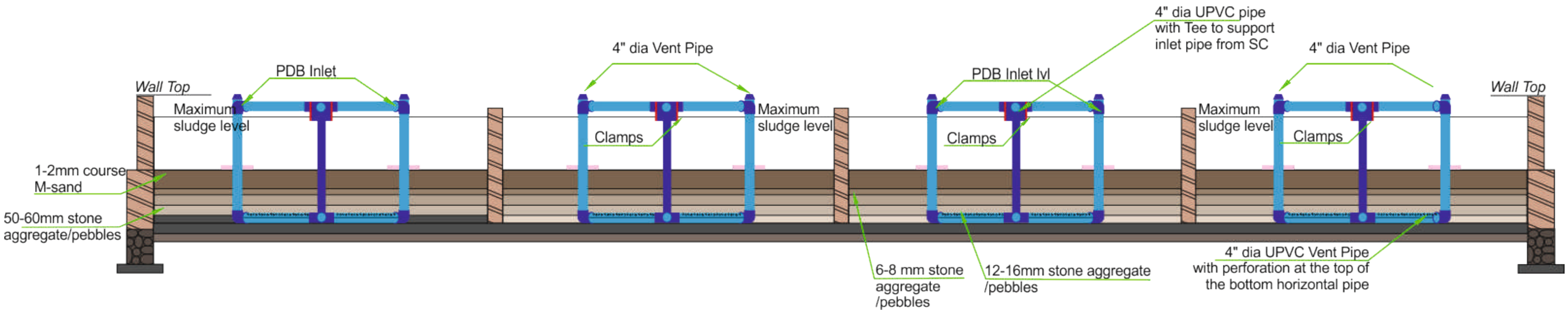


Sectional plan of Planted Drying bed

This subsection details planted drying bed.

- There are several pipe arrangements shown in the bed for inlet, vent pipe and perforated outlet pipe.
- Arrow represents the direction of flow of the percolate coming out from the planted drying bed.
- The perforated pipes on the sides are connected to one single pipe, which takes the percolate for further treatment into a DEWATS™ or other percolate treatment system.

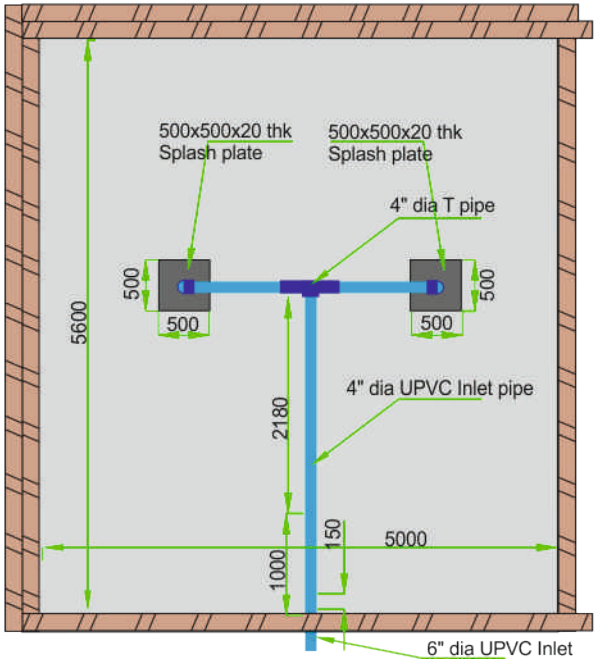
Longitudinal Section A-A of Planted Drying Bed



This subsection details the longitudinal section of the planted drying bed.

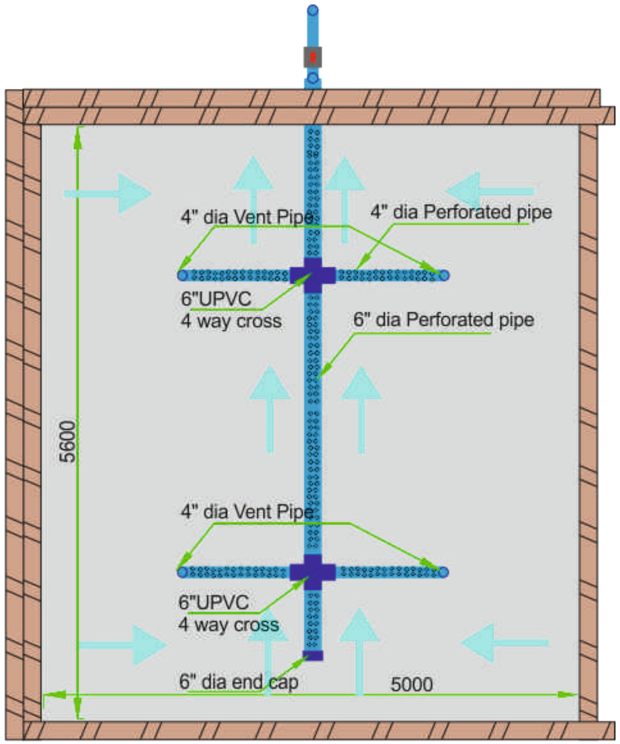
- The following filter media is used in the above drawing
    - 50-60 mm Stone aggregate
    - 12-16 mm Aggregate/pebbles
    - 6-8 mm aggregate/pebbles
    - 1-2 mm coarse M sand
- Before laying filter media in the bed, all the filter media should be washed properly so that the media is cleansed of mud and dust. This will ensure the system is not clogged during the treatment process.
- The sludge level is generally 600-750mm from the sand layer.
- The center vertical pipe is kept to support the inlet pipe of the planted drying bed.
- All the outlets of the planted drying bed are kept at the same level.

Plumbing Details of Planted Drying Bed

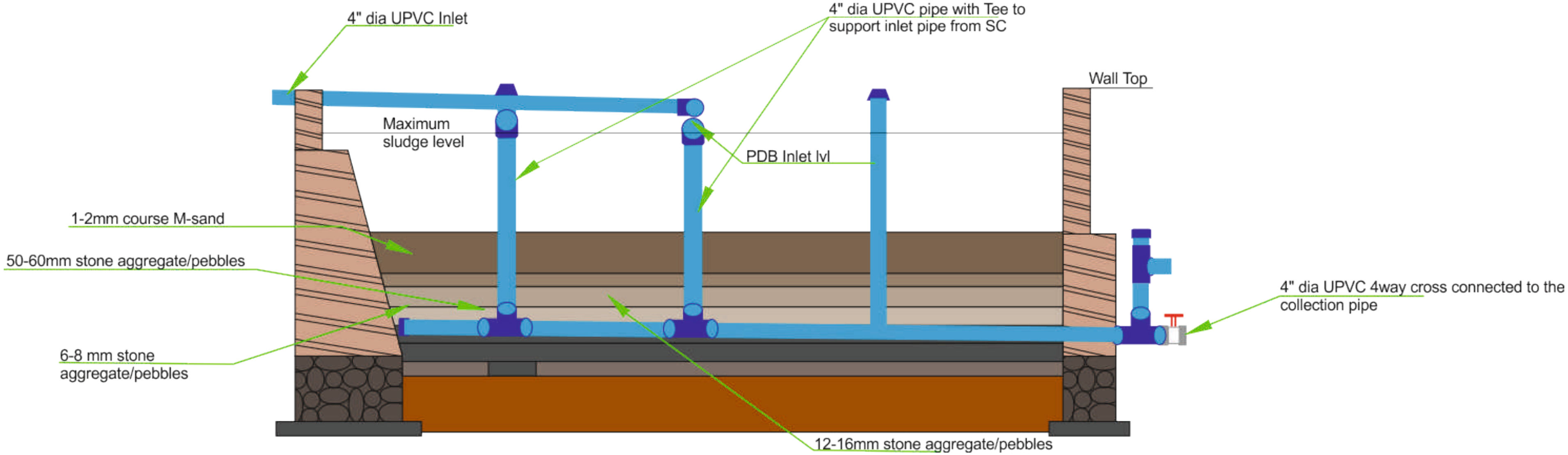


This subsection details the plumbing work inside the PDB.

- First drawing is for the inlet of the PDB pipe and second drawing provides details of bottom perforated pipe arrangement.

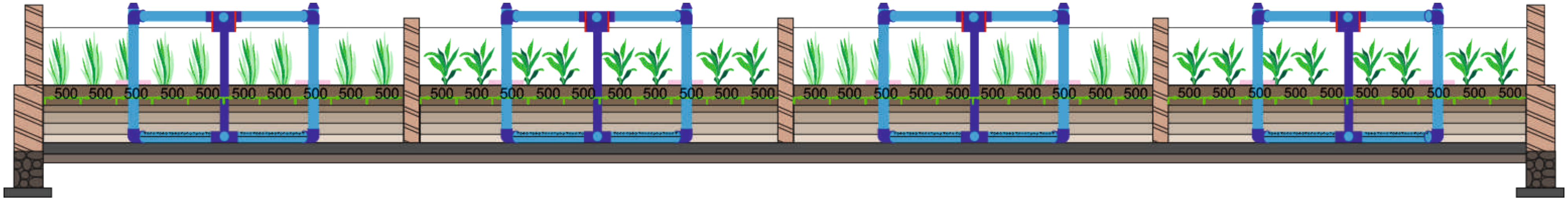


Cross section B-B of Planted Drying Bed

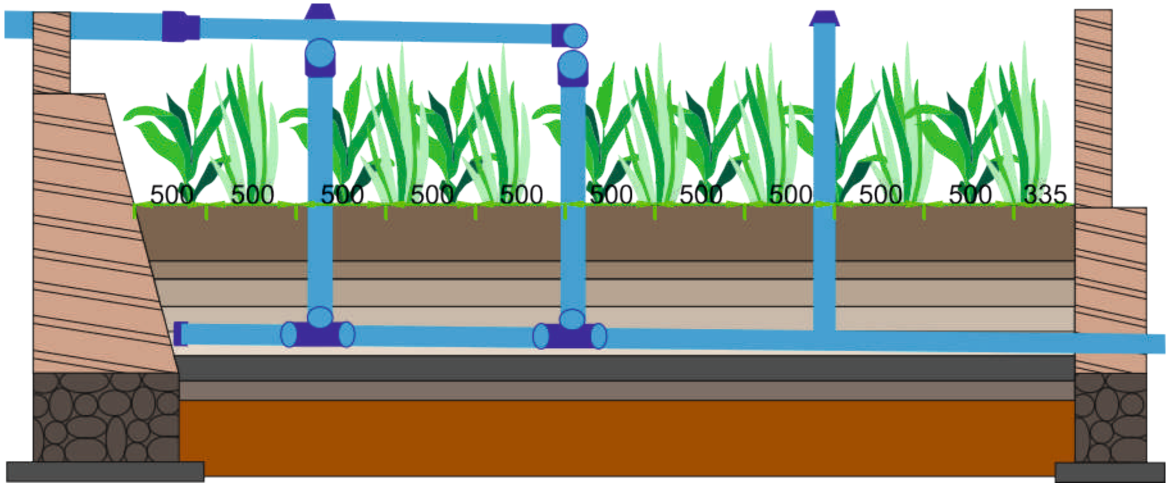


This subsection provides information on cross-section B-B of the planted drying bed.
- For ease of O&M, the outlet pipe is fixed with the valve arrangement.
- Two vertical supporting pipes with T-joint have been provided for inlet pipe.
- The center perforation is also kept in 1:100 slope, so that percolate can easily flow out of the planted drying bed.
- The outlet pipe arrangement is kept in such a way that maximum water level can be maintained till 6-8mm below the filter media.

Longitudinal section of Planted Drying Bed



Cross section view of Planted Drying Bed



NOTE:
Plant species common for Planted drying beds
1. Papyrus
2. Canna Indica
3. Colocasia
4. Typha
5. Reed Juncus

This section provides directions for planting in PDB.

- The species of plants recommended above are indicative. In case of non-availability of the aforementioned plants, one can use locally available plants which grow near any wastewater channel and use them after acclimatization.
- Acclimitization has to be done for any plants which will be used in the treatment systems for atleast 2 weeks to check the survival of the plants. This has to be done by growing the plants, initially, in containment (with draining out arrangement)having filter media placed similar to the drying bed by applying layers of FS every alternate day for 2 weeks.
- Four sprouted rhizomes should be placed per square meter while starting the plantation.

4.2.8 ISAF

Assumptions for Settler

Parameter/	Assumptions
Discharge (Q daily)	50%-70%
Time of peak flow (peak)	4 hrs.
Max. Chemical Oxygen Demand (COD in)	500 mg/l
Max. Biological Oxygen Demand (BOD in)	200 mg/l
Effluent COD (CODout)	<450 mg/l
Effluent BOD (BODout)	<200 mg/l
Hydraulic Retention Time (HRT)	2 hrs.
Depth assumed as	1.8 to 2 m

Assumptions for AF

Parameter	Assumptions
Discharge (Q daily)	50%-70%
Time of peak flow (peak)	4 hrs.
Max. Chemical Oxygen Demand (COD in)	<450 mg/l
Max. Biological Oxygen Demand (BOD in)	<200 mg/l
Effluent COD (CODout)	<150 mg/l
Effluent BOD (BODout)	<50 mg/l
Hydraulic Retention Time (HRT)	25 to 30 hrs.
Depth assumed as	1.8 to 2 m

Dimensions* of Integrated Settler + Anaerobic Filter

Sl. No.	Module	No. of chamber	Internal Length (m)	Internal Width (m)	Water Depth (m)	Volume (KL)
6 KLD						
1	Settler	2	1.7	1.2	1.8	3.67
2	Anaerobic filter	2	1.7	1.2	1.7	6.94
10 KLD						
1	Settler	2	1.7	1.5	1.8	4.59
2	Anaerobic filter	2	1.7	1.5	1.7	8.67
16 KLD						
1	Settler	2	2.3	1.5	1.9	6.56
2	Anaerobic filter	3	2	1.5	1.8	16.2

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

4.2.9 Planted Gravel Filter

Assumptions for PGF

Parameters	Assumptions
Percolate treatment quantity	50% - 70%
Total number of PGF Beds	1-2 No
Hydraulic Retention Time per PGF	2 days
COD outlet	<60 mg/l
BOD outlet	<15 mg/l
Hydraulic Conductivity	372 m/d

Dimensions* of Planted Gravel Filter

Capacity of FSTP	No. of chamber	Internal Length (m)	Internal Width (m)	Water Depth (m)	Volume (m^3)
6 KLD	1	10	5	0.6	30
10 KLD	1	10	6	0.6	36
16 KLD	2	10	4	0.6	48

**Please note that these dimensions are indicative and designers are free to alter the dimensions to suit the assumptions*

Choudwar FSTP under construction

5. Construction Guidelines

The design of FSTP through passive approaches outlined in this document majorly entails civil construction along with critical components like plumbing and filter media. The construction of FSTP thus follows IS codes or standard construction processes applicable across sectors.

However, there are **some critical aspects which need to be considered during FSTP construction** so as to minimize the risks during implementation. They are as follows:

- **The quality of the various materials have to follow the standards mentioned in the various schedule of rates(SORs)** of either respective state governments applicable for that region or central government. Also, the various standards for the materials to be procured and used has to comply with the IS standards/any other nodal agency's quality standards. Additionally, one can access the various standards available for different materials by accessing the following link.

https://www.washinstitute.org/pdf/Quality%20in%20FSM%20v1.0.pdf

- **Availability and selection of materials** plays an important role during designing of the treatment system. The following aspects are to be considered while designing FSTP's:
  - Firstly, one has to **analyze materials that are available and easily procurable** near to the site
  - The design process should take into account the various materials and use only those which are available near to the site/ locally. This ensures that the design is contextual as well as cost effective.
  - Sometimes due to unforeseen circumstances, there might arise an instance of non-availability of the planned material during implementation. In such cases locally available materials having similar properties can be utilized after undertaking required tests
  - If the size of materials (for example, bricks) differ from the plan, the treatment modules have to be redesigned to accommodate the sizes of readily available alternatives without compromising on the quality and strength of materials.

  - The human resource for/during the implementation of FSTP has to have basic understanding of the FSTP function and the objective of each modules.
- The entire system is based **majorly on gravity** and for this, it is **essential to maintain the hydraulic levels** as per the drawings
- The **plumbing** within the various modules are **to be maintained as per the design** drawings. The slope after laying/undertaking of plumbing works has to be checked at every step during the construction process.
- **Laying of filter media** is another major step which has to be handled with utmost care. Filter media should be **procured as per design** and has to be washed thoroughly before being arranged in respective modules. This ensures that the treatment works properly without any blockages
- The modules should be **water-tight structures** and it should be taken care that there are no leakages. This has to be properly checked by undertaking commissioning checks or tests for water-tightness after construction completion

NOTES

NOTES

NOTES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