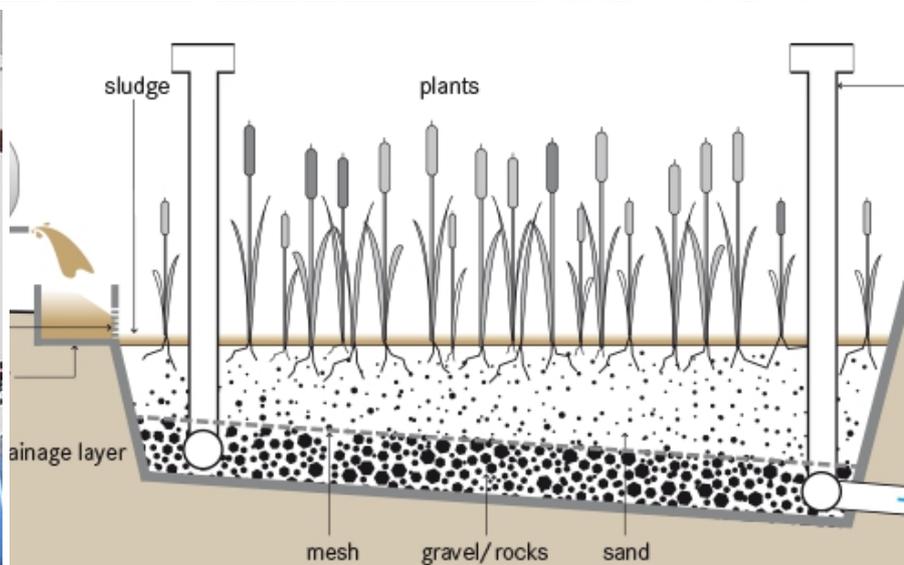




# COMPENDIUM OF INNOVATIVE TECHNOLOGIES FOR URBAN SANITATION

December 2018





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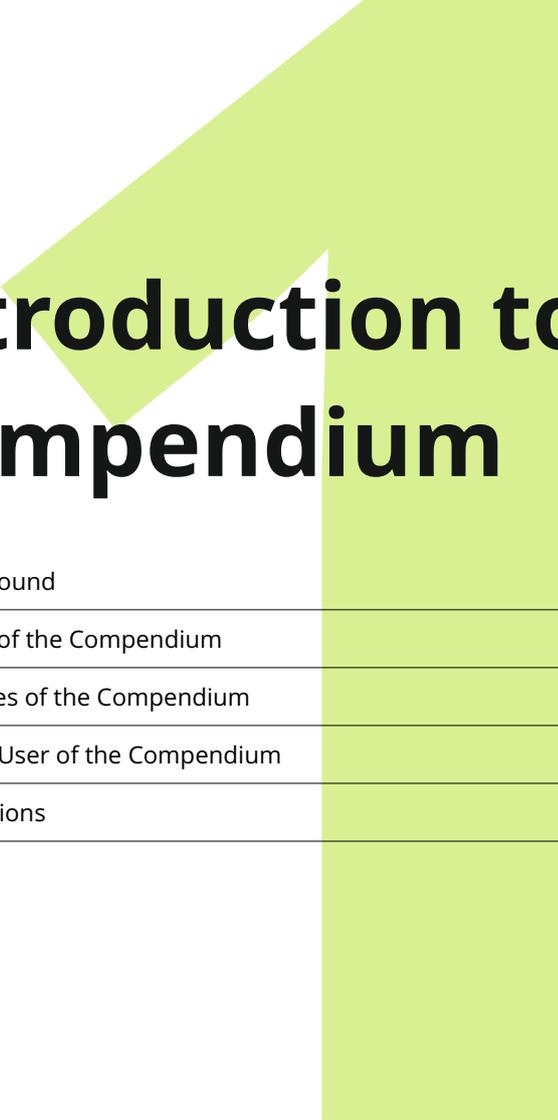
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## Abbreviations

|                |                                 |
|----------------|---------------------------------|
| <b>FSM</b>     | Faecal Sludge Management        |
| <b>BOD</b>     | Biochemical Oxygen Demand       |
| <b>COD</b>     | Chemical Oxygen Demand          |
| <b>O&amp;M</b> | Operation and Maintenance       |
| <b>TSS</b>     | Total Suspended Solids          |
| <b>UDDT</b>    | Urine-Diverting Dry Toilet      |
| <b>Ecosan</b>  | Ecological Sanitation Systems   |
| <b>UDS</b>     | Urine Diversion System          |
| <b>MAPET</b>   | Manual Pit Emptying Technology  |
| <b>VIP</b>     | Ventilated Improved Pit         |
| <b>FSOI</b>    | Faecal Sludge Omni-Ingester     |
| <b>PVC</b>     | Polyvinyl Chloride              |
| <b>OP</b>      | Omni Processor                  |
| <b>ABR</b>     | Anaerobic Baffle Reactor        |
| <b>WSP</b>     | Waste Stabilisation Pond        |
| <b>OEM</b>     | Original Equipment Manufacturer |
| <b>FRV</b>     | Fibre Reinforced Vinyl          |





# Introduction to Compendium

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| 1.2 Usage of the Compendium       | 3 |
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# 1. Introduction to Compendium

## 1.1. Background

Consortium for DEWATS Dissemination Society (CDD Society) is developing a Compendium<sup>1</sup> of technology options for various components in the sanitation value chain. This Compendium is contextual to the geographic and economic conditions for the state of Tamil Nadu. It aims to provide the user with a broad range of innovative sanitation systems and technologies that can be implemented on ground.

This document is designed to act as a reference guide and decision support tool for technical professionals of the urban local bodies, sanitation practitioners, and urban planners to select the appropriate technological intervention. Currently there is a huge gap between theories practiced on ground and the advancements happening at various research institutes across the globe. Innovations, especially in technology have found it difficult to diffuse findings from research to engineers implementing solutions on the ground. This gap is attributed to:

Infrastructure: Poor internet connectivity and insufficient means for accessing knowledge portals

Bulk information: There is a lot of unrefined information available on print and online media, which makes it difficult for the reader to synthesise information relevant to their individual requirements.

In addition, there is no common platform to compare technologies, which restricts the level of insight in these innovations. As a result, ULBs and practitioners find it difficult to review the claims made by experts under sanitation planning. This Compendium will address gaps by enlisting various innovations in the technology and thereby empowering stakeholders to play an informed role in the FSM planning.

## 1.2. Usage of the Compendium

The Compendium presents various innovations in technologies both on field and in laboratories. These technologies span across the faecal sludge value chain comprising user interface, containment, collection, transportation, treatment, and reuse. It provides reader of the Compendium with various options for implementation at the ground level contextual to demographic and geo-climatic situations. The Compendium is divided into various chapters, each pertaining to one component of the value chain.

Technologies are represented as a framework containing vital descriptions such as

- Working principles
- Advantages and disadvantages
- O&M requirement
- Design factors
- Health and acceptance
- Cost and supplier details

---

<sup>1</sup>We refer to the proposed collection of innovative technologies as Compendium

In addition to the above details, a case study on each technology is presented to give context to its application. Technologies have also been indexed for easy referencing based on cost, O&M requirement, area, etc., which aid the user to compare different technologies on a few common parameters.

### **1.3. Features of the Compendium**

This Compendium has the following features:

- Recent innovations in the FSM value chain, addressing problems existing with prevalent technologies that have been practised or piloted across the world in the last decade.
- Innovations that have been adapted to the geographic and socio-economic conditions of Tamil Nadu.
- Innovations in this Compendium are both incremental and disruptive. Incremental can be technologies that have a small change in the existing process through which there is an improvement in its effectiveness or efficiency. Disruptive can be a breakthrough or radical innovation that has adopted a new operating concept.

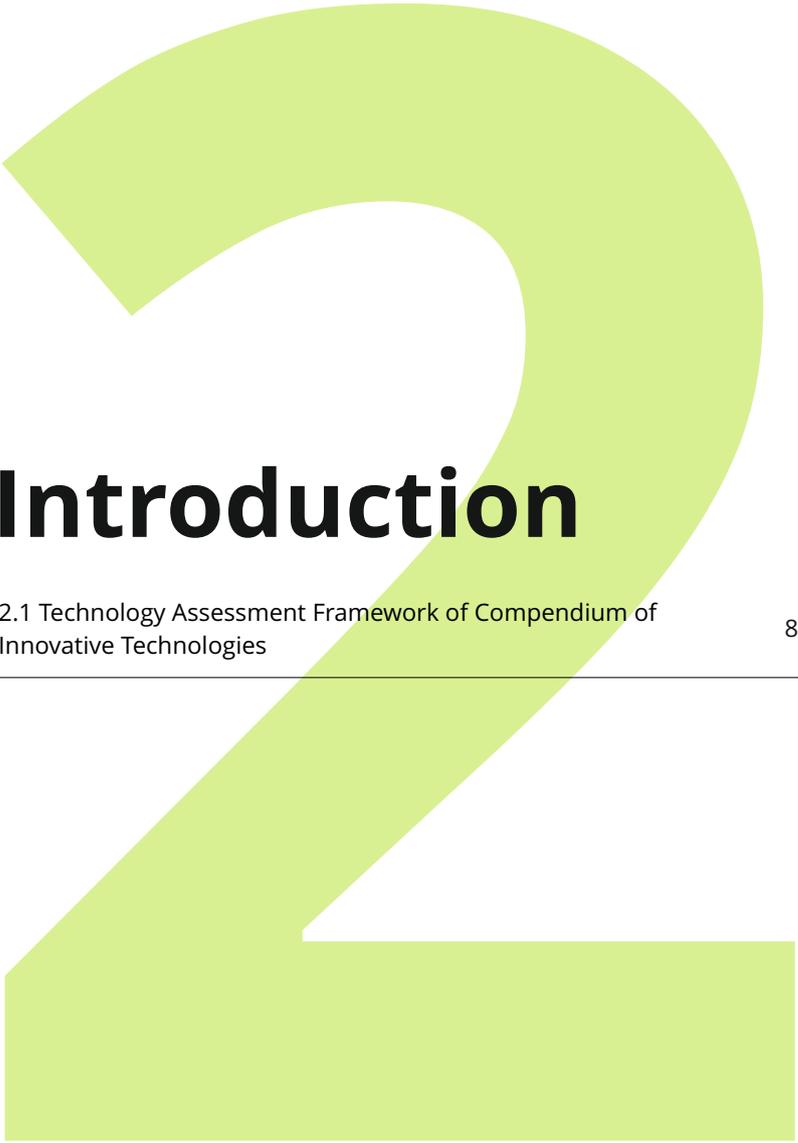
### **1.4. Target User of the Compendium**

The Compendium is intended to be used by engineers, planners and other technical professionals of Tamil Nadu Urban Local Bodies (ULBs), Sanitation Practitioners (Planners, builders, contractors, architects, etc.) and academicians (trainers from vocational training institutes) who are familiar with sanitation technologies and processes.

### **1.5. Limitations**

All efforts have been put into making this document a comprehensive data source for technologies in the FSM value chain; nevertheless, it has its inherent limitations such as:

- The Compendium is a library of innovative technologies; it is to be used as an addendum to existing resource pool of prevalent and available technologies.
- The Compendium is aimed at providing an orientation towards each of the innovations; it is not to be regarded as a design document that can be readily used for implementation.
- Cost, area requirement, O&M requirements are based on ideal scenarios as designated by the supplier or promoter of the innovation; it will differ according to local, site-specific conditions.
- Proprietary innovations included in the Compendium are based on interactions with the representative of the institution promoting the technology. CDD Society hence strongly recommends pilot trails to be conducted before adopting these on large-scale interventions.



# Introduction

2.1 Technology Assessment Framework of Compendium of Innovative Technologies

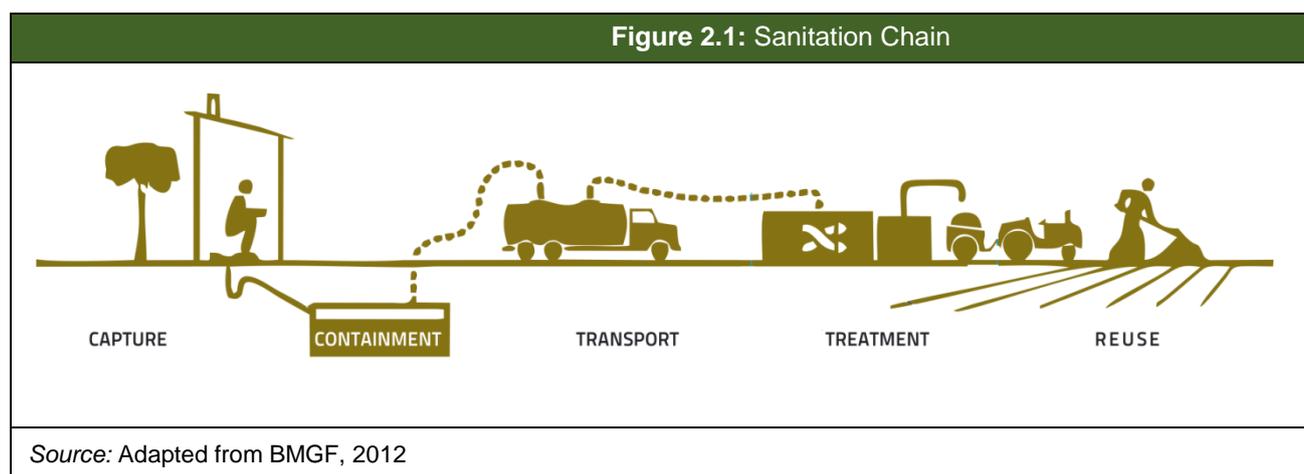
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## 2. Introduction

The sanitation value chain comprises all components and their interlinkages involved in the transportation of human excreta from its generation to safe disposal. The management of this value chain is termed as Faecal Sludge Management (FSM). FSM is an important and incremental approach catering to improved sanitation. In the past, faecal sludge management from onsite facilities has not been a major priority for engineers or municipalities, and has traditionally received little attention. Several generations of engineers have considered waterborne, sewer-based systems as the optimum, long-term solution to fulfil sanitation needs. It is a common perception that onsite technologies fulfil sanitation needs for rural areas, but in reality, around one billion onsite facilities worldwide are in urban areas. In many cities, onsite technologies have much wider coverage than sewer systems. Given that cities are expanding at an incremental rate and that the scope of funding from public sector remains unchanged, the plan to have all households connected to a sewer network remains a distant goal to be achieved. It is the cost and effort involved in constructing sewerage networks and associated treatment plants which lead practitioners and researchers in the field to think about a novel approach, thus mainstreaming FSM.



FSM involves interventions across the entire value chain of human excreta, beginning from the way interfaces are built at the point of generation of excreta, to its containment, conveyance, treatment, and finally safe disposal. There have been continuous efforts in bringing technological developments across various components of this chain. Many academic and private institutes have been funding research in this field. Till date most research has been focussed on user interface and containment systems, as they seem to have easy marketable potential. Though research is being carried out to develop innovative technologies in other components of the FSM chain, it has not been as substantial as compared to innovations that have been developed in toilets and flushing systems. Taking the example of faecal sludge treatment, very few proven technologies are available as of date, most of which are adopted from wastewater treatment systems (there is a tremendous difference in the characteristic of domestic wastewater and faecal sludge).

This Compendium has a compilation of technologies, most of which are considered innovative in the field. Technologies have been classified based on their application across the value chain. Nevertheless, there are technologies which overlap across various components of the value chain; they have been placed under components where the author felt it gained an appropriate representation.

## 2.1. Technology Assessment Framework of Compendium of Innovative Technologies

### Aim of the Assessment outcome for Innovative Technologies

The framework is suggested by the TSU in order to apprise and assess the Compendium of Innovative technologies on each component of the Full cycle of sanitation and if possible, rank the criterion.

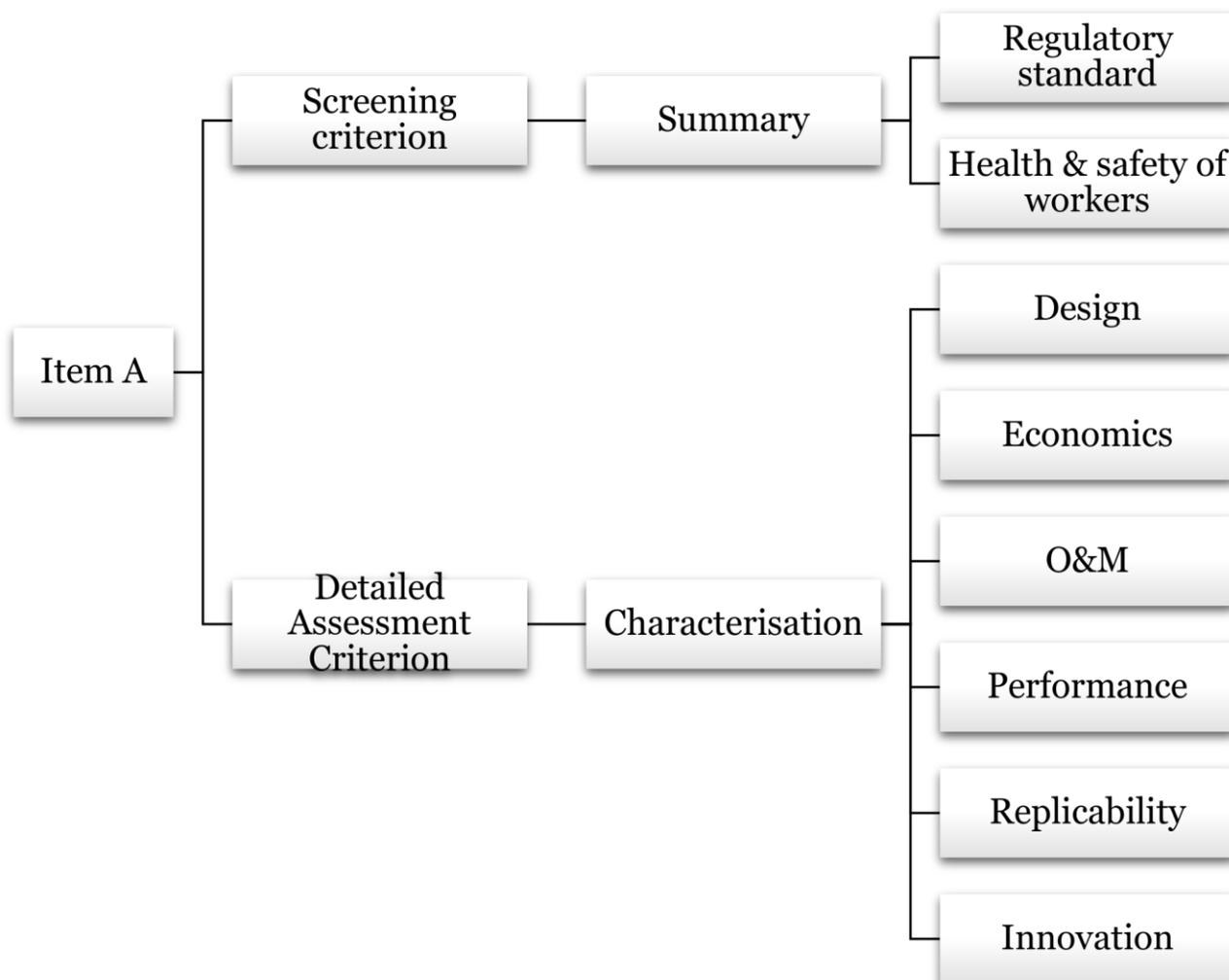
### Assessment criteria for characterisation

This report is about the characterisation outcome of the innovative technologies provided in the Compendium of Innovative technologies (CDD Society) carried out by the TSU to understand the framework, pros and cons of the innovative technologies in terms of design, performance, O&M, financial and scale up potential, and its applicability. The assessment is made for a random 2 technologies for few of the components of the fecal sludge value chain, in this case, User interface, Containment system and Treatment technologies. It was then extended and applied to all the remaining technologies listed in the 3 Chapters by CDD Society.

The hierarchy of assessment is based on summary evaluation, which is in turn based on regulatory standards as a screening step. This will be followed by detailed assessment based on treatment efficiency, operation and maintenance, energy and significance of the technology.

The selection process is envisaged broadly as a two-step process (also illustrated in the Organizational Chart):

Framework review of the technologies provided by the CDD Society in the Compendium



**1. Screening:** The technologies and options provided in the Compendium of Innovative Technologies by CDD Society is subjected to a preliminary screening. The screening was based on a desktop review, and the options were summarised based on a simple criteria such as environmental standards, safety of workers etc. Whether the technology does/does not meet the regulatory standard, and whether the technology poses adverse impacts on health and safety of workers and users, will be expressed in the framework. The input sheet based on the information in the Compendium and the associated assessment criteria is attached in Summary sheet.

Whatever be the outcome of Screening, the next course of detailed evaluation is undertaken. The missing information are required at a later date for validation.

**2. Detailed assessment:** The assessment in the second part of the report is more elaborate, but also desktop based characterisation. The desirable parameters that are adopted in addition to Regulatory standards indicated in Summary sheet, are design, operation & maintenance, performance, replicability etc., The input sheet is dependent on the information in the Compendium and the associated assessment criteria is attached in Characterisation sheet.

**All the listed technologies in the User interface, Containment and Treatment, are assessed from the Compendium:**

The comments and feedback column in the Summary and Characterisation, is based on the information provided in the Compendium and its associated references.

**Possible outcome of Screening and Characterisation for technologies**

1. Yes
2. No
3. Information not available right now. But will need more information to be validated later
4. Not applicable

**Limitation of the current Technology Assessment Framework**

It is not applied to the Chapters on: Collection and Transportation

**Reason for the limitation**

Different framework is required for different parts of the FSM Value chain. The current framework will serve for the assessment of technologies on User interface, Containment and Treatment.

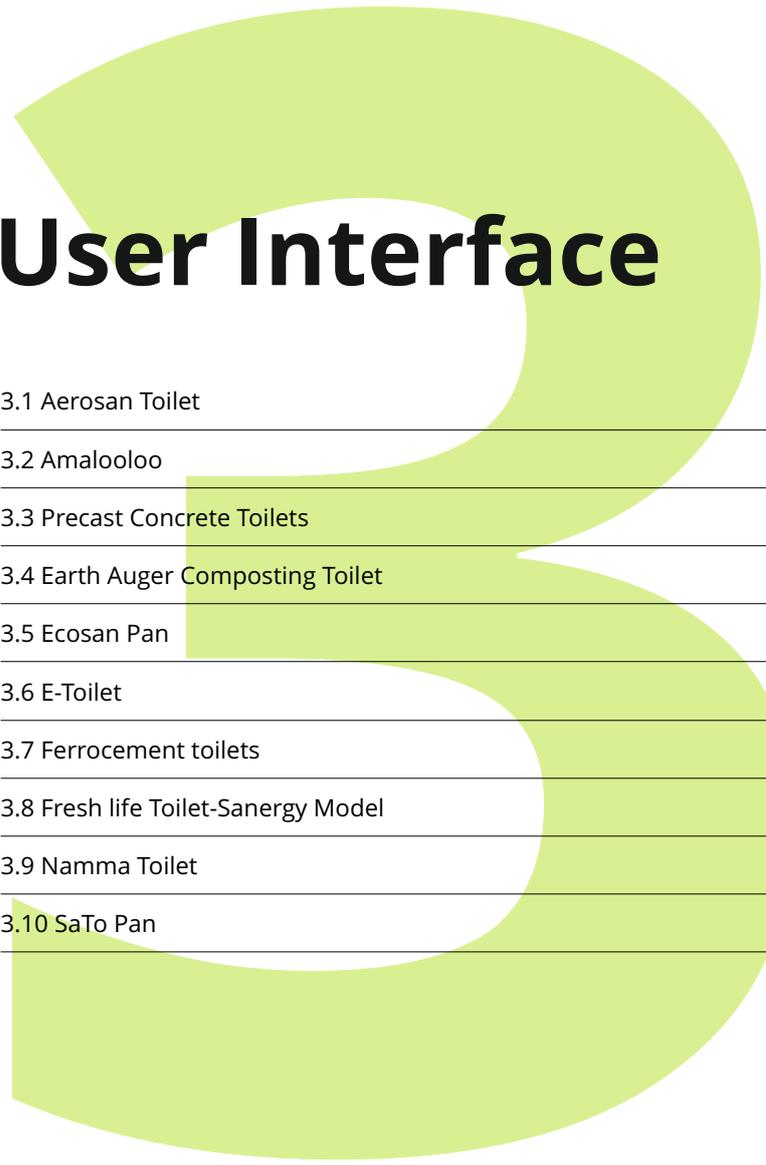
**Application of the Technology Assessment framework**

The Summary and Characterisation provided for a particular technology can be used as an Annexure or an Additional note after the description on the CDD Compendium itself. The number of technologies listed can be expanded beyond the current exercise framework, to accommodate the remaining technologies also. The visualization of the framework is also flexible, the can be modified by transposing the row into columns, if needed.

**Expected outcome of the exercise**

This would enable the readers and users to better understand the technology with a sense of a common assessment framework.





# User Interface

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| 3.10 SaTo Pan                       | 27 |



## 3. User Interface

User interface is the first component of the faecal sludge value chain which comprises the toilet structure, excreting pan and excreta pathway.

Toilet structures refer to the outer framework or shell encompassing the excreting pan. The primary purpose of this is to create a private space for defecation. It also acts as a protective barrier against the weather and animals. It can be made of natural substances such as bamboo, dried leaves, etc., or manmade structures such as concrete, bricks, plastic, etc.

The pan facilitates temporary collection of faeces and also provides the user with a platform to sit/squat. Excreta pathway allows for the movement of faeces from the pan to a containment unit that is away from the user. This includes structures such as 'P traps' and conveyance pipes. Excreta pathways referred to in this document relate only to structures till the onsite containment unit and do not include sewerage networks.

### 3.1. Aerosan Toilet

#### A brief about the technology

Aerosan toilets use low-cost alternate materials for the superstructure which reduces the construction cost of toilets, making them affordable. These toilets can be built using easily available resources, making the installations cost-effective and quick. Hence they are suitable for mobile toilet installations and areas not covered with sewerage network.

#### Technology description and Working principles

Aerosan toilets use a low cost re-purposed vinyl billboard for the toilet structure. The vinyl is wound around a bamboo or steel framework using wires or adhesive to make the toilet wall. There is a large cylindrical vent pipe which is housed along with the main structure. This extends to a height of 3 to 5 meters or more from the toilet base, creating a passive ventilation channel for the faecal containment unit. The ventilation creates aerobic conditions inside the containment unit thereby enhancing the degradation of faecal matter. The ventilation system also helps in removing moisture from the faecal matter by dehumidifying the air within the containment system. This enables faster degradation of sludge. The dried degraded faecal matter can be used as manure.

#### Advantages and Disadvantages

Advantages:

- Low cost of construction
- Easy construction and maintenance
- Low weight, easy to install
- Odour-free dry toilet

Figure 3.1: Aerosan Toilet



- Pan style: Squat or pedestal
- Can be installed everywhere, without any specific site conditions
- Drying leads to lower faecal sludge accumulation rate, increasing the desludging frequency

#### Disadvantages:

- Appropriate care must be taken during rainy days in preventing water from entering into the containment system through the vent pipe
- Low height of the vent pipe can lead to presence of mosquitoes and flies

#### O&M Requirement

- The vinyl might tear due to operational abuse or windy conditions. Adequate repairs must be carried out as and when required
- Degraded faecal matter has to be removed from the containment structure below the toilet pan as and when it gets filled
- Application of ash or sand on the pan after every use is advised to prevent stink

#### Health and Acceptance

- Aerosan toilets provide a hygienic toilet environment through provision of a large vent pipe resulting in less odour, reduced occurrence of flies and mosquitos and dry faecal matter.
- As these toilets are dry systems, currently they do not have provision for water-based anal cleansing, hence acceptance in India will have to be assessed before application
- This system is ideal for humanitarian and development applications during emergencies and in water-stressed areas

#### Design factors

- The key design is the use of low-cost, light-weight, durable materials, in the form of re-purposed vinyl billboard fabric, to ensure both cost effectiveness and easy installation
- The larger vent pipe improves air circulation, decreasing odours, minimising the occurrence of flies and other insects and speeding up desiccation.
- These systems are easy to package and transport as broken down flat modules.

#### Manufacturer/Supplier details

- Organization Name: Aerosan
- Location: Halifax, Canada
- Email: info@aerosantoilets.ca

#### Cost

- The bamboo or steel frame and the vinyl fabric forms the major component of the cost. As the cost of these vary across geographies, actual costing will have to be worked out based on local conditions.

#### References

- Bill & Melinda Gates Foundation. (2014). Reinvent Toilet Fair India 2014 Technical guide. 1sted. [pdf]. Available at:

<https://docs.gatesfoundation.org/documents/Reinvent%20the%20Toilet%20Fair%20India%202014%20Technical%20Guide.pdf>

- aerosantoilets.ca, (n.d).Aerosan.[online]Available at: <http://www.aerosantoilets.ca/>
- <http://forum.susana.org/forum/categories/106-user-interface/3425-urban-sanitation-solutions-for-high-use-flooded-and-difficult-to-serve-areas-in-haiti-aerosan-usa-and-haiti>

## 3.2. Amalooloo

### A brief about the technology

Amalooloo is a dry toilet system with an innovative design that conserves water by separating liquid and solid wastes and by integrating the hand wash unit with the flushing cistern. It uses a unique system to combine the features of a normal flushing type toilet with a dry toilet. It does so by separating the faeces from urine and anal cleansing/flushing water after each flush. The separated faecal matter is collected and treated in an underground composting chamber whereas the separated liquid component can be treated onsite using plant based drainage system and safely discharged.

Amalooloo can be implemented in regions having water scarcity and where reuse of dried composted faecal matter is acceptable.

### Technology description and working principles

The Amalooloo sanitation system, being a dry aerobic composting system, completely separates at source all the urine, hand washing water, pedestal cleaning and anal cleansing water, leaving only the faeces in the pit. The faeces left behind decreases in volume due to dehydration and decomposition by natural microbial organisms, after which it can be reused as manure in farmlands. The gasses generated in the degradation process are let out through a vent pipe.



The innovatively designed Amalooloo Urine Diversion System allows for liquid separation at the bottom of the pedestal without any issues of blockage.

The flushing cistern is integrated with a hand wash arrangement, where spent water from hand wash is stored and used during the flushing cycle.

### Advantages and Disadvantage

Advantages:

- The total water usage per person per toilet use is reduced as the water used in hand wash is collected and reused for flushing
- Dry and degraded faecal sludge can be used as a soil conditioner

Disadvantages:

- Chances of wash water/flush water/urine mixing with separated faecal matter are possible. This would result in dry faecal matter becoming wet, creating odour and vector issues, as well as slowing down degradation of faecal matter
- Leaking urine conduits, blocked vent pipes or poor maintenance of the system could cause the faeces to become wet and stink, aid flies to breed and pathogens to survive.
- Poor maintenance of pipes carrying the liquid can lead to system dysfunction
- Capital costs are higher than an in-situ built toilet

### **O&M Requirement**

- Skilled contractors are required for emptying and scheduled servicing

### **Health and acceptance**

- Amalooloo provides for hand wash facilities and solid liquid separation that allows for a clean toilet and improved onsite treatment
- Reusing dried faeces and collected urine in agriculture is not so prevalent in India, as there is a social stigma attached to it.
- Regular de-sludging equipment available in India are not capable of removing dried excreta from containment pits, hence de-sludging might have to be done manually

### **Manufacturer**

- Betram (Pvt)Ltd South Africa

### **Cost**

- Cost per unit is 225 USD

### **References**

- Amalooloo.com, (2009). Amalooloo. [online] Available at: <http://www.amalooloo.com/>
- <http://www.ircwash.org/sites/default/files/Jong-2010-Gendered.pdf>

## **3.3. Precast Concrete Toilets**

### **A brief about the technology**

Precast concrete toilets use innovative manufacturing and assembling techniques to construct toilets at low cost and within a short period of time. The structure and floor of the toilet is manufactured at an offsite location in large quantities, thereby benefiting from economies of scale. These castings are then transported to the place of implementation and assembled for use.

### **Technology description and working principles**

Pre-casting is a method adopted in civil engineering to manufacture components offsite where there is easy access to raw materials and labour.

### **Advantages and Disadvantages:**

Advantages:

- Concrete toilets can be economically manufactured to desired strength

- Concrete toilets are extremely durable
- Concrete toilets can be economically built on site and cast to any desired shape

Disadvantages:

- Transporting precast modules are a delicate affair, which might lead to cracks and breakages
- Installation requires skilled supervision, as these modules are fragile, especially during the fastening process
- Requires plenty of manpower to move and install the modules at the place of installation

**Design Factor:**

- The base of these structures need to be made stable using soling. The floor also needs to be checked for its load carrying capacity.
- Anchoring of these modules to the ground is made by embedding a few inches of the structure within the soil, to allow the soil to support it (this hugely depends on the local wind and soil conditions).
- It is advisable to use fibre or plastic doors, as precast concrete doors are heavy to use and cannot withstand operational abuse.

**Manufacturer**

- 3E-SERVICES
- #154 2nd 'A' Cross 6th Main  
7th Block, Nagarabhavi, 2nd Stage  
Bengaluru- 560072  
Contact No: +91 9945562870

**References**

- Conloo.co.za, (n.d). ConLoo. [online] Available at: <http://www.conloo.co.za>
- Indiaprecast.com, (n.d). Precast Toilet Block. [online] Available at: <http://indiaprecast.com/wall-panel/toilet-block.html>

**3.4. Earth Auger Composting Toilet**

**A brief about the technology**

Earth Auger Composting toilets are urine-diverting, composting toilets with innovation in the excreta pathway that does away with bad odour and the need to manually apply filler material before and after usage. The design innovation here sees an offset composting chamber away from the pan and provides mechanised means to discharge saw dust in the composting heap.

**Technology description and working principles**

Earth Auger Composting toilets have a normal pan arrangement (typically platform type) with modifications below the pan for conveyance of faeces and filler material. The pan also has an arrangement for separation of urine and faecal matter.

Below the pan is a screw conveyor (auger) to carry faecal matter from the pan to the composting chamber. Next to the pan is a pedal, which is connected to the conveyor. A storage chamber to store the filler material like saw dust or ash is also provided. The screw conveyor extends all the way from this storage bin to the

composting chamber, passing below the pan. Hence, it carries with it both the filler material and faeces. Urine is collected separately in containers outside of the system.

After using the toilet, the pedal is used to move the filler material and faeces to the composting chamber. The screw conveyor has knife blades mounted on it to help mix the filler material and faeces. Usually sawdust is recommended as filler material considering its richness in carbon, which makes the composting process faster and hence aids active reuse of end product.

The composting process takes around 4–5 months' time after which the end product can be used as a soil conditioner or manure. Collected urine can be harvested as a fertiliser for farming or can be disposed along with grey water.

### Advantages and Disadvantage

Advantages:

- The system eliminates the need for manual addition of sawdust/ash
- There is no foul odour while using the toilet, as the composting chamber is offset from the pan
- Mechanised application using human movement, reducing the reliance on external energy.
- Enhanced composting is ensured as there is proper mixture of excreta and saw dust

Disadvantages

- This system is designed for the wiping community, there is no arrangement for separation of anal cleansing water
- Thick faeces can get stuck to the screw conveyor leading to blockage and odour

### Design considerations

- The composting chamber has to be designed keeping in mind the retention time and loading rate
- The toilet has to be built on a raised platform to accommodate the auger and for easy removal of solids from composting chamber
- Anal cleansing water when mixed with faeces can increase the composting period of the faeces; hence the chamber has to be designed appropriately
- Urine to be collected in transparent containers which makes it possible to see how full the container is.

### Manufacturer

- Fundación in Terris

### Material:

- Pan and composting chamber is made of wood, and the screw conveyor is made of steel

**Figure 3.3:** Earth auger toilet under construction



## References

- Bill & Melinda Gates Foundation, (2012). Reinvent Toilet Fair program. 1st ed. PDF available at: <http://www.gatesfoundation.org/~media/Reinvent-the-Toilet-Fair-Program.pdf>
- Fioravanti, M. (2013). The Earth Auger Toilet: Innovation in waterless sanitation. [online] Sustainable Sanitation Alliance. Available at :<http://www.susana.org/en/resources/library/details/1779>

## 3.5. Ecosan Pan

### A brief about the technology

Ecological sanitation systems (Ecosan) are toilets that ensure separate collection of urine, faecal matter and anal cleansing water for reuse. These toilets allow for the safe recycling of nutrients to crop production in such a way that the use of non-renewable resources is minimised. The innovative aspect of the toilet is the separate anal cleansing water collection mechanism that has been designed keeping in mind the 'washers' community.

These systems have a strong potential to be sustainable sanitation systems if technical, institutional, social, and economic aspects are managed efficiently and appropriately.

### Technology description and working principles

Ecosan toilets have a pan arrangement with three openings, one for faeces, second for urine and third for anal cleansing water. The openings are placed as per the squatting style of the user. This pan is usually constructed above a composting chamber with the hole for excreta placed at the centre of the chamber. Urine and anal cleansing water are collected separately through means of a pipe and are conveyed away from the composting chamber. There are usually two composting chambers with a partition wall, along with two pan arrangements above them. The excreta hole is covered using a cap or any locally available material to keep out insects and eliminate foul odour dissemination both of which cause inconveniences to users.

Users in this system defecate by squatting over the pan. The opening in the front collects urine which is conveyed to a separate collection unit such as a can or bottle. After defecating the user has to apply a handful of ash or sawdust on the faeces to prevent bad odour and breeding of insects. The anal cleansing water is collected from the posterior portion of the pan and conveyed to a plant box (an arrangement similar to reed bed system) for treatment.

Composting chambers are designed for containing the faecal matter for an operational time of 6 to 12 months and resting time of 6 months (this is when the filled composting chamber is left for a certain period to allow for complete composting. During this time, an alternate chamber with pan arrangement is used). After a period of 12 to 15 months, the faecal matter turns into rich manure that can be used for farming. Collected urine can be mixed with water and applied as fertiliser for plants. Anal cleansing water after treatment can be allowed to percolate through the ground.

**Figure 3.4:** ECOSAN pans with separate openings for faeces, urine and anal cleansing water



## Advantages and Disadvantages

### Advantages

- Ecosan toilets do not require a constant source of water
- This toilet has no real issues with flies or odours if used and maintained correctly
- Toilets can be built and repaired with locally available materials
- It has low capital and operating costs

### Disadvantages

- It requires the user to change posture while anal cleansing
- It requires training and acceptance by the user for proper usage
- Removal of compost from the chamber is done manually, which might lead to manual scavenging

## Health and acceptance

- Ecosan system works as an alternative to leach pit toilets in places where water is scarce or where the water table is high to avoid groundwater contamination
- The toilet is based on the principle of recovery and recycling of nutrients from excreta to create a valuable resource for agriculture. Users or the community must be willing to use composted faecal matter as manure for farming. Social prejudices may prevent the user from adopting this toilet

## Cost:

- ₹16,000 for a toilet with cement and brick superstructure. (Based on local availability of resources and labour)

## Manufacturer:

- EcoSan
- Ernst Tiedt. G-TRADE INTERNATIONAL C.C.  
P.O. Box 71755, The Willows, 0041 Pretoria, Gauteng, South Africa  
Tel. +27 12 8075002. Cell. +27 82 5574979. Fax. +27 12 8075002  
e-mail - info@ecosan.co.za

## Material:

- Pans can be prefabricated or built in cement structures during construction. Prefabricated pans are not easily available in the market. They are usually made from FRV.

## References

- Eco-solutions.org, (2006). eco-solutions. [online] Available at: [www.eco-solutions.org](http://www.eco-solutions.org)
- Environment and public health organisation. (June 2007). Technical manual for creating eco-san toilets. [online]. Available at: [http://www.ewb.org.au/resources/download/1406P2010-11-18\\_19:47:47/L](http://www.ewb.org.au/resources/download/1406P2010-11-18_19:47:47/L)
- Gupta, A. (2014). Ecosan toilets- an alternative to conventional sanitation in vulnerable locations. [online] Water Aid. Available at: <http://www.wateraid.org/news/news/ecosan-toilets>

### 3.6. E-Toilet

#### A brief about the technology

E-toilets are self-cleaning and self-flushing pre-fabricated toilets that have revolutionised public toilets by providing a pleasant experience to users. Public toilets are traditionally plagued with poor operation and maintenance, and adding to this is the poor monitoring mechanism of operators which leads to unclean and miserable user experience. E-toilets have addressed this concern by providing man-less operation and remote monitoring of the system to ensure that a user has a comfortable experience every single time.

#### Technology description and working principles

E-Toilets use state-of-the-art technology from electronics and communication in ensuring that these toilets are maintained after every use. Here, the pans are flushed and floor washed automatically, thus avoiding bad odour. All users have access only on payment of a minimal fee. Every aspect of the toilet is monitored using sensors and communication devices from a central location by the original equipment manufacturer, from where maintenance decisions are taken.

Figure 3.5: E-toilet



The E-Toilet incorporates the full-cycle approach in sustainable sanitation by integrating convergence electronics, mechanical, web-mobile technologies, thereby controlling entry, usage, cleaning, exit, and remote monitoring capabilities with multiple revenue options.

These toilets work as follows:

- The user has to insert a coin
- The door opens automatically
- The sensor-based light system is turned on once the user enters the toilet
- The inset programme flushes 1.5 litres of water after three minutes of usage and 4.5 litres if the usage is longer.
- The toilet is also programmed to clean the platform on its own after the toilet has been used by 5 or 10 persons.
- An audio message guides the user through the entire process. An instructional note is also pasted outside the toilet to help the user get familiar with the functioning of this toilet.

The outputs from these toilets are either connected to onsite treatment units or sewerage network, based on the location and availability.

#### Advantages and Disadvantages

Advantages:

- These systems are built on the principles of water conservation
- The system is completely automated ensuring standard user interface after every use.
- Monitoring remotely saves supervision cost and ensure better management of assets

Disadvantages:

- Some components in the system can be damaged during abuse by users and other miscreants.
- These toilets have high capital cost and require continuous supply of electricity.

## O&M Requirement

- The service team conducts periodic visits to the toilets for maintenance and repairs
- Critical aspects of the toilets are remotely monitored and decisions are taken using a central control unit
- It requires continuous supply of electricity to run systems, failures lead to incomplete processes, thereby temporarily bringing a halt to services.

## Health and Acceptance

- The technology could put off laggards and others who are not comfortable using these instruments.
- Improper understanding of how to use the toilet can lead to people abusing the facility and damaging it. This will have severe cost implications.

## Design factors

- **Automatic Sterilisation:** Automatic sterilisation of toilet seat covers with the help of UV and steam treatment methods
- **Power Flushing:** Pressure assisted vacuum sucking mechanism developed for toilet flushing to minimise the amount of water.
- **Water minimisation using sensor-enabled systems** allows the amount of water utilised for each flush to be varied and kept to the minimum
- **Self-washing and cleaning:** Automatic cleaning of toilet bowls and floor with the help of water injection systems

Figure 3.6: E-toilet installed at parks in Bangalore



## Manufacturer/Supplier details

- Eram Scientific, Kerala

## Cost:

- ₹1 lakh–3.75 Lakh for each toilet system

## References

- Eram scientific.com, (n.d). Eram scientific. [online] Available at: <http://www.eramscientific.com/>
- Pareek, S. (2014). This e-toilet is changing the way the public sanitation works in India. The better India, [online]. Available at: <http://www.thebetterindia.com/13940/etoilet-changing-way-public-sanitation-works-india-eram-marico/>

### 3.7. Ferrocement toilets

#### A brief about the technology

Ferrocement is a construction material which is light, durable, and mouldable. The material makes it possible for a large number of toilets to be installed quickly, especially in situations such as post disaster rehabilitation. Ferrocement toilet structures are built offsite, transported using small vehicles, and installed wherever required. These are similar to prefabricated concrete structures except for the fact that these weigh less and hence, are easy to transport.

#### Technology description and working principles

Ferrocement uses chicken mesh or other smaller rebar's that act as reinforcement for mortar such as cement and gives the structure strength and durability with lesser weight. Ferrocement toilets are built module by module offsite and later assembled together on site. The pans used in these structures are also precast ferrocement structures.



Casting at a central location takes advantage of economies of scale thereby reducing manufacturing cost. Transportation costs are also kept minimal due to the small size of modules and less weight, making these an ideal alternative for low cost toilet construction.

#### Advantages and Disadvantages

Advantages:

- Raw materials are easily available
- It is easy to transport and handle
- Installation is easy and quick
- It is a low-cost alternative for toilet construction

Disadvantages:

- It requires setting up a manufacturing unit for casting
- Improper manufacturing can lead to rusting of reinforcement, reducing the life of the structure
- Installation requires skill as these materials are brittle and can break if not handled properly.

#### O&M Requirement

- It is easy to repair and virtually no maintenance is required
- The doors are built using ferrocement and can break due to operational abuse
- Structures can develop cracks due to extreme climate changes

Cost:

- Low-cost toilet made using Ferrocement is at ₹12,400 per unit

## References

- Weerasinghe, W.(2009). Ferro cement toilet. [online] Available at: <http://ferrocement.net/flist/index.php?topic=130.0>
- www.ferrocement.info,(n.d) Ferro Cement Resource center. [online] Available at: <http://www.ferrocement.info/projects/toilets>

### 3.8. Fresh life Toilet-Sanergy Model A brief about the technology

Sanergy is an organisation which has built low-cost toilets called Fresh Life Toilets. Made of precast structures such as concrete and Ferrocement, these toilets are equipped with appropriate systems for collection and treatment of faecal waste. The design innovation removes the need for a permanent containment structure at the household level thereby reducing the footprint, making it a favourable option for densely populated areas and slums. It has also used localised business models to provide access to improved sanitation for low-income households.

#### Technology Description and working principles

These toilets do not have permanent containment structures such as pits; rather, they use temporary containers such as plastic buckets or vessels. These vessels are emptied on a regular basis by the entrepreneur.

The toilet has a separate collection facility for faeces and urine, made possible by the urine diversion mechanism adopted in the pan design. The pan is made using low cost, yet highly durable plastic. The separately collected waste products are carried to a central processing facility where the faeces are composted and turned into manure. Urine on the other hand is used for farm applications after diluting with water.

The model runs on a franchise basis, where interested entrepreneurs can take up toilet construction and provide cleaning and collection services for a fee under a brand name. The franchise model under the brand name of Sanergy ensures that standard services are provided to the end-user at affordable cost.

Prefabrication is carried out at local centres by the entrepreneurs who undergo training from the Sanergy team. They use locally available materials and labour for manufacturing, ensuring that costs are kept low and employment opportunities are provided to the community.

#### Advantages and Disadvantages

##### Advantages

- It is made of high-quality materials that are easy to keep clean and maintain.
- It has a small footprint that enables installation in slums and densely populated household areas.
- It is cost-effective and includes essential features like hand-washing facilities in the toilet design.

##### Disadvantages

- It requires periodic de-sludging resulting in increase in cost of maintenance

Figure 3.8: Sanergy pans using high quality materials



- Business models become unfavourable in areas with scattered households
- If the containment unit is not de-sludged regularly, it can hinder the normal usage of toilets

#### **O&M Requirement.**

- Households must regularly de-sludge the containment unit
- Local entrepreneurs provide periodic O&M of the system
- Operators carry out functions such as cleaning the toilet pan, collection and transporting waste as well as managing the composting facility
- The central composting facility requires skill to operate.

#### **Cost:**

- The toilets are sold at cost at USD 500, which includes installation, painting and daily waste collection.

#### **Promoter:**

- Sanergy
  - Email: [info@saner.gy](mailto:info@saner.gy)

#### **Material:**

- Prefabricated Concrete structures and high quality plastic pans

#### **References**

- Mulupi, D (2013). Fresh Life toilets: A small business project and social initiative. [Online] how we made it in africa.com. Available at: <http://www.howwemadeitinafrica.com/fresh-life-toilets-a-small-business-project-and-social-initiative/>
- Manson, M. (2013). Sanergy's Fresh Life squat toilets tackle Kenyan poverty. [online] ft.com. Available at: <http://www.ft.com/cms/s/0/3dce051a-48a7-11e3-8237-00144feabdc0.html#axzz425KtrFM0>

### **3.9. Namma Toilet**

#### **A brief about the technology**

Namma Toilet is an initiative by the Commissionerate of Municipal Administration, Tamil Nadu along with participation of Urbane Industries Ltd. to eradicate open defecation in the State. Namma Toilets are public infrastructure built for mobile populations and communities. These toilets use innovative design and materials to reduce O&M cost, thereby increasing the operational life of the asset. Compared to regular public toilets these are easier to clean, maintain and also are resilient to operational abuse.

**Figure 3.9:** Namma toilet installed at public places



### **Technology description and working principles**

Namma toilets use prefabricated FRV materials for construction. Design considerations such as round edges, easy cleaning floor, durable doors, latches, etc., contribute to the success of this innovation. It is widely endorsed by the Government of Tamil Nadu for installation in public places.

Namma Toilets are user friendly with a stall each for elderly and disabled people. They have digesters to process the sewage at places where sewerage connection is not available. Solar powered sensor based automated LED lights (3W) light up the toilets when stalls are occupied at night. Each toilet pan is provided with a flushing cistern outside the superstructure, but the knob to operate it is placed inside to prevent damage and abuse to cistern equipment.

These toilets come equipped with a hand washing facility and overhead tank for water storage and dispensing. Since these toilets do not charge the user a fee, they do not require manpower at each facility to manage money and maintain assets. Contractors/ sanitary workers from the UIB visit periodically to clean and maintain these toilets.

### **Advantages and Disadvantage**

Advantages:

- The toilet is designed thoughtfully ensuring easy cleaning of surfaces and floor.
- Since the system is a pre-fabricated/modular one, it is easy to install.
- The plumbing work is not visible, thereby preventing vandalism
- The toilet's design considers access for the physically disabled

Disadvantages:

- This toilet does not have an economically sustainable operating model, as no revenue is generated for cleaning and maintaining the facilities.

- These facilities are used for unlawful activities such as smoking and drinking owing to lack of constant supervision.

### **O&M Requirement**

- The ULB assigns cleaning and maintenance to contractors/sanitary workers
- The toilets are periodically cleaned throughout the day by a mobile team visiting such toilets throughout the region, ensuring fewer O&M staff per toilet
- Only basic cleaning materials are required

### **Cost:**

- The average cost per (single seat toilet) unit ranges from ₹2.30 Lakhs to ₹2.90 Lakhs

### **Promoter:**

- Vega Aviation Pvt Ltd. Belgaum. Karnataka

### **Material:**

- Fibre Reinforced Polymer.

### **References**

- Chennai: exposure visit to Namma toilet (n.d). Chennai – exposure visit to Namma toilet. 1st ed.[pdf]. Available at: [http://www.apmepma.gov.in/files/ap\\_1497.pdf](http://www.apmepma.gov.in/files/ap_1497.pdf)
- www.cleanindiajournal.com,(2013) Solar toilets. Clean India journal, [online]. Available at: <http://www.cleanindiajournal.com/solar-toilets>

## **3.10. SaTo Pan**

### **A brief about the technology**

The SaTo pan is an inexpensive innovation designed to be fixed in toilets in poor households in cultures where squatting and pour flush latrines are the norm. Unlike the typical latrine pan, the SaTo pan uses plastic instead of concrete or ceramic. The SaTo Pan system consists of a trap door design, with an auto seal at the bottom of the pan, which opens up after toilet usage and allows for the transfer of faecal matter to a containment unit through a pipe.

### **Technology description and working principles**

The SaTo pan is a low-cost squatting device, made from plastic with an inbuilt auto-seal arrangement. The pan is usually fixed along with the toilet floor during construction. The seal uses a counter weight arrangement to regulate the flow of faeces from pan to containment system. A lever arrangement is provided at the outlet of the pan, and this lever is held in place by a weight (cement block or stone) that is added to its extended arm. The seal usually remains closed because of the weight. After using the toilet and flushing, the mixture attains a set weight by which the seal opens and the constituents are transferred to a containment unit through a pipe.

Traditional toilet designs employ a 'p' or 's' trap, which requires water for the seal arrangement. At places where the pan is directly above the pit, a hole is provided for disposal. In both the cases, i.e., where the toilet is directly above the toilet without a seal, or in toilets with a liquid seal, there are issues related to odour, insects and excessive usage of water respectively.

SaTo pan addresses this issue by providing a self-sealing arrangement that can be used for containment systems located either directly below the pan or units located away from the pan.

### Advantages and Disadvantages

Advantages:

- Low cost of the pan and seal
- It is self-sealing without the usage of water, and can be used in places where water is hardly available.
- The surface of the pan is easy to clean and smooth

Disadvantages:

- Can only be installed where squatting system of toilets are preferred
- If the trap breaks, then it is very difficult to repair as it is below the superstructure
- Faeces can leave stain on the trap door causing odour and attracting insects

**Figure 3.10:** Sato pan illustrating the seal arrangement



### O&M Requirement

- Requires periodic washing of the pan and trap door.

### Health and Acceptance

- This toilet can be installed where the squatting type of toilet is preferred and water availability is a constraint
- Ideal choice for pan above the pit type of toilets

### Manufacturer/Supplier details

- iDE Bangladesh  
No:+8801755524033  
Email: [conor.riggs@ide-bangladesh.org](mailto:conor.riggs@ide-bangladesh.org)  
Skype: conor.riggs

### Cost:

- The cost of this system is around USD1.50 per unit

### References

- [www.wateraid.org](http://www.wateraid.org), (n.d). Wateraid. [online] Available at: [www.wateraid.org](http://www.wateraid.org)
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**Table 3.1: User Interface - Summary**

| SI. No. | ASSESSMENT CRITERIA  | INDICATOR                                  | INFORMATION REQUIREMENT   | ASSESSMENT OUTCOME                                    | (A) Aerosan Toilet            | (B) Amalooloo                 | (C) Precast Concrete Toilets  | (D) Earth Auger Composting Toilet | (E) Ecosan Pan                | (F) E-Toilet                  | (G) Ferrocement toilets       | (H) Fresh life toilet-Sanergy model | (I) Namma Toilet              | (J) SaTo Pan                  |
|---------|----------------------|--|---|---|-------------------------------|-------------------------------|-------------------------------|-----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------------|-------------------------------|-------------------------------|
| 1       | Regulatory standard  | Organic load reduction in treated effluent | BOD, COD of influent and effluent   | Yes / No / Information not available / Not applicable | Information is not available.     | Information is not available. | Information is not available. | Information is not available. | Information is not available.       | Information is not available. | Information is not available. |
| 2       | Regulatory standard  | Total Solid reduction in treated effluent  | TS, TDS of influent and effluent  | Yes / No / Information not available / Not applicable | Information is not available.     | Information is not available. | Information is not available. | Information is not available. | Information is not available.       | Information is not available. | Information is not available. |
| 3       | Regulatory standard  | Pathogen reduction in treated effluent     | Helminths egg, E. coli of influent and effluent   | Yes / No / Information not available / Not applicable | Information is not available.     | Information is not available. | Information is not available. | Information is not available. | Information is not available.       | Information is not available. | Information is not available. |
| 4       | Regulatory standards | CPCB standards for discharge/reuse         | Is the end product, emissions, and effluent characteristic as per CPCB (2015) standards for discharge/ reuse? | Yes / No / Information not available / Not applicable | Not Applicable.               | Not Applicable.               | Not Applicable.               | Not Applicable.                   | Not Applicable.               | Not Applicable.               | Not Applicable.               | Not Applicable.                     | Not Applicable.               | Not Applicable.               |

**Table 3.1: User Interface - Summary**

| SI. No. | ASSESSMENT CRITERIA          | INDICATOR     | INFORMATION REQUIREMENT  | ASSESSMENT OUTCOME                                    | (A) Aerosan Toilet                                     | (B) Amalooloo   | (C) Precast Concrete Toilets  | (D) Earth Auger Composting Toilet   | (E) Ecosan Pan  | (F) E-Toilet  | (G) Ferrocement toilets   | (H) Fresh life toilet-Sanergy model | (I) Namma Toilet  | (J) SaTo Pan  |
|---------|------------------------------|---------------|--|---|--|---|-------------------------------|---|---|---|---|-------------------------------------|---|---|
| 5       | Health and safety of workers | Human Contact | Are there any activities or procedures that can lead to contact of sludge with humans?       | Yes / No / Information not available / Not applicable | Yes, manual removal of dried fecal sludge is required. | Yes, manual desludging of dried excreta is required.        | Information is not available. | Yes, removal of compost from the chamber is done manually, which might lead to manual scavenging. | Yes, removal of compost from the chamber is done manually, which might lead to manual scavenging. | No there is no human contact with the sludge.           | Yes, removal of compost from the chamber is done manually, which might lead to manual scavenging. | Not Applicable.                     | Yes, cleaning and maintenance is carried out by contract personnel assigned for this role by the ULB or sanitary workers. | Yes, removal of compost from the chamber is done manually, which might lead to manual scavenging. |
| 6       | Health and safety of workers | Spillage      | Does the sludge/effluent spill in and around the operational area?                           | Yes / No / Information not available / Not applicable | Yes, leaking pipes or poor O&M may cause spillage.     | Yes, leaking urine conduits or poor O&M may cause spillage. | Information is not available. | Information is not available.   | Yes, there are chances for the urine spillage if its not handled properly.                        | No, there is no spillage.                               | Information is not available.   | Information is not available.       | Information is not available.   | Information is not available.   |
| 7       | Health and safety of workers | Impact        | Does the technology have negative impact on the health and safety conditions of the workers? | Yes / No / Information not available / Not applicable | Information is not available.                          | Information is not available.                               | Information is not available. | Information is not available.   | Information is not available.   | No, there is no negative impact on the workers' health. | Information is not available.   | Information is not available.       | Information is not available.   | Information is not available.   |

**Table 3.2: User Interface - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR                    | INFORMATION REQUIREMENT  | (A) Aerosan Toilet  | (B) Amalooloo   | (C) Precast Concrete Toilets  | (D)Earth Auger Composting Toilet   | (E) Ecosan Pan  | (F) E-Toilet                  | (G) Ferrocement toilets  | (H) Fresh life toilet- Sanergy model  | (I) Namma Toilet              | (J) SaTo Pan   |
|---------|---------------------|------------------------------|--|---|---|---|--|---|-------------------------------|--|---|-------------------------------|--|
| 1       | Design              | Trash screening              | Does the system have a mechanism to manage trash present in FS?  | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.                              |   |                               |  |   |                               |  |
| 2       | Design              | Material of the wetted parts | What is the Material of Construction? Does the material used minimize weight, durability, corrosion vulnerability? | Low cost re-purposed vinyl billboard is used for the toilet structure. The vinyl is wound around a bamboo or steel framework using wires or adhesive to make the toilet wall. Any other information is not available. | Information is not available.                             | The structure and floor of the toilet is manufactured at an offsite location in large quantities, thereby benefiting from economies of scale. These castings are then transported to the place of implementation and assembled for use. | Pan and composting chamber is made of wood, while the screw conveyor is made of steel. | Pans can be prefabricated or build in cement structures during construction. Prefabricated pans are not easily available in the market. They are usually made from FRV. | Information is not available. | Ferro cement is a construction material which is light, durable and mouldable. It is advisable to use fibre or plastic doors, as precast concrete doors are heavy to use and cannot withstand operational abuse. | Made of precast structures such as concrete and Ferrocement, these toilets are equipped with appropriate systems for collection and treatment of fecal waste. | Information is not available. | SaTo pan is a low- cost squatting device, made from plastic with an inbuilt auto-seal arrangement. |
| 3       | Design              | Space requirement            | Minimum dimensions occupied by the system, Land area needed, Top surface usability                                 | Information is not available.   | Information is not available.                             | Information is not available.   |  |   |                               |  |   |                               |  |

**Table 3.2: User Interface - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR                 | INFORMATION REQUIREMENT   | (A) Aerosan Toilet  | (B) Amalooloo  | (C) Precast Concrete Toilets   | (D)Earth Auger Composting Toilet   | (E) Ecosan Pan   | (F) E-Toilet    | (G) Ferrocement toilets   | (H) Fresh life toilet- Sanergy model  | (I) Namma Toilet   | (J) SaTo Pan    |
|---------|---------------------|---------------------------|---|---|--|--|--|--|-----------------|---|---|--|-----------------|
| 4       | Design              | Reusability of the sludge | Can the decanted sludge be directly reused?   | Yes, the dried and degraded fecal matter can be directly reused as manure.  | Yes, the dried composted fecal matter can be directly reused.      |  | The composting process takes around 4-5 months after which the end product can be used as a soil conditioner or manure.<br><br>Collected urine can be harvested as a fertilizer for farming or can be disposed of along with grey water. | Yes, but the users or the community must be willing to use composted fecal matter as manure for farming. |                 |   |   |  |                 |
| 5       | Design              | Design life               | What is the actual / economic life of the equipment?  | The system life expectancy is 4-8 yrs   | Pit lifespan increases between 20-40 years if maintained correctly | Not Applicable.  | Not Applicable.  | Not Applicable.  | Not Applicable. | Not Applicable.   | Not Applicable.   | Not Applicable.  | Not Applicable. |
| 6       | Design              | Uniqueness                | Does the technology address a problem which is not addressed by any of the existing technologies? | The use of low-cost, light-weight, durable materials, in the form of re-purposed vinyl billboard fabric, is unique. | The hand wash unit linked to the flushing cistern, is unique.      | Concrete toilets can be economically built on site and cast to any desired shape | The design innovation here sees an offset composting chamber away from the pan and provides mechanized means to discharge saw dust in the composting heap.   |  |                 | Ferro cement uses chicken mesh or other smaller rebars that act as reinforcement for mortar such as cement and gives the structure strength and durability with lesser weight | The design innovation removes the need for a permanent containment structure at the household level thereby reducing the footprint. | Namma Toilets are user friendly with a stall each for elderly and disabled people. They have digesters to process the sewage at places where sewerage connection is not available. |                 |

**Table 3.2: User Interface - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR                        | INFORMATION REQUIREMENT  | (A) Aerosan Toilet   | (B) Amalooloo   | (C) Precast Concrete Toilets | (D)Earth Auger Composting Toilet   | (E) Ecosan Pan  | (F) E-Toilet   | (G) Ferrocement toilets                                  | (H) Fresh life toilet- Sanergy model  | (I) Namma Toilet  | (J) SaTo Pan  |
|---------|---------------------|----------------------------------|--|--|---|------------------------------|--|---|--|--|---|---|---|
| 7       | Design              | Power                            | What is the net energy requirement/generation? What is the source of power for the operation? State type, capacity and power consumption | No external source of power is needed for the operation. The other details are not available.  | No external source of power is needed for the operation. The other details are not available. |                              | No external source of power is needed for the operation.                             | No external source of power is needed for the operation.  | Yes, E-Toilet incorporates the full-cycle approach in sustainable sanitation by integrating convergence electronics, mechanical, web- mobile technologies, thereby controlling entry, usage, cleaning, exit, and remote monitoring capabilities with multiple revenue options. | No external source of power is needed for the operation. | No external source of power is needed for the operation.  | Sensor based automated LED lights (3 W) working on solar power light up the toilets when it is dark and when the stalls are occupied. |   |
| 8       | Economics           | Economic value and cost recovery | What is the economic value / possible revenue stream during operation to the user and operator?  | The revenue will be from the reuse of dried degraded fecal matter as manure.   | The revenue will be from the reuse of dried compost and stored urine in agriculture.          |                              | The revenue will be from the reuse of dried compost and stored urine in agriculture. | The revenue will be from the reuse of dried compost and stored urine in agriculture.                                |  |  |   |   |   |
| 9       | Economics           | CAPEX                            | What is the capital cost of the system?  | The cost involved is usually with the bamboo or steel frame and the vinyl fabric. As the cost of these vary across geographies, actual costing will have to be worked out based on local conditions. | The cost per unit is 225 USD.   | Not Applicable.              | Not Applicable.  | Rs.16,000 for a toilet with cement and brick superstructure . (Based on local availability of resources and labour) | Rs. 1 lakh- 3.75 lakh for each toilet system.  | Low cost toilet of Ferro cement at Rs.12,400 per unit.   | The toilets are sold at cost for USD 500, which includes installation, painting and daily waste collection. | Average cost per single seat toilet unit ranges from Rs.2.30 lakhs to Rs. 2.90 lakhs  | The cost of this system is around 1.50 USD per unit |

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| SI. No. | ASSESSMENT CRITERIA | INDICATOR  | INFORMATION REQUIREMENT   | (A) Aerosan Toilet  | (B) Amalooloo   | (C) Precast Concrete Toilets  | (D) Earth Auger Composting Toilet   | (E) Ecosan Pan  | (F) E-Toilet | (G) Ferrocement toilets  | (H) Fresh life toilet- Sanergy model  | (I) Namma Toilet  | (J) SaTo Pan |
|---------|---------------------|--|---|---|---|---|---|---|--------------|--|---|---|--------------|
| 10      | Economics           | OPEX   | What is the operational cost of the system per capita / per volume of input sludge?   | Information is not available.   | Information is not available.   |   |   |   |              |  |   |   |              |
| 11      | Ease of O&M         | Moving equipment                                   | Are there moving parts or devices which require frequent maintenance affecting operation continuity?                            | Information is not available.   | Yes, there are moving parts in the system, in the handwash unit with flushing cistern.                      |   |   |   |              |  |   |   |              |
| 12      | Ease of O&M         | Skill and spares for local repairs and maintenance | What are the skill sets required by the operator? Are skills and spares available locally for repairing or servicing equipment? | Repair of torn vinyl due to operational abuse or windy conditions, is required. Removal of degraded fecal matter from containment structure below toilet pan as and when it gets filled. The other details are not available. | Skilled contractors are required for emptying and scheduled servicing. The other details are not available. | Installation requires skilled supervision, as these modules are fragile, especially during the fastening process. | Requires skill to operate the central composting facility.                          | Toilets can be built and repaired with locally available materials.                       |              | Installation requires skill as these materials are brittle and can break due to improper handling. | Prefabrication is carried out at local centres by the entrepreneurs who undergo training from the Sanergy team. They use locally available materials and labour for manufacturing, ensuring that costs are kept low and employment opportunities are provided to the community. | Requires skill to operate the central composting facility |              |
| 13      | Performance         | Odour in the decanted sludge and treated effluent  | Is there any odour from sludge or in the treated effluent?  | Yes, if ash or sand is not applied on the pan after every use or due to low height of the vent pipe, odour issue will be there.   | Yes, if the wash water/flush water/urine mixes with separated fecal matter, odour issue will be there.      |   | Yes. Thick feces can get stuck to the screw conveyor leading to blockage and odour. | No. This toilet has no real issues with flies or odours if used and maintained correctly. |              |  |   |   |              |

**Table 3.2: User Interface - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR     | INFORMATION REQUIREMENT   | (A) Aerosan Toilet  | (B) Amalooloo  | (C) Precast Concrete Toilets  | (D)Earth Auger Composting Toilet | (E) Ecosan Pan | (F) E-Toilet  | (G) Ferrocement toilets | (H) Fresh life toilet- Sanergy model | (I) Namma Toilet | (J) SaTo Pan |
|---------|---------------------|---------------|---|---|--|---|----------------------------------|----------------|---|-------------------------|--------------------------------------|------------------|--------------|
| 14      | Replicability       | Manufacturing | Who can manufacture or assemble these systems? Are skills and resources locally available in the market to manufacture these systems? | Information is not available.   | It is mentioned that it can be easily constructed making use of local labour. Any other informations is not available.   | It uses innovative manufacturing and assembling techniques to construct toilets at low cost and within a short period of time.<br><br>The structure and floor of the toilet is manufactured at an offsite location in large quantities, thereby benefiting from economies of scale. These castings are then transported to the place of implementation and assembled for use. |                                  |                | Every aspect of the toilet is monitored using sensors and communication devices from a central location by the original equipment manufacturer, from where maintenance decisions are taken. |                         |                                      |                  |              |
| 15      | Innovation          | Performance   | Is this technology or similar technology tried elsewhere? Is there a significant impact of innovation on performance?                 | Yes, the technology has been tried elsewhere. The units are easy to pack and transport as broken down flat modules. | Yes, the technology has been tried elsewhere. The total water usage per person per toilet use is reduced as the water used in handwash is collected and reused for flushing. |   |                                  |                |   |                         |                                      |                  |              |

# Containment Systems

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## 4. Containment Systems

On-site sanitation refers to a system where storage facilities are contained within the plot occupied by a dwelling and its immediate surroundings. For some systems, (e.g., double-pit or vault latrines), faecal matter treatment is conducted on site or by extended in-pit consolidation and storage. Containment refers to any structure that stores black or grey water on a temporary basis before it is collected and transported for treatment. Although there is a certain level of treatment based on the type of technology, the main purpose of these systems is to safely contain the wastewater generated onsite.

The containment systems in this Compendium are classified based on a number of parameters to help the reader understand and classify the systems as per their needs.

The technologies are classified based on type of system

1. Dry or wet systems;
2. Nature of influent wastewater to the containment system— Urine, Excreta, Grey water and Black water.

They can also be categorised as per the treatment process that occurs during the storage period— biological/composting, chemical and electro-mechanical.

Maintenance is also indicated as an important factor to help the user get an idea about the O&M requirement for each system.

### 4.1. DRDO Bio-tank/Bio-digester A brief about the technology

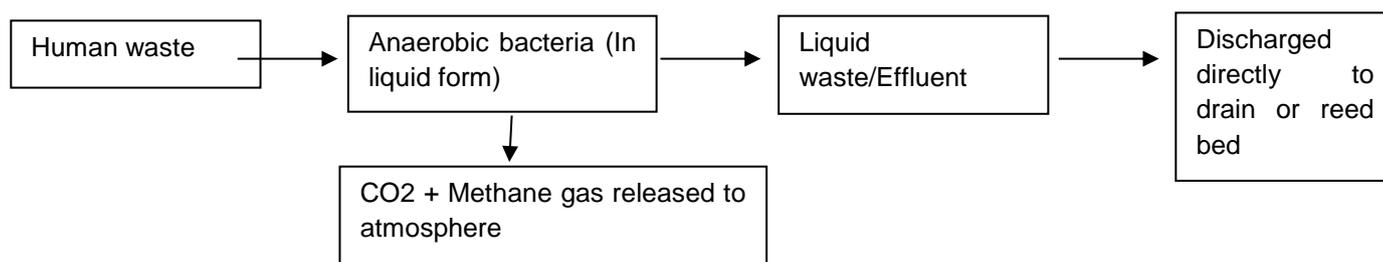
The Defence Research and Development Organisation (DRDO) has developed a technology using bacterial inoculums for sewage treatment under diverse geo-climatic conditions. The zero waste bio-tank/bio-digester technology breaks down human excreta completely into usable water and gas through anaerobic process. While the bio digesters are shells made up of FRP/steel, the bio-tanks are made up of masonry/concrete. It does not have any geographical or temperature limitation and also does away with the need to set up large sewage tanks and regular sludge cleaning. These units serve as excellent low cost alternatives to the conventional septic tanks used by individual houses and communities.



#### Technology description and working principles

The Bio-tank is a specially designed fermentation tank for accelerated microbial degradation of organic waste. It is made of FRP/SS/MS/bricks with an inlet provision for human waste and outlets for treated effluent and biogas. Faecal matter degradation occurs through microbial reaction which results in biogas. The treated effluent is free from odour, suspended particle matter, pathogens and is environmentally acceptable.

Working principle of Bio tank/Bio digester is as under:



## Advantages and Disadvantages

### Advantages

- The design is simple and can be built by masons or skilled labour
- It does not require de-sludging as there is no sludge accumulation.
- There is no bad smell in toilets from the tanks. There is no infestation of Cockroaches & flies
- There is a 90 per cent reduction in organic matter by. Partial treated effluent which can be further treated using reed beds
- There is a 99 per cent reduction in pathogens

### Disadvantages

- The effluents from bio-tank needs tertiary treatment
- Methane gas is released into atmosphere
- It requires inoculation using specialised microorganism available with DRDO registered organisations

## O&M Requirement

- Main maintenance of system is to check the inflow regularly.
- Laboratory analysis of treated wastewater to be carried out to know the efficiency of the system and to maintain effluent quality
- Ensuring inoculation of microorganism at the beginning of the system and at times when treatment efficiency is low

## Design factors

The bio-digester has several chambers to increase the length of the waste path thereby improving contact time, sedimentation and degradation. The design of the bio-digester depends on the number of users and quantity of wastewater flow.

## Manufacturer/Supplier details

- Defence Research & Development Establishment

## References

- Guidelines on Bio Tank for Indian Railways. (2014). 1st ed. [pdf]. Lucknow.
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- <http://drdoficciatac.com/TechnologyDetails.aspx?TechID=T00004>

## 4.2. Blue Diversion Toilet

### A brief about the technology

The Blue Diversion Toilet is a dry toilet which separates undiluted urine, dry faeces and used water at the source. Anal cleansing water and hand wash water are treated in a self-cleaning ultra-filtration unit and reused onsite. Urine and faeces are collected separately below the pan. A service can collect the urine and faeces twice a week and the old faeces container is replaced.

This system provides water for flushing, hand washing and personal hygiene (for washers and menstrual hygiene). Blue diversion toilets are created specifically for places with no access to water, electricity and sewerage network. This toilet uses innovation in integrating all aspects of sanitation such as hand wash, menstrual hygiene and wastewater treatment in one single module.

### Technology Description and working principles:

Blue diversion toilets use a urine diversion pan arrangement to separate the faeces, urine and anal cleansing water. Faeces and urine are collected in separate containers below the pan. These have a short retention time and need to be emptied on a regular basis. Anal cleansing water is treated onsite using bio membranes and filters to regain water that can be used for hand washing and anal cleansing. The system requires just 11.5 watts of power, which is provided by a solar panel. This keeps the water moving around the system with various pumps, and also powers the flushing mechanism.

Waste handling method adopted in the toilet:

- The used water is separated by the urine-water-separation mechanism below the toilet pan.
- The separated water is pumped into the treatment tank, which is a membrane-bioreactor. A bio-film converts organic matter and ammonia. Then, the water is filtered by gravity through the ultra-filtration membrane that retains pathogenic organisms (bacteria and virus).
- The clean water is pumped into the clean water tank where it is polished by an electrolysis unit. Traces of organic matter and ammonia are removed.

The water in the clean water tank is protected against the re-growth of pathogens by the residual chlorine produced by the electrolysis. The water is ready for reuse in flushing, hand washing and personal hygiene.

Filled containers of urine and faeces are collected by entrepreneurs who provide O&M support to these toilet installations. They carry it to a centralised treatment unit where these products are converted to fertiliser and bio-solids that can be used for farming.

### Advantages and Disadvantages

Advantages

- It is suitable for places having no access to water, electricity and sewerage network

Figure 4.2: Blue diversion toilet



- It is an appropriate solution for densely populated areas as it requires less floor area
- It can be installed in existing toilet structures
- It provides for a complete solution across the sanitation value chain

#### Disadvantages

- It needs frequent replacement of urine and faeces containers
- It is expensive compared to toilets with a single pit
- Households must subscribe for regular de-sludging with private operators, making it highly dependent on the external environment. Any problem with de-sludging service will hinder regular usage of the toilet
- Urine diversion toilet requires behaviour change for usage as compared to regular pour flush latrines

#### O&M Requirement

A narrow container underneath the toilet pan holds a 20 litre urine tank and a 15 litre faeces tank. This needs to be emptied every three to four days.

#### Design factors

Typical blue diversion toilet will be designed as follows:

- Dimensions: 190 cm high, 74 cm wide, 91 cm deep. The step to the toilet pan is 37cm
- Material: the tanks and the pan are made of LLDPE plastic
- Energy requirements: 11.5W electrical energy, provided by a 60Wp solar panel
- Electricity consumption is for electrolysis, the aeration pump, ventilation pump, water pumps, and electronics for control and flush
- Life span: 10 years

**Figure 4.3:** Hand carting the toilet through a busy street



Container dimensions: 20L urine tank and 15L faeces

#### Manufacturer/Supplier details

- Eawag (Swiss Federal Institute of Aquatic Science and Technology)
  - E-mail: [infoatbluediversiontoilet.com](mailto:infoatbluediversiontoilet.com)

#### Cost

- It costs around USD 500

#### References

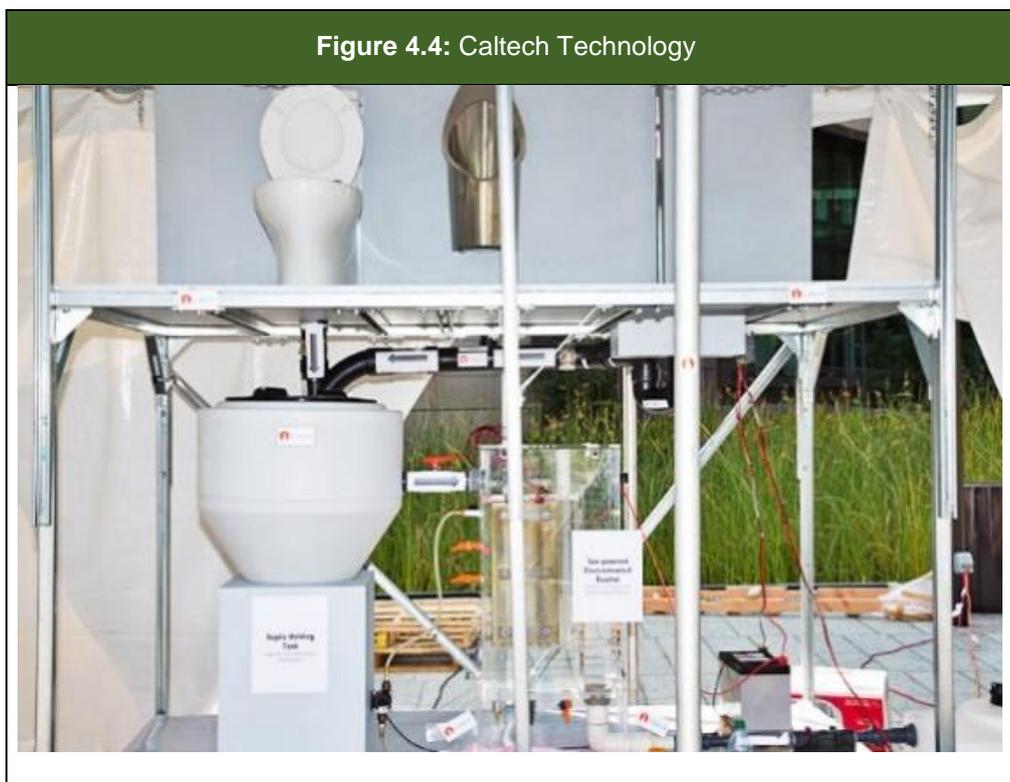
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### 4.3. Caltech Technology

#### A brief about the Technology

The Caltech Toilet is a solar-powered, self-cleaning toilet that converts used water and human waste into fertiliser and hydrogen, which can be stored in hydrogen fuel cells as energy. The treated water can then be reused to flush the toilet or for irrigation.



#### Technology Description and working principles:

The Caltech system is an onsite wastewater treatment and recycling unit that can be powered by solar panels or the electrical grid when connected. The toilet consists of a solar panel that powers an electrochemical reactor, which in turn, breaks down waste into sanitized solids and hydrogen that can be stored in fuel cells to power the reactor on cloudy days. A pump sends treated water to a reservoir on the top of the toilet, where it can be used for flushing or other purposes.

#### Advantages and Disadvantages:

##### Advantages

- Wastewater is treated onsite to reusable forms
- These toilets can be used at sites with no water, electricity and sewerage network
- It is an energy positive system, as it generates energy from faecal matter. Approximately 390kJ/user/day in Hydrogen Net Calorific Value energy recovered

### Disadvantages

- It involves complex instrument and sensors that need expert support
- The systems are not yet tested and validated for Indian Conditions.
- Local vendors require capacity building to manufacture parts used in the system
- The capital cost is high compared to regular toilets with a single pit

### Design Factors and Regions of Implementation

- 160L of flush water is required to initiate the process. After initiation, the water recycled from the toilet operations is used for flushing purposes. Tap water, seawater, or wastewater may be used for initiation
- Backup power of 2kW is recommended in case of failure of the photovoltaic panels
- One-time loading of 10kg of standard or industrial grade NaCl (salt) is used to improve electrolysis efficiency

### Cost:

- USD 2200 per unit

### Manufacturer:

- California Institute of technology
  - Email: [mrh@caltech.edu](mailto:mrh@caltech.edu)
  - Ph no: +1-626-395-4391

### Cost:

- Masonry bio-tank construction cost for 5 users is USD 370.

### References:

- <http://www.caltech.edu/news/winning-sanitation-solution-46978-46978>
- <http://inhabitat.com/bill-gates-awards-100000-prize-to-caltech-for-solar-powered-toilet/gates-foundation-caltech-solar-powered-toilet-sanitation-lead/>
- <http://www.sciencealert.com/the-gates-backed-toilet-of-the-future-is-now-being-trialled-in-india-and-china>

## 4.4. Composting Chamber

### A brief about the technology

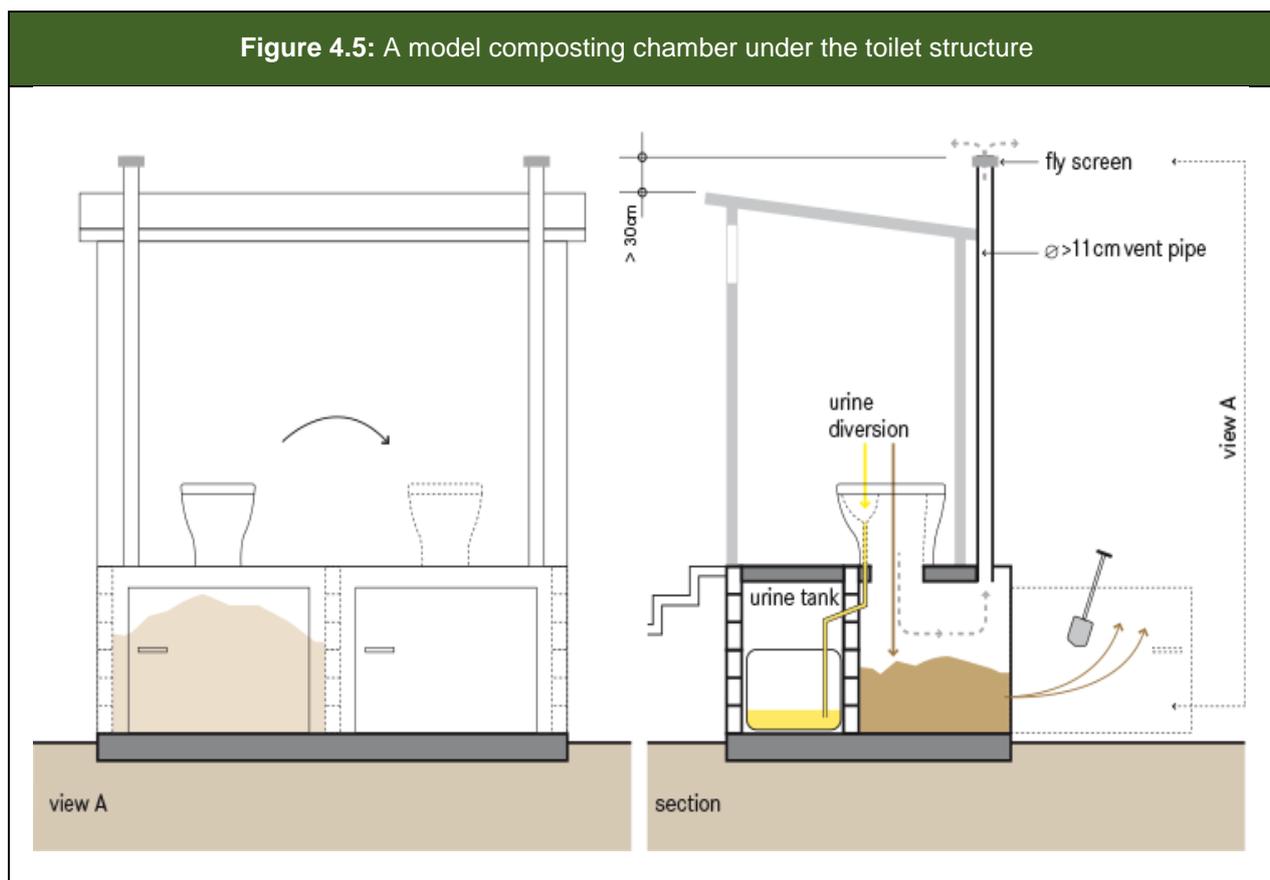
Composting is the process by which biodegradable matter is organically decomposed by microorganisms, mainly bacteria and fungi, under aerobic conditions. A composting chamber is designed to convert excreta and organics into compost which is a stable product that can be safely handled and used as a soil conditioner. Compared to single pits and septic tank, these provide local reuse potential.

### Technology description and working principles

Composting toilets are systems, which aim to minimise water-use and recycle nutrients contained in excreta and faeces. Compost is a valuable soil amendment which increases soil fertility. There are various systems based on the size and type of separation mechanism of waste (i.e., pits or vaults; urine diversion; low-tech and

high-tech; single-vault continuous or multiple vault batches). The functioning of the various different composting toilet systems is more or less the same. This technology usually requires four main parts:

- A reactor (storage chamber)
- A ventilation unit to provide oxygen and allow gases (CO<sub>2</sub>, water vapour) to escape
- A leachate collection system
- An access door to remove the mature product



Faeces are separately collected in the reactor by arrangements made in the pan. It is then mixed with additives such as organic waste, food waste, saw dust etc., to increase the effectiveness of the composting process. Sufficient oxygen, proper moisture, internal temperature of 40 to 50°C and a carbon to nitrogen ratio of 25:1 (theoretically) ensures good functioning of the system. Urine is separately collected and can be used as a fertilizer after diluting with water. Although the leachate from the composting process has high concentrations of nutrients it also contains pathogens. This needs to be collected and treated separately.

### Advantages and Disadvantages

Advantages:

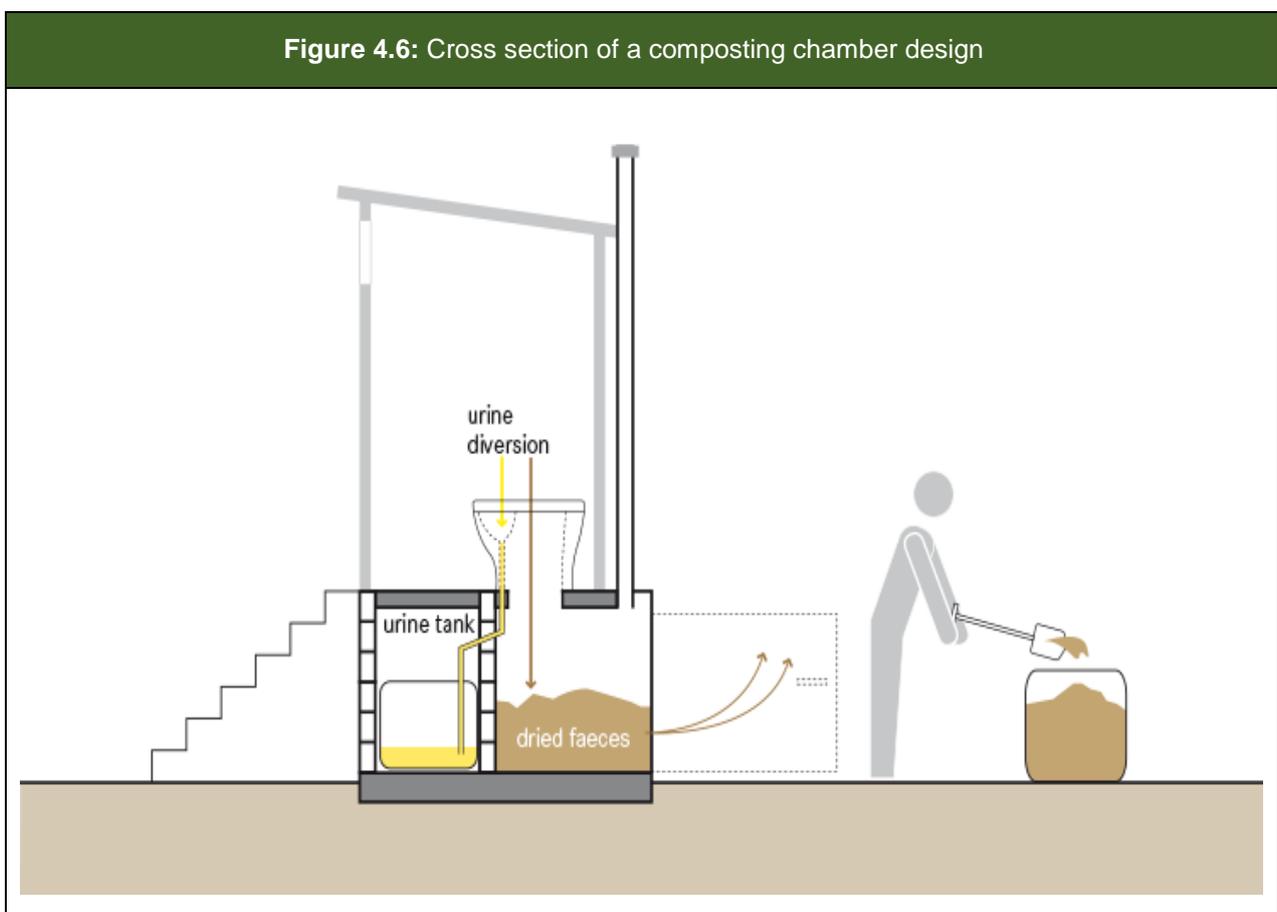
- It operates reliably during dry and wet seasons
- The process can reduce the volume of the faecal matter considerably (up to 30 per cent)
- There is a significant reduction in pathogens
- The compost can be used as a soil conditioner

- Organic solid waste can be managed concurrently
- It has a long service life
- It has low operating costs

Disadvantages:

- It requires bulking material and periodic supervision
- It requires well-trained user or service personnel for monitoring and maintenance
- The leachate requires treatment and/or appropriate discharge
- It requires a constant source of organic waste
- The compost will have to be removed manually.

**Figure 4.6:** Cross section of a composting chamber design



**O&M Requirement**

- After every defecation, a small amount of bulking material is added to absorb excess liquid, improve the aeration of the pile and balance the carbon availability
- Covering the fresh faeces immediately with an additive material also reduces odour and flies. Churning the material from time to time will boost oxygen supply
- Emptying the composting toilet constitutes a critical handling point. The emptying frequency depends on the size of the chambers, the feeding rate and the composting rate

## Health and acceptance

- A well-functioning composting chamber should not produce odours. If there is sufficient bulking material and good ventilation, there should be no problems with flies or other insects
- When removing the final product, it is advisable to wear protective clothing to prevent contact with (partially) composted material
- If operation conditions for thermophilic composting are adequate (moisture content 50 to 60 per cent, carbon to nitrogen ratio 30 to 35 and mixing with bulking material), the temperature will rise to between 50 and 65°C. Such temperatures will effectively inactivate pathogens. Otherwise, secondary treatment will be necessary

## Design factors

- A composting chamber can be designed in various configurations and constructed above or below ground, indoors or with a separate superstructure
- In continuous vault composting toilets, compost can continuously be harvested on one end, while faeces fall into the other. In batch systems, the composting chamber is changed once it is full and the next one is used during which the other one is closed and left aside for it to mature
- Composting is possible at high temperatures (thermophilic composting) and at low temperatures (ambient or mesophilic composting). Thermophilic composting is faster and more efficient in inactivating pathogens
- The optimal operational conditions for thermophilic composting are:
  - Good aeration
  - A moisture content of 50 to 60 per cent
  - A C/N ratio of 30 to 35
  - The carbon to nitrogen ratio (C/N) of excreta (including urine) is about 7 to 8, but for optimal thermophilic composting, it needs to be 20 to 35 (WHO, 2006).
- The addition of paper, wood or bark chips, sawdust, ash or other similar substances will help to increase the C/N ratio. A design value of 300L/person/year can be used to calculate the required chamber volume

## References

- Eawag, Spuhler. D.(n.d). Composting Chamber. [online] SSWM. Available at: <http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/site-storage-and-treatments/composting-t>

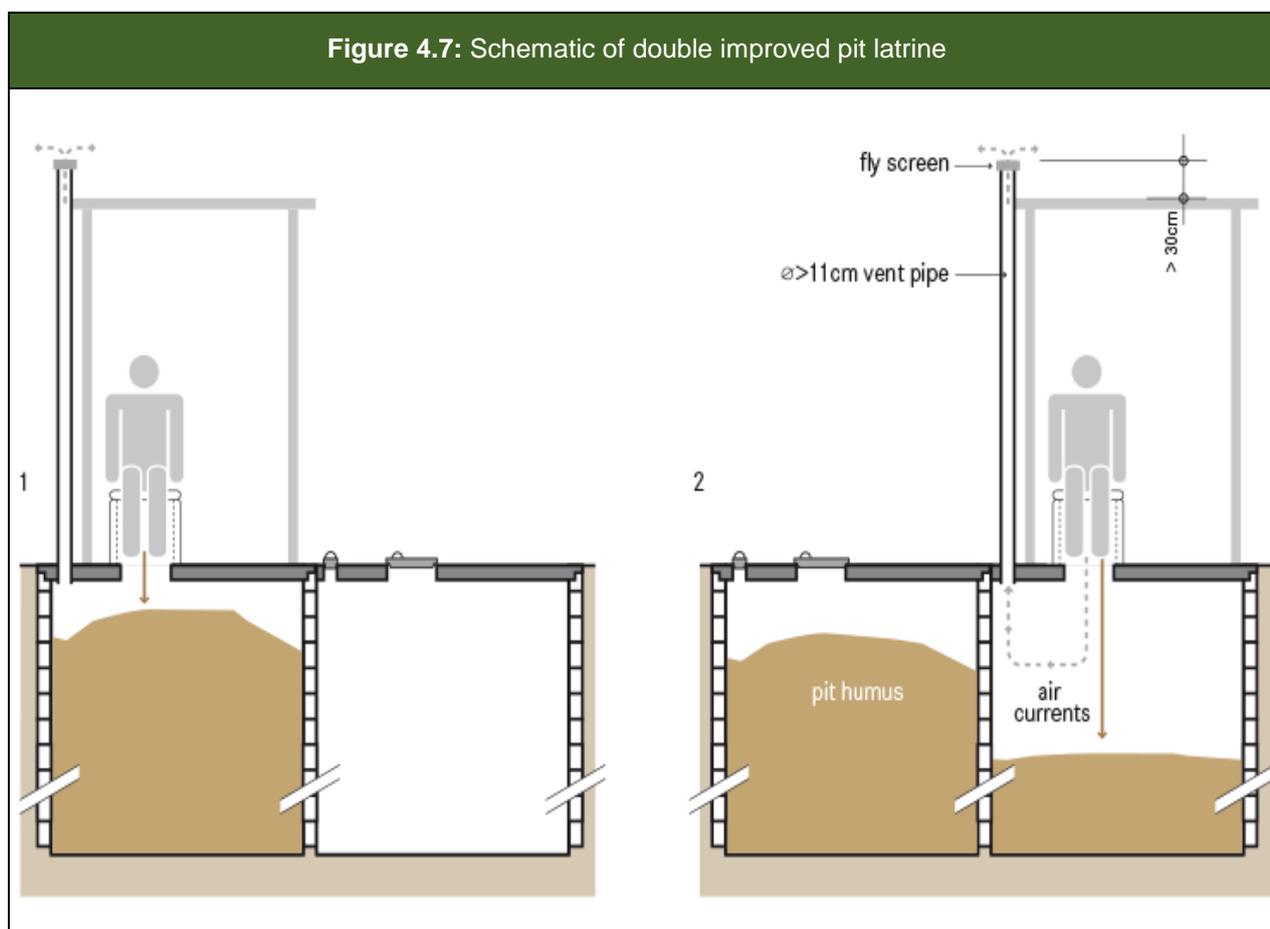
## 4.5. Double Ventilated Improved Pit (VIP)

### A brief about the technology

The Double VIP consists of a superstructure, a pit with cover slab, a hole for defecation and a vent pipe with a fly screen. It has almost the same design as the Single VIP, with the added advantage of a second pit that allows it to be used continuously and permits safer and easier emptying. It consists of a superstructure, a pit with cover slab and a hole for defecation, and a ventilation pipe with a fly screen.

## Technology description and working principles

The design of a VIP is nearly the same as a normal pit latrine comprising a superstructure, a pit cover slab and a hole for defecation. Innovation is in the ventilation pipe, provided with a durable fly screen on the top. Despite their simplicity, well-designed VIPs can be completely smell-free. The ventilation also allows odours to escape and minimises the attraction for flies. Flies that hatch in the pit are attracted to the light at the top of the ventilation pipe. When they fly towards the light and try to escape they are trapped by the fly-screen and die. The superstructure must be kept sufficiently dark so that the flies leave the pit through the pipe and not through the squat hole.



A small gap above the door or a louvre in the door allows air to enter. The flow of air is increased if the doorway of the superstructure faces prevailing winds. The VIP needs no water for its functioning. This is a big advantage over flush toilets in water scarce areas (see flush toilets, pour flush toilets or low-flush toilets).

The VIP design can be used for both single and double pits. Pits are designed with gaps in the side walls for water percolation. Single pits need to be emptied or relocated when full, however, in having two pits, one pit can be used, while the content of the second rests, drains, reduces in volume, and degrades. When the second pit is almost full, it is covered and the content of the first pit is removed and used as soil conditioner.

## Advantages and Disadvantages

### Advantages

- It has a longer life than single VIP (indefinite if maintained properly)
- Removal of dried bio solids are easier as they are dried and decomposed
- Flies and odours are significantly reduced (compared to non-ventilated pits)

- It can be built and repaired with locally available materials
- It does not require a constant source of water

#### Disadvantages

- The treatment processes in the Double VIP are limited, and therefore, pathogen reduction and organic degradation is very low compared to composting or dehydration toilets
- The leachate can contaminate groundwater
- Pits are susceptible to failure/overflowing during floods. Stagnant water in pits may promote insect breeding
- Manual removal of humus is required
- Higher capital costs than Single VIP; but reduced operating costs if self-emptied

#### O&M Requirement

- To keep the double VIP free of flies and odours, regular cleaning and maintenance is required. Dead flies, spider webs, dust and other debris should be removed from the ventilation screen to ensure good flow of air. The out-of-service pit should be well sealed to reduce water infiltration and a proper alternating schedule must be maintained
- When the second pit is filled up until half a meter below the top, the first pit needs to be emptied (see also human powered and motorised emptying). As the first has ideally stood for several years, the decomposed sludge will not cause any health problems and is beneficial as a fertiliser (see also use of compost in agriculture)

#### Design factors

- The superstructure may either extend over both holes or it may be designed to move from one pit to the other. In either case, the pit that is not being filled should be fully covered and sealed to prevent water, garbage and animals, or people from falling into the pit
- The ventilation of the two pits can be accomplished by moving one ventilation pipe back and forth between the pits, or each pit can be equipped with its own dedicated pipe
- The vent pipe should have an internal diameter of at least 110 mm to a maximum of 150 mm and reach more than 300 mm above the highest point of the toilet superstructure. It can be made out of PVC, bricks, pet bottles or iron pipes
- The vent works better in windy areas but where there is little wind, its effectiveness can be improved by painting the pipe black; the heat difference between the pit (cool) and the vent (warm) creates an updraft that pulls the air and odours up and out of the pit
- The mesh size of the fly screen must be large enough to prevent clogging with dust and allow air to circulate freely
- The two pits in the double VIP are continually used and should be well lined and supported to ensure longevity
- The depth of the pit is at least 2m, but usually more than 3m (UNEP 2002). The depth is usually limited by the groundwater table or rocky underground.

#### Health and acceptance

- The double VIP can be a very clean, comfortable and a well-accepted sanitation option, in some cases even more so than a water-based technology

- The leachate can contaminate groundwater
  - Pits are susceptible to failure and/or overflowing during floods
  - Health risks from flies are not completely removed by ventilation

## References

- Eawag. Spulher, D. (n.d).Double Ventilated Improved Pit (VIP).[online] SSWM. Available at:<http://www.sswm.info/content/double-ventilated-improved-pit-vip>
- [https://www.ethz.ch/content/dam/ethz/special-interest/gess/nadel-dam/documents/research/u-act/Ventilated\\_Latrine\\_Slum\\_Kampala.pdf](https://www.ethz.ch/content/dam/ethz/special-interest/gess/nadel-dam/documents/research/u-act/Ventilated_Latrine_Slum_Kampala.pdf)

## 4.6. Composting Ekolet Dry Toilet System

### A brief about the technology

Composting Ekolet Dry toilet is a composting toilet that can be used either indoors or outside. It makes efficient use of nature's own methods to compost both toilet and kitchen waste into odourless fertiliser, thus providing an integrated waste management solution for the household. This toilet requires no chemicals or additives, is odourless, and does not need a sewerage network.

### Technology description and working principles

Ekolet Toilet is manufactured from long-lasting, recyclable materials that do not allow the leakage of harmful substances into the surrounding. These toilets are composting toilets where kitchen waste is added into the containment system where it mixes with faeces matter and enhances the rate of composting.

The Ekolet VU version contains a rotating four-compartment composting tank with a lid and a seat with a cover, both made of rigid plastic. Air circulation via the ventilation pipe keeps the composting toilet odourless. The containment system is rotatable so that when one half of the containment is full, a thin layer of soil or compost is sprinkled over the top, and a new compartment is rotated into position. One compartment holds a summer's worth of faeces and bio-waste from a household of four persons.

### Advantages and Disadvantages

#### Advantages

- It requires no chemicals or additives`
- It is an odourless system
- It is an integrated waste management for organic waste and faeces

Figure 4.8: Ekolet Toilet



#### Disadvantages

- The leachate needs treatment
- It cannot be used by communities with washing culture

#### O&M Requirement

- The two main operations of this system are regularly feeding the composting chamber with kitchen waste and regularly emptying the filled tank.
- Once filled, the composting chambers need to be rotated.

#### Manufacturer/Supplier details

- Ekolet Ltd, Finland

#### Material

- Ekolet is manufactured from long-lasting, recyclable plastic

#### Cost:

Depends on capacity

- USD430 per unit

#### References

- [www.Ekolet.com](http://www.Ekolet.com), (n.d). ekolet –composting toilets.[online]Available at: <http://ekolet.com>
- <http://www.tekes.fi/en/whats-going-on/news/better-toilets-better-life---locals-test-finnish-ekolets-composting-toilets-in-rural-india>

### 4.7. Enviro Loo System

#### A brief about the technology

The Enviro Loo is an onsite sanitation system which uses forced ventilation and improved means of solid-liquid separation to enhance the composting of faecal matter. These systems can be used at places with no access to sewerage network and where dried faecal matter can be reused.

#### Technology description and working principles

The main components of the system include a ceramic toilet bowl, perforated plate, a forced ventilation unit, outlet, and inlet vent pipes and a black containment unit that aids in creating the right environment for dehydration and decomposition of waste.

Faecal matter, urine and anal cleansing water are separated by a perforated plate. The perforations permit the water and urine to pass through them, while solids are retained on the plate. The forced aeration system ensures that both the liquid and the solid waste are exposed to a continuous flow of air. The movement of air is assisted by a draft fan mounted on top of the outlet vent pipe creating a vacuum and sucking air through the inlet and toilet pan. As the air moves through the system it carries with it the moisture present in the faeces, enabling faster drying. The walls of the containment system are painted black, with a certain portion exposed to sunlight. This increases the temperature of the faeces and the surrounding air, enabling better degradation and ventilation. This also aids evaporation of the liquid that has drained to the bottom of the container.

At periodic intervals the faecal matter is removed from the system through an opening provided on top of the containment structure. Most urine and anal cleansing water evaporates from the system, nevertheless it is recommended that the level of liquid is checked and de-sludged using a submersible pump. The removed faecal matter is recommended to be left in a bag under the sun for a period of six months, where further dehydration and degradation happens, making it suitable for agricultural applications. Urine and anal cleansing water on evaporation leave behind high concentrations of salts and minerals which can be used as fertilisers.

### Advantages and Disadvantages

#### Advantages

- There is enhanced dehydration and degradation of faecal matter
- There is no smell because positive suction is created at the point of faecal discharge into the pan
- There is no use of electricity
- There is a reduction of solids to 5 per cent of its initial volume in the dehydrating chamber
- It is modular and possibility for relocation

#### Disadvantages

- The dehydration and evaporation can reduce at areas of low temperatures or high humidity
- Use of too much water for anal cleansing can flush away faecal matter from the perforated plate into the liquid chamber stalling the entire process
- There is no option for use of water for flushing. This can lead to faecal smears on toilet pans, which have to be cleaned periodically using appropriate non-water-based cleaning material

### O&M Requirement

- The pan surface of the toilet required periodic cleaning to get rid of faecal smears
- The user will have to carry out periodic de-sludging of faecal matter and liquids from the bottom of the chamber
- To promote effective heat transfer, the surface that is incident to sun rays needs regular cleaning.

### Health and acceptance

- If toilets are installed in dense locations which do not allow for easy pathway of air through the system, then the gases produced during degradation of faecal matter will enter into the user interface creating inconvenience. To some extent this can also lead to breeding of insects
- Cases from other countries show that most female users do not want to sit on the seats due to the heat which rises from the unit through the bowl and the fear of contracting vaginal infections
- End products are usually to be harvested by the household and reused locally. Growing urbanisation and reduction in open lands reduce places for application of bio solids and urine based fertiliser may be an issue.

**Figure 4.9: Enviro loo Toilet with containment structure**



## Design factors

- The important aspect of the system's functioning is the inflow of air and incidence of solar rays on the containment unit's surface. Hence the outdoor part of the system must be placed accordingly
- Places with high humidity will require longer dehydration periods and hence sufficient chamber volumes to be provided to accommodate moist faecal matter

## Manufacturer/Supplier details

- Enviro Options Pty Ltd, South Africa

## References

- Enviro-loo.com, (2013). Enviro Loo. [online] Available at: <http://www.enviro-loo.com>
- Washtechologies.com, (n.d). Technology Applicability Framework. [online] Available at: <http://www.washtechologies.net/en/taf/case-studies/details/6>
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## 4.8. EZ Loo Air Toilet System

### Brief about the technology

The Ez-Loo Air is a waterless composting toilet system designed for use where plumbing and electricity are not readily available. Natural air flow combined with microbiological activity establishes optimum conditions for efficient break-down of faecal matter and completely odour-free operation. It is an ideal choice for households and institutions having no access to sewerage or containment systems.

### Technology Description and working principles:

Ez-Loo is a composting toilet which reduces human waste to reusable organic products. The toilet interface has a pedestal pan which opens into a composting bin located directly below. There are two composting bins which are used alternatively in cycles of 3–6 months each. During the operational phase for each chamber there is continuous breakdown of faecal matter generating heat and thereby enhancing degradation by microorganisms, while there is dehydration and pathogen reduction during the resting phase (while the other bin is in use). Ez-loo toilets take advantage of natural ventilation for providing ambient environment for degradation. They have a provision for overflow of excess liquid (from urine) into soak away systems or other onsite containment systems.

### Advantages and Disadvantages

Advantages:



- There is no requirement of water for flushing or movement of faecal matter to containment unit
- No requirement of on-site containment unit
- Is very light weight and can be easily shifted and does not require plumbing

Disadvantages:

- To aid the complete breakdown process additional organic powder must be added
- An increase in O&M due to regular emptying
- Chances of odour exist as the composting chamber is directly below the user pan

**O&M Requirement**

- The Ez-Loo air toilet system requires minimum O&M which is restricted to the addition of an organic powder to aid optimum composting
- Regular emptying of compost is required
- For the Ez-Loo power toilet a reliable source of electric power is needed.

**Health and Acceptance**

- These toilets do not have provision for water-based anal cleansing. In fact, use of water for anal cleansing hinders the system operations. Hence its appropriateness with Indian conditions needs to be considered
- Composting pits are open chambers leading to smell and insect breeding, which can cause inconvenience to users

**Design factors**

All Ez-Loo toilet systems are designed based on full-time use by four people and part-time use by six. The toilet system is made of high grade UV-coated ABS plastic material. Currently there are three models:

- a) Ez-Loo air which uses natural draft ventilation
- b) Ez-Loo solar that uses solar energy for forced ventilation and
- c) Ez –Loo power which needs electricity for forced ventilation

**Cost:**

- Ez-Loo Air: USD950
- Ez-Loo Solar: USD979
- Ez-Loo Power: USD999

**Manufacturer:**

- Manufactured in the USA.
  - Bio Let Toilet Systems, Inc.  
830 West State Street, info@biolet.com

**References**

- Ez-loo.com,(2016). ez-loo.[online] Available at: <http://www.ez-loo.com/>

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- <https://letterstocreationists.wordpress.com/2015/03/14/comparison-of-composting-toilets-towards-a-global-commode/>

## 4.9. Flush-Tech System

### A brief about the technology

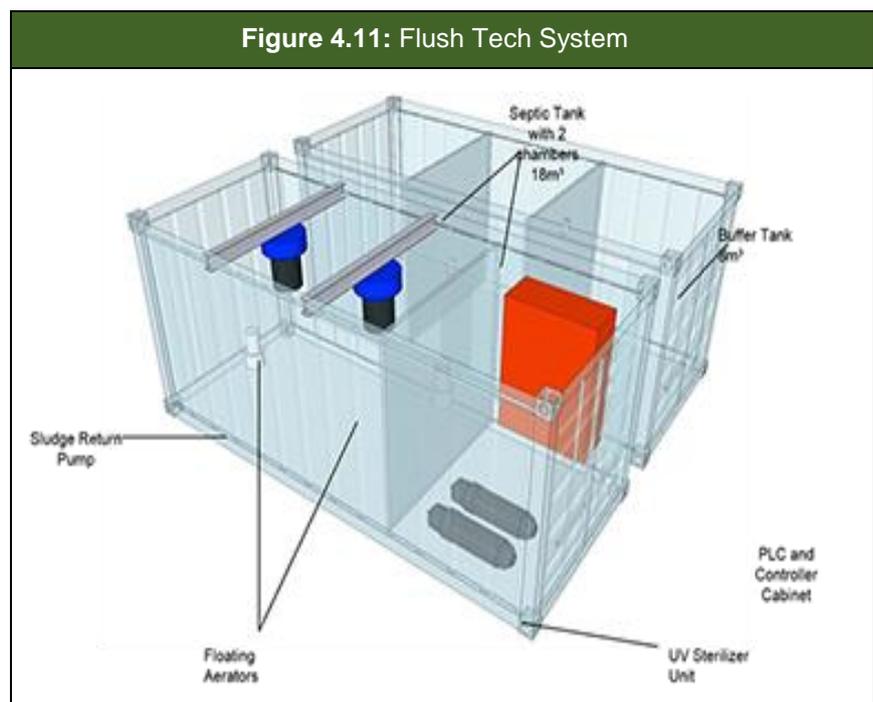
Flush-Tech system uses the principles of sequential batch reaction for treating wastewater generated at toilets in a cost-effective manner. It can be used with an external organic agent that decomposes the faecal matter and prevents any sludge build-up. The treated water which is the end product can be reused for irrigation or flushing.

These systems cost less and are easy to operate, thus proving to be an effective alternative to pit latrines built in rural communities.

### Technology description and working principles

The Flush-Tech system works on the Sequence Batch Reactor (SBR) principle, and is used simultaneously with an external agent called Bio Sol SL36, an organic product that enhances the decomposition of faecal matter.

The bacteria contained in the product breaks down organic waste inside the containment structure and prevents sludge build-up. The system consists of a closed vessel divided into three chambers of anaerobic, anoxic and aerobic zones. It uses electromechanical components such as pumps, aerators and diffusers to maintain the necessary conditions of the SBR treatment. The entire system is fully automated and is calibrated to operate for a specific Hydraulic Retention Time (HRT) of a few hours depending on the organic load rate present. The treated water can be used for flushing toilets after passing through a UV unit.



### Advantages and Disadvantages

#### Advantages

- The treated wastewater can be reused for flushing
- Solids do not accumulate in the containment eliminating the need for de-sludging
- They are flexibility in handling a wide variety of wastewater input characteristics

#### Disadvantages

- The system is not a stand-alone one; it is high-tech and will necessitate constant supervision by users
- The affordability of the technology for individual household use is a concern

### **O&M Requirement**

- Need to train people in use and maintenance of the system
- Bio Sol SL36 has to be purchased from registered suppliers periodically

### **Health and acceptance**

- It is an active system requiring continuous process control by the user. Hence capacity building of the user is vital
- The treatment system requires electricity for operation. Rural areas having erratic power supply can limit the treatment process.

### **Design factors**

- HRT needs to be calibrated based on the input wastewater quantity and quality
- Need to plan for dual pipeline for reuse of treated water in flushing system

### **Manufacturer/Supplier details**

- Bio power cooperation, RSA

### **References**

- Pollution Research Group, (2015). Sanitation Innovation Challenge. 1st ed. [pdf].
- Biopowercorp.co.za, (n.d). Products and Services. [online]. Available at: <http://biopowercorp.co.za/products.html>

## **4.10. Fossa Alterna**

### **A brief about the technology**

The Fossa Alterna is a short cycle alternating, waterless, double-pit technology. Compared to the double ventilated improved pit (VIP) which is just designed to collect, store and partially treat excreta, the Fossa Alterna is designed to make an earth-like end product that can be used as a nutrient-rich soil conditioner.

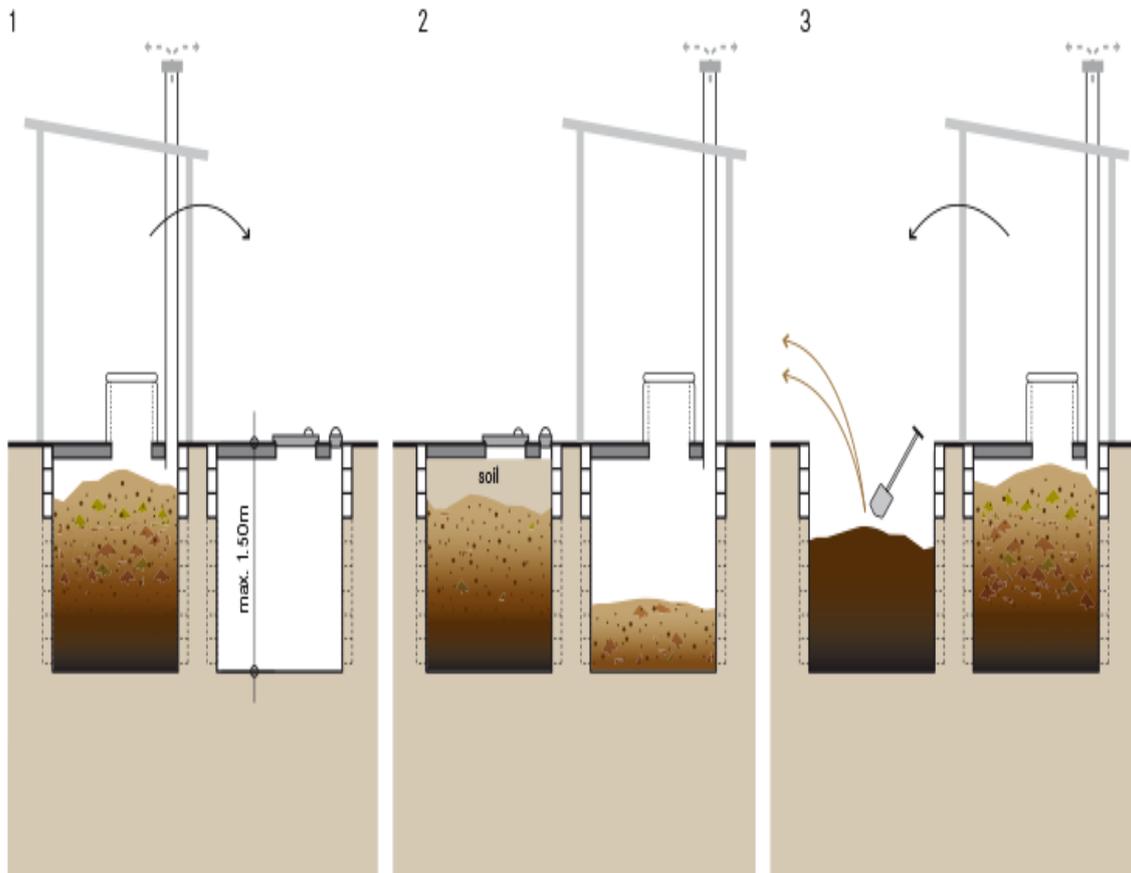
### **Technology description and working principles**

Fossa Alterna is a double-pit technology where both pits are lined and used sequentially. Once a pit gets filled, it is left to degrade while the second pit is filling, which, ideally should take a year. Soil, ash, and/or leaves are added, as cover material, to the pit after defecation which increases carbon content of the end product and also provides a porous layer for enhanced composting. The mixture attracts various higher organisms such as worms which further aid in decomposition. The material in the full pit will degrade into a dry, earth-like mixture that can be easily removed manually and used in agriculture.

The Fossa Alterna should be used for urine (if urine is not collected separately), but water should not be added. Therefore, it can be used with a UDDT, but only in circumstances when the soil cannot sufficiently absorb the urine or when the urine is highly valued for application.

An appropriate diversion mechanism for urine and anal cleansing water has to be provided otherwise if introduction in the pit, they will reduce composting efficiency.

Figure 4.12: Schematic of a fossa Alterna



Source: TILLEY et al. (2014)

### Advantages and Disadvantages

#### Advantages:

- As double pits are used alternately, their operational life is virtually unlimited
- Excavation of humus is easier than faecal sludge
- There is a significant reduction in pathogens
- It generates nutrient-rich humus with good potential for use as soil conditioner
- It can be built and repaired with locally available materials
- There are nil to low operating costs if self-emptied

#### Disadvantages:

- It requires a constant source of cover material (leaves, saw dust, etc.)
- Manual removal of humus is required (contact with remaining pathogens and microorganism)
- Although the facility requires only a small land area is required, it needs to be enough for two pits

- Mixing of solid waste may ruin end-use opportunities of the product
- It is not suitable for areas with high groundwater table

### O&M Requirement

- When the first pit is put into use, a layer of leaves should be put at the bottom of the pit. More leaves should be added regularly to increase the porosity and oxygen availability
- Following the addition of faeces to the pit, a small amount of soil, ash, and/or leaves should be added. Ash prevents foul odour and breeding of insects
- Depending on the dimensions of the pits, its contents should not be emptied more often than once a year

### Health and acceptance

- The pit in which the faeces is composting is open and can lead to bad smell and insects (when ash is not added in properly).
- This facility requires separate collection and management of urine and anal cleansing water, adding to the cost of infrastructure required at the household level
- It is ideal for peri-urban and rural areas where the end product can be used locally

### Design factors

- A Fossa Alterna pit would fill over a period of 12–24 months depending on its size and the number of users.
- Even though the pits are shallow (1 to 1.5 m), each of them can be used by a family of six for one year.
- This technology will only work properly if the two pits are used sequentially and not concurrently. Therefore, an adequate cover for the out-of-service pit is required
- The cover material used over the excreta reduces bad smells. A ventilation pipe can be added to further reduce the smells
- In either flood-prone areas or where the groundwater table is too high, the Fossa Alterna could be raised or built entirely above the ground to avoid water intrusion and groundwater pollution. Raising the pits could also be an option where the ground is rocky and soils are compacted and difficult to dig.

**Figure 4.13: Toilets built on the principles of Fossa Alterna**



## Cost

- The cost for a Fossa Alterna is around ₹2.5 Lakhs (includes slab casting, pit excavation and lining, and the superstructure)

## References

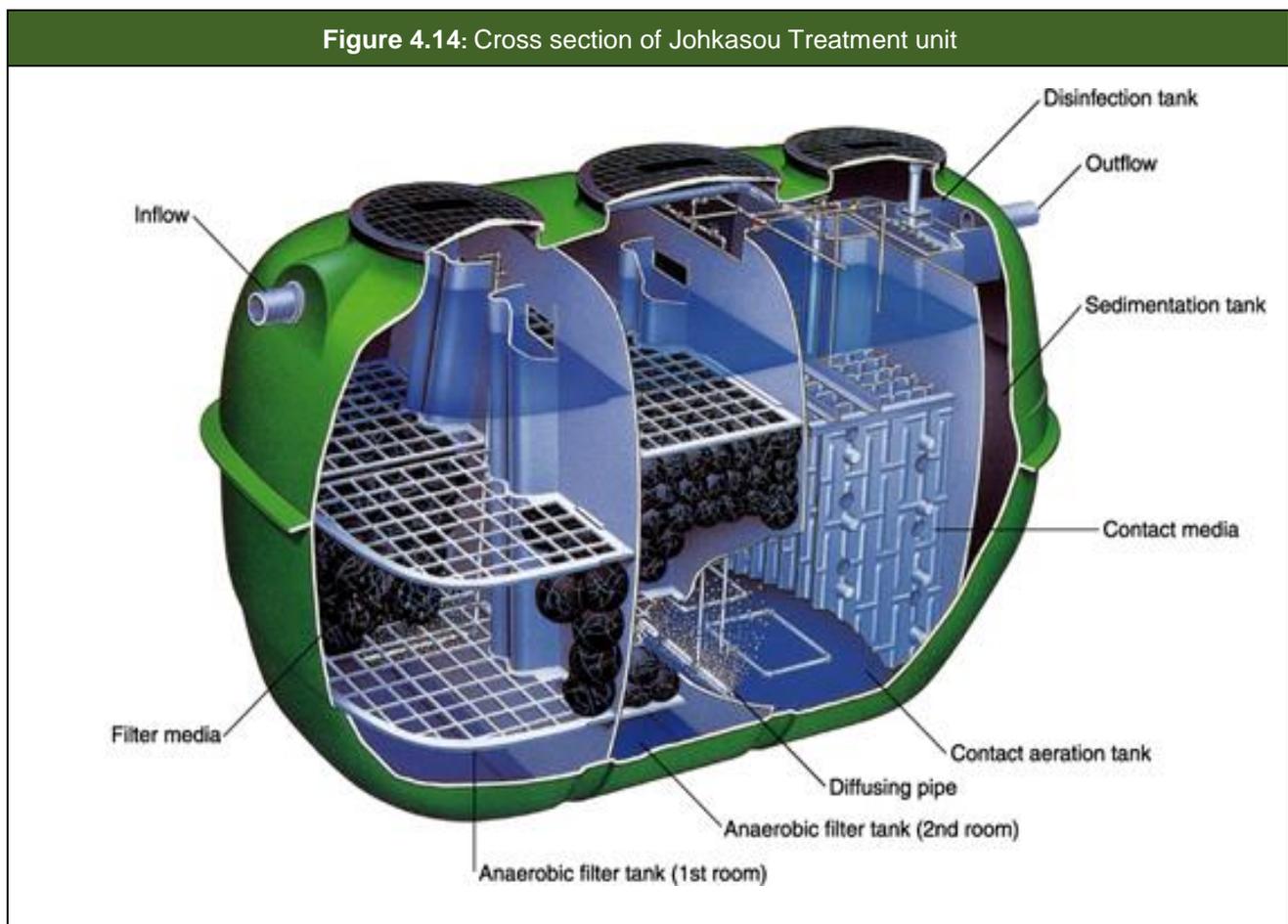
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- [http://www.ircwash.org/sites/default/files/cost\\_est\\_fossa\\_alterna\\_eng\\_1.pdf](http://www.ircwash.org/sites/default/files/cost_est_fossa_alterna_eng_1.pdf)

## 4.11. Johkasou System

### A brief about the technology

Johkasou is a packaged wastewater treatment system with four chambers, designed to be implemented at smaller scales, especially at household levels to treat black water for reuse. It uses innovative packaging in reducing the overall footprint required for treatment and hence can easily be accommodated within a household.

Figure 4.14: Cross section of Johkasou Treatment unit



### Technology description and working principles

In a Johkasou system, the wastewater passes through four different chambers, namely, the anaerobic tank, contact aeration tank, sedimentation tank, and disinfection tank. Anaerobic treatment is the first stage, where

wastewater comes in contact with a sludge blanket enriched with anaerobic bacteria providing for primary and secondary treatment. The wastewater then passes into the aeration tank, where a blower diffuses air through it, enhancing aerobic degradation of organics. This water is later passed through a sedimentation tank where ample retention time is given for heavier particles to settle down to the bottom of the chamber. The settled solids are pumped back into the first chamber—the anaerobic tank—enhancing the anaerobic digestion process. The supernatant from the sedimentation tank passes through a disinfection chamber where chlorine is added to kill pathogens and harmful microorganisms.

Jokhasou systems can treat black water to levels of biochemical oxygen demand (BOD) less than 20 mg/l which can be discharged into open drains. In India, Sintex provides packaged treatment system with the same concept for various sizes ranging from 500 litres per day to 50 KLD.

## **Advantages and Disadvantages**

### **Advantages**

- A small-scale Johkasou system can be installed in a short time and at low cost
- The treated water can be used for various purposes such as gardening, flushing, etc.
- The system is not very dependent on site specific conditions
- The sludge from Johkasou system can be used as fertiliser

### **Disadvantages**

- It requires regular maintenance to maintain effluent quality which is expensive
- The system uses power for aerobic treatment
- The de-sludging frequency is more owing to aerobic treatment

## **O&M Requirement**

- The rotating equipment (motors and blowers) needs regular lubrication
- The quality of the effluent needs periodic monitoring.
- The anaerobic chamber needs de-sludging at regular intervals

## **Health and Acceptance**

- Regular electricity is a primary criterion for the system to work.
- The Johkasou system is highly efficient for individual households or small communities located in rural or peri-urban areas where there is no access to a sewerage system

## **Design factors**

- The size of the system depends on the quantity of wastewater flowing into it
- Blower running time and return sludge pump operating time is set based on input wastewater characteristics and MLSS (Mixed Liquor Suspended Solids)

## **Manufacturer/Supplier details**

- Kubota Johkasou Systems Corporation, Japan

- Sintex
  - [http://www.sintex-plastics.com/product\\_details.aspx?Id=174](http://www.sintex-plastics.com/product_details.aspx?Id=174)

**Cost:**

- Sintex system for a household costs ₹1,20,000 per unit

**References**

- Ctc-n.org,(n.d). Climate Technology and Network. [online] Available at: <https://www.ctc-n.org/> (Climate technology centre network – Johkasou system)
- Ogaw, H (n.d). Domestic Wastewater treatment by Johkasou Systems in Japan. 1st ed. [pdf]. Tokyo. Available at: [https://www.env.go.jp/recycle/3r/en/asia/02\\_06/01.pdf](https://www.env.go.jp/recycle/3r/en/asia/02_06/01.pdf)
- [http://www.sintex-plastics.com/product\\_details.aspx?Id=174](http://www.sintex-plastics.com/product_details.aspx?Id=174)

**4.12. Loolaa boo Toilet**

**A brief about the technology**

The Loolaa boo toilet system is based on the concept of Terra Preta sanitation which includes a three-step process of collection (including urine diversion), lactic acid fermentation (lacto-fermentation) and vermi-composting. The innovation in the Loolaa boo system is in catering to a diverse set of toilet users (squatters and sitters) and the use of lactic acid for enhanced degradation of faeces.

**Figure 4.15: Loolaa Boo Toilet**



The Loolaa boo system provides improved sanitation and enriched reusable soil conditioners for farming as its end product. It can be used in places where access to water is low, sewerage network not available and electricity is erratic.

### **Technology Description and working principles:**

Inside the toilet is a storage tank for collecting faeces. Before the first use, a lactic-acid-bacteria-sugar solution is added to the storage tank. This prevents unpleasant smells from arising and sanitises the storage compartment. To support the process of lactic-acid-fermentation, the toilet's tank is kept air-tight by a sliding gate-valve. A pressure-spray nozzle is used to cleanse the bowl and can also be used for anal cleansing. Once a week, a pump truck empties the tank from outside the house. Through an opening in the wall, the toilet's storage tank can be accessed from outside. The service provider also refills the tank with a new lactic-acid-bacteria-sugar solution. The truck then transports the waste material to a composting facility for further processing. Nutrient-rich humus is produced after approximately three months. This highly fertile and nutrient rich humus is called Terra Preta (black soil) and can be applied to soil used to grow non-food crops.

### **Advantages and Disadvantages**

Advantages:

- The system produces no odour and there is no need for ventilation or dehydration system
- It can treat both human excreta and organic household waste
- It requires little space
- The end product is nutrient rich and humus-like with high market potential
- It is a stable process, which reduces pathogens drastically

Disadvantages:

- Operation and maintenance is crucial for correct functioning (e.g., growth of microbial mix)
- The toilet requires frequent de-sludging increasing the operation cost of such toilets
- Lactic acid is an expensive additive, and not commonly available locally in India

### **Operation and Maintenance**

- The main O&M work includes ensuring the faeces and urine chambers are air-tight, rinsing urine pipes from deposits; maintenance of the lacto-fermentation; changing containers and checking the vermi-composting and using the decomposed material in the garden.
- The microbial mix can be kept at the household level and continuously fed and cultivated. Generally, the bacteria duplicate every two days, but they should be fed at least once a week with some water, a sugar source, and sterilised milk
- The lacto-fermentation process takes at least for one month (up to six months) in a completely closed container. After which, the contents can be transferred to the facility for vermi-composting.

### **Health and Acceptance**

- The toilet system works for isolated houses, row-houses, small settlements and multi-storey living complexes

- Lactic acid and bacillus solutions are expensive to avail.

### **Design Factors**

- The volume of the containment chamber is designed based on the number of users and flushing pattern
- Appropriate access has to be created behind the toilet for de-sludging faecal matter periodically

### **Cost:**

- USD70 per toilet

### **Manufacturer:**

- Trifteen Design studio. Hamburg. Germany
  - TPS-Initiative  
c/o Hamburg University of Technology B-2  
Eissendorfer Str. 42  
21073 Hamburg, Germany

### **References**

- Loolaboo.com, (n.d). Loolaboo -The Terra Preta Toilet.[online] Available at: <http://www.loolaboo.com/>
- Sswm.info, (n.d). Terra Preta Toilet. [online] Available at: <http://www.sswm.info/category/implementation-tools/water-use/hardware/toilet-systems/terra-pret-toilet>

## **4.13. Nano Membrane Technology**

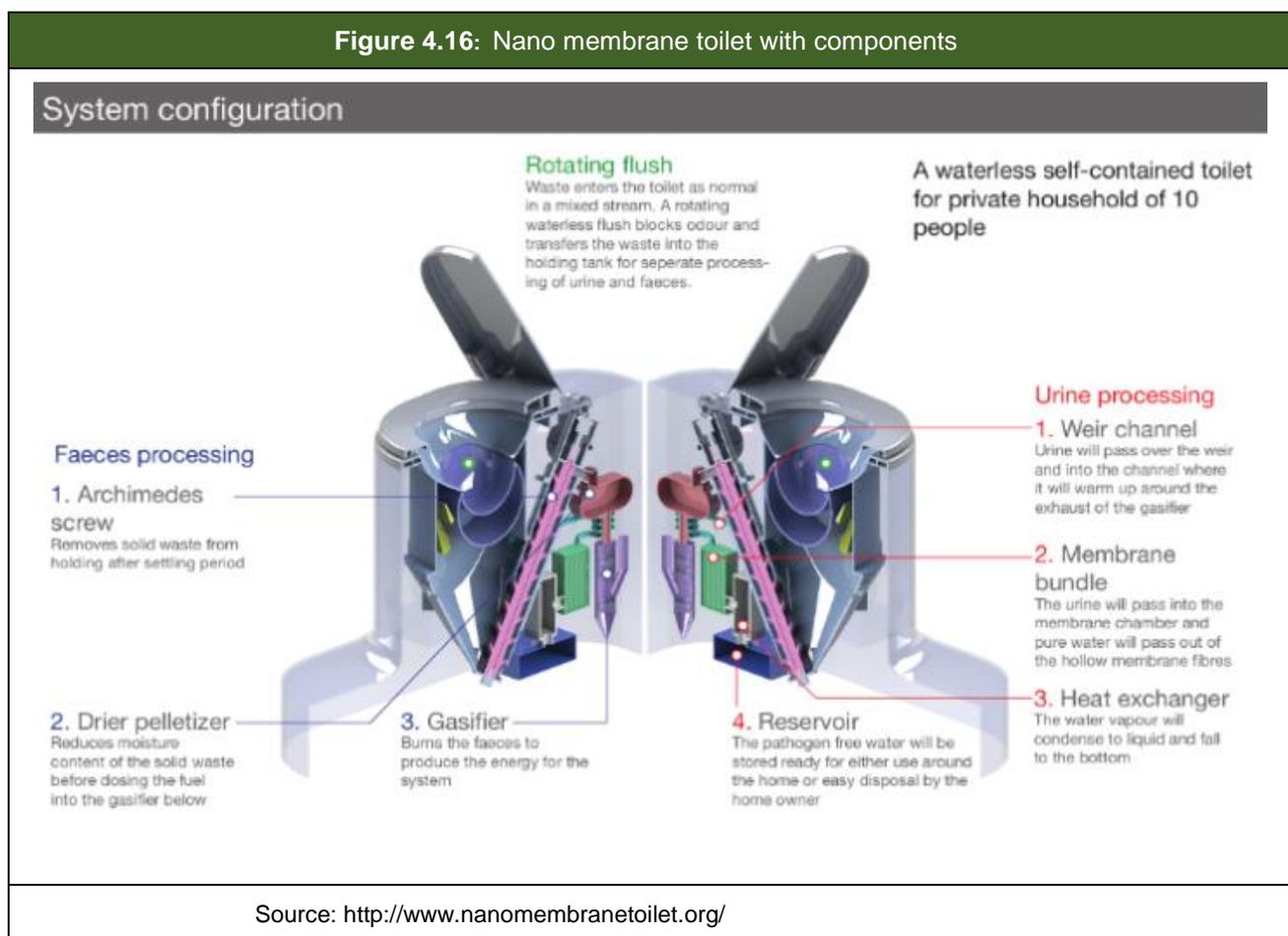
### **A brief about the technology**

The Nano Membrane toilet is a research project carried out by Cranfield University. It aims to use the inherent energy present in the faeces to dehydrate it and also enable conversion of urine and wastewater to treated water that can be reused for flushing. It is designed as a stand-alone system for households, providing complete sanitation.

### **Technology Description and working principles:**

It is a normal toilet with specialised instruments under the pan for processing faecal matter, urine and spent water. The mixed contents pass through an auger and weir mechanism for liquid and solid separation. Solids' separation (faeces) is principally accomplished through sedimentation. Once separated, solids are dried using hot exhaust from an inbuilt gasifier. The dried faecal matter is later introduced into a gasifier which uses inherent calorific content to fuel the burning process. The ash from gasifier is removed from the system and stored for disposal into solid waste sites. Excess heat generated from the gasifier is used to vaporise urine and other wastewater and pass through a specially designed membrane. The vapour particles later condense to form clear water which can be reused for flushing or washing of clothes. Excess heat energy is also converted into electrical energy which can be used to charge small electronic devices.

Figure 4.16: Nano membrane toilet with components



Source: <http://www.nanomembranetoilet.org/>

## Advantages and Disadvantages

### Advantages:

- Water for reuse: 1.5L/user/day
- Energy generated: 90Wh/user/day
- The system provides for complete sanitation without use of external energy and additives

### Disadvantages:

- The ash waste from the gasifier is produced and will need to be properly disposed
- The product is still in its research phase and needs to be tested for efficacy in field tests
- The calorific value of sludge changes across demographics and food habits, and hence the system needs calibration to suit local conditions

## O&M Requirements

- Field tests have to be carried out to ascertain the O&M requirements
- Ash needs frequent removal and handling
- The liquid compartment will have concentrated residues of urine and solids which has to be removed and disposed

## Health and Acceptance

- It is a progressive technology yet to be tested on the field. Field results will indicate challenges faced by users

## Cost:

- USD1000 for one unit. (tentative)

## Promoter:

- Cranfield University

## References

- Thenanomembranetoilet.org, (1999). The Nano Membrane Toilet. [online]. Available at: <http://www.nanomembranetoilet.org/blog.php>
- Bill & Melinda Gates Foundation. (2014). Reinvent Toilet Fair India 2014 Technical guide. 1st ed. [pdf]. Available at: <https://docs.gatesfoundation.org/documents/Reinvent%20the%20Toilet%20Fair%20India%202014%20Technical%20Guide.pdf>
- CranfieldUniversity.ac.uk, (2012). The Nano Membrane Toilet. [online] Available at: <https://www.cranfield.ac.uk/Research/Research-activity/Current-projects/research-projects/NanoMembrane-Toilet>

## 4.14. RTI International Toilet System

### A brief about the technology

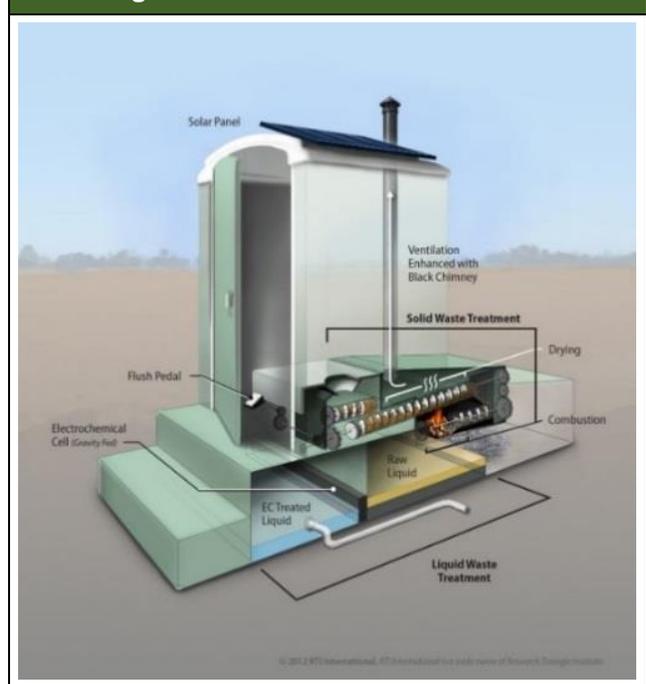
RTI International is working on a concept where the toilet uses energy available within the faecal matter for its treatment and safe disposal. The toilet uses mechanical and thermal systems to convert latent heat present in faeces to usable forms such as heat and electricity. These toilets are stand-alone system which can be used at places of low water supply, erratic electricity and non-availability of sewerage or FS collection system.

### Technology Description and working principles:

The RTI system is based on four core technology components:

- Solid liquid separation and solid waste drying via thermal convection
- Electrochemical disinfection of the liquid waste
- Combustion of the solid waste
- Thermoelectric energy harvesting

Figure 4.17: RTI International Toilet



A mechanical, auger-based process separates liquids and initiates the process of converting solid waste into combustible fuel. Solar energy, natural air drafts and heat from burning waste provide control to the drying process. As the waste dries it is converted into uniform-sized pellets, which is burned using a novel combustion unit. This self-powered human waste treatment unit also captures a portion of the heat produced, using thermoelectric energy harvesting, and converts it into electricity for powering the system.

Liquid waste which includes liquid removed from the solid waste, urine and flush water is disinfected through electrochemical processes using carbon-based electrodes. Liquid disinfection is powered by thermoelectric energy from the faecal waste treatment unit. The disinfected liquid will be suitable for use as flush water for the toilet, as a fertiliser supplement or for other non-potable applications.

## **Advantages and Disadvantages**

Advantages:

- It is a self-sustained system
- There is zero-waste discharge
- The system produces excess electricity that can be used for lighting purposes

Disadvantages:

- It is a complex system which requires skilled maintenance staff
- The capital costs are high
- It should be calibrated to suit different characteristics of sludge

## **O&M Requirement**

- As the process includes electrochemical mechanism the operation and maintenance of the system is rigorous
- Regular emptying of ash from the gasifier unit

## **Health and acceptance**

- It is a progressive system requiring heavy investment. It is unclear if low-income households can afford it
- Maintenance of these systems requires skilled labour and capacity building of locals is necessary for scaling up such interventions
- It solves the issue of frequent de-sludging and handling of faecal sludge by treating it at the point of generation, thus curbing environmental hazards linked to FSM.

## **Design factors**

- The retention time and gasifier must be calibrated to suit usage characteristics, i.e., amount of flush water, calorific value of faeces, etc.
- Further factors to be determined based on results of field tests.

**Cost:**

- The market cost of this toilet is unknown as it is a prototype toilet

**Manufacturer:**

- RTI international organisation, India

**References**

- Bill & Melinda Gates Foundation. (2014). Reinvent Toilet Fair India 2014 Technical guide. 1st ed. [pdf]. Available at: <https://docs.gatesfoundation.org/documents/Reinvent%20the%20Toilet%20Fair%20India%202014%20Technical%20Guide.pdf>
- Rti.org, (2012). RTI International to Develop Waterless Toilet that Processes, Recycles, and Disinfects Waste. [online]. Available at: <https://www.rti.org/newsroom/news.cfm?obj=EC9026C9-5056-B100-0C87415C9CAD0A95>

#### 4.15. Savvy Loo System

##### A brief about the technology

Savvy Loo is piloting a waterless sanitation solution implemented in rural communities and temporary settlements, potentially across Africa. The Savvy Loo system separates urine and desiccates faeces in three to five days to a dry bio-waste, which is easy to transport and converted to energy using gasifier systems. Savvy Loo's innovative design significantly reduces sanitation life-cycle costs when compared to pit latrines, water-based and chemical toilets.

##### Technology description and working principles

Savvy Loo is a desiccating toilet comprising a conical disc with a spiral arrangement that separates liquids from solids. Liquids get collected at the bottom chamber and are later drained through a soak-away arrangement. Solids adhere to the conical disc's surface and are guided by a fixed 'spiral guide' during the desiccation process until dry. The bio-solid (approximately 8 per cent to 15 per cent of the original mass) is deposited into a waste liner housed in a receptacle for easy removal and downstream processing. Dried faecal matter collected from these toilets can be used as a fuel in gasifiers.

Figure 4.18: Savvy Loo installations in Africa



## **Advantages and Disadvantages**

### **Advantages**

- The system does not require water for operation and can be installed where there is shallow groundwater or rock
- It has a compact design integrated with the toilet structure.
- It discharges the desiccated waste into a collection liner for improved handling and minimal faecal contact
- It overcomes the need of a sewerage pipe
- The isolation of faeces discourages breeding of flies and allows for minimal groundwater contamination

### **Disadvantages**

- It is difficult to install the toilet inside the house
- The liquids will have faecal waste mixed with the urine, and can therefore not be considered sterile for reuse application
- Ventilation of similar systems is often not adequate to prevent odours
- Waste may be visible when the toilet seat is opened
- Conveyance of faecal matter through the conical disc might be hindered by stickiness of faeces
- It might be difficult to remove the treated faecal matter

### **O&M Requirement**

- The inflow to the system needs to be checked periodically and regular de-sludging of accumulated sludge is essential
- The conical disc needs to be cleaned to remove faecal smears to prevent smell and breeding of insects
- The liquid chamber needs to be de-slugged regularly as it might contain settled solids

### **Health and acceptance**

- The solid liquid separation is based on the usage pattern; if too much water is used in anal cleansing, it can flush the solids into the liquid chamber
- Users might not be comfortable as the faeces is visible during defecation and can emit odour
- Improper cleaning can lead to breeding of disease causing vectors on the conical chamber, causing outbreaks of infectious diseases

### **Design factors**

- A desiccating toilet comprising a slightly conical disc that separates diarrhoeic and other liquids from solids with the slope of the disc being decided based on the total solids and flow ability of input

- Liquids drain into a soak-away via a central sump for liquids. A pump arrangement has to be provided to pump out liquid through the soak away and similar arrangements have to be made to prevent the backflow of rain water into the system during floods or water logging

### Manufacturer/Supplier details

- SEED
  - Website: [www.seed.uno](http://www.seed.uno)

### Cost:

- Unknown as the product is in its pilot phase and the organisation is awaiting funding opportunities.

### References

- seed.uno, (n.d). SavvyLoo. [online]. Available at: <https://www.seed.uno/awards/all/2015/1838-savvyloo-waterless-sanitation.html>

## 4.16. Sintex: Prefabricated Improved Septic Tanks

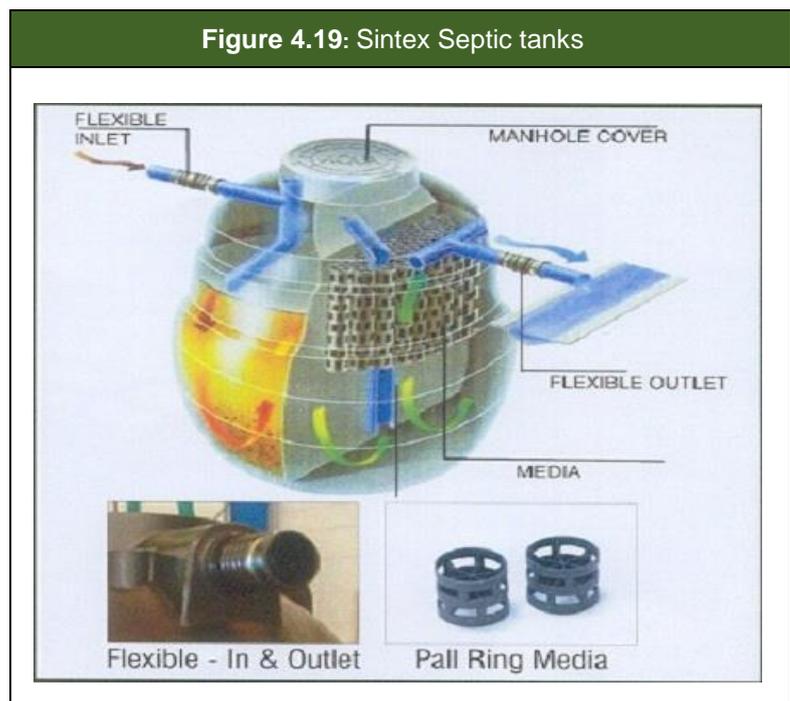
### A brief about the technology

Sintex, an Indian business unit with interests in plastics and water tanks has launched a prefabricated polyethylene septic tank system for individual households and institutions. The system takes septic tanks a level further by introducing filter media and aeration systems. It can be used as quick installation systems for households.

### Technology description and working principles

The prefabricated module is a two-chamber design with the first chamber acting as sedimentation and settling zone for heavier solid particles. A little bit of anaerobic digestion starts in this zone. The supernatant passes from the first chamber into the second by means of a down-take pipe. There is some amount of

settlement and anaerobic digestion at this stage as well. The supernatant then passes through a filter media and exits from the system to be drained away in a soak pit or soak away arrangement. The filter material provides a platform for fixed growth of microorganisms, increasing the contact area with wastewater and enabling digestion. The system has an organic load reduction capability of 50–60 per cent biochemical oxygen demand (BOD), hence the treated water is not fit for open discharge or reuse until tertiary treatment options are integrated.



## Advantages and Disadvantages

### Advantages

- It has a small footprint and can be placed underground, thereby saving space above
- Installation of this system is easy and fast
- The material of the tank is inert and corrosion resistant, therefore extending the life of the asset
- It performs better as compared to a regular septic tank
- It is simple system with a low operation and maintenance cost
- It has a non-permeable membrane which does not allow water to percolate through the ground

### Disadvantages

- Heavy weights cannot be placed above the tank structure
- The output needs further treatment to improve quality
- The system requires de-sludging every 12–24 months which increase maintenance costs

## Design factors

- It is a packaged system and hence the dimensions and modules depend on the quantity of wastewater flow per day. The minimum design capacity is 1000 litres per day.

## Manufactures

- SINTEX INDUSTRIES LIMITED.  
Gujarat. Email: plastic@sintex.co.in

## Cost:

- ₹25000 for an individual household generating 1000 litres per day (blackwater).

## References

- Sintex-plastics.com, (n.d). Sintex. [online] <http://www.sintex-plastics.com/>

## 4.17. Sun-Mar System

### A brief about the technology

Sun-Mar toilets are designed to optimise and accelerate natural processes of decomposition and evaporation to convert faecal and kitchen waste to nutrients. The superior oxygenation and moisture control provides an optimum environment for aerobic bacteria to carry out odourless degradation. The end products formed in the process are treated water and nutrient-rich compost. This system can be applied for areas where there is no arrangement for sewerage or sludge collection and processing.

## Technology description and working principles

The unique Sun-Mar Bio-drum ensures that aerobic microbes flourish and work quickly to break down waste. Waste and bulking material (such as saw dust) enter through the inlet port at the top of the drum which is rotated periodically using the handle on the front of self-contained units or on the side of central units. This allows the waste to mix and aerate. During rotation, the inlet door closes automatically keeping the compost in the drum. It takes about 3–4 weeks for the entire composting process. To empty the compost from the Bio-drum the drum locker is released and the drum is rotated backwards. The inlet port in the Bio-Drum then opens automatically and the compost drops directly into the finishing chamber. This compost can be used as a nutrient-rich soil conditioner for non-food plants. After rotating, the Bio-drum locks itself in a top dead centre position ready to receive new material.

## Advantages and Disadvantages

### Advantages

- This system uses less water
- It allows for treatment of organic and faecal matter in one system
- The end product is readily usable

### Disadvantages

- It requires operation and supervision by the user
- Improper operation and maintenance can lead to bad odours
- These toilets are not designed to handle anal cleansing water, and hence separate arrangements need to be made

## O&M Requirement

- Operation requires periodic rotation of the composting drum and addition of organic and filler material such as saw dust
- Maintenance requires regular cleaning of the composting drum and removal of compost from the system

## Design factors

- Controlling the amount of moisture to remain in the range of 40–60 per cent enhances the composting process. This can be controlled by natural draft and calibrating the composting period based on faecal input
- It is not suitable for cold climates, where the composting process is slow and heat is lost easily to the surroundings. Composting is an exothermic process and requires that heat is retained to enhance further degradation and pathogen reduction

## Manufacturer/Supplier details

- Sun-Mar Corp.  
600 Main St.  
Tonawanda, NY 14150

Figure 4.20: Sun Mar composting toilets



**Cost:**

- Sun-Mar toilet cost USD1740 per toilet system.

**References**

- Sun-mar.com, (n.d). Composting Toilets by Sun-Mar. [online] Available at: <http://www.sun-mar.com/>

**4.18. Tiger Toilets****A brief about the technology**

The Tiger Worm Toilet is a flushing system that treats both the liquid and solid waste using composting worms (*Ensenia fetida*). It consists of a pour-flush latrine connected to a concrete chamber called the bio digester. The worms eat the faecal matter, which reduces the pathogen load and the frequency with which it needs to be emptied. The system is smaller than a septic tank and the waste that is generated is safer and easier to handle. These systems can be installed at locations which are remote and where frequent de-sludging can be a challenge.

Figure 4.21: Tiger worms in action

**Technology description and working principles**

The flushable Tiger Toilet is compact, easy to maintain and hygienic to use. It uses worms to speed up the decomposition process in a digester. The 'solid accumulation rate' drops by 70 to 80 per cent and thus helps in reducing odour and pathogens in the toilets.

The bio-digester tank contains two semi-circular open baskets and at the top of the basket is a wire mesh basket that contains the worms and support material such as coir that the worms can attach to. The waste is flushed through a pipe into the semi-circular basket where the solids are captured and the liquid falls deeper into the tank. The solids are consumed by the worms and the liquid is filtered through the drainage layer. The liquid is treated with aerobic bacteria and allowed to evaporate or drain out of the tank into a soak-away system or leach pit. Both worms and the anaerobic bacteria assist in degradation of the solids. The degraded faecal matter and solids are collected in baskets positioned below these chambers.

Extensive laboratory scale trials found that the worms reduce the solids in the system by above 80 per cent and the effluent quality is higher than that from a septic tank.

## **Advantages and Disadvantages**

### **Advantages**

- The tiger worms increase the efficiency of degradation
- The treated sludge can be directly used as fertiliser
- A reduction in sludge volume enhances the life of containment systems

### **Disadvantages**

- Worms require a continuous supply of organic waste
- Extensive use of flushing water and anal cleansing water can flood the housing containing the worms and can kill them

## **O&M Requirement**

- It requires a one-time input of worms after which they multiply on their own, provided an enabling environment is maintained
- The treated effluent is not of standards that can be reused and hence appropriate tertiary systems or disposal techniques must be adopted and maintained

## **Health and acceptance**

- These toilets have open containment systems making the faecal matter visible to users. This might cause inconvenience in terms of sight and odour
- Leachate collected must be disposed scientifically, otherwise it can contaminate nearby water bodies or percolate into the ground
- Users might take time in adapting to worms being used in toilet, as the sight is not very pleasing
- Users may have to manually remove the composted matter, leading to chances of contact with pathogens

## **Design factors**

- The tank of tiger toilet is one meter in diameter and 1.2 meters' high
- This is smaller than traditional latrines and can fit in a smaller space, reducing costs involved in digging a huge pit
- Leachate handling must be designed considering the groundwater conditions and distance from nearby water sources

## Manufacturer/Supplier details

- Oxfam organization, UK

## Cost:

- Cost of one tiger toilet is USD200

## References

- Bill & Melinda Gates Foundation. (2012). Reinvent Toilet Fair program.1st ed. [pdf]. Available at: <http://www.gatesfoundation.org/~media/Reinvent-the-Toilet-Fair-Program.pdf>
- Oxfam.org, (n.d). Oxfam GB. [online]. Available at: <https://www.oxfam.org.uk/>
- Hydratelite.org, (2012). Eco-Latrine of the Future: Tiger Toilets. [online]. Available at: <http://www.hydratelite.org/?p=539>
- Sebambo, K. (2015). Tiger Worms Run This Toilet. [online] Designindaba.com. Available at: <http://www.designindaba.com/articles/creative-work/tiger-worms-run-toilet>

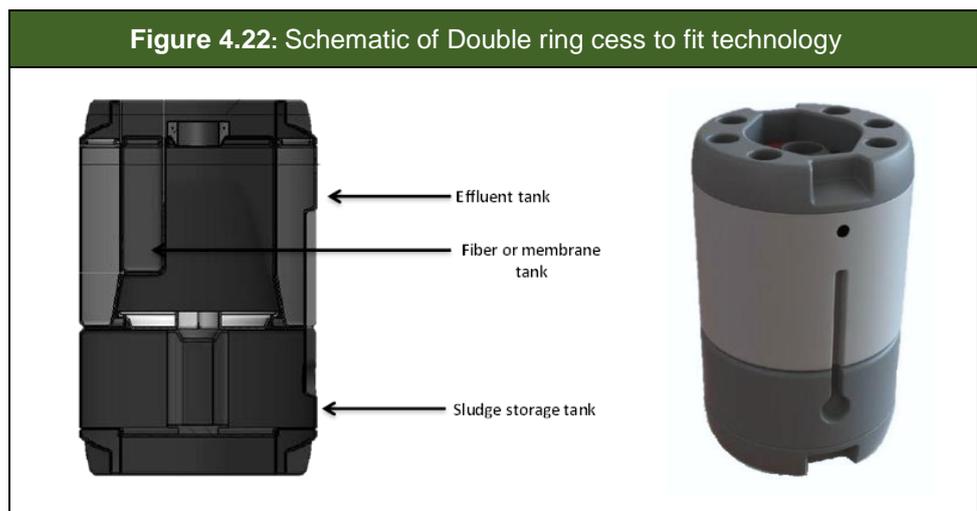
### 4.19. Double ring Cess to fit technology

#### A brief about the technology

Double ring Cess to fit technology is a closed system that can be retrofitted into existing pits/septic tanks. The innovation is in the treatment of the supernatant using photosynthesizing algae that aid in increasing the

dissolved oxygen of the treated water. These systems provide a better quality output as compared to a normal septic tank and are only marginally expensive.

Figure 4.22: Schematic of Double ring cess to fit technology



#### Technology description and working principles

The system comprises two chambers. The primary chamber receives brown water from toilets. Most solids settle here by sedimentation and undergo anaerobic decomposition. The supernatant from this chamber enters into the second chamber containing the algae. This chamber acts as a bio-filter reducing the organic load, turbidity and smell from the supernatant to a considerable extent compared to a regular septic tank. The photosynthesis process in this chamber is achieved by means of Light emitting diode (LED) placed along the liquid flow. These lights may need to be switched on for a period of time based on the retention time. The treated water is not of standards that can be disposed and hence requires tertiary treatment or other means of safe disposal.

The packaging of this system is done in a cylindrical container. The inner cylinder acts as the primary chamber while the outer chamber has the algae and LEDs. The packaging of the system in this fashion reduces the total area footprint. These systems are designed to be placed underground.

## **Advantages and Disadvantages**

### Advantages

- It is easy to retrofit with existing cesspool system
- It enhances the treatment efficiency of the existing containment system
- It is a low cost technology
- It is easy to install and maintain

### Disadvantages

- The primary chamber requires de-sludging every 1–2 years
- The LED light need to be replaced after a certain period of use

## **O&M requirement**

- The membrane filter should be cleaned on a timely basis
- The LED light should be replaced after prescribed periods
- The de-sludging of the primary tank i.e., sludge level should be monitored periodically, and emptied as required

## **Health and Acceptance**

- This technology improves the quality of effluents
- This technology has attracted public interest as it can be retrofitted and easily installed
- It is well accepted because of its low cost
- Cess to fit technology has been tested household level and has worked satisfactorily

## **Design factors**

- The current design is limited to 4–5 users in a single household

## **Manufacturer/Supplier details**

- Innosolt Co., Ltd, 251/69 Rama3 Road Bangkorleam, Bangkok, Thailand 10120. Email: [innosolt.technology@gmail.com](mailto:innosolt.technology@gmail.com)

## **References**

### Patentable innovation:

- Koottatep, T., Surinkul, N., Dulyakasem, S. Cess to Fit. (Date of application: 15/9/2014). Application number: 1401005382, Department of Intellectual Property (DIP), Thailand
- Koottatep, T., Surinkul, N., Singhopon, T. Double Rings Cess to Fit Equipped with LED Light. (Date of application: 18/05/2016). Application number: 1601008849. Department of Intellectual Property (DIP), Thailand.
- Koottatep, T., Surinkul, N., Singhopon, T. Double Rings Cess to Fit (Date of application: 18/05/2016). Application number: 1601002850. Department of Intellectual Property (DIP), Thailand.

## 4.20. Solar Septic Tanks

### A brief about the technology

Solar Septic Tanks (SST) is a modification of conventional septic tanks that use solar-heated water to improve their performance. The increased temperatures kill off pathogens and reduce sludge accumulation by increasing the speed of biodegradation of organic matter. These systems can be integrated into regular septic tanks at the household level.

Figure 4.23: Solar septic tank installed at field



### Technology description and working principles

It uses solar energy to increase temperature inside tanks. Such increment of temperature inside the septic tanks helps to inactivate pathogens, convert organic wastes into methane biogas and alleviate the negative environmental concerns associated with faecal sludge handling. Solar septic tank includes three main components: i) 1000 L-conventional septic tank, ii) disinfection chamber and iii) 6 m<sup>2</sup>-solar water heating device. The desired high temperature inside septic tank is achieved by circulating hot water from a solar water heating device through a heat transfer unit. The hot water is circulated at a rate of 5 L/min to maintain the temperature in the range of 40–55°C inside septic tanks. The system is equipped with a control panel and a temperature sensor to regulate the flow and maintain the temperature.

### Advantages and Disadvantages

#### Advantages

- The system produces improved effluent quality
- The heat inactivates pathogens in effluent >10<sup>3</sup> log (99.9%)

- It reduces sludge accumulation and thus reduces the de-sludging frequency
- It increases bio-gas production and offers re-useable water for agriculture

#### Disadvantages

- Energy is required to heat up the system
- The system demands a large rooftop area for installation of solar heating device
- The cost of solar panel is a major cost driver of the system

#### O&M Requirement

- Sludge needs to be removed from the system every 5–7 years
- Heat exchanger should be maintained every 2 years

#### Health and Acceptance

- SST reduces pathogens from effluent (to level <10<sup>3</sup>log) complying with the WHO guideline for agricultural reuse
- It alleviates the environmental problems associated with faecal sludge handling

#### Design Factors

- The temperature of the tank will be maintained in range of 40–50°C
- Hydraulic retention time (HRT) is about 24–48 hours
- An area of 6–12 m<sup>2</sup> is required for solar heated water for a septic tank size of 1000 L

#### Case Study

- Location: One at Asian institute of technology and other at a private residency in Thailand
- Scale: Small (2 units)
- Application: Field Testing (Institute)
- Year of Implementation: 2015
- Cost: Not available
- System Features:
  - 1000 L-conventional septic tank
  - disinfection chamber
  - 6 m<sup>2</sup>-solar water heating device.

#### Manufacturer/Supplier details

- Innosolt Co., Ltd. 251/69 Rama3 Road Bangkorleam, Bangkok, Thailand 10120. Email: [innosolt.technology@gmail.com](mailto:innosolt.technology@gmail.com)

#### References

Patentable Innovation

- 1. Pussayanavin, T., Koottatep, T, Polprasert, C. and Boonyaphalananth, B. Enhanced Sludge Reduction in Septic Tanks by Increasing Temperature, (Date of application: 03/07/2014) Application number: 1401001214
- 2. Pussayanavin, T., Koottatep, T, Polprasert, C. and Boonyaphalananth, B. Heating system in a Solar Septic Tank. (Date of application: 7/10/2014) Application number: 1401003996
- 3. Patent pending, filed for India and international patent

#### Journal Paper/conference proceedings

- 1. Koottatep T., Phuphisith, S., Pussayanavin, T., Panuvatvanich, A. and Polprasert C, 2013, Modeling of Pathogen Inactivation in Thermal Septic Tanks, Journal of Water, Sanitation and Hygiene for Development Vol 4 No 1 pp 81–88
- 2. Koottatep T., Eamrat. R., Pussayanavin, T. and Polprasert C., 2014, Hydraulic Evaluation and Performance of On-Site Sanitation Systems in Central Thailand: Environ Eng Res. 2014;19(3):269-274.
- 3. Pussayanavin T., Koottatep T., Eamrat. R. and Polprasert C., 2014, Enhanced Sludge Reduction in Septic Tanks by Increasing Temperature, Journal of Environmental Science and Health, Part A (2015) 50,1–9
- 4. Polprasert C., T., Koottatep, Suthirat K., Pussayanavin, T., New Generation and Research on Toilet, Keynote speaker: 3rd International Conference on Environmental Engineering, Science and Management, 26-28 March 2014
- 5. Pussayanavin T., Koottatep T., Arora, N., Jabade, S. and Polprasert C, 2014, Dynamic Modeling as a Tool to Investigate Performance of Conventional Septic Tank, 1<sup>st</sup> Specialist Conference on Municipal Water Management and Sanitation in Developing Countries, Dec 2014.
- 6. Polprasert C, Pussayanavin, T., Panuvatvanich, A and T., Koottatep: Environmental Technology for Water Pollution Control for Thailand and the Region, the Royal Institute, Oct 15 2014
- 7. Polprasert C, Pussayanavin, T., Panuvatvanich, A and T., Koottatep: Innovative Sanitation Technology for Control of Water Pollution and Health Problems in Developing Countries International Conference on Asian Environmental Chemistry (ICAEC), Proceeding.
- 8. Polprasert C, Pussayanavin, T. and Koottatep, T., Urban Development and Water Sustainability, Water and Urban Initiative, Working Paper series, Number 1-Aprli 2015

## 4.21. Zyclone Cube (Version-3)

### A brief about the technology

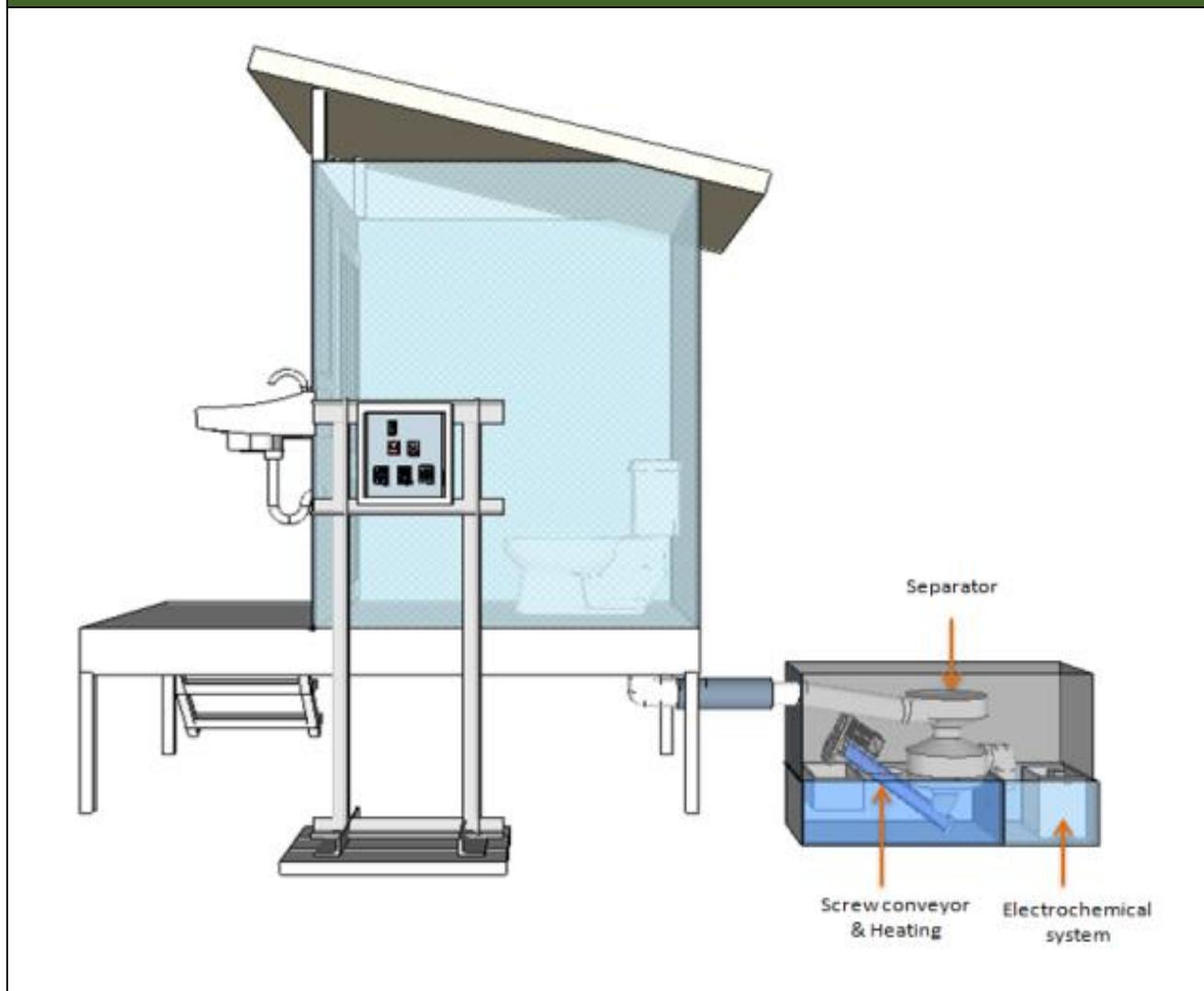
Zyclone Cube is an improved sanitation system that uses a centrifuge to separate liquids and solids and enhances degradation separately. This system can be integrated into any regular flush toilet having separate compartments for liquid and solid waste.

### Technology description and working principles

The overall system consists of three major components: i) solid liquid separator, ii) solid disinfection system and, iii) liquid disinfection system. The solid liquid separator uses the kinetic energy of the flush to convert the flow into a circular motion thereby centrifugally separating solids and liquids. The separated solid is treated by screw driven heating system, where heat is supplied by means of a heating coil. On the other hand, the

separated liquid is diverted through media baffle reactors and treated by an electrochemical method before being discharged. The hydroxyl radicals and hypochlorite ions generated in the electrochemical system act as disinfectants in this process. The treated water can be reused for flushing while the dried solids can be used as a source of fuel in a gasifier.

**Figure 4.24:** Schematic diagram of cyclone cube



### Advantages and Disadvantages

#### Advantages:

- It does not require emptying and post-treatment for faecal sludge as with conventional on-site sanitation systems
- It does not require high technical know-how for installation and maintenance
- It can be retrofitted to existing systems.
- Produces end products that have economical value (fuel source)

#### Disadvantages:

- The separator is sensitive to inert materials (such as sanitary napkin, cloths, stone) in flushing water

- Energy (electricity) is required for the operation of screw heater and electrochemical disinfection unit
- Maintenance of screw heater and electrochemical unit to be carried out on a periodic basis
- The initial cost of technology is relatively high

### **O&M Requirement**

- A flat area is required for vertical placement of separator
- Unwanted materials (e.g., plastics, stones, rubbers, sanitary pads, etc.) should not be flushed into the toilet
- Electricity is required to operate disinfection units
- Screw heater should be operated at given intervals (at present 3 days' interval) and treated faecal matters should be emptied once a month
- Electrode plates should be checked periodically for corrosion
- The service provider should be contacted in case problems such as clogging of separators and heating unit is observed.

### **Health and Acceptance**

- Treated solid and liquid can be safely released into the environment, or used as soil conditioner or fuel source and water as a source of irrigation
- Reduced health risks from faecal-oral route due to pathogen inactivation
- The system can be customised thereby making it acceptable to a wider range of users

### **Design factors**

Zyclone cube is designed typically for 4–5 users of individual household.

- Assembled Width: 1.1 m
- Assembled Length: 1.1 m
- Assembled Height: 1.2 m
- Material: PE Plastic

### **Manufacturer/Supplier details**

- Manufactured in Thailand
  - Innosolt Co., Ltd. 251/69 Rama3 Road Bangkorleam, Bangkok, Thailand 10120. Email: [innosolt.technology@gmail.com](mailto:innosolt.technology@gmail.com)

### **Reference:**

- Chapagain, S., Koottatep, T, Panuvatvanich, A. and Kanok-Nukulchai, W. E The device for separate between liquid and solid from the toilet flushing (Cyclone toilet), (Date of patent application: 17/12/2015), Application number: 1501007567, place: Department of Intellectual Property (DIP), Thailand
- Patent pending, filed for India and international patent

**Table 4.1: Containment - Summary**

| SI. No. | ASSESSMENT CRITERIA  | INDICATOR                                  | INFORMATION REQUIREMENT  | ASSESSMENT OUTCOME                                    | CONTAINMENTS  |  |  |  |   |   |   |   |   |  |   |   |  |   |
|---------|----------------------|--|--|---|---|--|--|--|---|---|---|---|---|--|---|---|--|---|
|         |                      |  |  |   | (A) DRDO Biotank  | (B) Blue Diversion toilet  | (C) Composting Chamber   | (D) Double Ventilated Improved Pit (VIP)                             | (E) Composting Ekolet Dry Toilet System   | (F) Enviro Loo System   | (G) Flush-Tech System   | (H) Fossa Alterna   | (I) Johkasou System   | (J) Loolaa Boo Toilet  | (K) Nano Membrane Technology  | (L) Savvy Loo System  | (M) Sintex: Prefabricated Improved Septic Tanks  | (N) Sun-Mar System  |
| 1       | Regulatory standard  | Organic load reduction in treated effluent | BOD, COD of influent and effluent  | Yes / No / Information not available / Not applicable | Yes, There are claims that 90% of the organic load reduction is achieved. (No COD, BOD data is available)   | Information is not available.  | Yes. Through the composting process, the organic content of the feces is completely reduced to manure. | No significant reduction in organic content                          | Significant reduction in organic content, since the feces is composted with kitchen waste | Due to exposure to sunlight and continuous ventilation, the fecal matter dries up and organic content reduces to a certain extent | Yes. Due to addition of bacterial inoculum and maintained under the SBR mode, the sludge generated is completely degraded in the containment. | As there is no water allowed into the pit, completed degradation of the organic content is achieved through the composting process. | As the sludge undergoes a series of anaerobic treatment processes, a significant reduction in organic content is achieved | Information is not available.  | Complete reduction of organic content, as the sludge is burnt down to ash.                    | No complete reduction in organic content is achieved                                    | Partial reduction of organic content is achieved through anaerobic digestion   | Organic matter in the feces is completely degraded to compost |
| 2       | Regulatory standard  | Total Solid reduction in treated effluent  | TS, TDS of influent and effluent   | Yes / No / Information not available / Not applicable | Yes, There are claims that there will be overall reduction in suspended solids in the effluent (No data available of TS)                                    | Information is not available.  | Information is not available.  | Information is not available.  | Information is not available.   | Solid content reduces up to 5 per cent from its initial volume in the dehydration unit  | Significantly, no sludge generated. Thus solid reduction will also be high.   | Information not available   | Yes there is some reduction in Total Solids   | Information is not available.  | Since the sludge is turned into ash, there will be significant reduction in Total Solids too. | Bio solids of 8- 15 per cent is achieved through sending the feces in conical disc too. | Information not available  | Information is not available.                                 |
| 3       | Regulatory standard  | Pathogen reduction in treated effluent     | Helminths egg, E. coli of influent and effluent  | Yes / No / Information not available / Not applicable | Information is not available. (Claims from the sources, states that all parameter are environmentally acceptable, but tertiary treatment is still required) | Yes. Through ultrafiltration the pathogen is removed and disinfected by electrolysis due to which residual chlorine is released. | No, not in the Leachate of the composted waste   | No, pathogen reduction achieved through the containment is very less | Pathogen reduction will be low and the leachate generated need to be further treated      | Information is not available.   | Since the liquid is reused after the UV treatment, pathogen reduction is quiet well achieved  | Due to increased temperature inside the pit during the composting process, pathogen reduction is achieved to a certain extent       | The final effluent is disinfected with chlorine to remove pathogens   | Information is not available.  | Information is not available.   | Information is not available.   | Information not available  | Information is not available.                                 |
| 4       | Regulatory standards | CPCB standards for discharge/reuse         | Is the end product, emissions, and effluent characteristic as per CPCB (2015) standards for discharge/reuse? | Yes / No / Information not available / Not applicable | Information is not available. (Claims from the sources, states that all parameter are environmentally acceptable, but still tertiary treatment is required) | Information is not available.  | Information is not available.  | Information is not available.  | Information is not available.   | Information is not available.   | Information is not available.   | Information is not available.   | Yes, it meets the BOD standard of effluent (20mg/l)   | Through a long term lactic acid bacterial degradation and vermicomposting, pathogen reduction is achieved to a certain extent. | Information is not available.   | Information is not available.   | Only 50 - 60 per cent of the BOD reduction is achieved, and hence not fit for discharge or reuse. This does not meet the standards | Information is not available.                                 |

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| SI. No. | ASSESSMENT CRITERIA          | INDICATOR     | INFORMATION REQUIREMENT  | ASSESSMENT OUTCOME                                    | CONTAINMENTS  |  |   |  |  |  |   |  |  |   |  |  |   |   |
|---------|------------------------------|---------------|--|---|---|--|---|--|--|--|---|--|--|---|--|--|---|---|
|         |                              |               |  |   | (A) DRDO Biotank  | (B) Blue Diversion toilet  | (C) Composting Chamber  | (D) Double Ventilated Improved Pit (VIP)                             | (E) Composting Ekolet Dry Toilet System  | (F) Enviro Loo System  | (G) Flush-Tech System   | (H) Fossa Alterna  | (I) Johkasou System  | (J) Loolaa Boo Toilet   | (K) Nano Membrane Technology   | (L) Savvy Loo System   | (M) Sintex: Prefabricated Improved Septic Tanks | (N) Sun-Mar System  |
| 5       | Health and safety of workers | Human Contact | Are there any activities or procedures that can lead to contact of sludge with humans?       | Yes / No / Information not available / Not applicable | No. (Sampling of effluent and Raw sludge input might lead to contact of sludge with humans) | Yes. Constant removal routine of urine and feces is involved in this practice.                 | Yes. Compost generated has to be emptied manually from the pits. Therefore, exposure to harmful pathogens is evident  | Yes, humus has to be emptied from the pit manually.                  | Yes, the compost generated has to be emptied from the compartments at regular intervals. | No, the remains like concentrated salt, liquid or sludge are desludged using submersible pump  | Since no desludging intervention is required, human contact with sludge is not a concern.                 | Composted content has to be emptied from the pits manually   | No human contact with the sludge generated, as the sludge is anaerobically degraded. | No human contact occurs at the source or while emptying. But contact may occur at the vermicomposting unit (still harmless as the sludge content is fermented completely) | Ash generated in the system and the concentrated liquid along with solids need to be disposed of carefully | The concentrated liquid (urine and cleansed water).  | No human contact involved                       | Human contact is involved during the time of emptying the compost from the drum         |
| 6       | Health and safety of workers | Spillage      | Does the sludge/ effluent spill in and around the operational area?                          | Yes / No / Information not available / Not applicable | Information is not available.   | Information is not available.  | No, there wont be any spillage of effluent  | Leachate generated have high potential of ground water contamination | Information is not available.  | No, since the chambers are sealed there is no possibility of spillage.   | No possible spillage as the containment is a compact container.   | Information is not available.  | Information is not available.  | No spillage occurrence possible, as there is proper access, and desludging technologies are used.   | Information is not available.  | Information is not available.  | Information is not available.                   | Information is not available.   |
| 7       | Health and safety of workers | Impact        | Does the technology have negative impact on the health and safety conditions of the workers? | Yes / No / Information not available / Not applicable | Only negative impact is the release of Methane gas into the atmosphere.                     | No direct health impacts. But emptying the pans need proper protective gears to ensure safety. | Since the leachate still contains Pathogens that need to be disinfected and compost might also contain harmful pathogens, it might affect the health of the workers if they are directly exposed without PPE. | Information is not available.  | Information is not available.  | Since no cleansing water is used, if the system not cleaned at regular interval, then there is a high chance of users getting health-related issues. | It is safe for users and workers maintaining the system as it requires less intervention for supervision. | Possibility of getting exposed to the undigested sludge, which may still have pathogens and harmful organisms. | Information is not available.  | Information is not available.   | Field study level study is still going on, and no significant information is available.                    | Users might have issues with smell and insects, spreading of diseases due to lack of sanitised conditions. | Information is not available.                   | May cause odour and other issues to the worker, if the system is not operated properly. |

**Table 4.2: Containment Systems - Characterization**

| SI. No | ASSESSMENT CRITERIA | INDICATOR                    | INFORMATION REQUIREMENT  | (A) DRDO Biotank   | (B) Blue diversion toilet   | (C) Composting Chamber                                    | (D) Double Ventilated Improved Pit (VIP)  | (E) Composting Ekolet Dry Toilet System  | (F) Enviro Loo System   | (G) Flush-Tech System                                     | (H) Fossa Alterna   | (I) Johkasou System                                       | (J) Loolaa boo Toilet                                     | (K) Nano Membrane Technology                              | (L) Savvy Loo System                                      | (M) Sintex: Prefabricated Improved Septic Tanks  | (N) Sun-Mar System  |                               |
|--------|---------------------|------------------------------|--|--|---|---|---|--|---|---|---|---|---|---|---|--|---|-------------------------------|
| 1      | Design              | Trash screening              | Does the system have a mechanism to manage trash present in FS?  | No, the system does not have a mechanism to manage trash.  | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.  | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. | The system takes septic tanks a level further by introducing filter media and aeration systems.                      | No, the system does not have a mechanism to manage trash. |                               |
| 2      | Design              | Material of the wetted parts | What is the material of construction? Does the material used minimize weight, durability, corrosion vulnerability? | Biodigester are made of FRP/SS/MS/ Bricks. The other information is not available.                       | Tanks and pan are made of LLDPE plastic. The other information is not available.  | Pre-fabricated bricks are used for construction.          | It can be made out of PVC, bricks, pet bottles or iron pipes.   | Ekolet Toilet is manufactured from long-lasting, recyclable materials that do not allow the leakage of harmful substances into the surrounding | The main components of the system include a ceramic toilet bowl, perforated plate, a forced ventilation unit, outlet and inlet vent pipes and a black containment unit. | Information is not available.                             | It is a normal toilet with specialised instruments under the pan for processing fecal matter, urine and spent water. | Pre-fabricated polyethylene tank system.                  | Information is not available. |
| 3      | Design              | Space requirement            | Minimum dimensions occupied by the system, land area needed, top surface usability.                                | Information is not available. The document says it is an excellent low cost alternative to septic tanks. | It requires less foot area. The dimensions are 190 cm high, 74 cm wide and 91 cm deep. The step to the toilet pan is 37 cm. | Information is not available.                             | The vent pipe should have an internal diameter of at least 110 mm to a maximum of 150 mm, and reach more than 300 mm above the highest point of the toilet superstructure | Information is not available.  | Information is not available.   | Information is not available.                             | Information is not available.                             | Information is not available.                             | Requires little space.                                    | Information is not available.                             | Information is not available.                             | Information is not available.  | Information is not available.                             | Information is not available. |

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|--------|---------------------|---------------------------|---|--|--|---|--|--|--|---|---|---|--|---|-------------------------------|--|--|
| 4      | Design              | Reusability of the sludge | Can the decanted sludge be directly reused?   | No, since the sludge cleaning is not carried out, no possibility of reusing decanted sludge.   | No, since the filled tanks of urine and feces has to be treated in a centralized treatment facility, where they may be converted to fertilizer and biosolids. This can then be used for farming. | Compost can be used as a soil conditioner. Organic solid waste can be managed concurrently.   | Information is not available.            | Integrated waste management for organic waste and feces. | End products are usually to be harvested by the household and reused locally. Growing urbanisation and reduction in open lands reduce places for application of bio solids and urine based fertiliser. | Information is not available.   | Fossa Alterna is designed to make an earth-like end product that can be used as a nutrient-rich soil conditioner. | Treated water can be used for various purposes such as gardening, flushing, etc. Sludge from Johkasou system can be used as fertilizer. | The Loolaa boo system provides improved sanitation. The system also provides enriched reusable soil conditioners for farming as its end product. | Water for reuse: 1.5L/user/day . Energy generated: 90Wh/user/day. | Information is not available. | Information is not available.  | The end products formed in the process are treated water and nutrient-rich compost.                                  |
| 5      | Design              | Design life               | What is the actual / economic life of the equipment?  | Information is not available. The document says it is an excellent low cost alternative to septic tanks.   | The life span is 10 years.   | Long service life.  | Information is not available.            | Information is not available.                            | Information is not available.  | Information is not available.   | Information is not available.   | Information is not available.   | Information is not available.  | Information is not available.                                     | Information is not available. | Material is inert to corrosion, thereby enabling longer life of the asset. | Information is not available.  |
| 6      | Design              | Uniqueness                | Does the technology address a problem which is not addressed by any of the existing technologies? | The technology serves as an excellent low cost alternative to conventional septic tanks for individual houses and communities under diverse geo climatic conditions. | The technology serves specifically for places with no access to water, electricity and sewerage network.   | Composting is possible at high temperatures (thermophilic composting) and at low temperatures (ambient or mesophilic composting). Thermophilic composting is faster and more efficient in inactivating pathogens. | Information is not available.            | Information is not available.                            | Modular and possibility for relocation.  | Treated wastewater can be reused for flushing . Flexibility in handling wide variety of wastewater input characteristics. There is no accumulation of solids in the containment eliminating the need for de-sludging. | Information is not available.   | Information is not available.   | Adding of Lactic acid solution to the system is one of its kind.   | Information is not available.                                     | Information is not available. | Information is not available.  | This system can be applied for areas where there is no arrangement for sewerage or sludge collection and processing. |

**Table 4.2: Containment Systems - Characterization**

| SI. No | ASSESSMENT CRITERIA | INDICATOR                        | INFORMATION REQUIREMENT   | (A) DRDO Biotank   | (B) Blue diversion toilet  | (C) Composting Chamber             | (D) Double Ventilated Improved Pit (VIP)          | (E) Composting Ekolet Dry Toilet System | (F) Enviro Loo System              | (G) Flush-Tech System                                    | (H) Fossa Alterna                           | (I) Johkasou System  | (J) Loolaa boo Toilet              | (K) Nano Membrane Technology       | (L) Savvy Loo System                    | (M) Sintex: Prefabricated Improved Septic Tanks        | (N) Sun-Mar System                       |
|--------|---------------------|----------------------------------|---|--|--|------------------------------------|---|---|------------------------------------|--|---|--|------------------------------------|------------------------------------|---|--|--|
| 7      | Design              | Power                            | What is the net energy requirement/generation? What is the source of power for the operation? State type, capacity and power consumption. | No external source of power is needed for the operation. The CO2 and methane gas from the tank is released into environment without recovery options. The other details are not available. | The energy requirement of 11.5 W electrical energy is provided by a 60Wp solar panel.  | No external power source required. | Information is not available.                     | No external power source required.      | No external power source required. | The entire system is fully automated and requires power. | No external power source required.          | Availability of electricity is a prime criterion for working of this system. It cannot work in areas where electric supply is irregular. | No external power source required. | Information is not available.      | No external power source required.      | Information is not available.                          | Information is not available.            |
| 8      | Economics           | Economic value and cost recovery | What is the economic value / possible revenue stream during operations for the user and operator?   | Information is not available. The document says it is an excellent low cost alternative to septic tanks.   | The filled tanks of urine and feces have to be treated in a centralised treatment facility, where they may be converted to fertilizer and biosolids. This can then be used for farming. Besides that, desludging, collection conveyance and transport operations are required. These may also be a possible stream of revenue. | Information is not available.      | Information is not available.                     | Information is not available.           | Information is not available.      | Information is not available.                            | Nil to low operating costs if self-emptied. | Information is not available.  | Information is not available.      | Information is not available.      | Information is not available.           | Information is not available.                          | Information is not available.            |
| 9      | Economics           | CAPEX                            | What is the capital cost of the system?   | Information is not available. The document says it is an   | Cost per unit is 500 USD.  | Information is not available.      | Higher capital costs than Single VIP; but reduced | Information is not available.           | Information is not available.      | These systems cost less and are easy to                  | The cost for a Fossa Alterna is around Rs.  | Sintex system for a household  | USD 70 per toilet.                 | USD 1000 for one unit (tentative). | Unknown, as the product is in its pilot | Rs. 25,000 for an individual household generating 1000 | Sun-Mar toilet cost USD 1,740 per toilet |

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|--------|---------------------|-----------|---|--|---|------------------------------|--|---|-------------------------------|--|---|-------------------------------|-------------------------------|-------------------------------|---|---|-------------------------------|
|        |                     |           |   | excellent low cost alternative to septic tanks.  |   |                              | operating costs if self-emptied.         |   |                               | operate, thus proving to be an effective alternative to pit latrines in rural communities. | 2.5 lakhs (includes slab casting, pit excavation and lining, and the superstructure). | costs Rs. 1,20,000 per unit.  |                               |                               | phase and the organisation is awaiting funding opportunities. | liters of blackwater per day.                   | system.                       |
| 10     | Economics           | OPEX      | What is the operational cost of the system per capita / per volume of input sludge? | Information is not available. The document says it is an excellent low cost alternative to septic tanks. | To ensure that upfront investment costs are not too high, people rent the toilet. The rental agreement covers the operation and maintenance of the toilet, and the collection services. The service fee pays for the manufacturing, installation, and maintenance costs of the blue diversion toilet, as well as the collection costs of the urine and feces. | Information is not available | Information is not available.            | Information is not available.           | Information is not available. | BioSol SL36 has to be purchased from the registered suppliers periodically.                | Information is not available.   | Information is not available. | Information is not available. | Information is not available. | Information is not available.                                 | Information is not available.                   | Information is not available. |

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|--------|---------------------|--|---|--|---|--|---|--|--|---|--|-------------------------------|---|-------------------------------|-------------------------------|---|--|
| 11     | Ease of O&M         | Moving equipment                                   | Are there moving parts or devices which require frequent maintenance affecting operation continuity?                            | No, there are no moving parts in the system.   | Yes, there are moving equipment in the system, which includes the urine diversion pan arrangement, feces and urine holding tank, pumps, filters, electrolysis and the flushing mechanism. | No, there are no moving parts in the system.   | No, there are no moving parts in the system.                        | No, there are no moving parts in the system.   | No, there are no moving parts in the system. | No, there are no moving parts in the system.  | No, there are no moving parts in the system.               | Information is not available. | Information is not available.   | Information is not available. | Information is not available. | No, there are no moving parts in the system.    | Information is not available.  |
| 12     | Ease of O&M         | Skill and spares for local repairs and maintenance | What are the skill sets required by the operator? Are skills and spares available locally for repairing or servicing equipment? | The operator has to check inflow regularly and test the treated water in the lab to know the treatment efficiency. The operator also has to perform the inoculation during startup and at times when treatment efficiency is low. The active licensee list that is provided in the link, may/may not provide repairing and servicing options. Spares for repairs may be easily available | There is a need for trained personnel. The skill sets are required for desludging, collection, conveyance and transport components. The other details are not available.                  | There is a need for trained personnel. The skill sets are required for desludging, collection, conveyance and transport components. The other details are not available. | Toilets can be built and repaired with locally available materials. | Regular feeding of kitchen waste to the toilet and regular emptying of the filled tank is the main operation of this system, for which training is required. |  | BioSol SL36 has to be purchased from registered suppliers periodically. There is a need to train people in use and maintenance of the system. | Can be built and repaired with locally available material. | Information is not available. | Operation and maintenance is crucial for correct functioning (Eg: growth of microbial mix). Skilled labour is required for maintenance and operation. | Information is not available. | Information is not available. | Information is not available.                   | There is a need for trained personnel for O&M. Local manufacturer and supplier details are provided as a link on who may provide repairing / servicing. The other details are not available. |

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| SI. No | ASSESSMENT CRITERIA | INDICATOR   | INFORMATION REQUIREMENT   | (A) DRDO Biotank   | (B) Blue diversion toilet  | (C) Composting Chamber   | (D) Double Ventilated Improved Pit (VIP)  | (E) Composting Ekolet Dry Toilet System  | (F) Enviro Loo System   | (G) Flush-Tech System | (H) Fossa Alterna  | (I) Johkasou System   | (J) Loolaa boo Toilet                                       | (K) Nano Membrane Technology  | (L) Savvy Loo System   | (M) Sintex: Prefabricated Improved Septic Tanks                               | (N) Sun-Mar System  |
|--------|---------------------|---|---|--|--|--|---|--|---|-----------------------|--|---|---|-------------------------------|--|---|---|
| 13     | Performance         | Odour in the decanted sludge and treated effluent | Is there any odour from sludge or in the treated effluent?  | No, treated effluent is free from odour. The other details are not available.  | Yes, there will be odour from stored containers of urine and feces.  | The immediate coverage of the fresh feces with an additive material also reduces odour or flies. Churning the material from time to time will boost the oxygen supply. | Flies and odours are significantly reduced (compared to non-ventilated pits).   | Odourless system.  | No smell due to positive suction created at the point of faecal discharge into the pan  |                       | Cover material used over the excreta reduces bad smells. A ventilation pipe can be added to further reduce the smells. | Information is not available.   | No odour and no need for ventilation or dehydration system. | Information is not available. | It's still in the pilot process and the odour issue still remains. | Output quality needs further treatment.                                       | The superior oxygenation and moisture control provides the optimum environment for aerobic bacteria to carry out odourless degradation. |
| 14     | Replicability       | Manufacturing                                     | Who can manufacture or assemble these systems? Are skills and resources locally available in the market to manufacture these systems? | Active licensee list that is provided in the link, takes care of the manufacturing, assembling and commissioning. Information on the availability of local skill is not available. | The complete system is provided by EAWAG, including manufacturing, assembling and commissioning. Information on the availability of local skills is not available. | Information is not available.  | Can be built and repaired with locally available materials.   | The complete system is provided by Ecolet, including manufacturing, assembling and commissioning. Information on the availability of local skill is not available. | The complete system is provided by Enviroloo, including manufacturing, assembling and commissioning. Information on the availability of local skill is not available. |                       |  | The complete system is provided by Johkasou system, including the manufacture, assembling and commissioning. Information on the availability of local skill is not available. | Information is not available.                               | Information is not available. | Information is not available.                                      | No, the system can't be built and repaired using locally available materials. | Information is not available.   |
| 15     | Innovation          | Performance                                       | Has this technology or similar technology been tried elsewhere? Is there a significant impact of innovation on performance?           | Yes, the technology has been tried elsewhere. The technology does not have any geographical or temperature limitation, and does away with the need                                 | Yes, the technology has been tried elsewhere. The innovation is about integrating all aspects of sanitation including handwashing, menstrual                       | Information is not available.  | The double VIP can be a very clean, comfortable and well accepted sanitation option, in some cases even more than a water-based technology. | Integrated waste management for organic waste and feces.   |   |                       |  | Johkasou system is highly efficient for individual households or small communities located in rural or peri-urban areas where there is no                                     | Information is not available.                               | Information is not available. | Information is not available.                                      | Information is not available.   | Yes, the technology has been tried elsewhere. The use of LEVAPOR bio carrier to the Imhoff tank is suggested to increase the            |

**Table 4.2: Containment Systems - Characterization**

| SI. No | ASSESSMENT CRITERIA | INDICATOR | INFORMATION REQUIREMENT | (A) DRDO Biotank                                  | (B) Blue diversion toilet                            | (C) Composting Chamber | (D) Double Ventilated Improved Pit (VIP) | (E) Composting Ekolet Dry Toilet System | (F) Enviro Loo System | (G) Flush-Tech System | (H) Fossa Alterna | (I) Johkasou System          | (J) Loolaa boo Toilet | (K) Nano Membrane Technology | (L) Savvy Loo System | (M) Sintex: Prefabricated Improved Septic Tanks | (N) Sun-Mar System    |
|--------|---------------------|-----------|-------------------------|---|--|------------------------|--|---|-----------------------|-----------------------|-------------------|------------------------------|-----------------------|------------------------------|----------------------|---|-----------------------|
|        |                     |           |                         | to set up large STPs and regular sewage cleaning. | hygeine and wastewater treatment in a single module. |                        |  |   |                       |                       |                   | access to a sewerage system. |                       |                              |                      |   | treatment efficiency. |



# Collection

|  |     |
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## 5. Collection

In this chapter we introduce different technologies for collection of faecal sludge. Apart from excavating the faecal sludge manually, there are both semi-mechanised and fully mechanised systems, to help make this a cleaner and easier process. The former still requires manpower to a certain extent, whereas fully mechanised systems are powered by an engine or external power source. Some of these technologies have been developed over the years and have been in use for quite some time now. Nevertheless, there have been some innovations to improve the process.

Pit emptying is a critical part of the sanitation value chain, because it is here that the whole chain gets connected. Clearing the pit goes hand in hand with proper conveyance of faecal sludge, but for the sake of simplicity we will look at these two separately.

When comparing the different systems, it becomes clear that each system has its advantages and disadvantages and thus has a certain scope of application for which it is best suitable. For many de-sludging technologies, solid waste from pit latrines is a significant problem given that it tends to clog. Furthermore, the sludge viscosity and pit depth are important factors that have to be considered and may pose problems for some technologies. We took all these factors into account and rated each technology accordingly. Generally, one observes that vacuum pumps are the most reliable. One also observes that complex systems have more errors. This is especially important when it comes to repairing and finding spare parts which is a challenge in rural areas.

### 5.1. Manual de-sludging with additional tools

#### A brief about the technology

Manual de-sludging is a simple technique which involves removal of sludge manually from pits/tanks using a long-handled bucket and shovel. The workers wear protective gear, which includes masks, gloves and boots. Instead of bucket and shovels there are different tools that make the emptying easier, faster and decrease the health risk.

#### Technology Description and Working Principles

Workers use shovels and buckets to empty the sludge which is then filled into barrels or tanks for transportation. Tools and equipment, designed specifically for manual pit emptying, could make the work easy and safe. With the appropriate tool it is possible to remove extremely dry solid sludge from the pit, increasing the safety of workers by preventing their entry into these systems. There are also shovels for lower viscosity sludge which a longer lever, additional holders, and a closable reservoir, increasing the operation depth and the emptying rate. The manual emptying is used in inaccessible regions where the willingness to pay for de-sludging is low.

Figure 5.1: Picture showing manual desludging and tool



## Advantages and Disadvantages

### Advantages:

- It requires equipment that is cheap and easily available
- Skill requirement of workers is low
- Cost of de-sludging is low

### Disadvantages:

- De-sludging using this process takes a long time
- High probability of human contact with faecal matter during de-sludging
- Workers often face social stigmas

Figure 5.2: Corer Tool



## O&M Requirement

- Equipment should be cleaned after the de-sludging to reduce health risk and increase the lifespan of the tools

## Health and Acceptance

- Depending on the social and political nature of the region, workers performing manual emptying may be viewed as providing an important service to the community
- Government programs should aim to legitimise and legalise the work of the labourer and provide an enabling environment
- Handling fresh excreta exposes the operators and general public to unhealthy and unsightly conditions. Therefore, the workers must have adequate protection with gloves, boots, overalls and facemasks
- Proper medical check-ups and vaccinations must be administered for everyone working with sludge

## Design factors

Many designs are possible to make the manual de-sludging easier. Special tools are available to improve the emptying rate depending on the viscosity level of sludge

- Depth of pits: Long lever tools are used to de-sludge deeper pits
- Viscosity of sludge: The bucket can be used for low viscosity sludge, shovels with closable chamber are good for medium viscosity sludge and the corer tool can remove very solid sludge from the pit. It depends on the characteristics of the sludge that has to be removed, which tools are worth an acquisition

## Manufacturer/Supplier details

The buckets and shovels are available all over the world. The designed tools can be produced locally in outlying regions with little effort.

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## 5.2. Manual Desludging Hand Pump (MDHP)-Gulper

### A brief about the technology

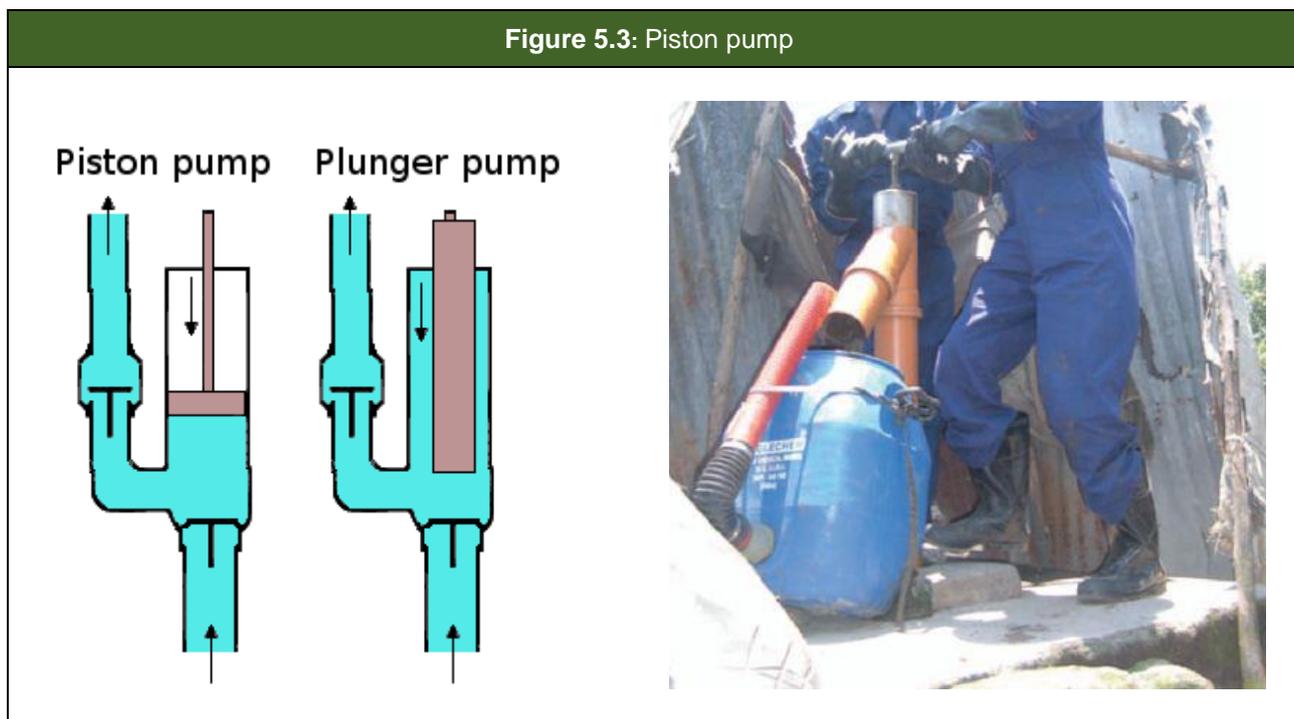
The Manual De-sludging Hand Pump or Gulper has a simple design which consists of a PVC riser pipe containing two stainless steel non-return butterfly valves. The Gulper is a relatively new invention that is inexpensive, portable and reduces sludge contact. It can be built using locally available materials and fabrication techniques common in low-income countries. It addresses the problems of accessibility and affordability in densely populated low-income areas.

### Technology description and Working principles

The Gulper is a piston pump on top of a pipe with an outlet pipe on the side. The upstroke of the piston draws sludge through a valve into the cylinder which is then discharged on the down stroke through a valve into the outlet. A bucket placed under the outlet pipe collects the waste during the de-sludging. The bottom of the pipe is lowered into the pit or tank. The pump is operated by 2–3 workers who push and pull a lever on top of the Gulper.

The system is available in different price ranges and quality categories. It is widely used by de-sludging providers in Africa and Asia. The Gulper can prove to be a good technology option, if the willingness to pay for de-sludging is low and pits and tanks are inaccessible for mechanised de-sludging systems.

Figure 5.3: Piston pump



### Advantages and Disadvantages

#### Advantages:

- It requires low capital investment and operational expenses, thereby making de-sludging affordable
- It can remove sludge of medium thickness, which cannot be normally pumped out
- Is easy to carry and hence can be operated from containment units not accessible to mechanised de-sludging systems
- It does not require an external source of power for operation

#### Disadvantages:

- It is a slow process
- Limitation on the operation depth. It cannot de-sludge from containment units which are deep
- Solid wastes choke the system and can lead to operational delays
- There is a high risk of sludge splashing during operation onto the user
- This system cannot remove dried or thick sludge

### O&M Requirement

- Equipment must be cleaned after every de-sludging to increase the life span of the tools
- A high amount of non-biodegradable material results in blockages which have to be removed as and when required

## Health and Acceptance

- Handling fresh excreta exposes operators and general public to unhealthy and unsightly conditions. Therefore, the workers must have adequate protection with gloves, boots, overalls and facemasks
- It has to be integrated with conveyance systems consisting of buckets and cans. Appropriate technologies have to be adopted in subsequent components of the value chain

## Design factors

The design of the Gulper depends on the following parameters:

- Length: The length is important for the operation depth and the access of the pit. The short type of Gulper is 180 cm and the long type is 230 cm. The longer the Gulper, the higher is operation depth and the bulkier it gets
- Material used: Many parts of the Gulper can be made out of metal or plastic. Metal increases the cost of the system but also the durability. Plastic decreases the cost but makes the system more vulnerable to damage
- Other equipment: Apart from the Gulper, other equipment required to carry out the pit emptying operation include a bucket (minimum 50 L), fibre bags if possible, a hoe and shovel, and protective equipment

## Manufacturer/Supplier details

- Simple Gulpers can be made locally from inhabitants. The needed parts are also available in developing countries.

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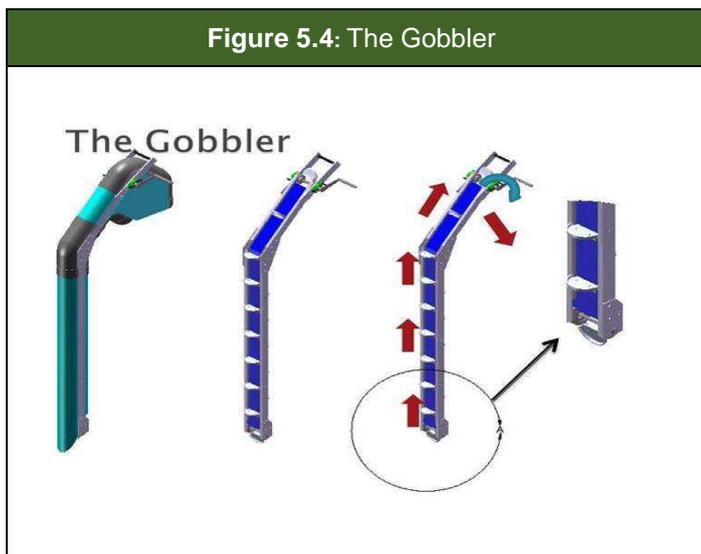
### 5.3. The Gobbler

#### A brief about the technology

The Gobbler is an improvised and mechanised excavator for removing medium viscosity sludge from pits and containment units. It does not clog easily and is very portable, making it an ideal choice for operations in remote areas. The prototype was built in 2009 and is currently being tested in parts of Africa.

#### Technology description and Working principles

The Gobbler consists of a rotating chain housed inside a pipe. The chain has scoops attached to it, which transfers the sludge from pit to the outlet placed at the top of the pipe. These chains are made from steel or durable plastic based on the design and cost of the equipment. The chain assembly is mounted on a sprocket which is rotated by means of an engine or a motor. Motor systems draw power from household, while small engines run on kerosene or petrol. An outlet is provided at the top portion of the pipe, where the scraper discharges the sludge due to gravity. The outlet has guide-ways which can assist in filling up containers or buckets (of volume 50–100 litres) for transportation of the sludge.



#### Advantages and Disadvantages

Advantages:

- It is a robust system which can be assembled locally
- It can remove medium viscous sludge from containment units without the need for pouring water
- It can be carried manually to containment units where other mechanised de-sludging equipment are not accessible.
- Driven by power and enclosed in a container leading to lower occupational hazard to the operator

Disadvantages:

- Sludge may stick to the scoop leading to blockages, and additionally, trash in the containment unit could also create similar problems
- Cannot remove sludge which is liquid

#### O&M Requirement

- Equipment should be cleaned after every de-sludging



- A high amount of non-biodegradable material results in blockages which have to be removed
- Chains must be lubricated appropriately

### **Design factors**

The design of the Gobbler depends on these few factors:

- **Materials:** Can vary from stainless steel to durable plastic, based on the life of the equipment and the type of sludge handled
- **Operation Depth:** it determines the length of the housing and the power requirement of the system
- **Capacity:** Determines the power requirement of the system. Bigger capacities can reduce the de-sludging time but might weigh heavy for manual transportation

### **Manufacturer/Supplier details**

- The system is still in the test phase and not available in market.

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## **5.4. Manual Pit Emptying Technology (MAPET)**

### **A brief about the technology**

The MAPET is a human-powered vacuum system for the collection and short-distance transport of sludge. It combines the advantages of a vacuum pump with the mobility of small de-sludging system. It is suitable for densely populated areas, especially those housing low-income groups, as the sludge in the containment unit is thick and often inaccessible due to narrow roads.

### **Technology description and Working principles**

MAPET uses a manually-powered piston pump to create vacuum and empty contents from the pit onto a collection tank. The tank's capacity is 200 litres and is mounted on a pushcart. Containment units with viscous sludge need to be diluted with water in order to ease the collection process. Once filled, the tanks can be pushed manually to a disposal point or transfer station.

### **Advantages and Disadvantages**

Advantages:

- Vacuum-based system eases the collection of viscous sludge and trash
- Small in size and hence can be manoeuvred into densely populated areas

- The system runs on low cost for both collection and conveyance

#### Disadvantages:

- It consists of parts which may not be available locally
- The tank capacity is limited to 200 litres, therefore big pits need multiple de-sludging cycles
- The system draws a limit on the depth of the containment system from which sludge can be collected.

#### O&M Requirement

- The equipment should be cleaned after the de-sludging. This can be done by vacuum sucking water to clean the inlet pipe and tank
- Removal of trash from the tank or inlet to prevent blockage

**Figure 5.6: Manual pit emptying technology**



#### Health and Acceptance

- Handling fresh excreta exposes operators and general public to unhealthy and unsightly conditions. Therefore, the workers must have adequate protection with gloves, boots, overalls and face masks.
- Requires arrangements upstream of the value chain for aggregating these small volumes and transporting to treatment plants

#### Design factors

- The pump has a 6 inch PVC cylinder made from sewage piping encasing a leather piston. A flywheel with a diameter of 800 mm and a rotation speed of 40–60 rotations per minute helps in easing the manual operation. The vacuum can pump up to 20 litres per minute.
- Initial attempts used an oil drum but this was discovered to be susceptible to corrosion and implosion at -0.4 bar (40,000 Pa)
- It is gourd shaped to optimise transport, steering, and tipping by maintaining a lower centre of gravity

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## 5.5. Pit Screw Auger (Motorised)-The Excrevator

### A brief about the technology

The Pit Screw Auger system is a simple technology for medium viscosity sludge which works on the principle of the Archimedes screw pump. These can be powered both manually and through external means like a motor or engine. These systems are designed to de-sludge thick faecal matter from pits which are not accessible by mechanised vacuum devises.

### Technology description and

#### Working principles

The Pit Screw Auger system is based on the Archimedean screw design. It consists of an auger placed inside a plastic riser pipe and protruding by approximately 5 to 15 cm from the bottom end of the pipe. Based on the source of power, there are three variants to this design–Manual, Motorised and Hydraulic. In all the three cases, the auger is housed inside a pipe. Rotation of the auger causes the sludge to raise and discharge from an outlet provided on top of the housing. At the outlet 1m long pipe with a diameter of 4-inches is provided to guide the sludge into a containment unit thereby reducing spillage and splashes during operation.

The manual version requires cranking by one person. However, the emptying speed of the non-motorised system is too slow and requires high operating time. The second version is driven by an electric motor which is mounted on top of the riser pipe where it is connected to the auger. Additional to the manual auger, three blades are provided at the bottom which aid in fluidising the sludge.

The manual version requires cranking by one person. However, the emptying speed of the non-motorised system is too slow and requires high operating time. The second version is driven by an electric motor which is mounted on top of the riser pipe where it is connected to the auger. Additional to the manual auger, three blades are provided at the bottom which aid in fluidising the sludge.

The Excrevator is a third version of the pit screw auger system. It is rotated by a hydraulic motor that provides high power and is easily reversible to discharge solids that enter the auger. The hydraulic motor is powered by a remotely located gasoline engine.

### Advantages and Disadvantages

Advantages:

- It can be used for medium viscosity sludge with little trash content
- It can run depending on power available- manual, electricity or gasoline

Figure 5.7: Motorised pit screw auger and the Excrevator



Disadvantages:

- The equipment is heavy to transport by one person to the containment unit
- It removes sludge from localised points in the pit and hence requires moving the equipment around for complete de-sludging. This can cause problems in big pits/containment units with limited access

### O&M Requirement

- The equipment should be cleaned after the de-sludging
- The auger inside the pipe is hard to clean as it is difficult to reach

### Design factors

The design of the pit screw auger depends on the following parameters:

- Diameter: A 125 mm outside diameter uPVC pipe, with no helix, proved the most successful. A 15 mm gap between the auger flight and pipe was found to be optimum
- Weight: An empty auger can weigh up to 20kgs. In operation, the auger plus sludge can weigh up to 40kgs. Weight of the motor or mechanised equipment is additional

Figure 5.8: An Excavator



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## 5.6. Manual and Motorized Diaphragm Pump

### A brief about the technology

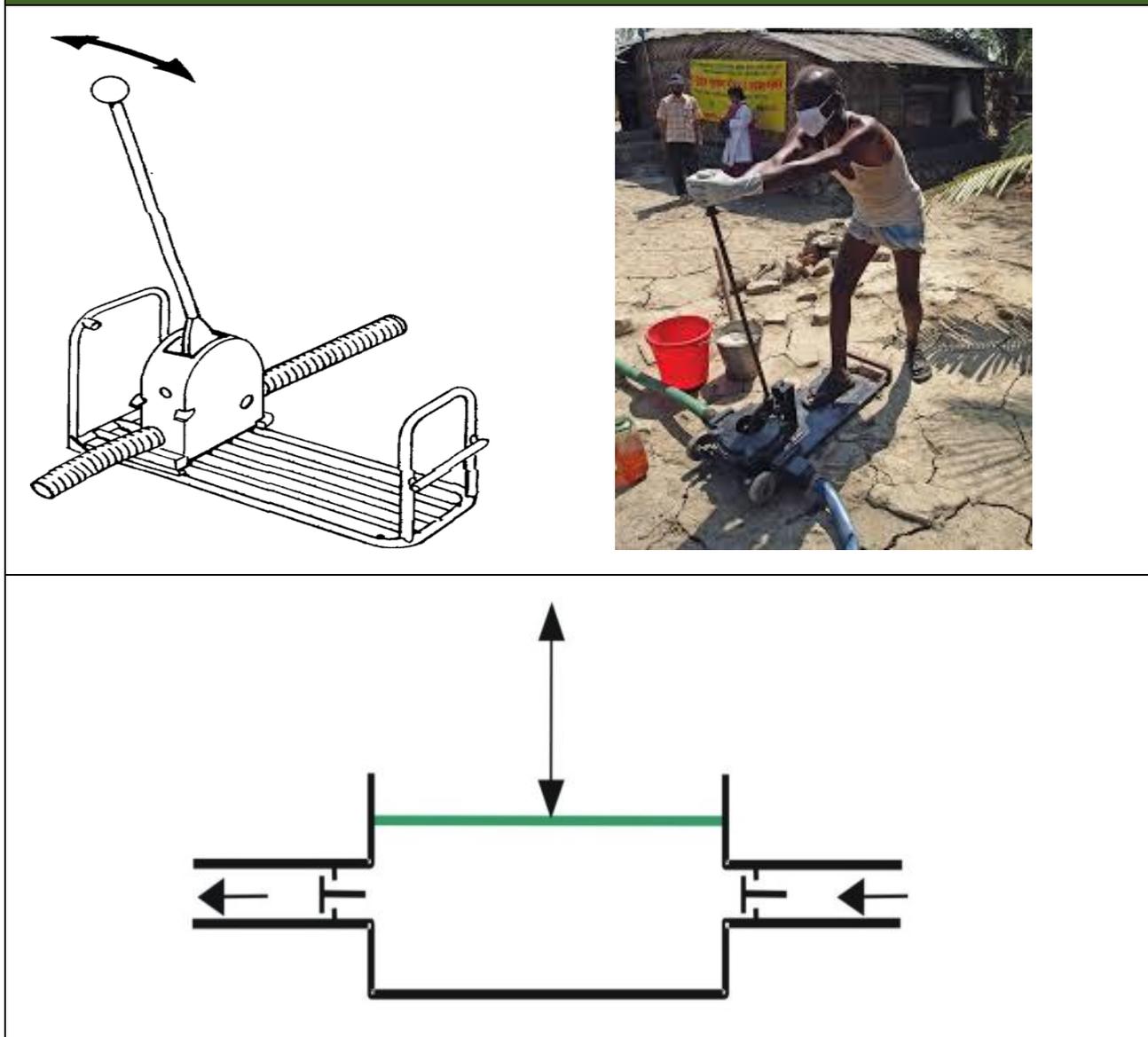
Diaphragm Pump uses a non-porous membrane to create partial vacuum which enables de-sludging of low viscous sludge from containment units. These are easy to operate and carry and hence can be used where limited skill is available for operations and where there are limitations on accessibility to the pits.

### Technology description and Working principles

The Diaphragm Pump is similar to a piston pump but a flexible rubber membrane called diaphragm is used instead of the piston. The advantage is that the diaphragm is absolutely airtight and hence creates better

suction. To operate the pump, the diaphragm is alternately pushed and pulled, causing it to deform into concave and convex shapes. A strainer and non-returning foot valve, fitted to the end of the inlet pipe, prevents non-biodegradable material from entering the pump and stops backflow of sludge during operation. The diaphragm is housed in a metallic casing with an inlet and outlet arrangement. The inlet and outlet have pipes connected to it which can be used for de-sludging and transporting sludge to a collection system.

Figure 5.9: Images of manual diaphragm pump



The diaphragm can be manually moved by a worker who handles a long lever by pushing and pulling it to create vacuum, or, it can be moved using an electric motor.

### Advantages and Disadvantages

Advantages:

- It is easy to operate
- It can de-sludge low and medium viscous sludge
- It is light and easy to transport, can be fitted with wheels

Disadvantages:

- The trash entering the system can block or hinder diaphragm operation
- Trials have indicated that the diaphragm breaks frequently
- The diaphragm is not locally available
- Input and output hose connections are not robust and can leak

### **O&M Requirement**

- A high amount of non-biodegradable material results in blockages which have to be removed. This increases the operation requirement
- The diaphragm has to be controlled and replaced frequently
- The system has to be airtight and this has to be checked before use each time

### **Design factors**

The design of manual and motorised diaphragm pumps depends on:

- Non-biodegradable material: The emptying rate of the manual system is high compared to other manual driven systems, but it depends on the amount of non-biodegradable material inside the sludge
- The pumps are typically mounted on a frame and can be moved manually by hand or by using a trolley for increased mobility
- A typical 3-inch pump can pump solids ranging in size from 40 to 60 mm. The maximum pumping head achieved is of 15 meters

### **Manufacturer/Supplier details**

- The manual diaphragm pumps can be made locally, but the motorised diaphragm may have to be imported.

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- Overview of Available Desludging Systems(n.d) Desludging products. 1st ed.[pdf] Available at: <https://watsanmissionassistant.wikispaces.com/file/view/Overview+of+Available+Desludging+Systems.pdf>

## **5.7. The Faecal Sludge Omni-Ingestor (FSOI)**

### **A brief about the technology**

The Faecal Sludge Omni-Ingestor is one of the first mobile pre-processing system and can separate solid material from the sludge and hygienically treat it right next to the pit. The FSOI suite of technologies includes pumping, debris extraction, sludge thickening and disinfection sub-systems. This system is innovative in

integrating the collection and treatment components at a single stage. Such a system reduces the requirement of transporting sludge to far distances for treatment and disposal and hence saves a lot to its user.

### Technology description and Working principles

The system consists of three stages—pumping, solid-liquid separation and solid-liquid disinfection. A grinder pump helps in de-sludging the contents of the containment unit. The debris extraction sub-system will extract trash from the waste stream, rinse the trash and disinfect it with chlorine. A secondary extraction sub-system aids in removing heavier particles such as sand, grit, glass and other particles present in the sludge. Finally, a sludge thickening sub-system reduces the moisture content of the sludge. There are multiple pumps at various stages to establish flow through different sub-systems and these are capable of handling sludge of varying viscosity. The trash, along with other separated heavier particles and water, is disinfected using chlorine and disposed locally during operation. The remaining sludge is stored and transported to sites where it can be treated or disposed in a safe manner.

Figure 5.10: Omni-Ingestor



### Advantages and Disadvantages

#### Advantages:

- It is an integrated solution of handling collection and treatment at point of operation
- It can handle different types of sludge viscosity
- Reduced need for dewatering at treatment plant
- It allows for only thickened sludge to be transported, reducing cost of transportation
- Provides an opportunity to reuse the sanitised water

#### Disadvantages:

- The capital cost is high
- It is a complex system and needs skilled manpower for operation and maintenance
- The system requires chlorine and electricity for operation

### **O&M Requirement**

- Chlorine has to be replenished as and when required
- Pumps and other moving parts need to be lubricated
- Trash and heavy particles must be collected and disposed

### **Design factors**

- Output liquid after separation and dewatering must have:
  - Less than 20mg/l TSS
  - Less than 20mg/l BOD
  - Less than 50mg/l COD
  - Turbidity less than 200 NTU
  - pH between 6.0 and 9.0
- Output solids after dewatering must have:
  - All free water removed (TS value of 12–15 per cent)
  - The target TS should be 25 per cent
  - Higher TS values are permitted but the cost of the additional performance will need to be relatively low

### **Manufacturer/Supplier details**

- The system is still in the test phase and not available for commercial purposes

### **References**

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## **5.8. Vacuum Pump: eVac**

### **A brief about the technology**

Vacuum pumps have been quite successful in de-sludging faecal sludge from containment units. The objective of the eVac is to combine the benefits of vacuum suction and the agility of a small system in serving populations of densely habituated regions.

**Figure 5.11: eVac system in action**



### **Technology description and Working principles**

e-Vac (works on similar principles of MAPET, the difference being the former is externally powered. The vacuum pump used in e-vac unlike the MAPET is an oil-lubricated vane pump. This pump is operated using a small motor, powered by onsite electricity or using a portable generator. The pump and motor are coupled using a belt drive and is mounted on a custom-made steel trolley which allows for indigenisation of the technology and its maintenance.

The e-Vac pump comes in two models, one with an attached tank while the other is a jig attachment to containers. The attached model has a small tank where the vacuum is applied and the sludge is collected from the containment unit. This can then be pushed outside the tank to a transporting arrangement by applying a positive pressure using the same pump. The Jig can be attached to any container which is used for collection and transporting of sludge. This jig helps by creating a vacuum in the container and enabling suction from the containment systems. In both the systems, the vacuum pump is provided with a float valve that prevents sludge entering into the pump.

### **Advantages and Disadvantages**

Advantages:

- It is a robust system for various operating conditions
- There is flexibility in operating with multiple designs of collection units
- De-sludging by application of vacuum is easy
- Accessible by densely populated areas as it is easy to manoeuvre

Disadvantages:

- It can be used for small containment systems as the emptying rate is low
- It can be used only for low viscosity sludge
- There is a possibility of sludge spillage while transferring to containers

### **O&M Requirement**

- Vacuum pumps require regular maintenance such as lubrication

- Equipment must be cleaned as there may be spillage and overflows
- Valves must be cleaned to avoid foreign particles and blockages

### **Design factors**

The design of a e-Vac depends on the following parameters:

- Type of containment units: This determines the size and capacity of the vacuum pump
- Type of external energy source available: This determines the need for a diesel generator attached to the system
- Foreign particles present in the system: This determines the requirement of a mesh for straining
- Depth and Accessibility of the containment unit: This determines the hose length and pump capacity

### **References**

- Still, D. Riodan, M. McBride, A. Louton, B. (July 2013). Adventures in search of the ideal portable pit-emptying machine.vol.32.[pdf] Practical Action Publishing. Available at: [http://www.sswm.info/sites/default/files/reference\\_attachments/adventures.pdf](http://www.sswm.info/sites/default/files/reference_attachments/adventures.pdf)
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## **5.9. Vacuum Tankers**

### **A brief about the technology**

Vacuum tankers consist of a truck or any other mobile vehicle combined with a tank and a vacuum pump. They use a de-sludging technology which is characterised by high tank volume, high mobility and fast de-sludging with the help of electricity.

### **Technology description and Working principles**

Vacuum tankers can empty pits or septic tanks rapidly and transport high amounts of sludge fast. They can be used for direct discharge on the fields. This system has a truck mounted with a tank and a vacuum pump. The vacuum pump creates a negative pressure inside the tank enabling desludging the containment unit through a hose connected at the outlet of the tank. An appropriate mechanism is put in place to prevent sludge travelling into the vacuum pump and damaging it. In the case of medium or high viscous sludge, water can be added and stirred so it can be easily sucked by the vacuum.

### **Advantages and Disadvantages**

Advantages:

- The de-sludging speed is high
- The system offers high storage volume
- The tanker makes it more mobile

#### Disadvantages:

- Since the tanker cannot reach areas with smaller roads, access is limited.
- Trash choking the inlet is a problem faced in this process
- The tanker requires high capital and operating costs
- The tankers require repairs, which can result in long delays

Figure 5.12: Vacuum tankers



#### O&M Requirement

- It is necessary to check the oil level of the vacuum pump, oil-cooling tank, hydraulic tank and tanker engine daily
- The cooling water and the wash water from the truck also should be checked
- In addition, it is necessary that the cooling radiators for the hydraulic oil and pump oil are kept running. After each day the oil and sludge separators should be drained
- The tire pressure, lights, indicators, horns, valves, gaskets and the hydraulic system should be checked weekly

#### Health and Acceptance

- Vacuum tankers are mostly used for services in well-designed communities, where the septic tanks and pit latrines are easily accessible and waste is fairly liquid and separated from solid waste
- Many of the residents living in unplanned areas cannot be serviced as roads are far too narrow to be accessed by the tanker trucks

#### Design factors

Vacuum tankers have a good emptying rate but differ in terms of speed of vehicle, the size of the tank and the power of the pump. The tank size varies between 3 and 12m<sup>3</sup>.

- There are altogether three factors which reduce the performance of the tanker—pit depth, height of tanker, the waste density and viscosity of the material that is being sucked

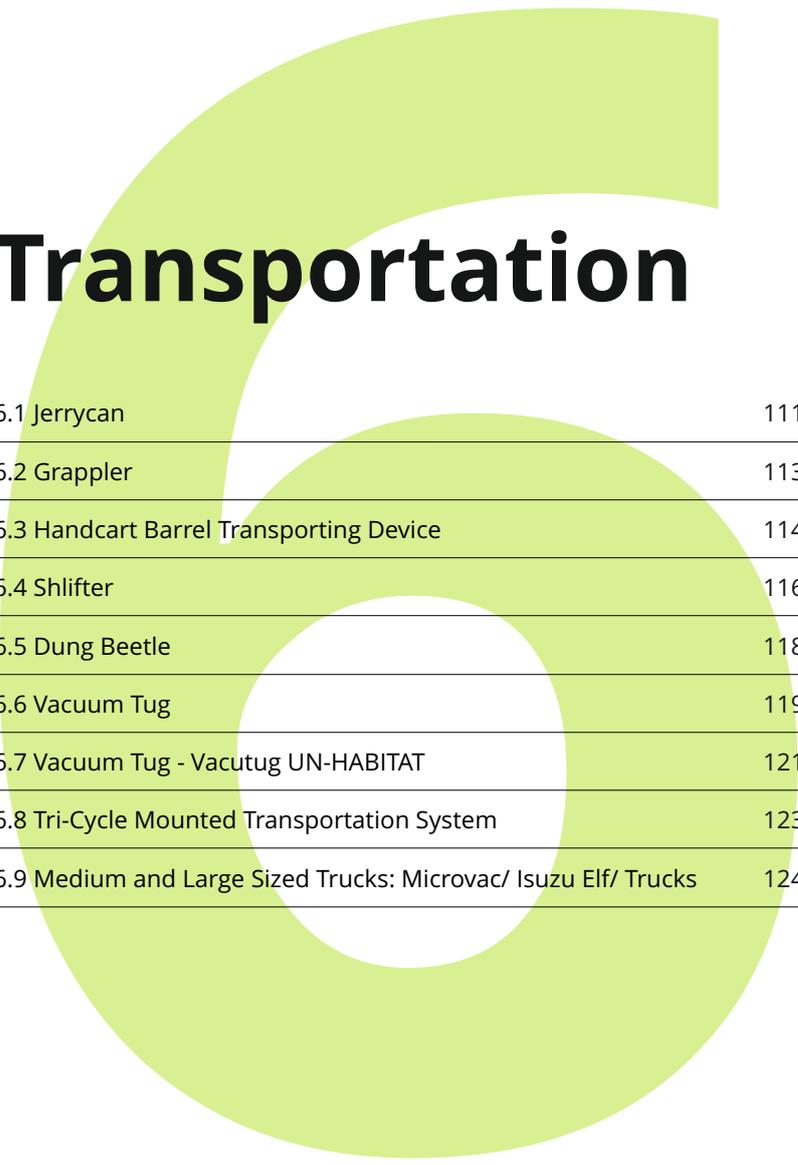
- Tank height: This is important because the hose is connected to the top of the tank, so the height of the tanker has to be subtracted from the operation depth
- Airflow: Air can enter the hose, break the flow and reduce the sucked sludge volume. This can be prevented by submerging the hose deep under the sludge (high vacuum/low airflow). However, it can also be used to de-sludge waste with higher viscosity (low vacuum/high airflow method)

### **Manufacturer/Supplier details**

Vacuum truck tankers are available in many different local versions depending on the region of use. Local inhabitants often build their own version of a vacuum tanker. They take an available truck, mount a tank on it and connect it to a pump.

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# Transportation

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## 6. Transportation

Conveyance of faecal sludge is closely linked to its collection, because those who collect it are also the ones who transport it and additionally, the de-sludging technology determines the means of transport. For example, if a vacuum pump is being used, it has to be connected to some sort of tank, which generally is already on wheels. When using semi-mechanised de-sludging technologies, generally buckets are used for collecting the sludge and a different conveyance method is used. Hence, we have classified transportation into manual approaches, small motorised devices and de-sludging vehicles/trucks.

Manual means of transportation describes the labour-intensive act of carrying the sludge buckets by hand. Currently there are a few tools under development to ease this process which will be described going forward. Manual transporting is mostly deployed when accessibility is poor and/or due to monetary constraints. Small motorised vehicles come with a pump and can convey the sludge at walking speed over short distances. When it comes to sludge trucks, there is a huge variety available and the only constraint is accessing the pits.

In discussing the means of transportation we will be concentrating on accessibility, tank capacity and range. Similar to de-sludging technologies, all these factors cannot be combined in a perfect way. When using, for example, big de-sludging trucks, their capacity and range are high, but access is limited. On the contrary, when using smaller transportation means, the accessibility increases but the tank capacity and range become significantly smaller.

Usually the treatment and reuse facilities for faecal sludge aren't close to the point of collection. To avoid the discharge of faecal sludge in the open, transfer stations are being made to ease the transportation of sludge over long distances. Here, smaller loads of sludge can be collected and a larger vehicle can come periodically and easily collect the sludge and bring it to a proper reuse or dispose facility.

### 6.1. Jerrycan

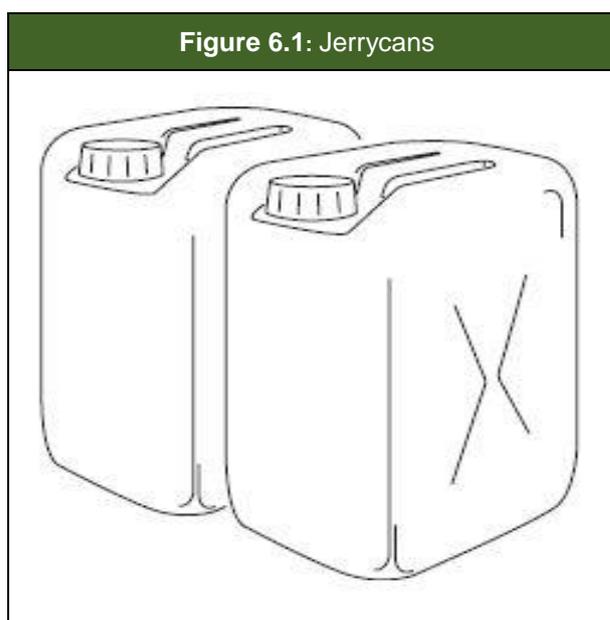
#### A brief about the technology

Jerrycans are small, 20-litre plastic containers used to store and transport urine over short distances. Figure 6.1 shows a Jerrycan container.

Since urine is a well-known fertiliser it can be used for gardening purposes or it can be sold to local farmers. This concept is based on a 'closing the loop' approach, because the nutrients are recovered.

#### Technology description and Working principles

Jerrycans were originally designed to hold fuel and were made from steel. Nowadays they are also made from plastic and fibreglass and are used for a variety of things. When properly sealed they can be used to safely store or transport urine. As steel Jerrycans are prone to corrosion, those made of plastic or fibreglass are preferred.



Urine can be directly collected in Jerrycans or they can be filled with the urine stored in storage tanks. Direct connection of a Jerrycan to a urinal is possible with a pipe. To avoid blockages and other flaws the pipe length should be as short and steep as possible. Sharp angles should be avoided in the design. If the intended use of urine is at the household level, a direct application is safe.

The second option involves the installation of a large storage tank instead of a Jerrycan with the latter used for transporting the urine. Furthermore, the installation of a centralised storage tank could be considered near the agriculture fields so that the urine can be quickly accessed and used as a fertiliser when required. These tanks can be placed outdoors, indoors, above or below the ground, as long as they are easy to access.

The WHO guidelines recommend a period of at least one month between application of urine and harvesting the crop to minimise risk of pathogen contamination. The usage of a centralised storage tank for urine as described earlier in combination with the withholding period of a month seems to be a safe way to sanitise and reuse urine.

### **Advantages and Disadvantages**

Advantages:

- Jerrycans are widely available, cheap, robust, easy to clean and are re-useable
- The risk of pathogen transmission is low and as urine is a good fertiliser it can be reused in agriculture
- There is potential for local job creation

Disadvantages:

- Jerrycans still require some manpower for carrying them
- The urine may spill while being transported
- Odour can spread when handling Jerrycans, e.g., when filling cans or tanks

### **O&M Requirement**

- Attention needs to be paid when Jerrycans are directly connected to the systems to prevent overflow
- Once filled, Jerrycans can be stored on site or transported immediately
- Storage of urine in a larger tank should be considered and Jerrycans may be used for transporting to the field (short distances)
- Jerrycans need to be cleaned frequently to keep out bacteria and settlements
- The operation and maintenance costs are very low

### **Health and Acceptance**

- For health reasons Jerrycans should be used only for urine to avoid mixing with higher pathogenic liquids such as black water
- Since urine is normally sterile, there are low health risks. If basic security precautions are taken during the collection and transportation process, the risk of pathogen transmission can be kept at a minimum.
- When placed in a dark container, urine becomes bacteria-free in 30–45 days, without the addition of chemicals. Storage of more than six months sanitises the urine almost completely. Acceptance for reusing it as a fertiliser may vary across geographies and may require some awareness program

- Before applying the Jerrycan system, the need for the fertiliser in agriculture should be thoroughly confirmed. Otherwise the urine might become a pollutant and installation of storage tanks would serve no purpose
- Households would have to pay for the collection of the Jerrycans, as well as the farmers, who would pay for the fertiliser. For both parties this is considerably cheaper than the alternatives and in some cases urine might even be collected free of charge

### Design factors

Owing to their uniform design Jerrycans are widely available, even in remote areas.

- Capacity: The design of Jerrycans is very similar all over the world. In general, Jerrycans have a capacity of 20 litres and a family of five fills it up in three to four days
- Length of pipe: If the Jerrycan is directly connected to the toilet or urinal with a pipe, care should be taken to minimise its length since precipitates will accumulate
- Pipe diameter and slope: Pipes should have large diameters, a steep slope (> 1%) and no sharp angles

### Manufacturer/Supplier details

- Widely available

### References

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## 6.2. Grappler

### A brief about the technology

The Grappler is a small device that can be used to efficiently carry 50 litre barrels using two persons. The product aims to cut out the need for a handcart and barrel lifting. The prototype was developed in Kampala, Uganda where workers found it difficult to transport 250 kilograms of sludge around the slums. The product consists of a main shaft that is hooked onto the two sides of the barrel beneath the indent. This is achieved by the grips attached to the bushes on the shaft.

### Technology Description and Working Principles

Operators can empty five 50 litre barrels at one time, then carry the five barrels to the pickup truck. If required they can then remove five more and do the same. This approach breaks down the work of operating the pump, and allows operators to share the weight when 'fetching'.

The Grappler allows for a barrel to be held by the device (shaft?) securely in a matter of seconds and then disconnected from the device as quickly. Figure 49 shows the device being used in Kampala.

### Advantages and Disadvantages

Advantages:

- This can ease the process of moving sludge barrels
- Instead of 220 litres (barrels) only 50 litres would need to be carried at a time
- There aren't too many technical challenges with the product

Disadvantages:

- Has some issues socially, more so with the perceived value of the service from the customers



### O&M Requirement

- For simple lifting onto the back of a pickup truck it is possible for one operator to do so, but it is a lot easier with two operators

### Manufacturer/Supplier details

- The Grappler is still in its development stages. In Kampala, the design work for the Grappler was done at Water for People through Sanitation Solutions. The fabricator is in charge of selling the product and finding customers for the product.

### References

- Sanitation Extraction & Transport.(n.d).Review on Transport Devices for Urban Settlements.[pdf] 20

## 6.3. Handcart Barrel Transporting Device

### A brief about the technology

The Handcart has been designed as a product to work alongside the Shlifter. It is a transporting device that is capable of transporting both 150 litre barrels and 220 litre barrels and is an example for oil barrel transporting.

### Technology description and Working principles

The Handcart works on a very simple lifting action as in scissors, with an outer frame and inner frame working together around a pivot. The inner frame has an adjustable clamp which is the main connection to a barrel. The outer frame has a footstool that allows the inner frame to fit inside it. Locking pins hold the frames in position, preventing them from moving and dropping the load carried. The maximum weight that can be carried by the device is 250kg. The handles of the device are 1.5 meters from the load and two operators are ideal to carry a load of 250kg.

**Figure 6.3:** Handcart barrel transporting devices



### **Advantages and Disadvantages**

#### Advantages:

- It eases the process of moving sludge barrels (on solid ground)
- It minimizes the possibility of tipping over and spilling sludge
- Handles heavy weights like 220 l (requires 2 operators). Barrels of 150 l require just one operator

#### Disadvantages:

- It is not possible to pass through very narrow passages such as in slums
- Is very hard to move the cart if the ground is not solid

### **O&M Requirement**

- During field testing there were two operators to navigate the handcart from pit latrine to the pickup truck
- It is possible to do it alone provided it is a flat surface

### **Health and Acceptance**

The health and acceptance described below is with reference to its implementation in Uganda.

- The feedback from the entrepreneurs and operators in Uganda was very positive
- The use of Handcart can aid the sharing model of a pickup truck between entrepreneurs and make it much easier for them to work on pit latrines
- The Handcart has been designed as a product to work alongside the Shlifter and aid the business model behind sharing a pickup truck. So using the Handcart and Shlifter together can generate more income for the pit emptying entrepreneurs. Entrepreneurs have a better chance of targeting more households in one day which means they are not relying on one household to purchase six barrels to be removed

## Design factors

- When loaded onto a pickup truck the cart can lie flat on the top of a barrel

## Manufacturer/Supplier details

- This specific design is not yet scaled up/sophisticated, but there are many other barrel carts in the market too
- Prototype:  
Pentagon Technical Services, Sir Apollo, Kampala, Uganda, +256774182973

## References

- Sanitation Extraction & Transport.(n.d).Review on Transport Devices for Urban Settlements.[pdf] 20.

## 6.4. Shlifter

### A brief about the technology

In Kampala, Uganda, there was a need to develop transport devices like the Shlifter to improve the time taken to carry out pit emptying operation as well as allow entrepreneurs to share the pick-up hiring cost. The Shlifter is a barrel lifting device capable of lifting any barrel size up to 220 litres. The lifting device is based on a lever system using counterweight force to lift a given load of approximately 250kg.

### Technology description and Working principles

The Shlifter barrel lifting device works on the simple principle of counterweight. Using a long enough lever allows you to lift a barrel to a height at which a pickup truck can reverse underneath it. The barrel is attached to one end of the lever using a seat belt and a hook, and is lifted at the other end by operators with the help of a rope attached to the lever. Figure 51 shows the parts of the Shlifter.

The product is easily transportable and can be assembled or disassembled in two minutes. This ensures that the product can fit onto the back of a pickup truck without the operator having to reduce the amount of barrels they can carry.

### Advantages and Disadvantages

Advantages:

- The process of fetching can be cut out when using the Shlifter
- The device allows entrepreneurs to reach higher profit margins for their business, because it allows them to target more than one household in a given area
- The design of the device is fine and it works well enough for it to be taken up as a barrel lifting device and to be used by pit emptying operators

Figure 6.4: Shlifter



Disadvantages:

- The Shlifter is heavy when full
- The amount of force needed to lift the barrels is also high
- The challenge to adopt the barrel lifting device depends on the entrepreneurs' attitudes, because they are set in their ways

### **O&M Requirement**

- It is a low maintenance system, requiring only adequate lubrication at moving joints and protecting the structure against corrosion.
- Operation involves human effort, but leverages on mechanical movement.

### **Health and Acceptance**

The health and acceptance described below is with reference to its implementation in Uganda.

- The Shlifter is designed to coordinate pit emptying entrepreneurs to work together and share the cost of hiring a pickup truck
- Thus entrepreneurs can find multiple pits to work on in a given area

One of the main challenges with the Shlifter is convincing the entrepreneurs to invest in the product.

- They can fail to see the benefits of the barrel lifting and how it can improve the operation when working with other entrepreneurs
- Introducing change is also difficult, because the entrepreneurs are used to using the Gulper
- They see the device as more work and do not want to take it on

### **Design factors**

The Shlifter's first prototype has gone through different development stages to reach its current stage. The design of the Shlifter depends on the following:

- Size of the lever: the optimum size of the lever required for lifting
- The first prototype that we made has a lever size of five meters; the fulcrum was placed at 1.5m from the load it was lifting and 3.5m from the operators
- Weight of the lifting arm: the weight of the lifting arm was too high and subsequently has been redesigned

### **Manufacturer/Supplier details**

- Watcom Technical Services, Katwe, Kampala, Uganda, +256704613626
- Pentagon Technical Services, Sir Apollo, Kampala, Uganda, +256774182973
- Bakibongo Engineering Services, Mengo, Kampala, Uganda, +256772407256

### **References**

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## 6.5. Dung Beetle

### A brief about the technology

Vacuum tankers are used to empty sludge from a majority of households in Ghana. The Dung Beetle is an example of a vacuum tanker which uses a two-wheel tractor-based drive, with the driver sitting on the tank and steering using the long handles of the machine. Sludge can be conveyed to a nearby transfer station or faecal sludge treatment facility. The Dung Beetle has been successfully adopted since many years in Ghana.

### Technology description and Working principles

The Dung Beetle can reach a maximum speed of 12 km per hour. The body of the tanker is fairly low with a length of 3.5 meters. The machine is prone to fall over in spite of its weight.



The sludge tank has a volume of approximately 800 litres and can create a maximum vacuum of 0.8 bar. The total weight when fully loaded, including that of the driver is approximately 1550 kg.

### Advantages and Disadvantages

Advantages:

- Enables access to remote or densely populated areas with small roads

Disadvantages:

- It has a relatively short range
- It can transport only small loads of sludge at a time

### O&M Requirement

- Regular lubrication and maintenance of the two-wheeled tractor and the vacuum pump.
- Cleaning of the collection tank on periodic basis

### Health and Acceptance

- Due to their relatively compact size, Dung Beetles are adept at emptying bucket latrines, but are still too large to access some of the most densely-populated areas of the city of Accra, Ghana.

### Design factors

Some specifications for the Dung Beetle are given below:

- **Type:** 2-wheeled universal; walking' tractor
- **Engine:** 2-cycle. 4 stroke 16 hp diesel engine with electric starter

- **Transmission:** 4-speeds forward plus 1 reverse. Engagable differential lock.
- **Power Take Off:** Independently operating. Vacuum pump powered through V-belt.
- **Brakes:** Handle-operated drum brakes on front wheels with separate parking brake. Pedal operated drum brakes on rear wheels.
- **Turning radius:** 3.05m within kerbs, 3.3m within walls
- **Body:** Self-supporting tank, twisting angle through pivot point limited to + 20 degrees.
- **Valves:** Suction valve 3"

### Manufacturer/Supplier details

- Larsen Dung Beetles, manufactured in Denmark, and deployed with success in Accra, Ghana

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## 6.6. Vacuum Tug

### A brief about the technology

The Vacuum Tug used in Hai Phong transfers the sludge from households to a container/tanker in the streets. This has been successful in areas difficult to access.

### Technology description and Working principles

For de-sludging purposes, the tug accesses households and serves as a transfer medium for sludge which is moved to tankers waiting in the streets. The Vacuum Tug has a capacity of approximately 350–450 litres and an empty weight of 250 kg.

### Advantages and Disadvantages

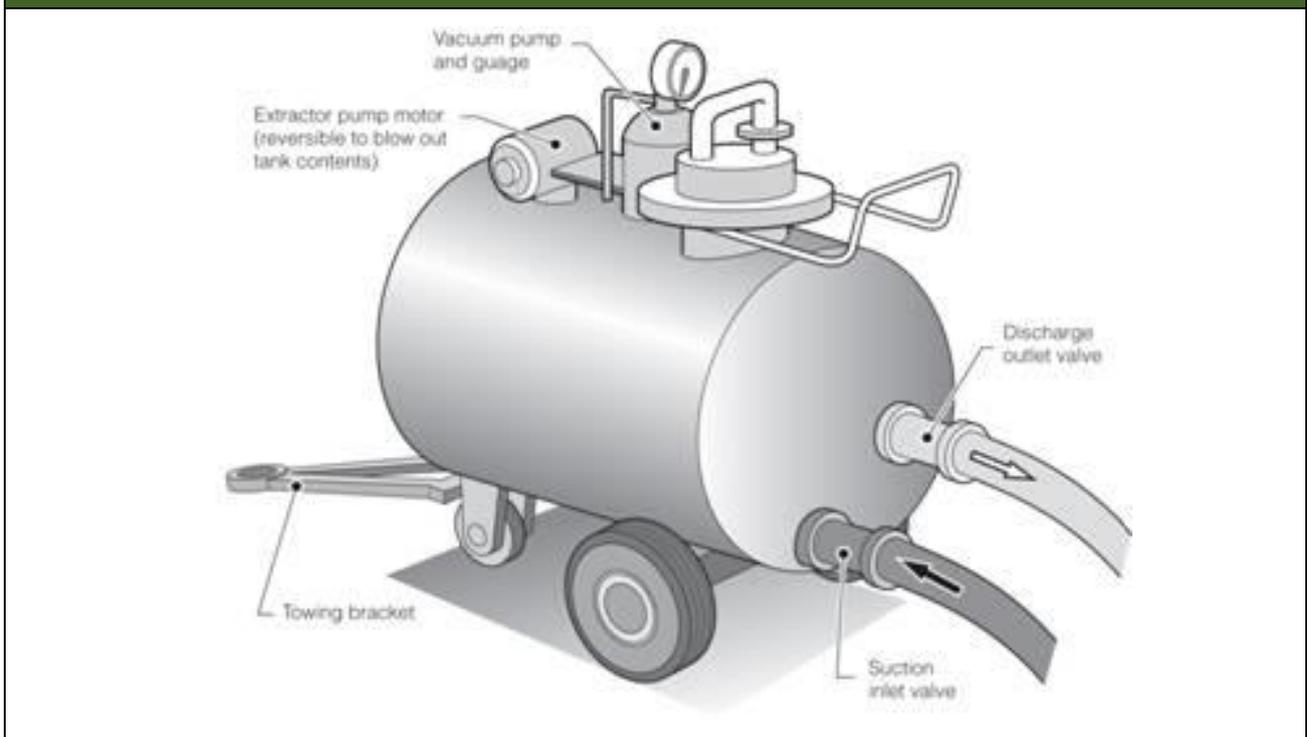
Advantages:

- Has high accessibility to remote areas

Disadvantages:

- It can transport only small loads of sludge

Figure 6.6: Vacuum tug



### Health and Acceptance

- In Nam Dinh, Vacuum Tugs access septic tanks located in extremely narrow lanes, where emptying by hand is still in practice. In this way the tug provides a more hygienic alternative.

### Design factors

The Vacuum Tug has a:

- Hose length of 18 m and
- Its size is: Length 1.20 m; width 0.80 m

### Manufacturer/Supplier details

- Local manufacturer, cost around USD4000

### References

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## 6.7. Vacuum Tug - Vacutug UN-HABITAT

### A brief about the technology

Vacuum tugs are small scale suction machines that are used both for de-sludging and transportation. Vacutug is an example of mechanical systems to empty pits and septic tanks. The UN-Habitat Vacutug device consists of a tank, pump and a flexible hosepipe. The project was funded by the British Development Fund for International Development (DFID). The project evolved out of the need for a low cost and fully sustainable system for emptying pit latrines in unplanned, peri-urban areas and refugee camps in the developing world.

Figure 6.7: Vacutug UN-HABITAT



### Technology Description and Working Principles

Vacuum tug operates on the principle of vacuum suction. Vacuum has been found to be one of the most efficient ways to remove sludge from a diverse set of containment systems.

The Vacutug comprises a 0.5 cubic metre steel vacuum tank connected to a sliding vane vacuum pump capable of producing a -0.8 bar vacuum. The machine is equipped with a throttle, a clutch in the form of an adjustable belt drive and two brakes. A petrol engine can be connected either to the vacuum pump or a friction roller to drive the front wheels through an adjustable belt drive.

The vacuum tank is fitted with 3-inch diameter valves at the top and bottom of the tank and the waste is evacuated from the pit through a PVC vacuum hose. The sludge can be discharged under gravity or by slight pressurisation of the vacuum tank.

The sludge is transported to a neighbourhood collection/disposal point from where vacuum tankers transfer it to city treatment plants.

### Advantages and Disadvantages

Advantages:

- It can access remote areas, provided it has enough space to pass narrow areas

- It has low operation costs
- It is small and can turn within its own length

#### Disadvantages:

- Only short conveyance distances are possible
- Uncontrolled disposal of sludge happens too often
- Solids are often not removed from pits or tanks, because they clog the hose
- The handling is poor and the machine often falls over
- The spare parts are not always locally available and take very long time to be replaced
- The road speed is only 5 km/h
- Tank capacity at 500 litres is not very high
- Variability of faecal sludge viscosity influences the performance and makes pricing difficult

#### O&M Requirement

- Operators require training and regulation

#### Health and Acceptance

- Vacutug and MAPET technologies can be used to transport excreta in high-density areas with small, unpaved streets
- Although designed to empty pits and septic tanks, these devices can also deal with urine
- The system depends on a communal approach and economy of scale in order to allow these options to be sustainable
- Wherever mechanised emptying is considered, the designs of the pits or (septic) tanks themselves should also be considered

#### Design factors

The Vacutug' s main specifications are presented below:

- **Weight:** 950 kg
- **Size:** L 3900 mm; W 1350 mm; H 2000 mm
- **Speed:** 5 km/h
- **Engine:** Four stroke 8 HP Honda models GX240 petrol engine with electronic ignition.
- **Vacuum pump:** Battioni & Pavesi Type 2000P. Manufacturer's rated vacuum 0.9 bar, rated pressure 2.0 bar. Run by a small gasoline engine that has the capacity to remove sludge (or urine) at 1700 litres a minute
- **Vacuum Tank:** 500 litres capacity sludge tank with two sight glasses and pressure relief valves. Rated at 0.9 bar vacuum and 1.0 bar pressure

#### Manufacturer/Supplier details

- The first version, Mark I, was developed in Ireland by Manus Coffey Associates (MCA), and tested in Kenya by the Kenya Water and Health Organisation (KWAHO). Since then, four more versions have been developed in Bangladesh, and several units of each sold. The capital cost range is from 5.100 to

20.000 USD (excluding freight) for the different models. The machines are manufactured in Bangladesh and shipped from there.

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## 6.8. Tri-Cycle Mounted Transportation System

### A brief about the technology

The Tri-Cycle mounted transportation system is a manual or motorised method of transporting sludge from the pits or small septic tanks to the disposal area or transfer station.

Figure 6.8: Images of tri-cycle mounted transportation system



### Technology description and Working principles

It consists of a cart operated by a person to transport sludge, which is usually collected in small volume containers such as a bucket. The non-motorised or motorised tricycle consists of a cart for holding the sludge container and the framework/structure a bicycle or motor bike for transportation.

A maximum of 200 litres of sludge can be carried manually with a non-motorised system. However, more volumes of sludge can be transported using motor driven tri-cycle. The maximum distance of transport for the non-motorised system is 1–2km and for the motorised system 3–5km.

### **Advantages and Disadvantages**

Advantages:

- Enables access to remote or densely populated areas with small roads
- Has a lower capital cost as compared to sludge trucks

Disadvantages:

The range for a tricycle is relatively short

- The non-motorised tricycle is very labour intensive
- Only small loads of sludge can be transported at a time, hence the process is very time consuming

### **O&M Requirement**

- Manpower required for operation: maximum two persons

### **Health and Acceptance**

- A tricycle system is best suited for transporting small quantities of sludge
- It is ideal for dense areas with limited access, such as slums and roads with a width lesser than 2m

### **Design factors**

- Transport option: Non-motorised tri-cycle, motorised tri-cycle
- Maximum volume that can be transported: Around 200 litres of sludge in containers can be carried manually through the non-motorised system. This includes around 4–5 buckets of 40 litres capacity. However, more volumes of sludge can be transported using motor driven tri-cycle
- Maximum distance of transport:
  - Non-motorised system: up to 1–2km
  - Motorised system: 3–5km

### **Manufacturer/Supplier details**

- Tricycles are easily available in Asia and only need to be adjusted to the sludge collection process at a cheap local rate

### **References**

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## **6.9. Medium and Large Sized Trucks: Microvac/ Isuzu Elf/ Trucks**

### **A brief about the technology**

Medium and large-size trucks are mounted with large capacity tanks that allow for efficient transportation of huge quantities of sludge from big containment units or transfer stations to treatment plants.

The emergence of shared containment systems for densely populated regions and the model of transfer stations for faecal sludge collection and transportation have led to the prolific use of medium and large scale transport vehicles.

Figure 6.9: Isuzu Elf, Microvac and trucks



### Technology description and Working principles

The vehicles are equipped with a pump and a hose, which the operators have to insert manually into the pit for de-sludging. The hose length can vary from 12 to 60 meters but generally de-sludging is easier and more effective when the vehicle is closer to the pit. The sludge is collected in the tank mounted on the back of the vehicle. In some cases, the tank can even separate the solids and liquids, resulting in a much higher efficiency. Vacuum trucks are a significant health improvement over manual emptying.

On the smaller scale there are vehicles such as the Microvac or pickup trucks that are modified for sludge collection and conveyance purpose. Their tank capacities range from 500 to 2000 litres. Compared to the smaller motorised systems they enable faster service and have a larger range.

Larger vacuum trucks have a storage capacity of up to approximately 15.000 litres, a horsepower of more than 400 and their pumps are capable of generating a pressure of 170 bar (amounting to 330 l/min). As a result, they are most suitable for emptying higher viscosity sludge typically found at the bottom of a pit. Since the pumps are usually powered by the truck's transmission, naturally larger trucks have stronger pumps. Although large vacuum trucks can't access areas with narrow or non-motorable roads, they remain the norm for municipalities

and sanitation authorities. The higher travel speed and higher storage capacity allows for greater range and more pits to be emptied.

### **Advantages and Disadvantages**

Advantages:

- Vacuum trucks provide fast, hygienic and generally effective sludge removal
- Efficient transport is possible with large vacuum trucks
- They are ideal for transporting large quantities of sludge over long distances

Disadvantages:

- Large tankers may be very expensive and not easily available which is why older versions with higher maintenance costs are being used
- Besides the difficulties in accessing certain areas, not every household can afford to hire a vacuum truck

### **O&M Requirement**

- Since these vehicles are built on non-standard platforms (chassis and engine), they usually have higher downtimes due to non-availability of parts locally.
- Most of the O&M requirement related to the suction equipment and the collection tank is similar to a usual desludging vehicle.

### **Health and Acceptance**

- These trucks carry huge quantities of faecal sludge between two points, thereby reducing the transfer time and cost of transportation
- These are also used in large cities that have adopted FSM (faecal sludge management) where the treatment plant is usually away from the city

### **Design factors**

- A variety of vehicles are available for conveyance of faecal sludge and according to their design and dimensions are appropriate for different areas and purposes.
- Length: 4.54–9.60 m
- Width: 1.69–2.5 m

### **Manufacturer/Supplier details**

- Variable operating costs depending on use and maintenance

### **References**

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# Treatment Technologies

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# 7. Treatment Technologies

Compared to wastewater management, treatment options to handle faecal sludge in developing countries have been overlooked. A strong plan of action and development of technologies has yet to evolve. Only recently have authorities in a few cities focussed on investing in improved faecal sludge management (FSM) and treatment. An appropriate and adequate FSM deriving from onsite technologies is crucial for human and environmental health.

There are a number of technologies available for the treatment of faecal sludge (FS); however, the same level of operational information is not available for all of them. The choice of technologies cannot be made without cost comparison. It is difficult to provide precise costs for each technology as costs are strongly context specific and there are many factors and parameters that affect this decision. There is a lack of long-term experience of operational FS treatment implementations which further complicates reliable cost estimation. In this Compendium we have provided an index system which will help the reader in selecting the appropriate technologies suitable for their locality.

We can classify technologies as per these factors: location-on-site or off-site; input to treatment system-grey water, blackwater and brown water; and type of treatment-part treatment, stand-alone and combination treatment. Here, we will classify treatment technologies according to type of treatment. Part treatment refers to what usually is the first stage of wastewater treatment and needs further treatment modules. Stand-alone Treatment technologies are those that do not require further treatment modules while Combination Treatment systems use a combination of the first two. This Compendium has also identified which treatment technologies are natural, physical, chemical, microbial, and electro-mechanical.

## 7.1. Settling Tank

### A brief about the technology

Settling tanks are rectangular tanks, where faecal sludge is discharged into an inlet at the top of one side and the effluent leaves through an outlet on the opposite side, while solids settle to the bottom of the tank, and scum floats on the surface.

LEVAPOR Bio Carrier can be added to settling tanks to increase the treatment efficiency. Conditioning faecal sludge can significantly improve settling and dewatering processes. Conditioners, particularly commercial conditioners, such as polyelectrolytes and hydrolysed metals are commonly used to increase efficiency of settling and dewatering in treatment.

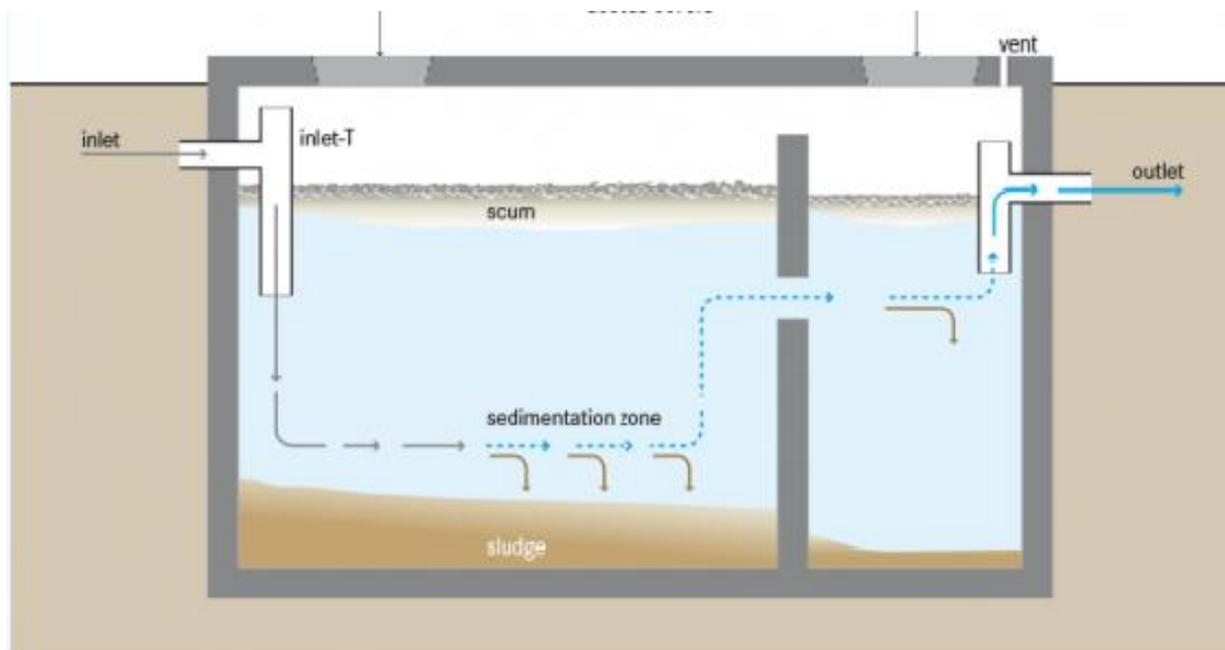
### Technology Description and Working principles

Settling tanks are watertight chambers which provide primary treatment for wastewater. The liquid flows through the tank and heavy particles (sludge) sink to the bottom, while scum (mostly oil and grease) float at the top. The biochemical oxygen demand (BOD) reduction is about 30 to 50 per cent and total suspended solids (TSS) reduction is about 40 to 60. The Hydraulic Retention Time is about one day. This technology is not efficient at removing nutrients and pathogens.

The settling tanks should be appropriately sized and the accumulated sludge and scum must be removed every 2–3 years. At least two settling-thickening tanks should be operated alternately in parallel, in order to allow for sludge removal without overloading the tanks in the process. The loading of FS, and the compaction and removal of the thickened sludge and scum comprise the main phases of an operating cycle. These periods allow for the expected solids-liquid separation and thickening operations.

**Aqua privy** is a simple modified settling tank that is located directly below the toilet so that the excreta fall into it through a pipe. The bottom of the pipe is submerged in a liquid in the tank, forming a water seal to prevent escape of flies, mosquitoes and odour

Figure 7.1: Settling tank



### Advantages and Disadvantages

Advantages:

- The settler has a low operation cost
- It requires little space due to underground construction
- It can be built and repaired with locally available materials
- It has no real issues with flies or odours if used correctly
- It does not require electrical energy

Disadvantages:

- Settlers have a long start-up phase
- There is a lack of experience in operating with FS
- Lack of empirical data and results on which to base designs for pathogen removal is low
- Effluent and sludge require further treatment

### O&M Requirement

- The settling tanks should be regularly checked to ensure it is watertight, and for scum and sludge levels

- Sludge needs to be dug out every 1–5 years and discharged properly
- Settling tanks need to be vented

### Health and Acceptance

- Even though the settling tank is watertight, it should not be constructed in areas with high groundwater tables or where there is frequent flooding
- Users do not come in contact with the influent or effluent during operation of settling tanks
- Most of the time, enough consideration is not given to the disposal of the tank effluent. Effluent, scum and sludge must be handled with care as they contain high levels of pathogens
- As the treatment in settling tanks happens anaerobically, the effluent contains large numbers of pathogens and therefore can be a potential source of infection. Motorised emptying using a vacuum truck or a manual technology like a sludge gulper can decrease the health risks
- Users should be careful when opening the tank because flammable gases may be released. Thus, open fire should be avoided when opening the septic tank

### Design factors

- The design of a settling tank depends on the number of users, the amount of water used per capita, the average annual temperature, the de-sludging frequency and the characteristics of the wastewater
- A settling tank should have at least two chambers made out of concrete or brick work. Less expensive options such as pre-fabricated concrete rings, PVC or fibreglass septic tanks are also available.
- The first chamber of a settler should be at least half of the total length and when there are only two chambers, it should be two thirds of the total length. Most of the solids settle down in the first chamber
- To prevent scum and solids from escaping with the effluent, a baffle/separation between the chambers is provided.
- A T-shaped outlet pipe, the lower arm of which dives 30 cm below the water level, further reduces the scum and solids that are discharged
- To have easy maintenance, access ports to all chambers are provided
- Septic tanks should be vented for controlled release of odorous and potentially harmful gases

### Manufacturer/Supplier details

- CDD Society, Bangalore
- <http://dir.indiamart.com/mumbai/settling-tanks.html>

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## 7.2.Imhoff Tank

### A brief about the technology

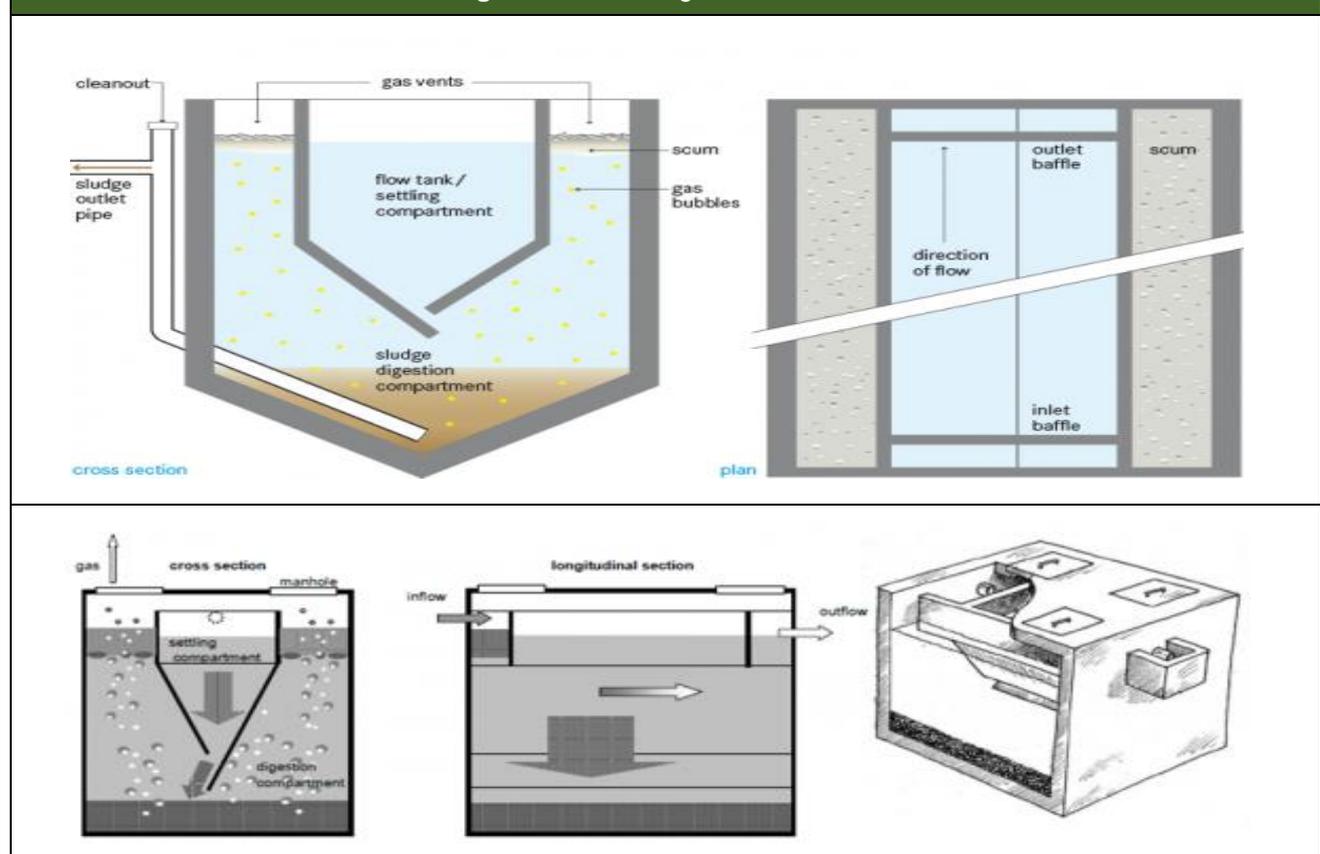
Imhoff tank is a primary treatment technology for raw wastewater. It is designed for solid-liquid separation and digestion of the settled sludge. It removes 25 to 50 per cent of Chemical Oxygen Demand (COD), reduces suspended solids by 50 to 70 per cent but pathogen removal remains low. Imhoff tanks are ideal for small communities.

We can add Levapor bio-carriers porous, flexible, easily fluidisable plastic foam cubes) to the Imhoff tank to increase the treatment efficiency.

### Technology Description and Working principles

The Imhoff Tank works similar to a septic tank, enabling COD and suspended solid reduction. Depending on design and external conditions it offers potentially good sludge stabilisation.

Figure 7.2: Working of Imhoff tank



It consists of a V-shaped settling compartment above a tapering sludge digestion chamber with gas vents. In the digestion chamber, the settled solids are anaerobically digested, generating biogas. The gas is deflected by baffles to the gas vent channels to prevent it from disturbing the settling process.

The pre-treated wastewater from the Imhoff tank requires a secondary treatment like horizontal flow, vertical flow or free-surface constructed wetland. The faecal sludge needs to be correctly disposed of and further treated in thickening ponds or drying beds. The sludge can be composted either directly or after drying. It can be used as fertiliser to improve the soil quality.

### **Advantages and Disadvantages:**

Advantages:

- The Imhoff Tank is a robust and effective settler where, land-use is limited as it is usually built underground with reinforced concrete
- It can also be built above ground which makes sludge removal easier
- Investment costs are low and the O&M is simple

Disadvantages:

- The pathogen removal and treatment efficiency is low and further secondary treatment of the effluent is required
- The tanks must be de-sludged regularly
- The construction costs are slightly higher as compared to a septic tank

### **O&M Requirement**

- With trained personnel the O&M cost is low
- Flow paths have to be kept open and cleaned out weekly
- Scum in the settling chamber and the gas vents has to be removed daily
- The sides of the settling chamber and slot have to be regularly cleaned Backwash of water to even up the solids in the digestion chamber has to be done twice a month
- Sludge needs to be dug out every 1 to 5 years and discharged properly
- A minimum clearance of 50 cm between the sludge blanket and the slot of the settling chamber has to be ensured at all times

### **Health and Acceptance**

- Imhoff Tanks are good as primary treatment as the effluent is almost odourless. Greenhouse gases produced in low quantities may, however, generate odours locally
- Even though pathogen removal is low, the entire tank is usually below the surface so users do not come in contact with any of the wastewater
- Sufficient protective clothing is necessary for workers who may get in contact with the effluent, scum or sludge
- Users should not attempt to empty the pit themselves except with a manual technology like the Gulper
- A vacuum truck should be used to empty the sludge, if there is no pumped outlet installed

- Users should be careful when opening the tank because toxic and flammable gases may be released

### Design factors

- The Imhoff Tank is designed with three compartments
  - Upper compartment for sedimentation
  - Lower section for sludge digestion
  - Gas vent and scum section
- The Hydraulic retention time is usually not more than two to four hours to maintain an aerobic effluent for further treatment or discharge
- In order to reduce velocity and prevent scum from leaving the system, T-shaped pipes or baffles are used at the inlet and the outlet
- The total water depth in the tank from the bottom to the water surface may reach 7 to 9.5 m
- The typical slope of bottom of the settling compartment is 1.25 to 1.75 V: 1 H and the slot opening can be 150 to 300 mm wide
- Dimensions of the anaerobic digestion compartment depends mainly on sludge production per population equivalent, and on the targeted degree of sludge stabilisation

### Manufacturer/Supplier details

- Mr. Devender Singla
  - Chief Executive
  - SINGHLA SCIENTIFIC INDUSTRIES- No-5309/27, Punjabi Mohalla, Ambala Cantt - 133001, Haryana, India

### References

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## 7.3. Ammonia Addition

### A brief about the technology

Adding ammonia to inactivate pathogens has been applied for wastewater sludge, where it is commonly referred to as alkaline stabilisation. There is similarly a need to inactivate the pathogens in faecal sludge to reduce health risks. Ammonia addition is a simple technology which only requires uncharged ammonia and airtight storage for a sufficient amount of time.

## Technology Description and Working Principles

Investigations have been conducted on using the ammonia from excreta for pathogen reduction in faecal sludge. This can be done by collecting urine (which has high ammonia concentration) separately, and then mixing it with faecal sludge. For sludge with low ammonia concentration, additional ammonia in the form of the synthetic urea can be added to enhance the treatment.

Urea treatment is based on the effect of increased pH in combination with cell alkalisation by uncharged ammonia ( $\text{NH}_3$ ). Ammonia treatment is based on the fact that ammonia ( $\text{NH}_3$ ) enters cells, takes up intracellular protons for the formation of ammonium ( $\text{NH}_4^+$ ) and as a charged ion disrupts the functioning of organisms until eventually resulting in cell death. The enzyme urease present in faeces is required for the conversion of urea into ammonia.

Figure 7.3: Structure of Ammonia

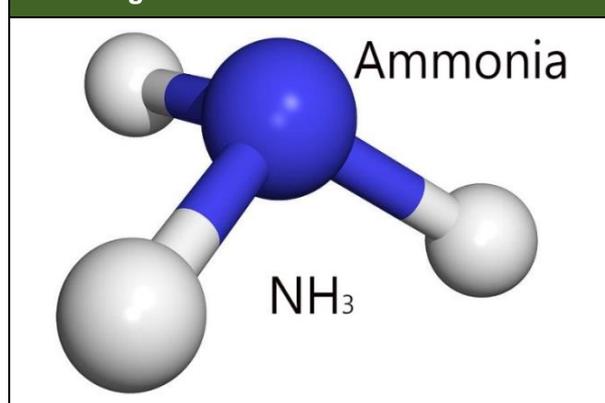
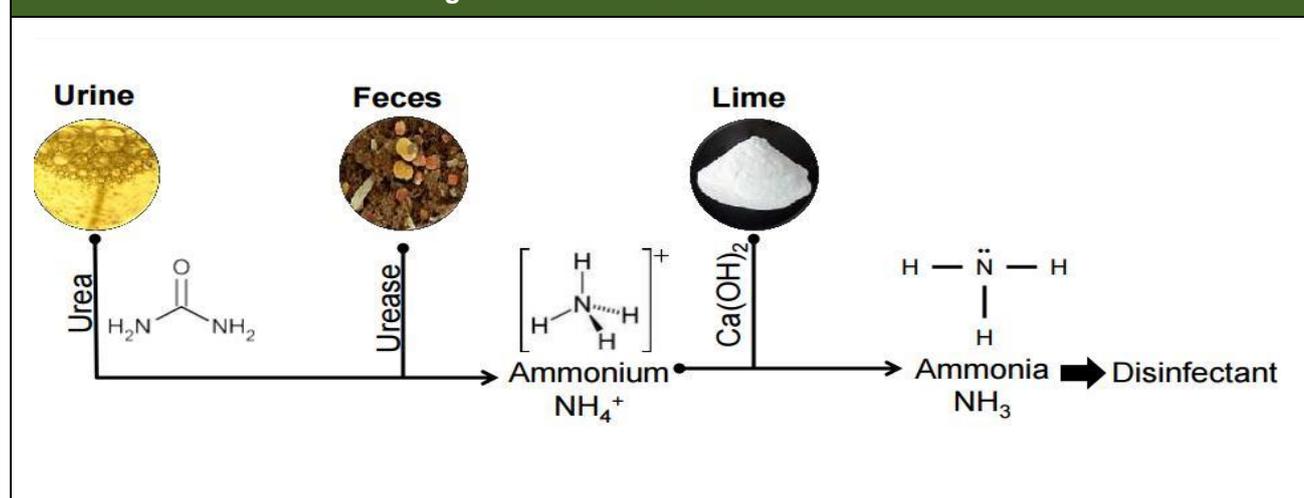


Figure 7.4: Ammonia addition to faeces



## Advantages and Disadvantages

Advantages:

- Ammonia requires less rigid storage conditions and is applicable in regions with urine diverting dehydrating toilets (UDDTs)
- Appropriate for long-term sanitation systems when the treated faecal sludge is to be used as a fertiliser

Disadvantages:

- Where synthetic urea needs to be applied, the costs are higher, which may restrict the technology feasibility economically and also make it less sustainable
- Another constraint is the stability of nitrogen in end products, and whether the full nutrient benefit can be achieved
- Urea-treated sludge is not stabilised and has an odour as it has been exposed to anaerobic conditions

## O&M Requirement

- Regular monitoring of pH & ammonia should be done
- Should have at least 20 mm of ammonia
- Treatment time dimensioning with Ascaris model

## Design factors

- The amount of uncharged ammonia depends on urea added and the conversion rate, which is governed by temperature and pH and the medium
- Head space and ventilation are important parameters as the amount of unionized ammonia is also dependent upon the equilibrium with ammonia gas
- It was found that at higher temperatures, the inactivation of Ascaris eggs was faster and the required ammonia concentration lower. This makes the system well suited to many tropical low-income countries where there is a dire need for fertilisers and faecal sludge sanitisation
  - The design requirements for Safe Sludge process is that it has to be done as a two-stage process-
  - First stage requiring the detention time for hydrolysis to occur, followed by the,
  - Second stage which involves the addition of alkalinising agent. There is no need for water and electricity

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## 7.4. Lime Addition

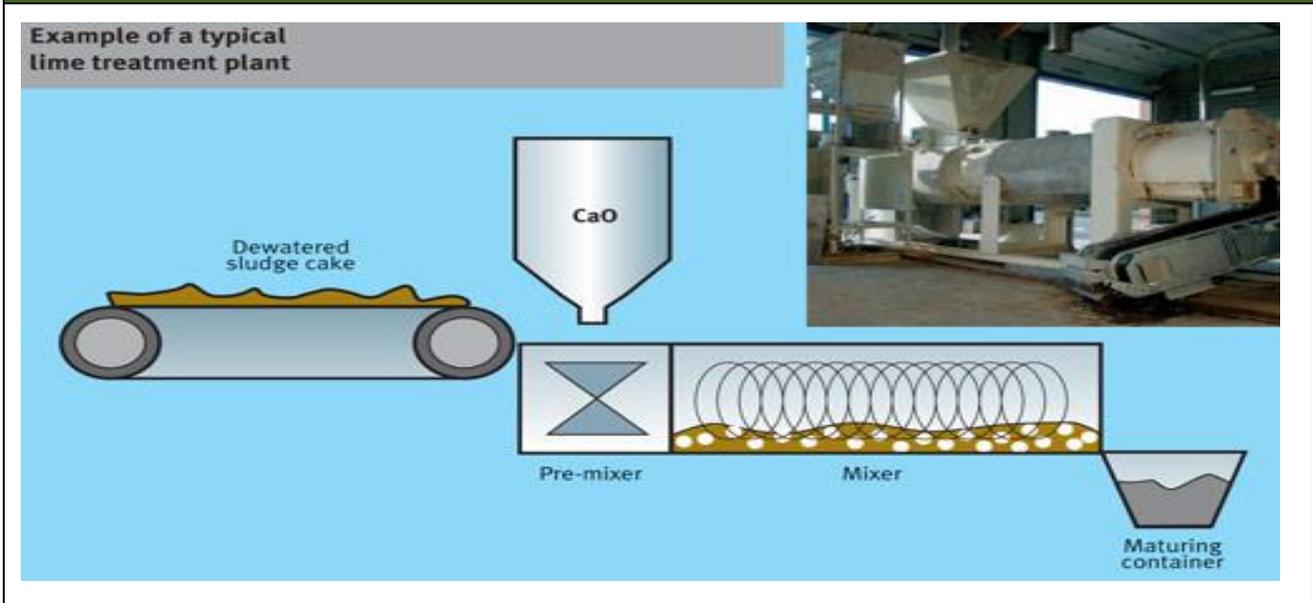
### A brief about the technology

Lime is used in wastewater sludge treatment to achieve the reduction of pathogens, odours, and degradable organic matter. It also acts as a sludge conditioner to precipitate metals and phosphorus. The process of pathogen reduction during alkaline stabilisation is based on an increase of pH, temperature and ammonia concentration. Its effect is enhanced by a longer contact time and higher dosing amount.

### Technology Description and Working Principles

Lime addition involves the application of a hydrated (slack) lime ( $\text{Ca(OH)}_2$ ) to create an alkaline environment which is hostile to biological activity. At pH levels higher than 12, the cell membranes of harmful pathogens are destroyed. This high pH also leads to high fractions of non-ionised ammonium which acts as a biocide and helps in pathogen removal.

Figure 7.5: Typical Lime treatment plant



Most common forms of lime are quick lime ( $\text{CaO}$ ) and slaked lime  $\text{Ca(OH)}_2$ . Quick lime is derived from lime stone by a high temperature calcination process; quick lime is then hydrated to get slaked lime, also known as hydrated lime, or calcium hydroxide. The high pH due to the formation of  $\text{CaHCO}_3$  provides an environment that stops or decreases microbial degradation of organic matter.

Figure 7.6: Typical Layout of a lime stabilization system

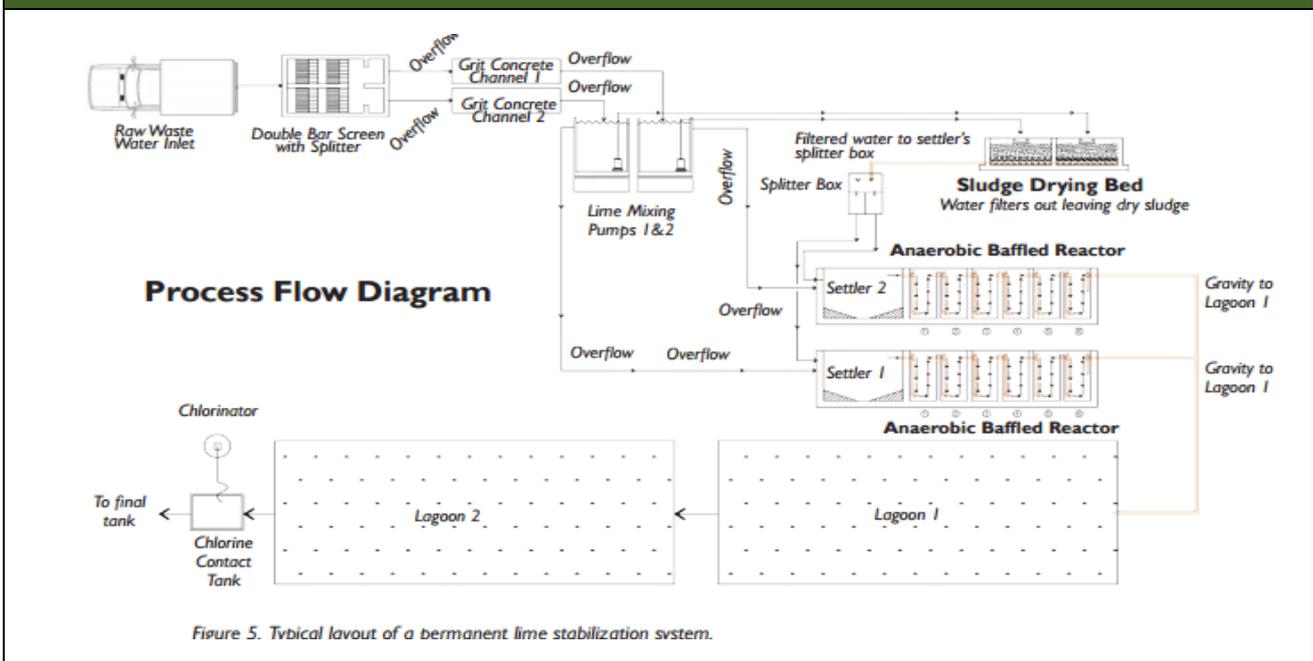


Figure 5. Typical layout of a permanent lime stabilization system.

After lime treatment the stabilised sludge can go to sand drying beds and the liquid effluent sent for further treatment. However, lime stabilisation does not result in complete disinfection. Additional treatment steps may be required for final treatment and proper disposal of the remaining liquid effluent and bio-solids into the environment.

## **Advantages and Disadvantages**

### Advantages:

- This process can take place in lined pits or an open tank, making them more versatile options for an emergency setting
- Lime treatment has low treatment cost, short sanitation time, operational stability under temperature changes and aerobic conditions
- It requires a dry storage area

### Disadvantages:

- One major concern here is pathogen re-growth
- Lime is an alkaline material which reacts strongly with moisture and is hazardous to the eyes, skin and respiratory system
- Skilled staff is required and they must follow health and safety procedures

## **O&M Requirement**

- The operator should check sludge loads that come into the facility. Segregation of non-standard loads, such as those contaminated by fuel or other contaminants, should be done and these treated separately using the lime stabilisation process
- Workers must wear eye protection (goggles) and other protective gear, especially when mixing lime to form the slurry
- Mechanical mixing with paddles, blowers or pumps is recommended as hand mixing is inefficient and labour intensive

## **Health and Acceptance**

- Lime stabilisation can be done as a first phase following a disaster and in the next phase, a municipal or city-wide program to de-sludge all septic tanks on a regular schedule using treatment technologies besides lime stabilization can be established
- The process for lime stabilisation following a disaster focusses on reaction in trenches or pits, with liquid effluent being discharged to the environment, or first put on sand drying beds
- The site selected should be such that it is not too close to residential housing areas and is not prone to flooding and other geo-hazards
- As lime is highly alkaline in nature it is very important the workers are trained and use protective gear while dealing with lime

## **Design factors**

- It is important to consider a number of design parameters like sludge characteristics, lime dose, contact time and pH in order to achieve optimum results from lime stabilisation in the most economical way possible
- It is recommended to use hydrated lime for septage or wastewater stabilisation. The amount of lime needed depends on the quality of the lime, how well it is mixed, and the temperature

- Research in the Philippines shows that we can start with 20 kilograms for 4,000 litres of septage. If a batch system is used then it is advisable to start adding lime and mixing, not adding any more septage

## Case Study

### Lime Stabilisation as was done in Philippines:

The treatment involved four processes. The first was pre-treatment which included screens and grit chambers. The second step was stabilisation—here, the pre-treated sludge is mixed with lime and retained for a specific time period in a reactor. The next step involved sand drying beds for dewatering and drying of bio-solids. The fourth and final process included secondary treatment—effluent treatment and disinfection.

Figure 7.7: Lime stabilization in Indonesia



### Manufacturer/Supplier details

- Pablito S Paluca- Philippines Association of Water Districts, President

### References

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## 7.5. Geotextile Bags and Tubes

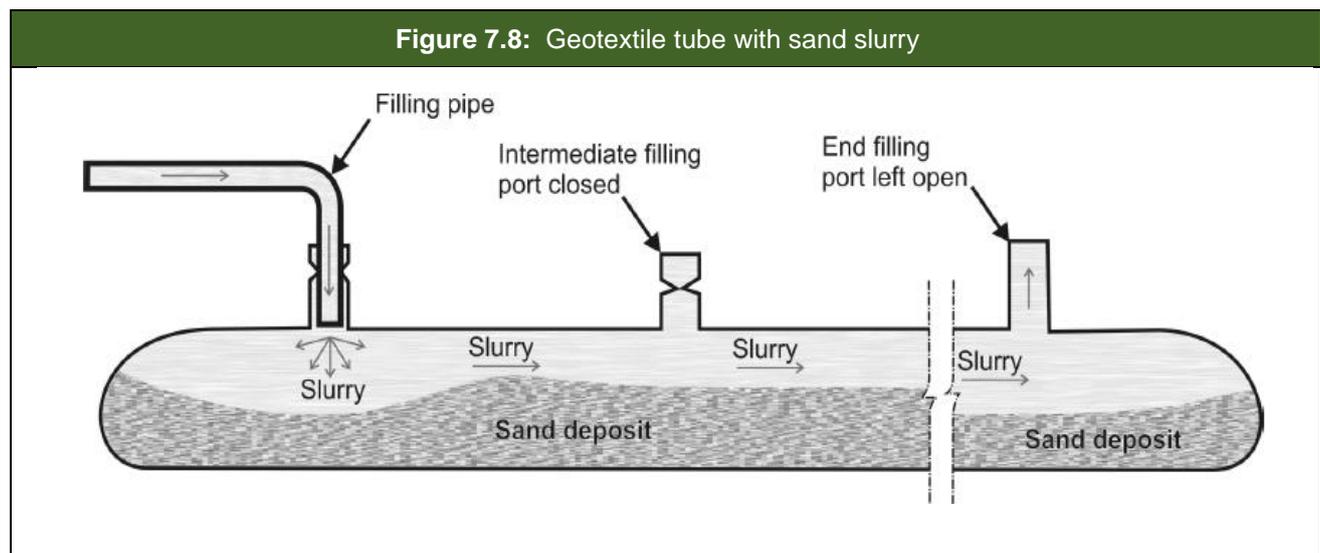
### A brief about the technology

Geo tubes are permeable containers that can be used for dewatering sludge and sediment. Geo bags are porous tubular containers made with high strength woven geo-textiles (polyethylene material) mainly used for dewatering sludge.

Additives such as polymers, fly ash, or highly oxidised water are recommended to be added during or after consolidation in the geo tubes to achieve increased bacterial reduction.

### Technology Description and Working principles

Geotextile dewatering tubes can remove large amounts of sludge, sediment or silt as compared to geo bags as they are designed with significantly larger dimensions and a stronger fabric. They can be used without having to constantly change out or replace bags. Due to their high strength and large capacity, dewatering tubes are used extensively in Wastewater Treatment Projects (WWTPs), agricultural ponds, aquaculture facilities, pulp and paper mills and numerous industrial lagoons. These can be used in conjunction with other treatment technologies like Settler, Waste Stabilisation pond and sludge drying beds.



The geotextile dewatering tubes are normally filled to 85 per cent with slurry mix and then allowed to consolidate. Once consolidation has taken place, the dewatering tubes are then refilled, and the cycle is repeated until consolidated solids reaches 85 per cent of the tube's total capacity.

In order to achieve the optimum volume reduction, geotextile dewatering tubes should be left in place to dewater over extended periods of the time. Reduction rates vary from site to site and depend on the slurry, organics and conditions of the particular location. After the removal process is done, consolidated materials can be transported to an off-site location for disposal or use as fill or compost.

## Advantages and Disadvantages

### Advantages:

- Geotextiles can retain the fine grained sewage sludge and, are capable of filtering the sludge so that the effluent water passing through the fabrics will meets the 30 mg/l discharge requirements of EPS in less than 11 minutes of drainage time
- They are also capable of competing economically with other alternative dewatering techniques for sludge

### Disadvantages:

- They require proper monitoring during tube filling if a polymer is being used

## O&M Requirement

- This is a passive technique and does not require extensive or constant labour and maintenance of equipment
- The correct use of polymer can reduce total time and provide huge savings on a geotextile dewatering tube system but must be carefully monitored during the tube filling operation
- It is important to contact a polymer specialist to treat the sludge and also the necessary management and labour to establish/maintain a sludge tube dewatering process and placement of inlets for distribution of sludge/solids in each tube
- There should be proper drainage of clear, free-flowing filtrate from each tube

## Design factors

- Simple soil analysis along with hanging bag tests can economically determine the correct fabric and pore size necessary for the local conditions to safely deploy the dewatering tube safely. Tube height should not exceed 5 feet. Additional tubes placed one over the other need to be balanced for stability. The type of additive used in geo tubes is an important factor.

## Case Study

Geo tubes are containers made of permeable textiles used for dewatering sludge and sediment. This solution has worked well in Malaysia, where the utility placed geo tubes in several strategic locations, resulting in a reduction of overall operations expenses by 37 per cent and an increase of 35 per cent in revenues.

### Manufacturer/Supplier details

- Sam, Business Development Manager
  - TenCate Geosynthetics Asia Sdn Bhd 140 Jalan Kapar 27/89 Seksyen 2740400 Shah Alam Selangor Darul Ehsan Malaysia

Figure 7.9: Case study - Geobags



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## 7.6. Mechanical Dewatering

### A brief about the technology

The principal methods of mechanical dewatering are belt filter presses, centrifuges and chamber filter presses. These techniques are usually sophisticated and rarely cost-efficient for smaller systems to be implemented on a community level. The process does not treat the sludge; it only separates solid from liquid. Both solid and liquid parts still contain pathogens and pollutants.

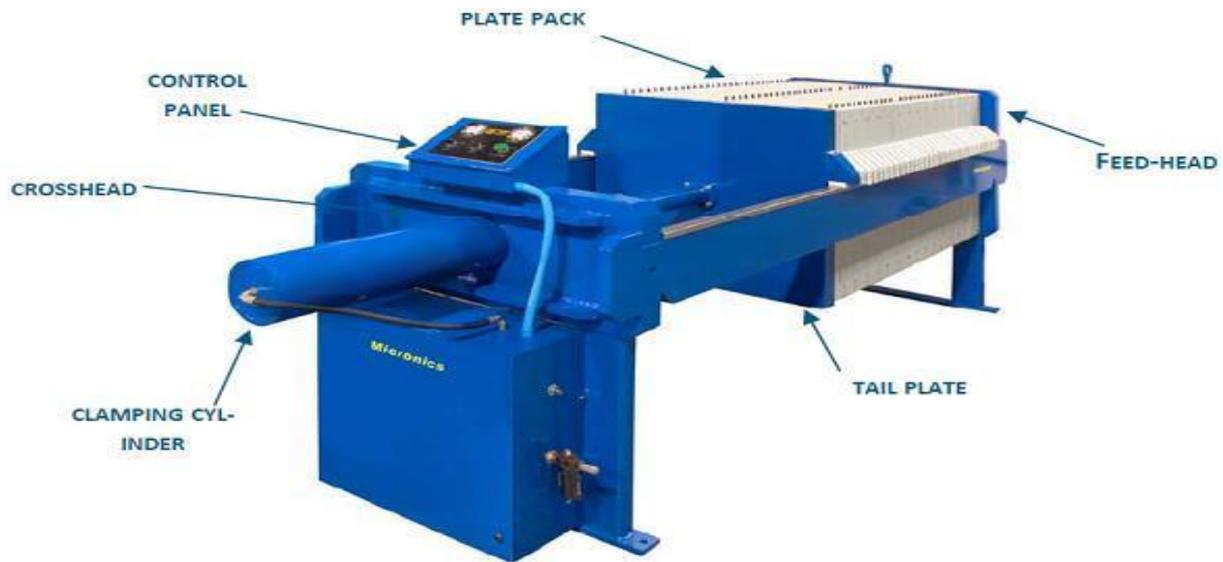
### Technology Description and Working Principles

**Belt filter press:** This allows the water to be squeezed out of the sludge as it gets compressed between two belts. This system consists of:

- a gravity drainage zone where the flocculated sludge is deposited and conveyed on a porous and mobile belt;
- a compression zone where a second belt is applied on the upper layer of the sludge, and compresses it to a pressure that can reach 7 bars;
- a zone where the belts are separated and the dewatered sludge is released

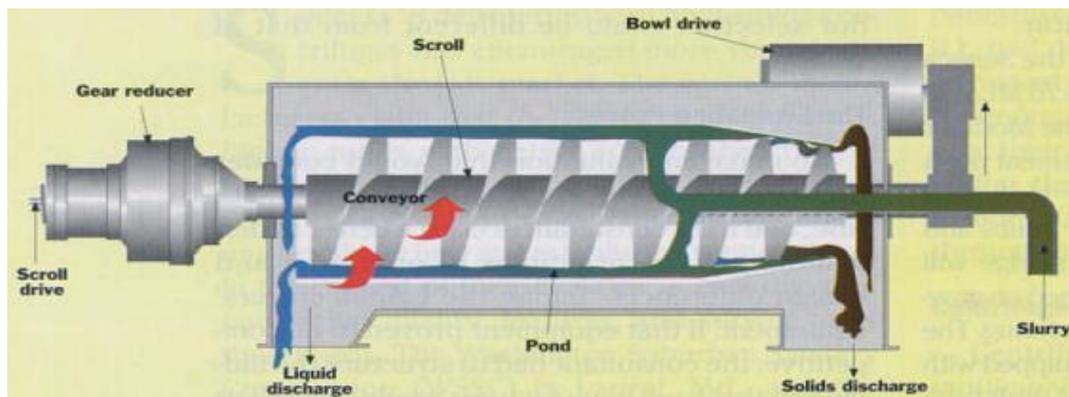
The main disadvantages of a belt filter press compared to other mechanical dewatering techniques are the need for skilled maintenance and difficulty in controlling odours.

**Figure 7.10:** A chamber filter press for mechanical dewatering of sludge



Source: MICRONICS (n.y.)

**Figure 7.11:** The schematic design of a centrifuge thickening and dewatering system



Source: EPA (2000)

**Centrifuge:** This process dries the faecal sludge as it is squeezed outwards on the surface of a cylinder rotating around its horizontal axis, due to the centrifugal force. The flocculated sludge is injected into the middle of this cylinder, and the particles are sent outwards against the surface. An Archimedean screw transports the released liquid to the side where the sludge entered, while another transports the sludge to the other end. High energy requirement is a major constraint for this technology.

**Frame filter press:** This system consists of porous vertical frames fixed on two walls placed in front of one another to create a chamber. This involves a batch process in which the sludge is filled into the chamber at high pressure after which the leachate is released through the porous frames and the dewatered sludge is let out through the opening of the lower wall.

**Screw press:** This consists of a rotational screw placed in a perforated cylinder. The sludge is loaded at one end, it is pressurised due to a decreasing space between the screw and the cylinder. The liquid that is squeezed out is removed through the pores in the cylinder. The dewatered sludge is discharged at the other end. Screw

presses provide dewatering at relatively low equipment and operational costs. Minimal maintenance skills are required.

### **Advantages and Disadvantages**

Advantages:

- The compactness of the system
- The speed of the process
- The investment costs of the system
- The O&M requirement of the system
- The need to add flocculants

Disadvantages:

This is an expensive high-tech solution for dewatering sludge and only used in large scale treatment plants.

- It needs expert design
- Operation and maintenance needs qualified workers
- Constant power supply is needed
- Both dewatered sludge and effluents are still infectious, and further treatment is necessary

### **O&M Requirement**

- Requires a high degree of operator supervision and training
- The mechanical systems such as filters, belts, tensioning systems or bearings have to be maintained correctly to guarantee correct functioning
- The performance of primary treatment systems prior to the mechanical stage is also a critical determinant of performance
- Routine use of flocculants is essential, normally selected at installation on advice and the results of on-site testing from polymer chemical suppliers

### **Health and Acceptance**

- This is an expensive high-tech solution for dewatering sludge and only used in large-scale treatment plants
- This process does not treat wastewater; it only separates solids from liquids
- Both solid and liquid parts still contain pathogens and pollutants and have to be treated

### **Manufacturer/Supplier details**

- HUBER SE  
Industrie park Erasbach A1  
D-92334 Berching  
Germanyinfo@huber.de

## References

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## 7.7. Levapor Carriers

### A brief about the technology

LEVAPOR is a synthetic bio-carrier that allows fast colonisation of specialists microorganisms with extremely high surface area. It allows adsorption of hazardous, inhibiting pollutants on the carrier surface and reduction of inhibitory effects in the liquid phase.

### Technology Description and Working principles

LEVAPOR carriers consist of porous, flexible, easily fluidisable plastic foam cubes, impregnated with adsorbing pigments. Depending on the bioprocess and reactor type, LEVAPOR carriers can be applied in fluidised, expanded and fixed-bed reactors for the following bioprocesses—biotreatment of municipal and industrial effluents—especially in nitrification and denitrification, anaerobic and aerobic treatment of complex effluents and removal of persistent and hazardous pollutants and micro pollutants.

### Advantages and Disadvantages

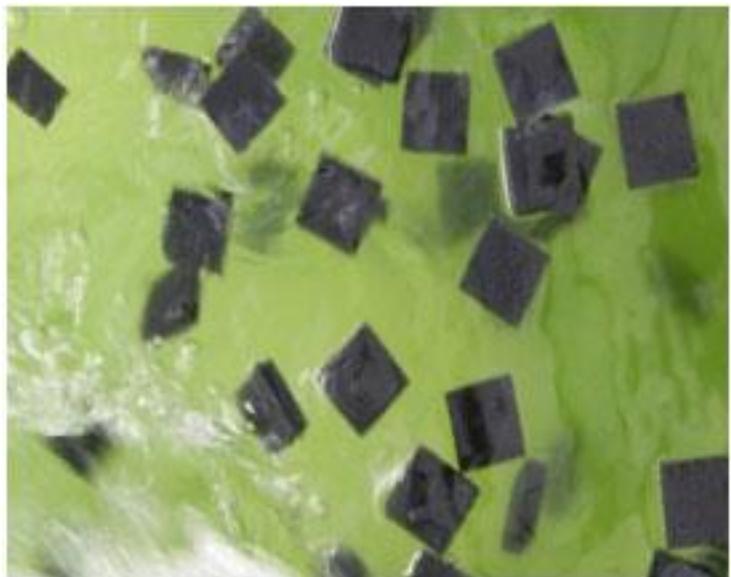
Advantages:

- It has a short start-up period for the bioprocesses
- Higher process performance, of 100 per cent to 300 per cent compared with suspended cells
- Has higher process stability, lower sludge yield
- Lower degree of reactor filling; only 12 to 15 per cent instead of 40 to 65 per cent by MBBR using plastic carriers. This translates to lower energy consumption

Disadvantages:

- The constraint with regards to the integrity of the cage that is used and its clogging due to solids. Such issues have however not been observed with aerobic applications as an aerator pump is used which keeps the media and screen from clogging

Figure 7.12: Levapor Plastic Foam Cubes



## O&M Requirement

For safety and trouble-free operation, the following tasks should be performed periodically:

- O&M requirement for LEVAPOR septic tank applications are same as any other suspended growth based septic tank
- Cleaning of cages periodically for any clogging
- Checking cage integrity periodically for prevention of media loss
- If required, the media can be taken out of cages and washed with hydrochloric acid to remove any clogging

## Design factors

- The cost of LEVAPOR carriers per cubic metre is around 550 EUR Ex, Germany. This is exclusive of import duty and transport
- The cage could cost around 350–500 EUR. For a small septic tank of 2–4 PE, 1 cage may be required.
- The media can be used for 10–12 years for such simple applications like a septic tank

## Manufacturer/Supplier details

- Amit Christian
- Levopar
  - Tel.: ++ 49-2173-938715
  - Germany Mobile: ++ 49-177-786 5533
  - Website: [www.levapor.com](http://www.levapor.com)
  - E-mail: [levapor@web.de](mailto:levapor@web.de)

## References:

- <http://www.environmental-expert.com/companies/levapor-gmbh-biofilm-technologies-33262>

## 7.8. Breathable Membranes

### A brief about the technology

Breathable membranes are suitable for lining containment systems such as septic tanks and twin pits. These on-site containment systems are usually not made waterproof at the bottom to provide for seepage of wastewater. The wastewater carries along with it harmful pollutants that contaminate the underground aquifers.

Breathable membranes are hydrophobic linings that allow water vapour to pass through it, while repelling solid particles and any water molecules attached to it. Hence the membrane is suitable as a pit enclosure that allows sludge to dry while the solar and internal heat generated from digestion expels water vapour from the containment structure. At the same time, particulate or dissolved constituents are prevented from escaping.

## Technology Description and Working Principles

Breathable membranes have pores that allow passage of water vapour but repel any particles of water as they are hydrophobic. Temperature is an important characteristic of the contained matter that leads to separation. Digestion of sludge and the falling solar radiation increase the temperature of the matter, thereby aiding in evaporation of the moisture. This moisture is lost through the membrane as vapour. Over a period of time, the moisture content in the matter reduces, leading to reduced volume, hence increasing the life of containment systems.

This membrane can act as a cost-effective retrofit option for containment units with permeable base. Research suggests that a pit latrine lined with the breathable membrane removes moisture at a rate equal to or exceeding the likely loading from a population of several families.

The tensile nature of the membrane allows for sufficient loading of sludge without rupture leading to leakages. Additionally, these membranes also find their use in biogas digesters used for anaerobic digestion of sludge. The supernatant of these digesters can be made to pass through these membranes to reduce its moisture content thereby increasing the efficiency of further treatment.

## Advantages and Disadvantages

Advantages:

- A simple and appropriate technology, it retains particulate and dissolved contaminants including pathogens
- It allows water vapour to escape. A small temperature gradient assists in the gradual escape of water vapour
- It has minimal deposit on the fabric which can be rinsed off
- It has no possibility of clogging as faecal sludge has minimal contact with the membrane. Hence the fabric can be re-used multiple times

However, more research and ground testing need to be conducted to ensure that there is no clogging.

## O&M Requirement

- Ensuring a temperature gradient is important. This is done through ensuring presence of sunlight
- The membrane can be re-used multiple times since clogging does not occur

## Health and Acceptance

- Breathable membranes are suitable for hot and dry climates which facilitate drying of faecal sludge at the points of collection and storage
- They can be readily used without much maintenance as clogging is not significant
- They are cost effective as they are reusable multiple times

## Design factors

- Temperature plays a significant role in driving water vapour through the pores. However, even though greater temperature difference accelerates drying, a mere 2°C difference appears sufficient
- The pit dimensions are of significance since the drying rate depends on the membrane surface area

## Manufacturer/Supplier details

- Susana-Steven Dentel, University of Delaware in the U.S

- customerservice@kingspaninsulation.co.uk
- kingspaninsulation.co.uk

## References:

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## 7.9. Co-composting with Municipal Waste

### A brief about the technology

Co-composting is the process which involves controlled aerobic degradation of organics, using faecal sludge and organic solid waste. Organic waste forms the largest portion of municipal waste, thereby making composting systems important in managing waste as well as creating employment. Composting produces a product that contributes towards food security in developing countries.

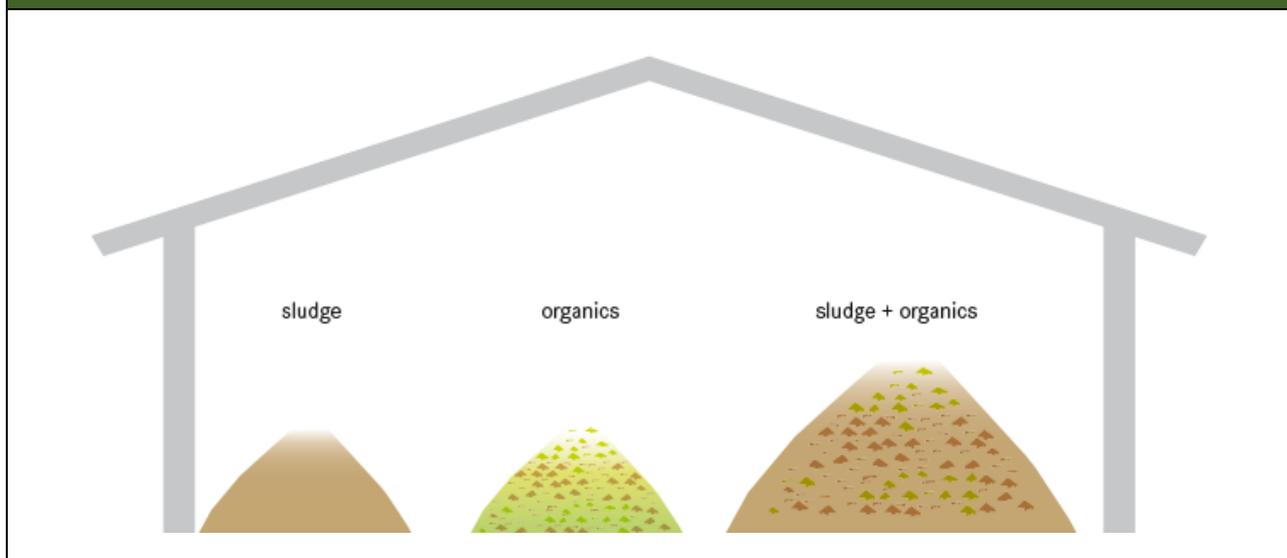
Co-composting faecal sludge and municipal solid waste (MSW) is favourable because the two materials complement each other. Human waste has relatively high nitrogen content and moisture while the MSW is relatively high in organic carbon (OC) content and has good bulking quality.

### Technology Description and Working principles

There are essentially two types of composting: Open composting and In-Vessel Composting.

**Open composting** is a slow but simple process in which the sludge and solid waste is stacked into long heaps called windrows and left to decompose. The windrow stacks or heaps are periodically churned to ensure that all parts of the pile are exposed to the same heat and are well aerated. Aeration can also be ensured by the addition of bulky materials and passive or active ventilation. Trench and pit systems are characterised by heaps, which are partly or fully contained under the soil surface, thereby reducing any construction cost.

Figure 7.13: Schematic for Co-composting



**In-Vessel Composting** needs less space. Here the compost is placed in bricks or wood or mesh boxes with holes in between and a screen at the bottom. This composting requires controlled moisture and air supply, as well as mechanical mixing. It is generally not appropriate for decentralised facilities but is less labour intensive than open composting.

### Advantages and Disadvantages

Advantages:

- Co-composting involves low operating cost and requires no electrical energy
- Reduces the cost of solid waste management and is relatively easy to set up with locally available materials
- This process can be easily maintained with appropriate training
- It improves local agriculture and food production and reduces dependency on chemical fertilisers
- This process can ensure removal of a large percentage of helminth eggs

Disadvantages:

- It requires a large land area
- It requires expert design and long storage time
- It requires professional collection and marketing of the compost
- It is labour intensive and the compost can be too bulky to be economically transported over long distances

### O&M Requirement

- Well-trained staff is needed for O&M of the facility
- It would be useful to monitor helminth egg inactivation as a proxy measure of sterilisation

- Forced aeration systems must be carefully controlled and monitored
- Periodic turning must be done using either a front-end loader or by hand
- Robust grinders for shredding large pieces of solid waste and pile turners help to optimise the process, thus reducing manual labour, and ensuring a more homogenous final product

### Health and Acceptance

- A compost plant (requiring about 800 square metre space for a 3 ton per day plant) has to be set up and a private entrepreneur or NGO with the necessary technical and managerial skills has to manage the plant
- Solid waste containing plastics and garbage must first be sorted.
- The finished compost is safe to handle and care should be taken when dealing with the sludge irrespective of the treatment. The temperature in the pile should be kept between 55 and 60°C to reduce the pathogen load in the sludge to a level which is safe to work with.
- If the material is found to be dusty, workers should wear protective clothing and use appropriate respiratory equipment. It is crucial to have proper ventilation and dust control for the safety of workers

### Design factors

- The same process parameters valid for composting must be adhered to. They play a role in co-composting of human waste with organic solid waste
- The mixture must be carefully designed so that it has the proper C: N ratio, moisture and oxygen content
- Some of the other factors that influence design include particle size, degree of decomposition, pH, temperature, turning frequency, nitrogen conversion, as well as microorganisms
- The distance to source is an important factor. Ideally the facility should be located close to the source of organic waste and faecal sludge to minimise transport costs. Care should also be taken to keep it at a sufficient distance away from homes and businesses
- **Open system area:** The total land area required for a 3 ton per day compost plant is about 810 square metre
- **In-vessel system area:** The total land area required for a 3 ton per day compost plant is about 770 square metre

### Manufacturer/Supplier details

- HK GLOBAL ENTERPRISES- based in INDIA
  - <http://www.environmental-expert.com/companies/hk-global-enterprises-59571>

### References

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## **7.10. Deep Row Entrenchment**

### **A brief about the technology**

Deep row entrenchment is a process which involves digging deep pits or trenches, filling them up with sludge and covering with soil. Trees which are then planted on top benefit from the organic matter and nutrients that are slowly released from the faecal sludge (FS).

Deep Row Entrenchment has proved to be a viable sludge treatment option in South Africa. Further research is being done on this technology to ensure that there is no contamination to groundwater tables in regions where it is being employed.

Further studies are required to understand aspects like the effect of different sludge loading rates over a full growth cycle on crop growth and nutrient concentrations, the quantity of nitrogen at an entrenchment site, movement and concentration of nutrients through the soil profile and groundwater, and the role of soil fungi in degradation of sludge.

### **Technology Description and Working principles**

There are different methods of applying sludge in this process. Raw sludge is spread out on farm fields during the dry season, and then incorporated into fields when crops are planted during the rainy season. A pit method is also used, where faecal sludge is buried with other crop residues and left to mature for a few months prior to use. In areas such as northern Ghana, where this is practiced, there is a large demand for faecal sludge and almost 90 per cent of FS is used as a fertiliser.

The potential benefits of the nutrients like nitrogen, phosphorus and potassium and the high organic carbon content of sludge have been studied and are well known. Entrenchment of sludge enables nutrients to be preserved and used by plants over time. Deep Row Entrenchment is best implemented in arid to semi-arid regions. It must be ensured that adequate barriers are in place and that there is sufficient land area available.

### **Advantages and Disadvantages**

Advantages:

- This is a simple, low cost process
- It has limited O&M issues and has no visible and odour nuisances
- Primary benefits include increased growth of trees

Disadvantages:

- It requires large area of land
- The need to ensure that groundwater table doesn't get affected
- There is a lack of legislation in countries regarding this option

### **O&M Requirement**

For municipalities in South Africa, the deep row entrenchment method opens a much needed avenue for the beneficial disposal of sludge.

- It is important that there is regular monitoring of groundwater and soil
- Mutually beneficial partnerships between municipalities and forestry could provide a viable solution, where forestry companies handle, apply and monitor sludge on their own land

- Municipalities can also monitor sludge entrenched on municipal land with a forestry company contracted to manage a timber crop on the entrenchment site

## Health and Acceptance

- Deep row entrenchment is considered most appropriate in forestry rural areas where the water supply is not directly obtained from the groundwater source and where sufficient land is available.
- The hindrance here is that the sludge has to be transportable to rural and peri-urban areas as it is mostly appropriate for forested rural areas
- In many countries legislation for this option is still lacking. This needs to be addressed in Tamil Nadu before considering it as a viable option

## Design factors

- Factors like soil type and porosity, ground water depth, proximity to drinking water sources, and background nutrient concentrations are to be considered before implementing deep row entrenchment
- The role of soil fungi in degradation of sludge needs to be further studied
- The fate of nitrogen at an entrenchment site requires a better understanding of the processes of leaching and denitrification. The appropriate loading of nutrients needs to be considered to prevent environmental contamination
- The effect on groundwater needs to be further studied and a case-by-case analysis has to be done to ensure environmental protection when using this method

## References

- [http://www.unesco-ihe.org/sites/default/files/fsm\\_ch05.pdf](http://www.unesco-ihe.org/sites/default/files/fsm_ch05.pdf)
- [http://www.susana.org/\\_resources/documents/default/2-1679-wrc-1829-investigating-the-potential-of-deep-row-entrenchment-for-sludge-disposal.pdf](http://www.susana.org/_resources/documents/default/2-1679-wrc-1829-investigating-the-potential-of-deep-row-entrenchment-for-sludge-disposal.pdf)
- <http://prg.ukzn.ac.za/projects/completed-projects/k5-1829>

## 7.11. Unplanted Drying Beds

### A brief about the technology

Unplanted Drying Bed is a simple, permeable bed filled with several drainage layers. When loaded with sludge, it collects percolated leachate and allows the sludge to dry by percolation and evaporation.

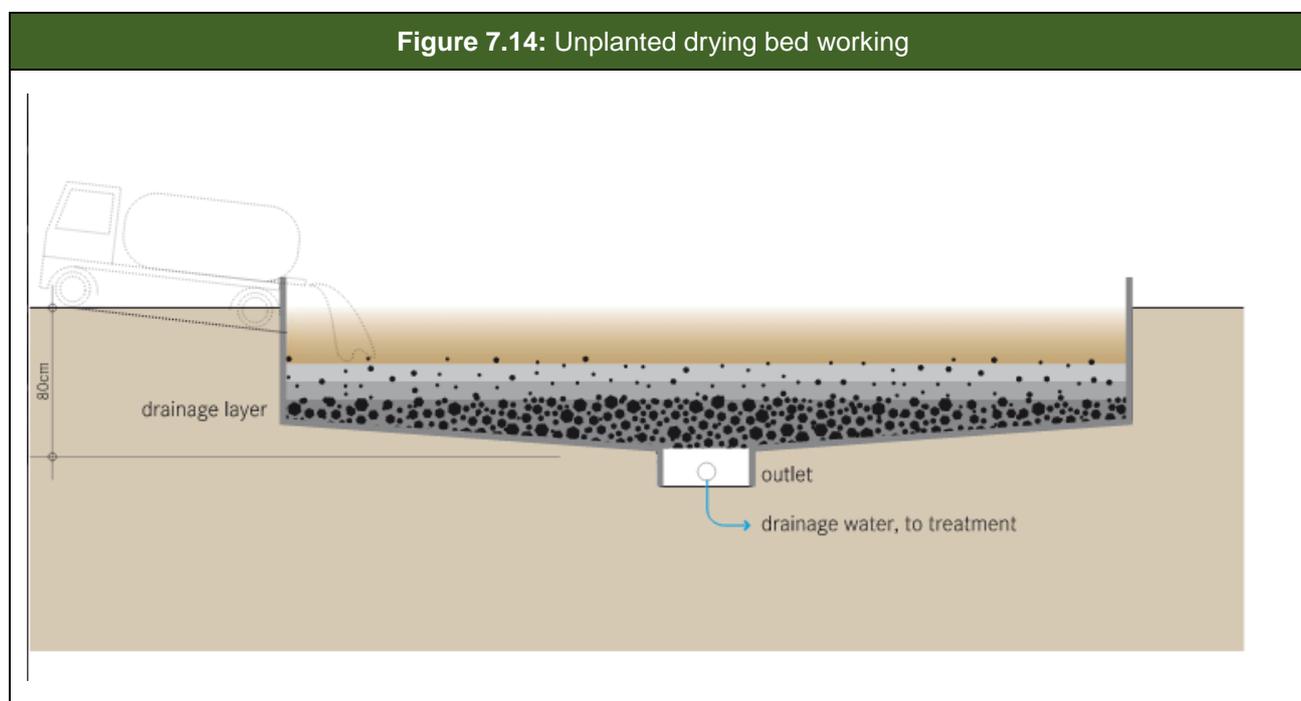
Approximately 50–80 per cent of the sludge volume drains off as liquid or evaporates. This sludge needs additional treatment by composting before it can be safely disposed of or used as a nutrient-rich soil conditioner in agriculture. The percolate, however, still contains pathogens and needs to be further treated.

### Technology Description and Working Principles:

Unplanted drying beds are one of the simplest and oldest techniques to dewater sludge. It includes a simple technique to reduce the volume of the sludge and prepare its reuse as fertiliser. The bottom of the drying bed is lined with perforated pipes to drain away the leachate that percolates through the bed. On top of the pipes are layers of gravel and sand that support the sludge and allow the liquid to infiltrate and collect in the pipe. While the solid fraction remains on the filter surface and is dried by natural evaporation, the liquid percolates.

Sludge is applied in layers on top of the gravel beds and is naturally dried. It should not be applied in layers that are too thick as this will deter drying. The final moisture content after 10 to 15 days of drying should be approximately 60 per cent.

When the *sludge* is dried, it must be separated from the sand layer and transported for further treatment, *end-use* or final disposal. The leachate that is collected in drainage pipes must be treated further.



### Advantages and Disadvantages

Advantages:

- Unplanted drying beds are easy to construct
- They have low maintenance
- They have moderate cost operation and investment costs when land prices are low and filter material (gravel/sand) is locally available
- These beds do not need complicated equipment

Disadvantages:

- Need to de-sludge before fresh sludge is applied
- They require large surface areas and mechanical power for regular desludging.
- These beds are not ideal for regions where water table is high and rainfall is heavy with frequent flooding

### O&M Requirement

- Trained staff is required for operation and maintenance
- Well-organised community groups having experience in organic fertiliser use and preparation should be involved in the O&M aspect

- Depending on the climate conditions, dried sludge can be removed after 10 to 15 days. The top layer of filter material must be replaced when it gets thin. The discharge area must be kept clean and the effluent drains should be regularly flushed

### **Health and Acceptance**

- They should be located sufficiently away from residential areas as they can prove to be a nuisance for nearby residents due to the presence of flies and bad odours, especially when sludge has been freshly applied
- Dried sludge and effluent may require further treatment or storage, depending on the end-use. Sludge can be composted before reuse
- Workers should be equipped with proper protective attire like boots, gloves, and clothing as they have to handle sludge

### **Design factors**

- Sludge is applied in a batch mode about once per week in layers of no more than 20 to 30cm. Around 100 to 200kg TS/m<sup>2</sup> of sludge can be applied on a drying bed, on an annual basis. The drying process usually takes 10 to 20 days
- Land requirement is 0.05 square metre per capita for a 10-day cycle
- Before fresh sludge is applied, dried sludge needs to be de-sludged, and then brought to a composting site
- To improve drying and percolation, sludge application can alternate between two or more beds. About 50–80 per cent of the initial volume is removed by percolation, resulting in a TS content of 20–70 per cent, depending on the local weather conditions
- A splash plate has to be provided at the inlet to prevent erosion of the sand layer and to allow for even distribution of the sludge
- While designing unplanted drying beds, ensuring accessibility to people and trucks into the site for regular maintenance at all times is absolutely essential

### **Manufacturer/Supplier details**

- WaterWiki Community Manager
  - Phone: +44 (0)20 7654 5503
  - email: scooper@iwap.co.uk
- Margarita Lygizou
  - Digital Marketing Manager
  - Phone: +44 (0)20 7654 5517
  - email: mlygizou@iwap.co.uk

### **References**

- www.sswm.info,(n.d).Unplanted drying beds.[online] Available at: <http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/sludge-treatment/unplanted-drying-beds>

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## 7.12. Janicki Omni Processor- Model S200

### A brief about the technology

Omni Processor (OP) s a combination of physical, biological or chemical treatment processes for treating faecal sludge in developing countries.

Faecal sludge causes the spread of diseases, for which one major treatment goal is the removal of pathogen from it. The Omni processor helps achieve all this and more.

### Technology description and Working principles

Omni Processor-Model S200 is a stationary, combined heat and power plant that converts faecal sludge and other combustible waste streams into electricity, potable water and ash.

Figure 7.15: Janicki Omni processor



Heat generated from combustion within a fluidised sand bed is utilised to generate high pressure steam expanding in a reciprocating piston steam engine connected to a generator and producing electricity. The exhaust (process heat) from this engine is used to dry the incoming faecal sludge. Water evaporated from the

sludge is collected and treated to meet clean drinking water standards. Combustion gases are treated as essential to meet local emission standards.

### **Advantages and Disadvantages**

Advantages:

- Is mobile, modular, flexible, adaptable, clean and quiet
- It can process various kinds of waste streams, including wet waste streams and some solid waste streams
- It generates own power
- It collects revenue from tipping fees and sale of water. The excess electricity CAPEX may be higher than the more primitive forms of waste treatment

Disadvantages:

- The approach is technical to an extent, and requires operators with a certain level of technical skill

### **O&M Requirement**

- Omni Processor will be internet-connected, remotely monitored and operated by a central command centre
- Technical expertise will be provided on an ongoing basis to every unit without the technical expert being physically present. This enables continuous access to software upgrades for the customer, thereby enhancing the performance of their unit
- Personal Required: 1–2 people per shift

### **Health and Acceptance**

- The Janicki Omni Processor revolutionises the treatment of faecal sludge and other waste products
- It has a revenue potential instead of only parasitic cost

### **Design factors**

Omni Processor technology is extremely versatile. It can be sized to fit the specific needs of the user's application.

Footprint

- Core unit: 11.5m x 20m (37.5' x 65')
- Overall plant: 11.5m x 29m (37.5' x 95.5')
- Plant capacity sludge processed per day 20–80m (5,000–20,000 gal) depending on configuration. Dry solids requirement per day 5–11 MT (6–12 t)

Output products

- Electricity 150–250KW (200–335HP)
- Depending on water produced: water 10,000–70,000 l (2,500–18,000 gal) depending on power produced: heat 30–60 gj per day ash 1 m (35 ft) average. per day
- Utilities of municipal input requirements: none. Op does not require outside electrical or water lines

### **Manufacturer/Supplier details**

- Janicki Bioenergy

- 719 Metcalf Street
- Sedro-Woolley, WA 98284. USA
- Phone: (360) 399-6193
- [www.janickibioenergy.com](http://www.janickibioenergy.com)
- email: [info@janickibioenergy.com](mailto:info@janickibioenergy.com)

#### References:

- Emails from Todd Babok from Janicki
- Janicki\_bioenergy(n.d).OMNI PROCESSOR The future of waste processing.[image].Available at: <http://www.australianmanufacturing.com.au/wp-content/uploads/2015/01/omni.jpg>
- Omni-Processor Information Packet

### 7.13. Vermicomposting

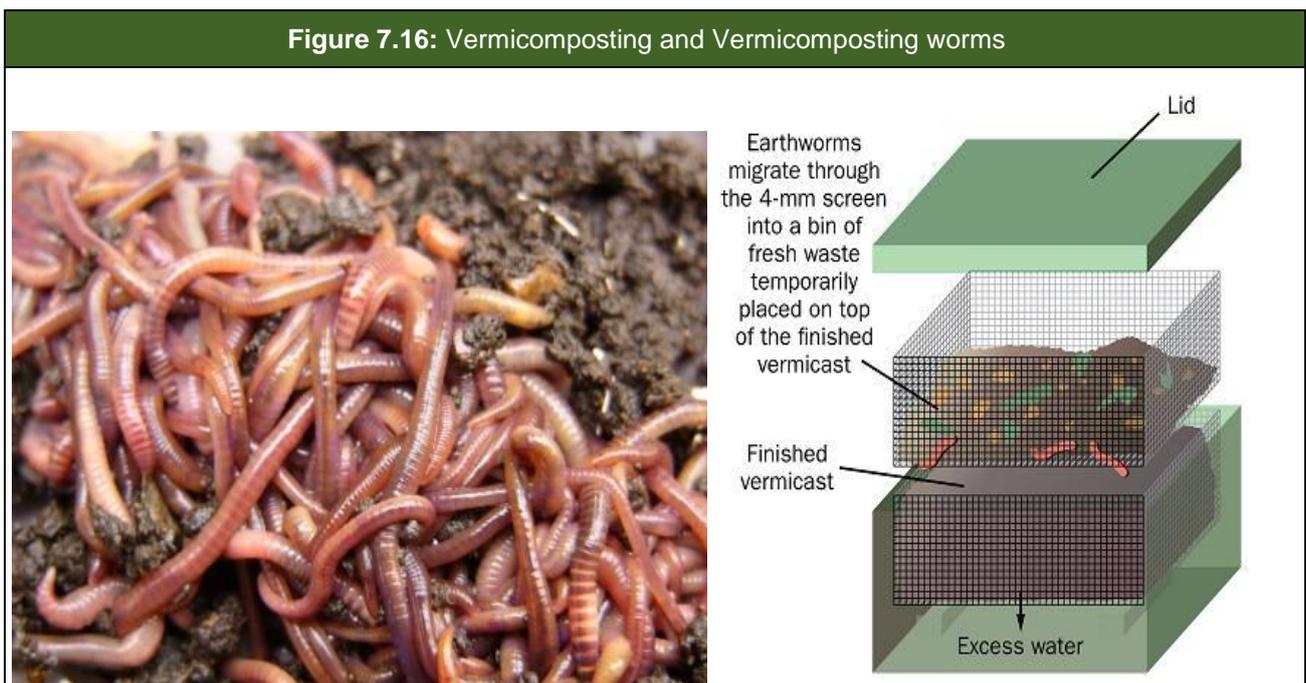
#### A brief about the technology

Vermicomposting involves using special types of earthworms to convert organic waste into worm casting, which can also be done in decentralised composting facility.

#### Technology Description and Working principles

Vermicomposting results in better quality compost, but the worms need more care than aerobic composting. In a vermicomposting plant, the waste is first composted aerobically for about two weeks as in an ordinary plant. Then, the semi-decomposed waste is put in boxes with special types of worms, such as *Eisenia foetida*, *Lumbricus rubellus*, and *Eisenia hortensis*. For vermicomposting, the pile does not need to be stirred, but the temperature and moisture needs to be optimum for the worms at all times to ensure their survival. The earthworms function in synergy with bacterial communities within the filter. Worms cannot survive in fresh faeces and need some kind of support in the form of layers of soil and vermicompost.

Figure 7.16: Vermicomposting and Vermicomposting worms



## Advantages and Disadvantages

Advantages:

- Vermicomposting results in better quality compost
- Results show that the worms can not only reduce the waste material by 75 per cent, but also reduce the metal content in the waste by a similar percentage

## O&M Requirement

- The worms used in vermicomposting need more care as compared to aerobic composting
- The material must be allowed to adequately mature before being removed from the system. Then, it can be used without further treatment
- Workers should wear appropriate protective clothing

## Health and Acceptance

- Compost and pit humus are inoffensive, earth-like products. Yet, people might refrain from handling and using them
- Conducting demonstration activities that promote hands-on experience can effectively show the non-offensive nature of the compost

## References

- Ronteltap, M. Dodane, P. Bassan, M. (n.d) Overview of treatment technologies.[pdf]. Available at: [http://www.unesco-ihe.org/sites/default/files/fsm\\_ch05.pdf](http://www.unesco-ihe.org/sites/default/files/fsm_ch05.pdf)
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## 7.14. Anaerobic Digestion

### A brief about the technology

Large-scale anaerobic biogas digesters are used for the conversion of the organic portion of large volumes of slurries and sludge into biogas by anaerobic digestion. Biogas is recovered and used either directly for heating the reactors or transformed into combined power and heat and fed into the grid.

### Technology Description and Working principles

Biogas reactors are utilised for converting organic wastes into biogas. Typical substrates include excess sludge from large-scale wastewater treatment plants, agricultural and food industry wastes, (e.g., manure, from stock farming, sugar refining, starch production, coffee processing, alcohol generation, slaughterhouses or industrial wastes), etc.

Anaerobic digestion can be carried out in the mesophilic (20 to 35°C) or the thermophilic range (50 to 60°C). Thermophilic processes produce more biogas in a shorter time. Mesophilic processes are often preferred compared to thermophilic, as high temperatures require higher energy input.

Figure 7.17: Biogas reactor

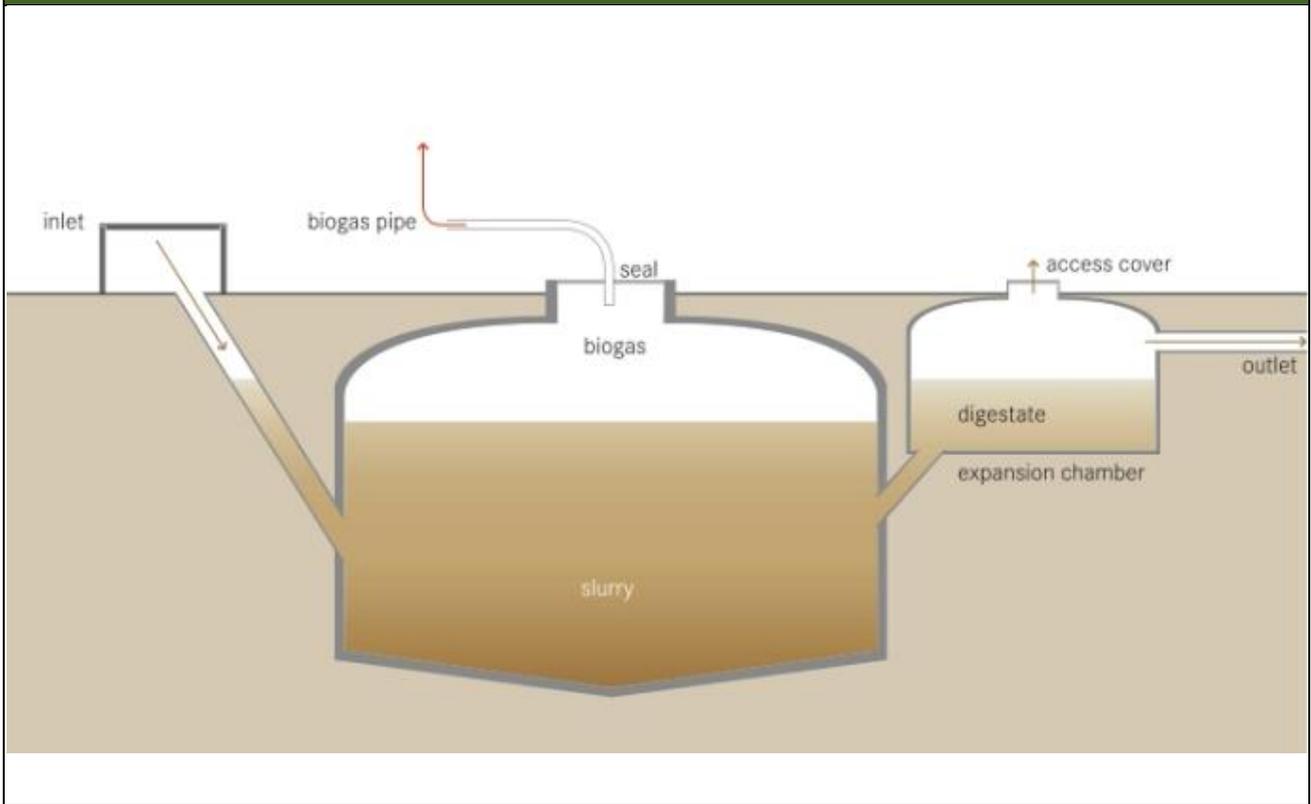
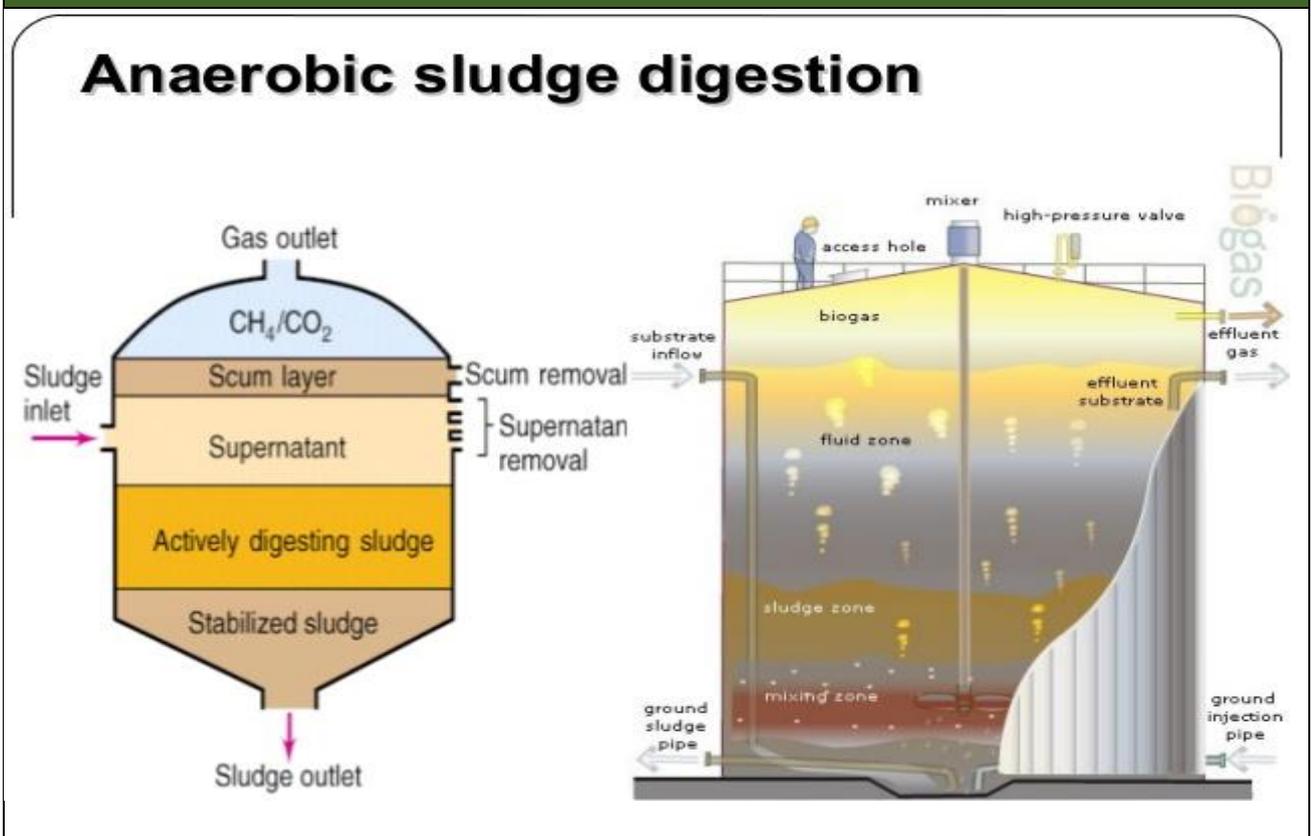


Figure 7.18: Anaerobic sludge digester



## Advantages and Disadvantages

Advantages:

- A high volume municipal, agricultural and industrial wastes are reduced by this process
- There is a relatively high pathogen removal
- It generates green energy and has the potential for greenhouse gas reduction

Disadvantages:

- The process requires an expert design
- This process is high-tech in nature and cost intensive

## O&M Requirement

- Operation and maintenance requires strict organisation and the continuous involvement of experts

## Health and Acceptance

- Large-scale anaerobic digesters are complex in design, planning and operation and are therefore only adapted at a large scale, involving the collaboration of various experts

## Design factors

- Large-scale anaerobic digesters treating slurries are generally designed according to the wet digestion process with 10 to 20 per cent of total solids (TS)
- The volumes of the reactors range from several hundred to several thousand cubic metres
- Due to the size of the plant, the respective objectives and special requirements concerning operation and substrates, the anaerobic treatment of waste materials and wastewater at a large-scale requires a different set of planning mechanisms, plant types and implementation factors
- Scaling up from small to large is not that simple. When a low-tech solution is required, it is possible to construct several low-tech small and decentralised biogas plants instead of one single large digester in order to facilitate operation and maintenance
- The most common forms of large-scale digesters are batch reactors and continuous-flow, plug-flow and continuously stirred tank reactor (PFR and CSTR)
- Completely mixed and batch systems are generally built vertically
- Plug-flow reactors are usually horizontal reactors. Horizontal reactors are often constructed similar to floating or expandable plastic dome plants but are much larger

## References

- [www.sswm.info](http://www.sswm.info),(n.d). Anaerobic digestion (large-scale).[online] Available at: <http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/sludge-treatment/anaerobic-digestion-lar>

## 7.15. Planted Drying Beds

### A brief about the technology

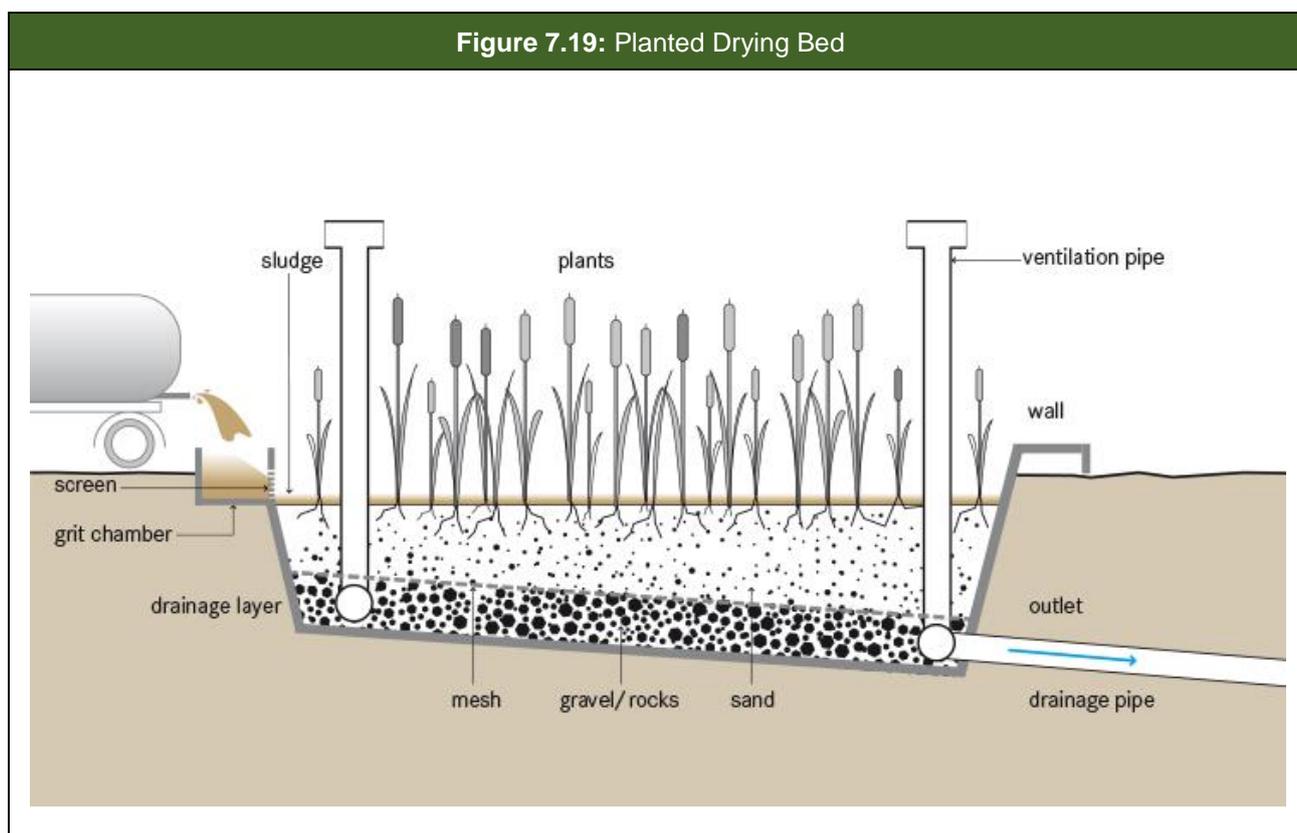
A planted drying bed (also known as Humification Bed) is a shallow pond consisting of several drainage layers designed to separate the liquid fraction of (faecal) sludge from latrines, septic tanks, biogas reactors, trickling filters, etc. Here sludge is dried naturally by a combination of percolation and evaporation.

The main advantage of the planted bed over the unplanted 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. The plants and their root systems maintain the porosity of the filter.

Planted drying beds require de-sludging only once every five to 10 years and the removed sludge can be directly reused in agriculture, as it is a nutrient-rich soil conditioner.

### Technology Description and Working principles

Planted drying bed looks very similar to a Vertical Flow Constructed Wetland. The beds are filled with sand and gravel to support the vegetation. Instead of effluent, sludge is applied to the surface. The filtrate flows down through the subsurface and is collected in drains, while the solid fraction remains on the filter surface and is dried while the liquid percolates. The plants enhance evaporation by transpiration.



The leachate collected in the drains may require further treatment depending on the age and quality of the applied sludge. Sludge can be composted before reuse.

Planted sludge drying beds, also designated as reed beds or constructed wetlands, could minimise the need for frequent removal of dried sludge as they can be operated for several years before sludge removal becomes necessary.

## **Advantages and Disadvantages**

### Advantages:

Planted drying beds can handle high loading and offer better sludge treatment as compared to unplanted drying beds.

- They have filters that do not need to be de-sludged after each feeding cycle
- Fresh sludge can be directly applied above the previous layer
- They have plants that maintain the porosity of the filter through their root systems
- They require de-sludging only once every 5 to 10 years
- The removed sludge is a nutrient-rich soil amendment that can be directly reused in agriculture
- They can generate income through the fruit or forage growing in the beds
- They are resistant to clogging
- They are easy to operate
- They can be built and repaired with locally available materials
- They have relatively low capital costs and operating costs
- They do not require electrical energy

### Disadvantages:

- Faecal sludge is hazardous and anyone working with it should wear protective clothing, boots and gloves
- In dry climates moisture stress, along with high salt conditions, resulting from the application of faecal sludge, creates harsh conditions for plant growth
- The beds should be installed at a certain distance from the settlements, owing to odour issues
- The percolates from sludge drying beds contain pathogens and need to be further treated

## **O&M Requirement**

- Planted drying beds are easy to operate. No experts are required but the personnel should be trained
- Maintenance activities should ensure that the primary treatment is effective in reducing the solid concentration and also that trees do not grow in the area as roots can harm the lining of the drying beds
- During the first growing season it is important to remove weeds that can compete with planted wetland vegetation
- Distribution pipes should be cleaned once a year
- With time the gravel may become blocked and resting periods may restore the hydraulic conductivity of the bed

## **Health and Acceptance**

- There should be few problems of acceptance because of the pleasing aesthetics, especially if it is located at a sufficient distance away from dense housing

- Undisturbed plants can attract wildlife, including poisonous snakes
- Faecal sludge is hazardous and anyone working with it should wear protective clothing, boots and gloves
- The beds should be installed at a certain distance to settlements, as odour emanates when the sludge is fresh
- Percolates from sludge drying beds contain pathogens and need to be further treated
- The degree of pathogen reduction of the sludge will vary with the climate
- Depending on the desired end-use, further storage and drying might be required

### Design factors

- The bed frame is usually made from concrete or a plastic liner with the bottom surfaces slightly sloped in order to facilitate percolation and drainage
- A general design for layering the bed is:
  - 250 mm of coarse gravel (grain diameter of 20 mm);
  - 250 mm of fine gravel (grain diameter of 5 mm); and
  - 100 to 150 mm of sand (EAWAG/SANDEC 2008).
  - Free space (1 m) should be left above the top of the sand layer to account for about years of accumulation.
- Ventilation pipes connected to the drainage system contribute to aerobic conditions in the filter
- Reeds, cattails, antelope grass and papyrus are suitable plants, depending on the climate. Local, non-invasive species can be used if they grow in humid environments
- Sludge should be applied in layers between 75 and 100 mm thick and reapplied every 3 to 7 days, depending on the *sludge* characteristics, the environment and operating constraints
- Planted beds do not need de-sludging before each new application as the root system of the plants maintains the permeability
- Sludge application rates of 100 to 250 kg/m<sup>2</sup>/year have been reported in warm tropical climates. In colder climates, such as northern Europe, rates up to 80 kg/m<sup>2</sup>/year are typical
- It is best to stop applying sludge one or two years before removing it

### References

- Ronteltap, M. Dodane, P. Bassan, M. (n.d) Overview of treatment technologies. [pdf]. Available at: [http://www.unesco-ihe.org/sites/default/files/fsm\\_ch05.pdf](http://www.unesco-ihe.org/sites/default/files/fsm_ch05.pdf)
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## 7.16. Thermal Drying: LadePa and Pulse Combustion Dryer

### A brief about the technology

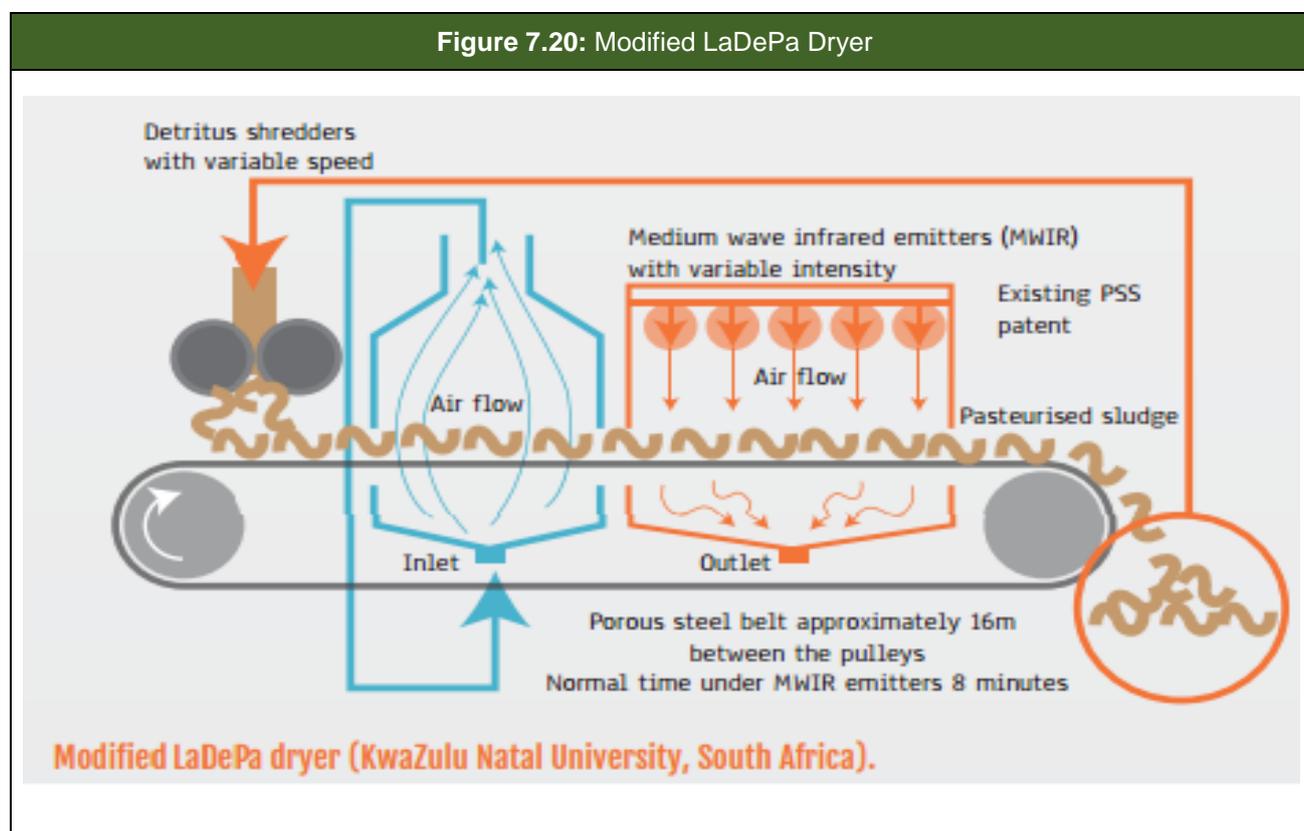
The LaDePa (Latrine Dehydration Pasteurisation) is a drying technique which is a combination of a belt and a medium wave infrared radiation drying section. Figure 76 shows the LaDePa technique.

Pulse Combustion Dryer (PCD), a drying technique based on spraying wet sludge in a combustion chamber with high-frequency pulsating combustion. Figure 77 shows the Pulse Combustion Dryer.

### Technology Description and Working principles

**LaDePa dryer:** The focus of the original LaDePa dryer is to obtain a dried and disinfected product that can be used as fertiliser. However, as the gasification process produces a disinfected low-carbon (low calorific value) product, the LaDePa dryer for the TU Delft concept has been modified to use medium wave infrared radiation for intensification of the drying instead of disinfection. Modifications are also related to the adjustment of the belt length, the introduction of recycle flows of dried material (back-mixing) and heated air to improve the energy efficiency of this dryer.

Figure 7.20: Modified LaDePa Dryer



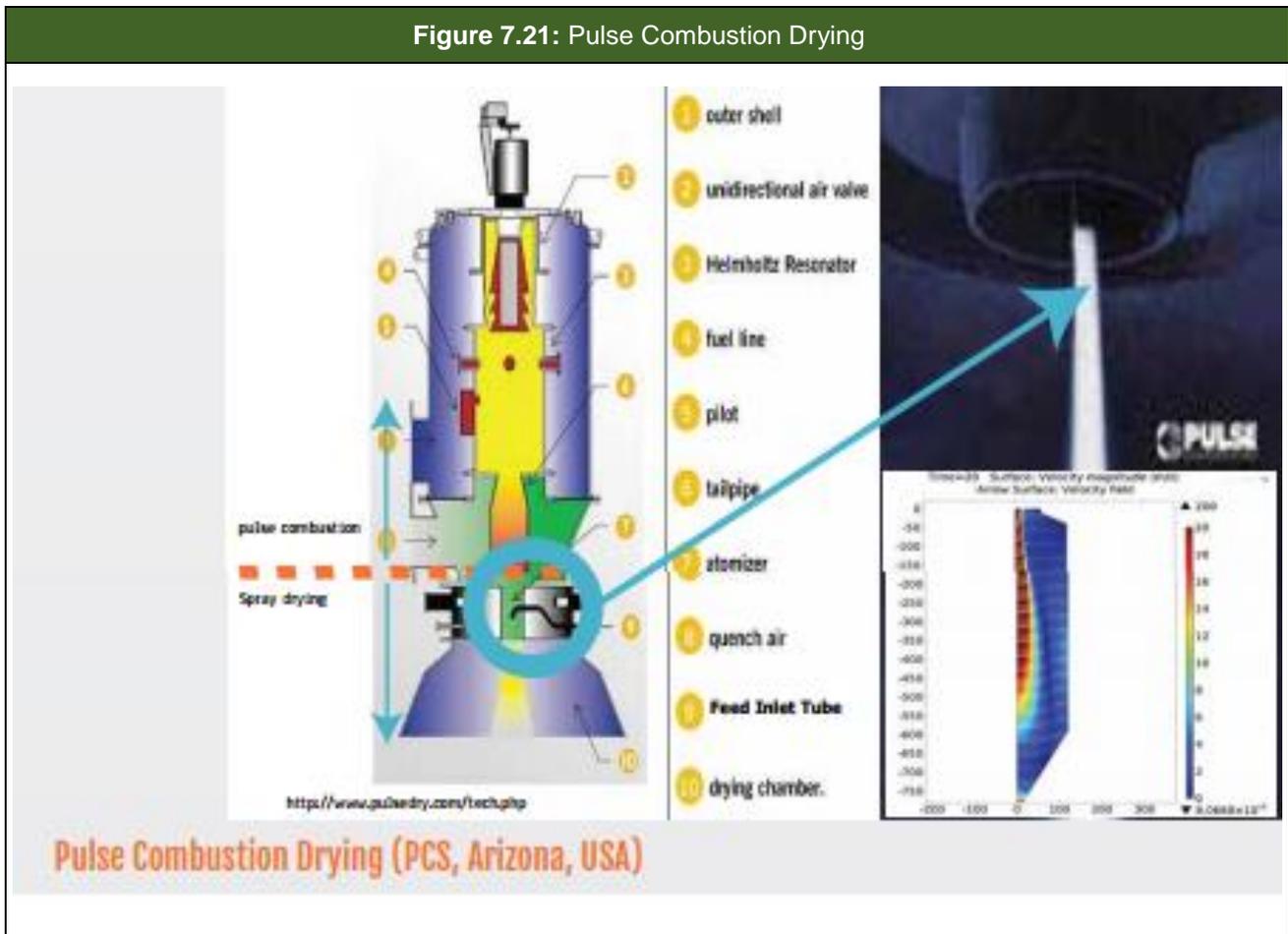
**Pulse combustion drying** is an efficient intensified process. New is the aspect of stable combustion of low calorific value gas (off gas derived from the Fuel Cell).

Characteristics of the feed and products

- Feed (TS content: 20–35 per cent): up to 1,000 kg h<sup>-1</sup>
- Detritus (15 per cent): up to 150 kg h<sup>-1</sup>
- Final product: up to 300 kg h<sup>-1</sup> @ 80–90 per cent solids
- Characteristics of the machine

- Belt width: 0.95 m; apertures: 300 microns
- Dryer width: 1.35 m; length: 11 m; height: 1.2 m
- Diameter of pellets: 6 mm

Figure 7.21: Pulse Combustion Drying



Pulse Combustion Drying (PCS, Arizona, USA)

## Advantages and Disadvantages

### LaDePa Plant

#### Advantages:

- LaDePa Plant is compact and neat allowing door-to-door operation
- There is limited odour/nuisance generation
- It has low processing time compared to composting or other methods

#### Disadvantages:

- It has high operating costs due to high energy demand
- It is only applicable to pit latrine FS. O&M requires trained staff (1–2 people for operation)
- The pellets are not stabilised for use in agriculture

### Pulse Combustion Dryer

#### Advantages:

- PCD Foot print is relatively small and maintenance is low

Disadvantages:

- Noise is a big constraint in this technology

Design factors

LaDePa

- LaDePa drier has been in testing with close cooperation from KwaZulu Natal University (South Africa).
- Temperature of drying influenced by MIR height and intensity •
- Longer residence time and high intensity result into better drying

**Figure 7.22:** Figure showing the different dryer sizes

| DRYER SIZE/MODEL | NO. OF PEOPLE | FOOTPRINT (M <sup>2</sup> ) | RETAIL PRICE (US\$) <sup>1</sup> | MAXIMUM POWER REQUIRED (KW) <sup>2</sup> | FEED (KG H <sup>-1</sup> ) <sup>3</sup> |
|------------------|---------------|-----------------------------|----------------------------------|--|---|
| SBD600 + 30      | 1,000         | 3                           | 51,000                           | 32.8                                     | 100                                     |
| SBD600 + 45      | 1,500         | 3.5                         | 51,100                           | 47.8                                     | 200                                     |
| SBD600 + 60      | 2,000         | 4                           | 53,500                           | 63.15                                    | 300                                     |
| SBD600 + 75      | 2,500         | 4                           | 53,900                           | 78.15                                    | 400                                     |
| SBD600 + 90      | 3,000         | 4.5                         | 56,600                           | 94.25                                    | 500                                     |

**Figure 7.23:** General requirements for LADEPA Pellet production

|  |           |
|--|-----------|
| Minimum amount of excreta from dry toilets per year (metric tons) <sup>1</sup> | 1,667     |
| Sanitized DFS pellets produced (metric tons per year)                          | 500       |
| Required organic wastes (metric tons per year)                                 | 0         |
| Footprint of the facility (m <sup>2</sup> )                                    | 30        |
| Energy requirement (kWh)   | Up to 160 |

<sup>1</sup> The excreta must contain 20-35% of TS.

### Manufacturer/Supplier details

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  - P.V.Aravind@tudelft.nl

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  - Wiebren.dejong@tudelft.nl
  - X.Meng@tudelft.nl

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## 7.17. Solar Drying

### A brief about the technology

Solar drying is an application of solar energy where ‘drying’ involves moisture removal from the product. Solar drying technology has been used on a large scale since the nineteenth century in Europe and USA for the treatment of wastewater sludge. This technology is usually constructed in greenhouse structures with transparent covers, concrete basins and walls. Sludge is disposed into these basins and processed for about 10 to 20 days.

The removal of moisture prevents the growth of microorganisms like bacteria, yeasts and molds causing decay and decreases many of the moisture-mediated deteriorative reactions. In this process there is a reduction in weight and volume, thereby reducing packing, storage, and transportation costs. It also enables storability of the product under ambient temperatures. These features are especially important for developing countries.

In this process we can have either open or closed solar drying with batch or continuous operation, with devices to control the conditions in the greenhouses.

Breathable membranes can be used with this technology to increase treatment efficiency.

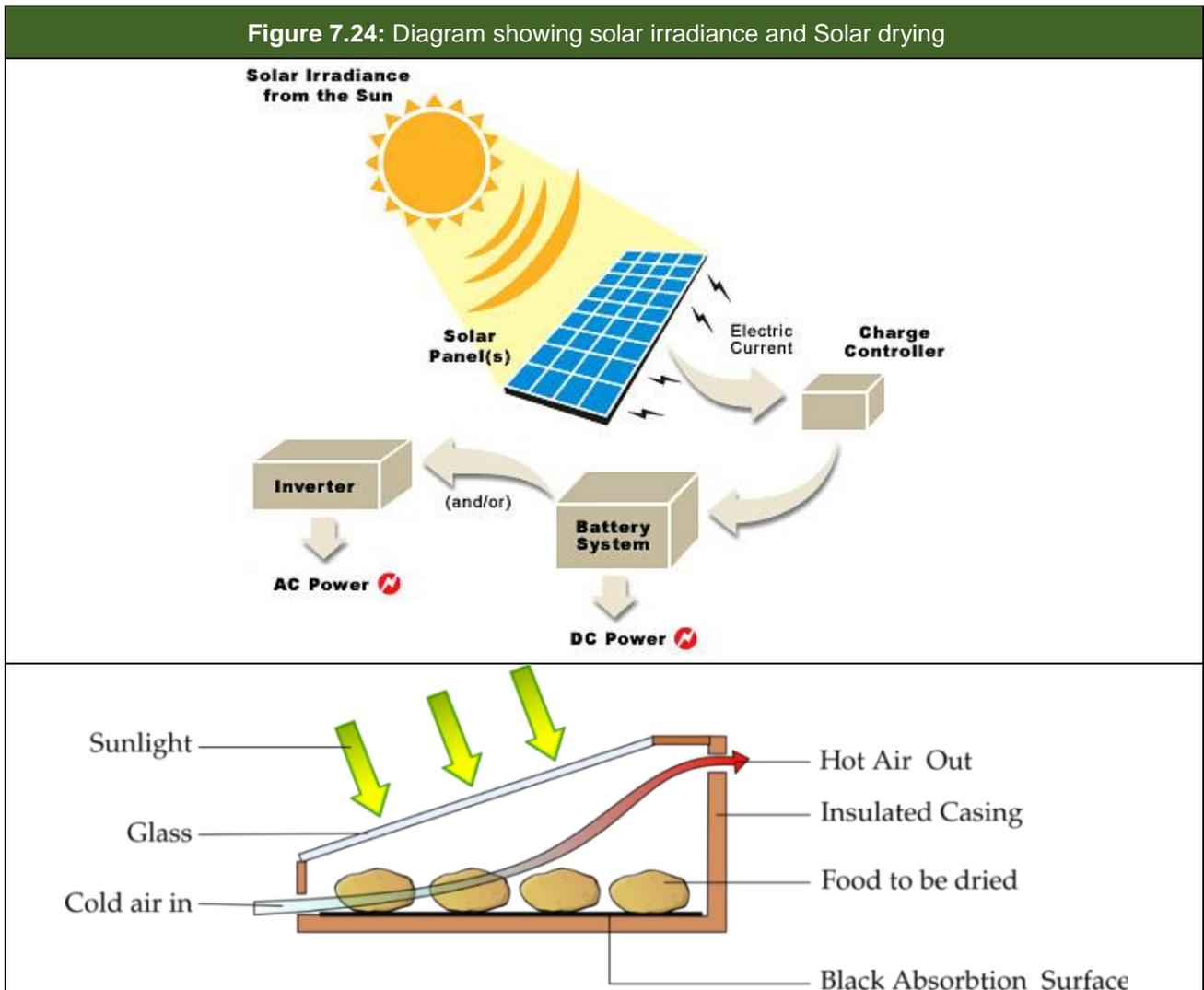
### Technology Description and Working principles

Solar drying plants consist of a greenhouse made with transparent material and a floor, where the product is spread in thick layers. Ventilations can be used in order to have homogeneous distribution of the air inside the greenhouse with replacement of humidified air with fresh air. Mixing of the sludge layer for better evaporation rates could be done either manually or automated by use of use machines.

There is an open solar drying method as well as covered solar drying methods. The covered solar drying system can be applied in cities receiving high solar radiation. It provides regulated indoor conditions for controlling emission, odour, and issues around vector attraction. To solve odour issues and treat the air, bio-filters can be used. Covered solar drying has given better results than open solar drying.

The overall effectiveness of the solar dryer can be determined by evaluating the thermal and microbiological performances. Water content in sludge during the process is an indicator of thermal effectiveness. Regarding effectiveness of microbiological removal, there is a strong dependence between the number of bacteria present and the water content in the sludge. Dewatering of sludge also leads to significant reduction in pathogen count in the remaining solids.

**Figure 7.24: Diagram showing solar irradiance and Solar drying**



### Advantages and Disadvantages

Advantages:

- This simple technology has low energy requirements, and low investment costs
- It also has high potential dewatering efficiency

Disadvantages:

- The space required is a major constraint

- The need for mechanical means to stir the sludge
- Ventilating the greenhouses is also a huge constraint
- Lack of information available on the use of solar drying technology for the treatment of FS in low-income countries or on design and operating parameters that need to be considered for this purpose

### Design factors

- The main factors influencing the evaporation efficiency are the solar variation, the air temperature and the ventilation rate, with initial dry solid content of the sludge and air mixing also influencing the process
- In covered solar drying, short wavelengths light, such as UV is blocked by the cover. Therefore, the pathogen reduction efficiency is slightly reduced, especially for faecal coliforms. A greater pathogen reduction was obtained within the covered sludge drying system than the open system
- Covered sludge drying plant is better than an open sludge drying plant both during summer and winter
- While the open sludge drying plant can receive rain thereby reducing the drying of the sludge and rate of pathogen reduction
- The covered drying plant uses solar energy effectively to dry the sludge and allows pathogen reduction
- The covered solar drying plants also function as a place for temporarily storing the dried sludge

### Case Study

In Dakar, Senegal, enhanced drying to reduce the footprint of drying beds for fuel production was evaluated.



'Greenhouses did not increase drying rates over uncovered beds, however, daily mixing of FS on the surface of the beds resulted in a six-day reduction to achieve 90 per cent total solids (TS). FS was dried to 90 per cent TS in two weeks for loading rates of 100 kg TS/m<sup>2</sup>\*year, and 3 weeks for 150 kg TS/m<sup>2</sup>\*year. The results indicate that with simple but innovative adaptations, footprints of treatment plants could be reduced and/or treatment capacities increased by 20 per cent. FS can be adequately dried in Dakar to produce fuel.'

### **Manufacturer/Supplier details**

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  - Tel/Fax: +302541079376.
- HUBER Solar Active Dryer SRT
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**Table 7.1: Treatment - Summary**

| SI. No. | ASSESSMENT CRITERIA          | INDICATOR                                  | INFORMATION REQUIREMENT  | ASSESSMENT OUTCOME                                    | Treatment technologies   |  |                               |   |                               |  |                               |                               |  |   |
|---------|------------------------------|--|--|---|--|--|-------------------------------|---|-------------------------------|--|-------------------------------|-------------------------------|--|---|
|         |                              |  |  |   | (A) Settling tank  | (B) Imhoff tank  | (C) Ammonia Addition          | (D) Lime Addition   | (E) Geotextile Bags and Tubes | (F) Mechanical Dewatering                                  | (G) Levapor Carriers          | (H) Breathable Membranes      | (I) Co-composting with Municipal Waste       | (J) Deep Row Entrenchment                   |
| 1       | Regulatory standard          | Organic load reduction in treated effluent | BOD, COD of influent and effluent  | Yes / No / Information not available / Not applicable | The Biochemical Oxygen Demand (BOD) reduction is about 30 to 50%.  | It removes 25 to 50% of Chemical Oxygen Demand (COD).  | Information is not available. | Information is not available.   | Information is not available. | It does not reduce organic effluent                        | Information is not available. | Information is not available. | Information is not available.                | Information is not available.               |
| 2       | Regulatory standard          | Total Solid reduction in treated effluent  | TS, TDS of influent and effluent   | Yes / No / Information not available / Not applicable | TSS reduction is 40 to 60%. Other information is not available.  | Reduces suspended solids by 50 to 70%.   | Information is not available. | Information is not available.   | Information is not available. | No reduction.  | Information is not available. | Information is not available. | Information is not available.                | Information is not available.               |
| 3       | Regulatory standard          | Pathogen reduction in treated effluent     | Helminths egg, E. coli of influent and effluent  | Yes / No / Information not available / Not applicable | Pathogen removal is reported to be low. Other information is not available.  | Pathogen removal remains low.  | Pathogen removal takes place. | Pathogen re-growth takes place. No additional information is available. | Information is not available. | Pathogens are not removed. It simply a separation process. | Information is not available. | Pathogens are reduced.        | Ensures high level removal of Helminth eggs. | Information is not available.               |
| 4       | Regulatory standards         | CPCB standards for discharge/reuse         | Is the end product, emissions, and effluent characteristic as per CPCB (2015) standards for discharge/reuse? | Yes / No / Information not available / Not applicable | Information is not available.  | Information is not available.  | Information is not available. | Information is not available.   | Information is not available. | Information is not available.                              | Information is not available. | Information is not available. | Information is not available.                | Information is not available.               |
| 5       | Health and safety of workers | Human Contact                              | Are there any activities or procedures that can lead to contact of sludge with humans                        | Yes / No / Information not available / Not applicable | Yes, motorized emptying using vacuum truck or manually with a sludge gulper is required. When emptying is done manually, there is evident human contact. | Yes, motorized emptying using vacuum truck or manually with a sludge gulper is required. When emptying is done manually, there is evident human contact. | Information is not available. | Information is not available.   | Information is not available. | Information is not available.                              | Information is not available. | Information is not available. | Information is not available.                | Yes, human contact happens in this process. |

**Table 7.1: Treatment - Summary**

| SI. No. | ASSESSMENT CRITERIA          | INDICATOR | INFORMATION REQUIREMENT  | ASSESSMENT OUTCOME                                    | Treatment technologies   |   |                               |   |                               |  |                               |                               |  |                               |
|---------|------------------------------|-----------|--|---|--|---|-------------------------------|---|-------------------------------|--|-------------------------------|-------------------------------|--|-------------------------------|
|         |                              |           |  |   | (A) Settling tank  | (B) Imhoff tank   | (C) Ammonia Addition          | (D) Lime Addition   | (E) Geotextile Bags and Tubes | (F) Mechanical Dewatering                                    | (G) Levapor Carriers          | (H) Breathable Membranes      | (I) Co-composting with Municipal Waste | (J) Deep Row Entrenchment     |
| 6       | Health and safety of workers | Spillage  | Does the sludge/ effluent spill in and around the operational area?                          | Yes / No / Information not available / Not applicable | A T-shaped outlet pipe, the lower arm of which dives 30 cm below the water level, further reduces the scum and solids that are discharged. | No, T-shaped pipes or baffles are used at inlet and outlet to reduce velocity and prevent scum from leaving the system. So the spills in and around the operational area are addressed. | Information is not available. | Information is not available.   | Information is not available. | Information is not available.                                | Information is not available. | Information is not available. | Information is not available.          | Information is not available. |
| 7       | Health and safety of workers | Impact    | Does the technology have negative impact on the health and safety conditions of the workers? | Yes / No / Information not available / Not applicable | Yes, toxic and inflammable gases release poses fire hazard while opening the tank.   | Yes, toxic and inflammable gases release pose fire hazard while opening the tank.   | Information is not available. | Lime is an alkaline material which reacts strongly with moisture and is hazardous to the eyes, skin and respiratory system. | Information is not available. | It does not treat the sludge. Hence, it has negative impact. | Information is not available. | Information is not available. | Information is not available.          | Information is not available. |

**Table 7.2: Treatment - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR                    | INFORMATION REQUIREMENT  | Treatment technologies  |   |   |   |   |   |   |   |   |  |  |
|---------|---------------------|------------------------------|--|---|---|---|---|---|---|---|---|---|--|--|
|         |                     |                              |  | (A) Settling tank   | (B) Imhoff tank   | (C) Ammonia Addition                                      | (D) Lime Addition   | (E) Geotextile Bags and Tubes   | (F) Mechanical Dewatering   | (G) Levapor Carriers  | (H) Breathable Membranes                                  | (I) Co-composting with Municipal Waste                    | (J) Deep Row Entrenchment  |  |
| 1       | Design              | Trash screening              | Does the system have a mechanism to manage trash present in FS?  | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash.   | No, the system does not have a mechanism to manage trash. | No, the system does not have a mechanism to manage trash. |  |  |
| 2       | Design              | Material of the wetted parts | What is the Material of Construction? Does the material used minimize weight, durability, corrosion vulnerability? | The structure is designed using concrete or brick work, or as pre-fabricated concrete rings, PVC or fibreglass tanks. The other information is not available. | The structure can be made with reinforced concrete. The other information is not available.                               | N/A   | N/A   | Geo bags are porous, tubular containers made from high strength woven geo-textiles (polyethylene material) mainly used for dewatering sludge. |   | LEVAPOR carriers consist of porous, flexible, easily fluidisable plastic foam cubes, impregnated with adsorbing pigments. | Breathable membranes are hydrophobic linings.             |   | N/A  |  |
| 3       | Design              | Space requirement            | Minimum dimensions occupied by the system, Land area needed, Top surface usability                                 | The land space requirement is less due to the option of underground construction. The exact information is not available.                                     | The land space requirement is less due to the option of underground construction. The exact information is not available. | N/A   | The site selected should be such that it is not too close to residential housing areas and is not prone to flooding and other geo-hazards |   |   |   |   |   | Requires about 800 square metre space for a 3 ton per day plant. | Land area  |
| 4       | Design              | Reusability of the sludge    | Can the decanted sludge be directly reused?  | No, sludge requires further treatment.  | Yes, fecal sludge can be dried and composted and used in agriculture.   |   |   |   | The process does not treat the sludge, it only separates solids from liquids. Both the solid and liquid parts still contain pathogens and pollutants. |   |   |   |  | Primary benefit include increased growth of trees. |

**Table 7.2: Treatment - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR   | INFORMATION REQUIREMENT  | Treatment technologies  |   |  |   |  |                           |  |   |   |                           |
|---------|---------------------|-------------|--|---|---|--|---|--|---------------------------|--|---|---|---------------------------|
|         |                     |             |  | (A) Settling tank   | (B) Imhoff tank   | (C) Ammonia Addition   | (D) Lime Addition   | (E) Geotextile Bags and Tubes  | (F) Mechanical Dewatering | (G) Levapor Carriers   | (H) Breathable Membranes  | (I) Co-composting with Municipal Waste  | (J) Deep Row Entrenchment |
| 5       | Design              | Design life | What is the actual / economic life of the equipment?   | Information is not available. But the document states that the construction cost of (F) is higher than (E).                             | Information is not available. But the document states that the construction cost of (F) is higher than (E). |  | Lime treatment has low treatment cost, short sanitation time, operational stability under temperature changes and aerobic conditions. |  | Around 10-12 yrs.         |  | Over a period of time, the moisture content in the matter reduces, leading to reduced volume, hence increasing the life of containment systems. |   | N/A                       |
| 6       | Design              | Uniqueness  | Does the technology address a problem which is not addressed by any of the existing technologies?  | The Aquaprivy model is a modified settling tank, located directly below the toilet so that the excreta can fall into it through a pipe. | Information is not available. But the document states that the construction cost of (F) is higher than (E). | Ammonia requires less rigid storage conditions and is applicable in regions with urine diverting dehydrating toilets (UDDTs) | It also acts as a sludge conditioner to precipitate metals and phosphorus.  | These are capable of competing economically with other alternative dewatering techniques for sludge. |                           | LEVAPOR carriers can be applied in fluidised, expanded and fixed-bed reactors respectively in bio-trickling filters. | The membrane can be re-used multiple times since clogging does not occur.   |   |                           |
| 7       | Design              | Power       | What is the net energy requirement/generation? What is the source of power for the operation? State type, capacity and power consumption | No external source of power is needed for the operation. The other details are not available.   | No external source of power is needed for the operation. The other details are not available.               | No external source of power is needed for the operation. The other details are not available.                                | No external source of power is needed for the operation. The other details are not available.   | No external source of power is needed for the operation. The other details are not available.        | Requires constant power.  |  |   | No external source of power is needed for the operation. The other details are not available. | N/A                       |

**Table 7.2: Treatment - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR                        | INFORMATION REQUIREMENT   | Treatment technologies  |   |                      |                   |   |                           |   |  |  |                           |     |
|---------|---------------------|----------------------------------|---|---|---|----------------------|-------------------|---|---------------------------|---|--|--|---------------------------|-----|
|         |                     |                                  |   | (A) Settling tank   | (B) Imhoff tank   | (C) Ammonia Addition | (D) Lime Addition | (E) Geotextile Bags and Tubes   | (F) Mechanical Dewatering | (G) Levapor Carriers                    | (H) Breathable Membranes   | (I) Co-composting with Municipal Waste     | (J) Deep Row Entrenchment |     |
| 8       | Economics           | Economic value and cost recovery | What is the economic value / possible revenue stream during operation to the user and operator? | Information is not available. But the document states that the construction cost of (F) is higher than (E). | Fecal sludge can be dried on the thickening pond or drying bed and composted.<br><br>The use of compost in agriculture may be a possible revenue operation. |                      |                   | The utility placed geo tubes in several strategic locations, resulting in a reduction of overall operations expenses by 37% and an increase of 35% in revenues. |                           | The cage could cost around 350-500 EUR. | This membrane can act as a cost-effective retrofit option for containment units with permeable base. | Co-composting involves low operating cost. |                           |     |
| 9       | Economics           | CAPEX                            | What is the capital cost of the system?   | Information is not available. But the document states that the construction cost of (F) is higher than (E). | Information is not available. But the document states that the construction cost of (F) is higher than (E).   |                      |                   |   |                           |   |  |  |                           | N/A |
| 10      | Economics           | OPEX                             | What is the operational cost of the system per capita / per volume of input sludge?             | Information is not available. But the document states that the construction cost of (F) is higher than (E). | Information is not available.   |                      |                   |   |                           |   |  |  |                           | N/A |

**Table 7.2: Treatment - Characterization**

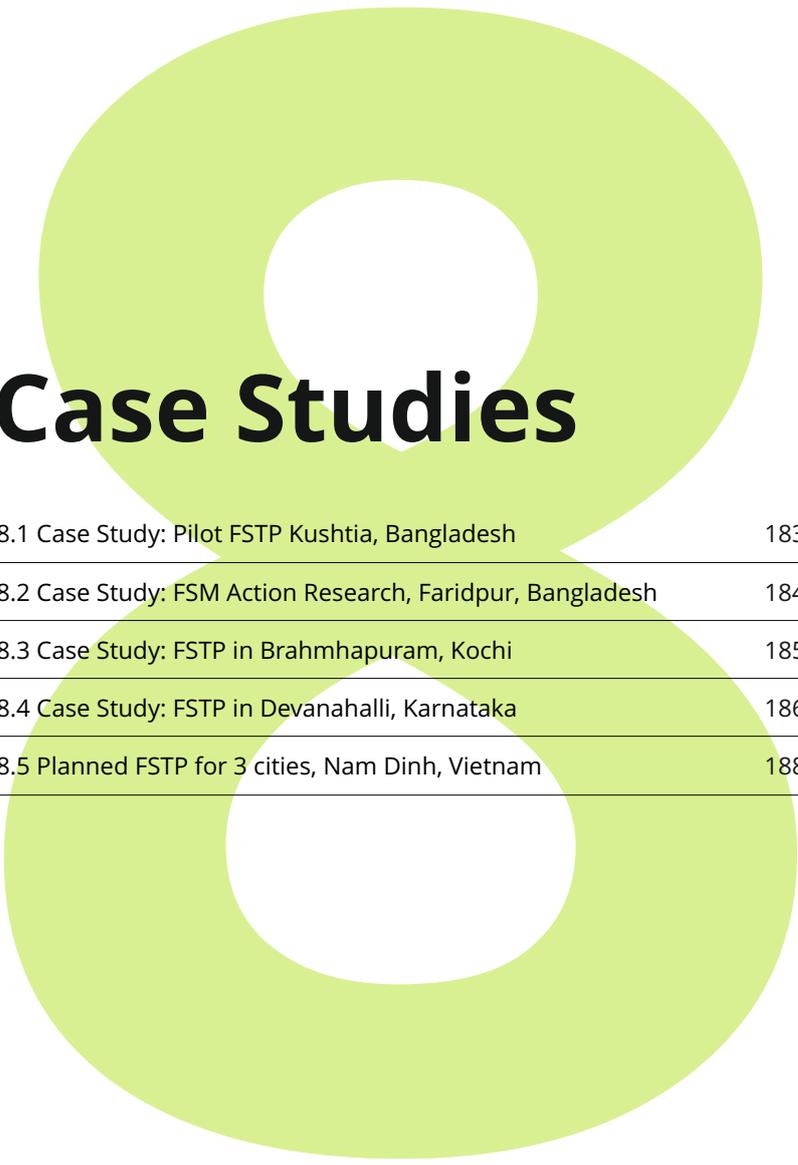
| SI. No. | ASSESSMENT CRITERIA | INDICATOR  | INFORMATION REQUIREMENT   | Treatment technologies  |  |   |  |                               |  |  |  |  |                           |  |     |
|---------|---------------------|--|---|---|--|---|--|-------------------------------|--|--|--|--|---------------------------|--|-----|
|         |                     |  |   | (A) Settling tank   | (B) Imhoff tank  | (C) Ammonia Addition  | (D) Lime Addition  | (E) Geotextile Bags and Tubes | (F) Mechanical Dewatering                          | (G) Levapor Carriers   | (H) Breathable Membranes                           | (I) Co-composting with Municipal Waste | (J) Deep Row Entrenchment |  |     |
| 11      | Ease of O&M         | Moving equipment                                   | Are there moving parts or devices which require frequent maintenance affecting operation continuity?                            | No, there are no moving parts in the system.  | No, there are no moving parts in the system.   |   |  |                               |  | This is a passive technique and does not require extensive or constant labour and maintenance of equipment.          |  |  |                           |  | N/A |
| 12      | Ease of O&M         | Skill and spares for local repairs and maintenance | What are the skill sets required by the operator? Are skills and spares available locally for repairing or servicing equipment? | The operator has to regularly check to ensure if it is water tight and check for sludge and scum level.<br><br>Local manufacturer and supplier details are provided as a link to who may provide repairing/ servicing. Spares and repairs can be done with locally available materials. | There is a need for trained personnel for O&M. Local manufacturer and supplier details are provided as a link to who may provide repairing / servicing. The other details are not available. | Regular monitoring of pH & ammonia should be done.<br><br>Should have at least 20 mm of ammonia treatment time dimensioning with Ascaris model. | Skilled staff is required and they must follow health and safety procedures. |                               | Operation and maintenance needs qualified workers. | O&M requirement for LEVAPOR<br><br>septic tank applications are same as any other suspended growth based septic tank | Operation and maintenance needs qualified workers. |  |                           |  | N/A |

**Table 7.2: Treatment - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR   | INFORMATION REQUIREMENT   | Treatment technologies   |  |                      |                   |   |                                    |                      |                          |   |                           |
|---------|---------------------|---|---|--|--|----------------------|-------------------|---|------------------------------------|----------------------|--------------------------|---|---------------------------|
|         |                     |   |   | (A) Settling tank  | (B) Imhoff tank  | (C) Ammonia Addition | (D) Lime Addition | (E) Geotextile Bags and Tubes   | (F) Mechanical Dewatering          | (G) Levapor Carriers | (H) Breathable Membranes | (I) Co-composting with Municipal Waste                | (J) Deep Row Entrenchment |
| 13      | Performance         | Odour in the decanted sludge and treated effluent | Is there any odour from sludge or in the treated effluent?  | Yes, presence of toxic and flammable gases will be there, if not properly vented. Yes, there will be odour in the treated effluent.          | Yes, presence of toxic and flammable gases will be there, if not properly vented. But in Aquaprivy model, use of a water seal prevents escape of odour. The treated water is almost odourless. |                      |                   | Yes, presence of toxic and flammable gases will be there, if not properly vented. Yes, there will be odour in the treated effluent. | The odour has to be taken care of. |                      |                          | Well-trained staff is needed for O&M of the facility. | N/A                       |
| 14      | Replicability       | Manufacturing                                     | Who can manufacture or assemble these systems? Are skills and resources locally available in the market to manufacture these systems? | Yes, the system can be built and repaired using locally available materials. Local manufacturer and supplier details are provided as a link. | Yes, local manufacturer and supplier details are provided as a link. The other information is not available.   |                      |                   |   |                                    |                      |                          |   | N/A                       |

**Table 7.2: Treatment - Characterization**

| SI. No. | ASSESSMENT CRITERIA | INDICATOR   | INFORMATION REQUIREMENT  | Treatment technologies   |   |                      |                   |                               |                           |   |                          |  |                           |
|---------|---------------------|-------------|--|--|---|----------------------|-------------------|-------------------------------|---------------------------|---|--------------------------|--|---------------------------|
|         |                     |             |  | (A) Settling tank  | (B) Imhoff tank   | (C) Ammonia Addition | (D) Lime Addition | (E) Geotextile Bags and Tubes | (F) Mechanical Dewatering | (G) Levapor Carriers  | (H) Breathable Membranes | (I) Co-composting with Municipal Waste   | (J) Deep Row Entrenchment |
| 15      | Innovation          | Performance | Is the technology or similar technology tried elsewhere? Is there a significant impact of innovation on performance? | <p>Yes, the technology is tried elsewhere. The use of LEVAPOR bio carrier to the settling tank is suggested to increase the treatment efficiency.</p> <p>Addition of conditioners such as polyelectrolytes and hydrolysed metals is advised, to increase settling and dewatering efficiency.</p> | <p>Yes, the technology is tried elsewhere. The use of LEVAPOR bio carrier to the Imhoff tank is suggested to increase the treatment efficiency.</p> |                      |                   |                               |                           | <p>This is an expensive high-tech solution for dewatering sludge and only used in large-scale treatment plants.</p> <p>This process does not treat wastewater; it only separates solids from liquids . Both solid and liquid parts still contain pathogens and pollutants and have to be treated.</p> |                          | <p>Reduces the cost of solid waste management and is relatively easy to set up with locally available materials.</p> | N/A                       |



# Case Studies

|   |     |
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## 8. Case Studies

### 8.1. Case Study: Pilot FSTP Kushtia, Bangladesh

**Technology:** Composting, Cocoa Pit Filter and Faecal Sludge Drying Bed

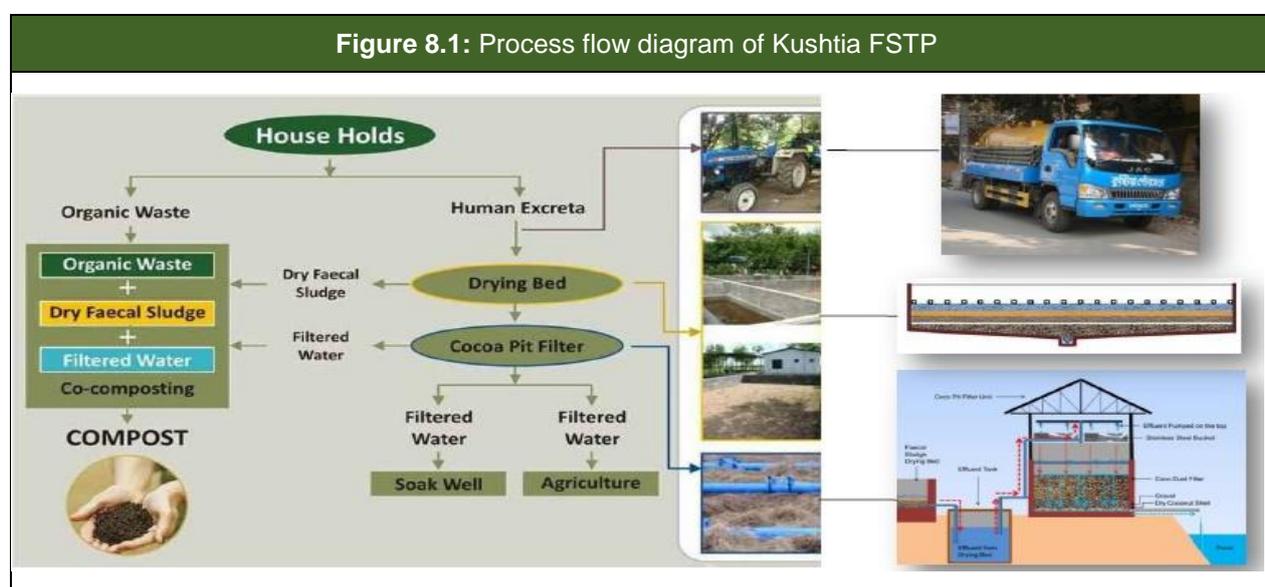
**Capacity:** 9 cum/day

**Reuse:** compost

**Capital Cost:** 135,000 USD

**O&M Cost:** 2,914 USD per month

**Year of operation:** 2012



Kushtia is a small city and capital of Kushtia District, in north-west Bangladesh. Approximately 40 tonnes of solid waste are generated in the city each day, 20–25 tonnes of which the municipality collects. Additionally, the city's residents generate some 180 cubic metres of faecal sludge each day. In this project, the collected sludge is transported to the treatment facility at the IRRC. The liquid faecal sludge is poured into a sludge tank, from where it passed into the sludge drying bed. When the drying bed is full, the sludge dries over a period of 7–12 days. After filtration, the water is high in nutrients and also compliant with the national wastewater quality standards, and can be safely used on agricultural land for irrigation. The revenue streams derive from the collection fees and the sale of compost and recyclables in the local market.

The project has achieved good results in a number of important areas. First, the amount of waste disposed through open dumping has reduced. The compost produced is of high quality. Third, the financial management of the operation has been successful, mainly due to strong support from the municipal authority.

#### References:

- Kushtia, Bangladesh(n.d). Kushtia, Bangladesh [pdf] Available at: <http://www.unescap.org/sites/default/files/1.%20Kushtia.pdf>.

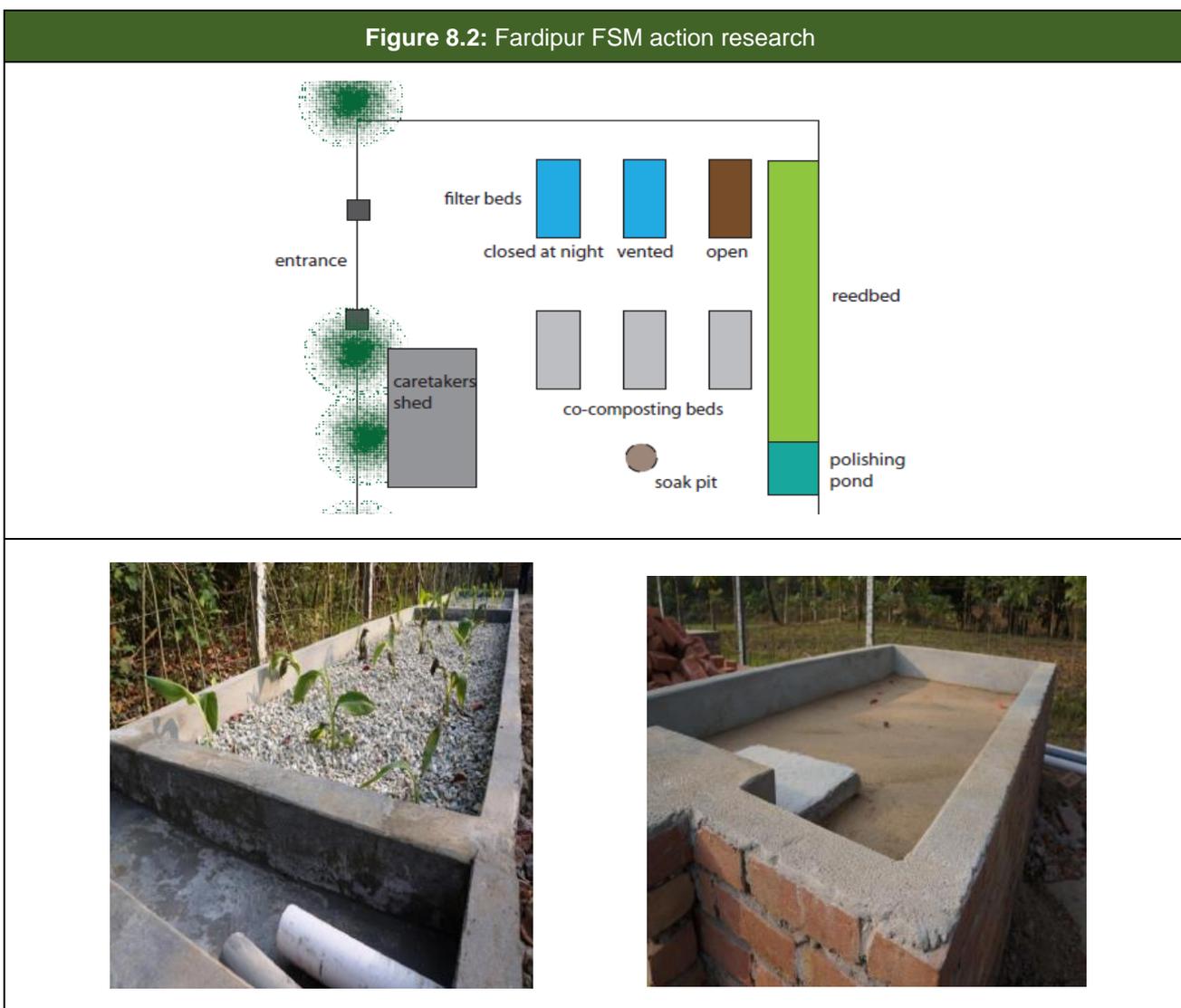
## 8.2. Case Study: FSM Action Research, Faridpur, Bangladesh

**Technology:** Composting, Sludge Drying Bed (6 nos.) and Horizontal flow constructed wetland

**Capacity:** 0.9 cum/per SDB

**Reuse:** compost

**Year of operation:** 2012



This case study briefly states the two phases of testing the action research work undertaken as part of the Faecal Sludge Management Action Research Project. A pilot site in Faridpur was used to develop the design and allowed comparability of results.

The first phase of testing consisted of constructing six drying beds of approximately 3m internal length x 1.5m internal width (10ft x 5ft). Three were built with sand filters in the base, and three had flat bases. This was done to test and see if there was a necessity to have sand filters as a part of the design. Phase one also tested the optimum roof material; CGI (metal), thatch and polythene roofs were placed on both filter and non-filter bases, and their performance was compared.

The purpose of the second phase of work was to optimise the design tested in the previous phase and gain more knowledge about the performance of the system under different weather conditions. The previous phase of work took place during the cool season, in December, whereas this phase's testing was completed in March during the hot dry season.

An improved design of plastic roof was tested, against a 'no-roof' option, and two different ventilation strategies were compared. Phase Two compared the best performing design of Phase One (plastic roof with a filter bed) with a ventilation controlled filter bed with a plastic roof, and a filter bed with no roof.

#### References:

- [policy.practicalaction.org](http://policy.practicalaction.org),(n.d).Situation Analysis Report on Faecal Sludge Management in Faridpur Municipality, Bangladesh [online] Available at:  
<http://policy.practicalaction.org/component/dspace/item/situation-analysis-report-on-faecal-sludge-management-in-faridpur-municipality-bangladeshPg> 42
- FSM Action Research, Bangladesh Design Development Report: Phase 2. (2013). FSM Action Research, Bangladesh Design Development Report: Phase 2.[pdf] BuroHappol. Available at:  
<http://practicalaction.org/media/download/43316>

### 8.3. Case Study: FSTP in Brahmhapuram, Kochi

**Technology:** Anaerobic stabilisation and aerobic treatment for supernatant

**Chemicals used:** Lime to maintain pH in UASB and Alum as flocculent in MBR

Capacity: 100 m<sup>3</sup>

**Capital cost:** 4.25 crore with 5 yrs operations

**Operational cost:** approximately 1 lakh

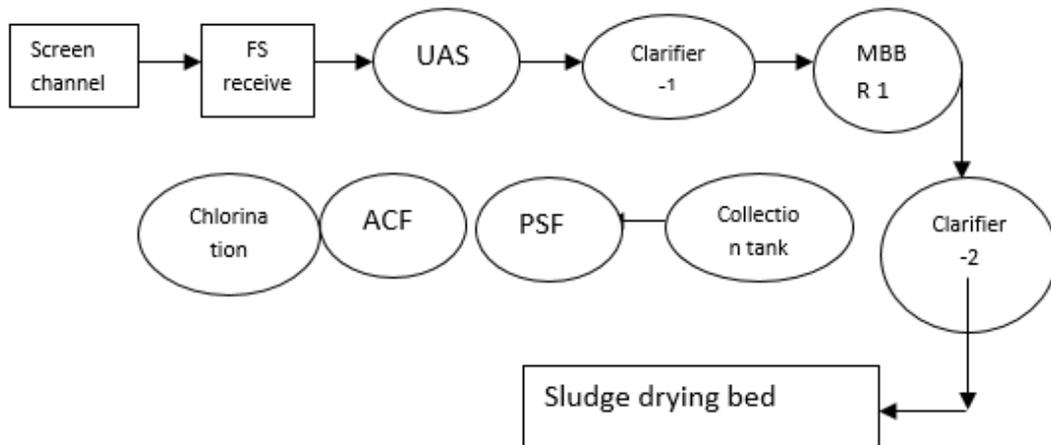
Area: 40 cents 30\*40 sq.m

Year of Operation:

The septage/faecal sludge from the onsite sanitation systems is 100 times more concentrated than the wastewater flowing in the sewer systems and hence, cannot be disposed directly to the sewage treatment plants (STP). Therefore, an additional module can be attached to the STP for receiving the septage and treating it to remove solid part and reducing the high organic load prior to the liquid part.

Faecal sludge always comes with lot of solid waste which needs to be screened out before taking it to treatment. This is achieved through having double stage screening process in receive channel. The faecal sludge is mainly digested in up-flow anaerobic sludge blanket (UASB) reactor. As a pre requisite, the faecal sludge is neutralised using lime. The treated Faecal Sludge from the UASB is taken into double stage Moving Bed Bio-Reactor (MBBR) units. The treated water from MBBR is treated in double stage filtration unit in sand filters and activated carbon filter. The treated water from the filtration unit is disinfected using chlorine. The treated water from the unit is reused for gardening and also for cleaning of de-sludging vehicles after disposal. The sludge from the 2nd MBBR is de-sludged regularly to sludge drying bed for dewatering.

Figure 8.3: Brahmhapuram FSTP



**References:**

- Internal document from CDD Society

**8.4. Case Study: FSTP in Devanahalli, Karnataka**

**Technology:** Feeding Tank with screen chamber, anaerobic digester (Biogas digester with Stabilisation tank), integrated settler + ABR+AF, PGF, SDB, Collection tank

Capacity: 6m3

**Reuse:** compost, biogas, treated water

Capital Cost:

O&M Cost: 70 lakhs

Year of operation: November 2015

Devanahalli Town Municipal Council (TMC) is the headquarter of Devanahalli Taluk. Devanahalli is situated 39 km north-east of Bangalore city. With an increase in growth of the population in the Bangalore city and being the nearest town panchayat to the Bangalore international airport, the population flux into Devanahalli is also increasing. The fast growth and lack of proper sanitation facilities in the town is leading to environmental pollution and risks to the human health.

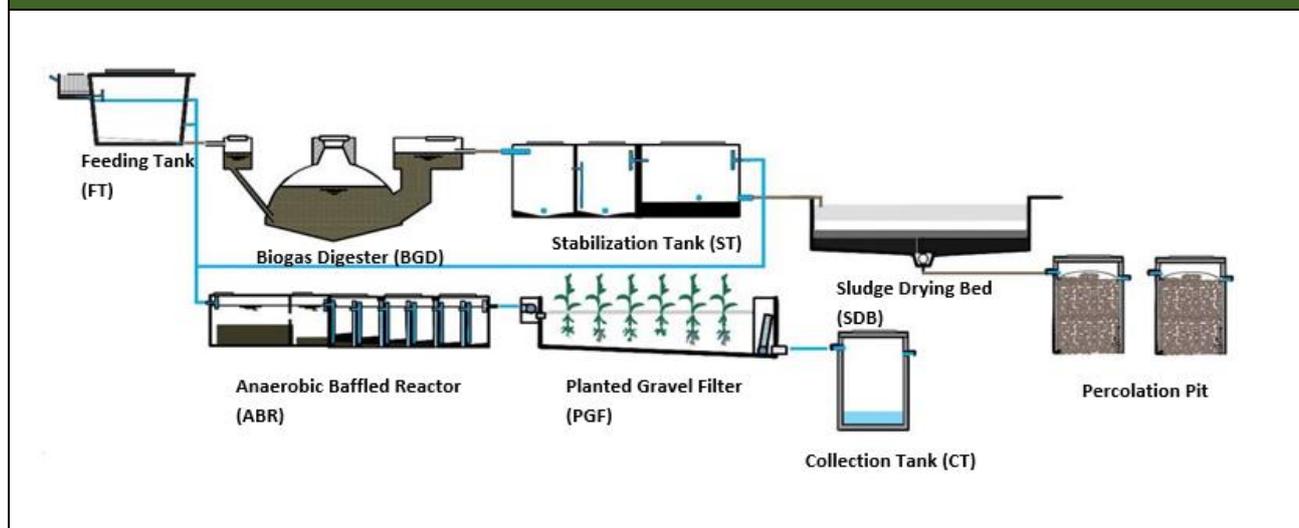
CDD Society identified the above problem and proposed to implement faecal sludge treatment plant (DEWATS) within the town limits of Devanahalli in order to treat the faecal sludge collected from septic tanks and pits of households, commercial establishments and government buildings.

The faecal sludge is conveyed to the proposed treatment location through a cesspool vehicle. The proposed DEWATS™ modules for the faecal sludge treatment are as follows: Feeding Tank (FT), Biogas Settler (BGS), Stabilisation Tank (ST), Sludge Drying Bed (SDB), Integrated Settler, Anaerobic Baffled Reactor with filter chambers, Planted Gravel Filter (PGF) and Collection Tank (CT). The plant is maintained by the Devanahalli Town Municipal Council with external support from some not-for-profit organisations.

Figure 8.4: Devanahalli FSTP



Figure 8.5: Process flow diagram of Kushtia FSTP



## References:

- Gopalakrishnan, S. (2015). Country's First Fecal Sludge Management Treatment Plant Is Now Active in Devanahalli. [online]. Available at: <http://sanitation.indiawaterportal.org/english/node/4177>
- Internal document –CDD –R-FSTP- Brief Note-150730-Devanahalli

## 8.5. Planned FSTP for 3 cities, Nam Dinh, Vietnam

**Capacity:** 8 cum/day (2,500 cum/year)

Technology:

- a) Constructed Wetlands and Polishing ponds
- b) Drying beds and Polishing ponds
- c) Settling/Thickening tank, Sedimentation Pond and Drying Beds

**Reuse:** Biosolids

**Capital Cost:** a) 23,200 USD; b) 24,350 USD; c) 24,100 USD (2001) 51,000 @ 6% inflation

**O&M Cost:** a) 1,400 USD/year; b) 2,010 USD/year; c) 6,180 USD/year

**Other:** Without land cost and final polishing of effluent

On-site sanitation installations—septic tanks, unsewered family and public pit or vault toilets and bucket latrines—are the common forms of sanitation in the majority of towns and cities in Vietnam as well as in other South East Asian countries. Yet, the faecal sludge from the pits and vaults in Nam Dinh and other Vietnamese cities are either discharged untreated into drainage ditches, natural or man-made surface waters, or on unused land.

The options (core treatment processes) below were considered potentially feasible under the socio-economic, technical and institutional conditions prevailing in Nam Dinh (which may be typical of other cities in Vietnam):

- Constructed wetlands
- Sludge drying beds, and
- Settling/thickening followed by pond treatment

Expected content of viable pathogens in all three treatment options are very low.

### Reference:

- Klingel, F., Montangero, A., Strauss, M. (n.d) Nam Dinh – Planning for Improved Faecal Sludge Management and Treatment.[pdf]. Duebendorf: EWAG/SANDEC. Available at: [https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Journals/WSA\\_paper\\_Klingel.pdf](https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Journals/WSA_paper_Klingel.pdf)









Tamil Nadu Urban Sanitation Support Programme (TNUSSP) supports the Government of Tamil Nadu and cities in making improvements along the entire urban sanitation chain.

The TNUSSP is implemented by a consortium of organisations led by the Indian Institute for Human Settlements (IIHS), in association with CDD Society, Gramalaya and Keystone Foundation.