Centre for Science and Environment

Ministry of Urban Development

SEPTAGE MANAGEMENT

A Practitioner's Guide

Urban India's journey beyond ODF

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Abbreviations

ABR	Anaerobic baffled reactor
AD	Anaerobic digester
AF	Anaerobic filter
ASP	Activated sludge process
BD	Biogas digester
BIS	Bureau of Indian Standards
BOD	Biochemical oxygen demand
CAPEX	Capital expenditure
CBO	Community-based organization
COD	Chemical oxygen demand
CPHEEO	Central Public Health and Environmental Engineering Organization
CSE	Centre for Science and Environment
CSP	City sanitation plans
CW	Constructed wetland
DRDO	Defence Research Development Organization
DWWT	Decentralized wastewater treatment
EIA	Environmental impact assessment
FRP	Fibre glass-reinforced polymer
FS	Faecal sludge
FSM	Faecal sludge management
FSSM	Faecal sludge and septage management
FT	Feeding tank
GoI	Government of India
GoM	Government of Maharashtra
GWMC	Greater Warangal Municipal Corporation
IEC	Information, education and communication
IS	Indian Standard
IST	Improved septic tank
IT	Imhoff tank
IWK	Indah Water Konsortium
km	Kilometer
KwH	Kilowatt hour
LGU	Local government unit
MBR	Membrane bioreactor
MCC	Mysuru City Corporation
MD	Mechanical dewatering
MDG	Millennium Development Goal
MLD	Million litres per day
MoUD	Ministry of Urban Development
NFSSM	National Faecal Sludge and Septage Management Alliance
NGO	Non-governmental organization
NUSP	National Urban Sanitation Policy

NWSC	National Water and Sewerage Corporation
O&M	Operation and maintenance
ODF	Open defecation free
OPEX	Operational expenditure
OSS	Onsite sanitation system
PDB	Planted drying bed
PHED	Public Health and Engineering Department
PPE	Personal protective equipment
PT	Public toilet
RWA	Resident welfare association
SBM	Swachh Bharat Mission
SBR	Sequential batch reactor
SBT	Soil biotechnology
SFD	Shit flow diagram
SDG	Sustainable Development Goal
SMP	Sewage management plan
SS	Stainless steel
SSP	Sanitation Safety Planning
STP	Sewage treatment plant
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
UASB	Up-flow anaerobic sludge blanket
UDB	Unplanted drying bed
ULB	Urban local body
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VIP	Ventilated improved pit
VP	Value proposition
WHO	World Health Organization
WSP	Waste stabilization pond
WWTP	Wastewater treatment plant

Glossary

Black water: A mixture of urine, faeces and flush water along with anal cleansing water (if water is used for cleansing), and/or dry cleansing materials. Black water contains pathogens of faeces and the nutrients of urine that are diluted in the flush water.

Effluent: The supernatant liquid discharged from a septic tank. The liquid separated out from the septage is also referred to as effluent.

Faecal sludge: The settled contents of pit latrines and septic tanks. It differs from sludge produced in municipal wastewater treatment plants. The characteristics of faecal sludge can differ widely from household to household, city to city, and country to country. The physical, chemical and biological qualities of faecal sludge are influenced by the duration of storage, temperature, soil conditions, and intrusion of groundwater or surface-water into septic tanks or pits, performance of septic tanks, and tank emptying technology and pattern.

Grey water: The total volume of water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets. It may contain traces of excreta and, therefore, also pathogens. Grey water accounts for approximately 65 per cent of the wastewater produced in households with flush toilets.

Pit latrine: Latrine with one or two pits for collection and decomposition of excreta. The liquid generally infiltrates into the surrounding soil.

Pour-flush latrine: Latrine with a rural pan, where small quantities of water are poured from a container by hand, to flush away faeces.

Scum: Grease, oil and other substances floating on the surface of a septic tank.

Septage: The semi-solid matter from onsite sanitation systems like septic tanks. It has an offensive odour, appearance and high concentration of BOD, COD and TSS etc.

Septic tank: A water-tight single-storied tank in which sewage is retained long enough to permit sedimentation and digestion.

Self-cleansing velocity: Velocity of liquid which is high enough to initiate self-scrubbing action.

Sludge: The settled matter in a semi-solid condition.

Soakpit: A porous, covered chamber that allows wastewater to permeate into the ground. It is also known as a soak-away or leach pit.

Suspended solids: Small solid particles which remain in suspension in sewage, septage or effluent.

Vacuum tanker or truck: A vehicle that has a pump and a tank, designed to pneumatically suck liquids and slurries (like septage). These vehicles are also used to transport extracted liquids.

Executive summary

Most of urban India is dependent on onsite systems like septic tanks and pits for the disposal of septage. The number of such systems is only going to increase as India moves towards achieving the ambitious, country-wide goal of putting an end to open defecation. But in many onsite systems, limited attention has been accorded to proper construction, operation and maintenance, and the management of septage generated. Despite Environment Protection Act, 1986 forbidding disposal of waste into water bodies, septage is dumped anywhere and everywhere, polluting water sources (both groundwater and surface-water), leading to severe health implications.

It is recognized that septage management is essential to achieve citywide sanitation, as more than 70 per cent urban population in India is dependent on onsite sanitation systems (OSS). There is also enough evidence that conventional systems cost a lot of money and water.

This guide to septage management is meant to assist practitioners involved in the sanitation sector as well as urban designing and planning. The purpose of the guide is to explore the steps involved in managing septage throughout the sanitation chain (containment, emptying, transportation, treatment and end-use or disposal) and to demonstrate how septage management can be applied in cities.

The guide explains all stages of the sanitation chain for urban centres dependent on OSS by discussing the current scenario in India for each stage. It describes innovative tools that can be used to assess and plan for improving each stage. It explains the calculations through an example city (wherever possible) and showcases best management practices through case studies (international and national) throughout the guide.

Septage management is not just managing faecal sludge from septic tanks but also pits existing in urban centres. Moreover, this guide recognizes that just managing the sludge component would be an incomplete solution to the sanitation challenges rapidly growing urban centres face. Therefore, it is essential that the liquid component, or effluent, from these onsite systems is also managed, and end use of treated water is promoted to reduce freshwater demand.

The approach used in this guide conforms with 2030 Sustainable Development Goals (SDGs), which include clean water, sanitation and sustainable cities with community involvement as major priorities. In a nutshell, this guide intends to assist practitioners manage septage as a resource, by integrating it into city sanitation planning.

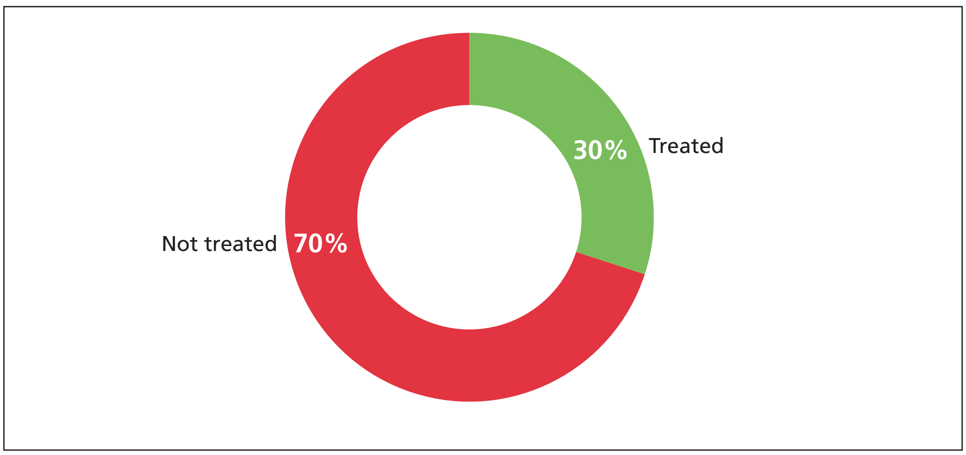
1. Introduction

1.1 Background

A survey of 423 cities under different categories undertaken by the Ministry of Urban Development (MoUD) in 2009 highlighted the need for urgent action in terms of improving sanitation to make town and cities healthy and clean. The 2011 Census indicates that 81.4 per cent households in urban India have a toilet facility. But only 40 per cent households with a toilet facility are connected to a piped sewer network. Treatment of sewage is a significant challenge. Across India, 62,000 million litres a day (MLD) of sewage is generated. There are 816 sewage treatment plants installed in India (of which, 522 were operational, as of March 2015), with a treatment capacity of about 23,277 million litres per day (MLD). However, only about 18,883 MLD of sewage is treated (see *Figure 1: Sewage treatment in India*).[1] Cities with more than 35 million population have 68 per cent of total installed wastewater treatment capacity, but nearly 39 per cent of these treatment plants do not adhere to standards for discharging into water bodies.[2] Clearly, the sewerage systems are failing to keep up with the excreta challenge.[3]

Furthermore, under the Swachh Bharat Mission (SBM), an initiative of the Central government, a total of 18 crore toilets with containment systems will be up and ready by 2019.[4] With the advent of SBM and allied sanitation-related reforms, the focus has been only on increasing the number of toilets, and little on treatment of the waste generated. By constructing so many toilets with onsite systems, we are just holding back the problem, not resolving it. Thus, it is time we bring into focus discussions about the management of the waste from these toilets. This will ensure not just an open defecation-free (ODF) India, but pollution-free water bodies, cities and towns as well. Septage management in cities would also help achieve the aims of SDG-6, which includes improving water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing global recycling and safe end use by 2030.

Figure 1: Sewage treatment in India



Source: Inventorization of sewage treatment plants, Central Pollution Control Board, 2015

Key points from *Excreta Matters: Seventh State of India's Environment Report*

- Pollution from one city distorts water supply plans of those downstream.
- Cities, having encroached and polluted their lakes, seek to source water from further and further away. The hidden costs of pollution are electrifying.
- Costs of building centralized wastewater treatment system is high.
- Cities can build sewerage system for few not all.
- Cities spend to treat waste of some, which eventually gets mixed with untreated waste of the majority.
- The result is pollution; and cities drowning in their own excreta.

There is poor or no septage management in Indian cities, though, (i) there is enough evidence to prove the adverse impacts of lack of septage management on public health and environment and, (ii) there are legislative provisions to enforce septage management in the country. A rapid assessment of septage management in Asia carried out by United States Agency for International Development (USAID) in 2010 revealed that by 2017 about 148 million people in urban areas would depend on septic tanks in India. This was also recognized by the National Urban Sanitation Policy (NUSP), 2008, which emphasizes the need for proper collection, treatment and disposal of septage from onsite installations.[5]

There is enough evidence to show that faecal sludge and septage management is not only affordable and sustainable as compared to centralized sewerage system but can also be implemented quickly to make cities clean and healthy.[6] In order to address the issue in a time-bound manner, MoUD issued an advisory note to all urban local bodies (ULBs) based on the policy paper on septage management prepared by Centre for Science and Environment (CSE). The advisory supplements the NUSP by outlining the contents and steps of developing a septage management sub-plan (SMP) as a part of the city sanitation plan (CSP), being prepared and implemented by cities.[7] *Figure 2: India's septage management—timeline and the way forward* gives a temporal overview of India's septage management.

In 2015–16, CSE conducted a study of 27 cities from different agro-climatic zones of India, to understand the excreta management of the selected cities (see *Figure 3: Status of excreta management of 27 cities*). A tool called 'shit flow diagram' was used to understand the flow of excreta from containment to disposal. If we leave Delhi out of the calculations, the study revealed that 55 per cent of the population is dependent on OSS, and 8 per cent practice open defecation. Overall, excreta of only 29 per cent population is safely managed. If Delhi is also considered, the population dependent on OSS decreases to 37 per cent and those defecating in the open comes out to be 5 per cent, clearly indicating how sewerage systems are dominant in metropolitan cities. Even then, excreta managed safely comes out to be only 47 per cent (for details of the study of each of the 27 cities, refer to *Appendix 1*). It can be concluded from the study that the smaller and medium-sized towns and cities are completely dependent on onsite systems and limited service provisions are available to manage the excreta of such towns. Bigger cities also do not have enough sewers, and there is a huge demand for septage management in all kinds of urban centres.

Figure 2: India's septage management—timeline and the way forward

2008

National Urban Sanitation Policy

- 100% safe confinment of human excreta and liquid waste
- Mandate states to develop State Sanitation Strategy and City Sanitation Plan
- Guide to decision making sanitation technology options in urban India

2009

Ranking of Indian cities

- 423 cities ranked on 19 sanitation parameters
- None of the cities found to be healthy and clean

CSE recognised as COE

- MoUD recognises CSE as Center of Excellence in urban development for sustainable water management

2011

Policy Paper on Septage Management

- Centre for Science and Environment prepared policy paper on Septage Management in India to assist MoUD

2012

Report by CSE

- Report on State of India's Environment based on 71 Indian cities
- It demonstrated how urban India is soaking up water, polluting rivers and drowning in its own excreta (in 2 volumes)

2013

Advisory note on Septage Management

- Issued by MoUD based on policy paper by CSE
- Septage management sub plan to be incorporated in City Sanitation Plan

2014

CSE-COE invited to:

- Develop and conduct first training programme on septage management
- Conduct sensitisation workshop on septage management
- Establish helpdesk on decentralised waste water and septage management to support pilot initiatives
- Prepare a practitioner's guide on septage management

Swachh Bharat Mission

- Aims to eradicate open defecation by 2019

Atal Mission for Rejuvenation and Urban Transformation

- Has provision for funding on septage management

2015

Preparation of City Sanitation Plan

- CSE - GIZ handholding support to 34 ULBs (from Kerela, Telangana and Andhra Pradesh) to develop CSPs including septage management
- Developed toolkit for preparation of CSPs
- Tamil Nadu developed septage management guidelines

Capacity building on water and waste management

- CSE-BMGF hanholding support to 10 towns in Ganga basin including septage management

Excreta Flow Diagram

- Handholding support to develop SFD in 11 cities
- Established SFD helpdesk

2016

Down To Earth

- Cover stories in DTE magazine on septage management in Indian cities based on 21 SFDs
- CSE's State of India's Environment 2015 & 2017, reports on need for septage management

Online course on FSM

- First online course on FSM delivered by 6 global partners including CSE
- Global e-learning allliance of alumni formed

National faecal sludge and septage management

- CSE, CPR, CEPT, ASCI and other organisations came together to make an alliance
- A primer on FSSM and Rapid Assessment Tool for budgetary calculation for FSM was launched
- Maharashtra developed septage management guidelines supported by CEPT
- 131 towns/cities identified as flagship cities for city's journey beyond ODF
- CSE to provide handholding support to 23 cities for preparing city sanitation plan and effective FSSM strategy

2017

National Policy on Faecal Sludge and Septage Management

- National Faecal Sludge and Septage Management policy issued by MoUD
- FSM 4 International Conference organised at Chennai with MoUD and Govt. of Tamil Nadu as local host/partner

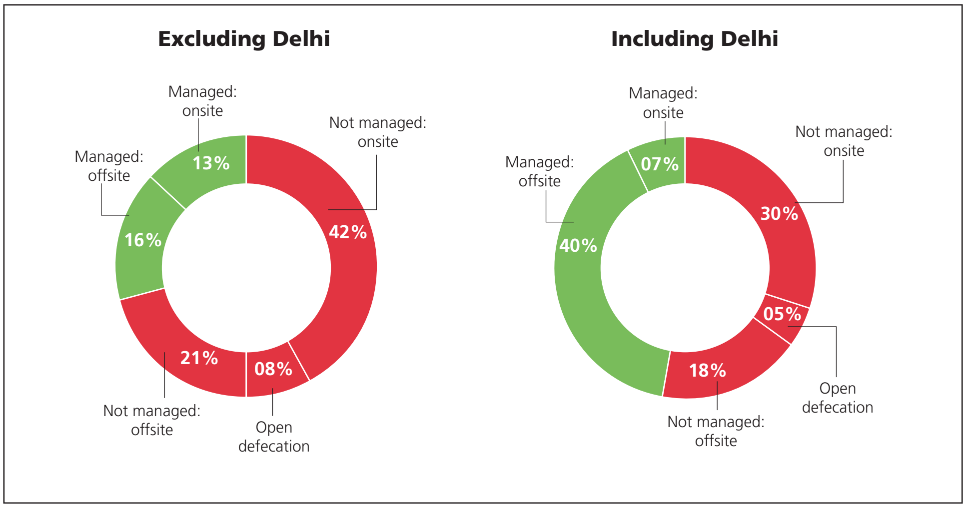
2019

Way forward: City's journey beyond ODF

- Implementation of integrated waste water and septage management plan, based on CSP
- Treatment of septage and sewage at decentralised scale
- Reuse and recycle of treated waste (solid and liquid)
- CSE-COE: School of water and sanitation at AAETI, Nimli to act as capacity building hub for ULBs and others

Source: Compiled by CSE, 2017

Figure 3: Status of excreta management of 27 cities



Source: Compiled by CSE, 2016

Figure 4: Benefits of septage management over a conventional sewerage system

	Conventional sewerage	Septage management
Water requirement	High (>135 lpcd)	Low
Capital costs	High	Low
Operation and maintenance costs	High	Low
Technical expertise	High conveyance; High treatment	Low conveyance; Low treatment
Maintenance requirement	High on service; Low on households	Low on service; High on households
High treatment	High	Low
Implementation challenges	High	Low

Source: Septage management guidelines, UDD, GoM, 2016

Figure 4: Benefits of septage management over a conventional sewerage system depicts that septage management, once implemented, can prove to be a sustainable step towards citywide sanitation due to its advantages over conventional sewerage systems.

National Faecal Sludge and Septage Management Policy, 2017

MoUD issued the National Policy on Faecal Sludge and Septage Management (FSSM) in early 2017. The policy aims to facilitate nationwide implementation of FSSM services in all ULBs and to set the context, priorities, and direction for safe and sustainable sanitation in each and every household in India.[8] Some key features of the policy are as follows:

- State-level guidelines, framework, objectives, timelines and implementation plans to address septage management.
- Formulating strategy at the Central level to initiate capacity-building for training on FSSM.
- Creating a sanitation benchmark framework which can be used by ULBs to develop a database and registry of certified onsite sanitation system, and a robust reporting format.
- Funding for facilitation of FSSM projects and encouragement to increase public private partnerships (PPP).
- Achieving integrated citywide sanitation along with safe disposal.
- Revised service-level benchmarking for sanitation (Refer to *Appendix 2*).

1.2 Need for a guide

Cities have already started to face the consequences of growing septage mismanagement, with overflowing drains during rains, and faecal waste polluting groundwater. A policy on FSSM launched by MoUD in February 2017 clearly recognizes the fact that sewerage networks alone cannot help achieve citywide sanitation (see *Box: National Faecal Sludge and Septage Management Policy, 2017*). National environmental regulatory provisions (acts, notifications, etc.) do not allow unsafe disposal of domestic waste. States like Tamil Nadu, Maharashtra and Odisha have taken initiatives towards septage management by issuing operative guidelines for ULBs in 2014 (Tamil Nadu) and 2016 (Maharashtra and Odisha). There are over 25 million OSS in urban India, however, there are limited septage management programmes or treatment facilities implemented in the country.[9] Both solid and liquid waste discharged from the OSS is one of the important reasons of water source pollution (surface and groundwater) and environmental degradation. SBM aims to make India clean, sanitized and ODF by 2019, but just constructing toilets will aggravate the existing problem of septage mismanagement. This mismanagement has led to great environmental, economic and health impacts. Due to absence of any aggregated septage management practices, all the improved sanitation solutions and facilities will continue to degrade surface-water bodies and groundwater resources. Therefore, there is a necessity to practice septage management as a supplement to conventional sewerage systems to achieve citywide sanitation.

CSE has been recognized as a Centre of Excellence in the area of citywide sanitation, including septage management. A policy paper on septage management in India by CSE was one of the first initiatives in the field of septage management in India. The policy paper was a stepping stone towards sensitization of relevant stakeholders, which was observed in the *Advisory Note on Septage Management* released by MoUD.

This practitioner's guide is devised to widen the outreach of CSE's capacity-building programme on septage management. This guide intends to sensitize the reader by answering questions like:

- What is septage management?
- Why do we need to manage septage?
- How do we manage septage?

Through this guide, it is intended that septage will be seen as a resource instead of waste. If managed properly, it contains nutrients such as nitrogen, phosphorus and, in some case varying amounts of micro-nutrients such as boron, copper, iron, manganese, molybdenum, and zinc.[10]

1.3 Objectives

- To sensitize practitioners about the need for septage management to achieve citywide sanitation.
- To provide steps to improve service delivery for each stage of the sanitation chain.
- To list down various innovative tools available to assess and improve the service delivery.
- To present successful case studies of various stages of septage management.

1.4 How to use this guide

This guide will present information in an understandable and accessible form to demonstrate to the various users and implementers how citywide sanitation can be achieved by managing septage. The stages of the sanitation chain are explained, the existing scenario in India at each stage is described, and action points for each stage are also proposed. The guide enumerates various tools that a reader can refer to at different stages of septage management. It signposts a wide range of guidance sources, and presents numerous examples of good practices to show what is possible across the spectrum of septage management.

An example of City X is taken to understand how to implement a septage management plan at each stage of the sanitation chain. It becomes clear with the example, how to calculate septage load, number of trucks required, capacity of the treatment plant etc. The examples of cities given in this document are completely fictitious, made with an intention to help reader relate with the context of the document. Any resemblance to an existing settlement is purely coincidental.

1.5 Target group

The target audience for this guide comprises city officials from ULBs and development authorities, such as urban planners, architects, town planning officers, public health engineers, sanitary inspectors, and others involved in preparing and enforcing regional, master, zonal, city development, and city sanitation plans, and developing other local planning provisions or design standards. It can be incorporated in the course module of various technical courses recognized by Central Public Health and Environmental Engineering organization (CPHEEO), MoUD. Further non-state actors such as decision-makers and technical staff from private organizations and resident welfare associations (RWAs) can also benefit from these suggestions. *Table 1: Target users* provides an overview of the major user groups based on the involvement in the formulation and implementation of septage management strategies.

(a) **Primary users:** Primary users have a direct influence on implementation of septage management in a town or city, and mainly includes government

Table 1: Target users

Primary users	
Government bodies	**Technical staff and decision-makers**
• Development authorities • State urban development agencies • Town and country planning organizations	• Urban planners: Chief town planners, senior town planners, junior town assistant planners
• Municipal corporations • Municipalities • Other ULBs	• Engineers: Superintending engineers, executive engineers, assistant engineers, environment engineers, and project officers
• Public health engineering departments • Water supply and sewerage boards • Urban shelter improvement boards	• Engineers, health and sanitary inspectors
Engineering colleges and institutes under the following courses Post-graduate course in public health engineering and environmental engineering, short-term courses in public health engineering and environmental engineering and refresher courses on various aspects of citywide sanitation	• Students of Bachelors of Engineering, Bachelors of Technology (civil and environmental), i.e. future engineers in this sector; and their teachers
Private organizations Consultants (Environmental impact assessment; EIA) Private organizations Community-based organizations (CBOs): RWAs, residents	• Technical staff and decision-makers
Secondary users	
Non-governmental organizations and decision-makers working in the sanitation sector	

Source: Compiled by CSE, 2016

officials. The guide will assist the primary user in identifying and scoping issues that need to be addressed while preparing septage management plans and also help them to implement them at a citywide level. Teachers and students of Public Health Engineering and Environmental Engineering can benefit by adding septage management in their course curriculum.

(b) **Secondary users:** Secondary users may not directly have an impact on septage management plans, but can capacitate or influence decision-makers about the process. Examples include NGOs and consultants.

2. Understanding septage and its management

This chapter aims to provide the reader in depth understanding of septage and its management and how it is different from faecal sludge and sewage.

Septage

Septage or septic tank waste refers to the partially treated matter stored in and pumped out of a septic tank. In other words, faecal sludge from septic tanks is known as septage, but faecal sludge and septage are interchangeably used in India. Septage is a by-product of pretreatment of household wastewater in a septic tank where it accumulates over time. It is generally pumped out of a septic tank or onsite sanitation system using a vacuum tanker.

Septage is the liquid and solid material that is pumped from a septic tank, cesspool, or other such onsite treatment facilities after it has accumulated over a period of time. Usually, septic tank retains 60–70 per cent of the solids, oil and grease that enter it. The scum accumulates on the top and the sludge settles to the bottom, comprising 20–50 per cent of the total volume of the septic tank. Offensive odour and appearance are the most prominent characteristics of septage. It is a host of many disease-causing organisms along with significant level of grease, grit, hair and debris.[11]

Septage has three main components:

Scum: The layer of solids formed by wastewater constituents that floats to the surface of a tank or reactor (such as oil, grease, hair or any other light material).[12]

Effluent: The liquid fraction collected in between scum and sludge in a septic tank is known as effluent, sometimes also referred to as a supernatant.

Sludge: Solids which collect at the bottom of the tank.[13]

Faecal sludge vs septage

There appears to be a very thin line between septage and faecal sludge. Septage is limited to septic tanks, and has already undergone partial digestion, whereas faecal sludge includes contents from other onsite technologies, including septic tanks, and may or may not be digested. Given the number of countries in the region and ULBs in India that use the term 'septage' to describe waste in onsite sanitation, this report also uses the term for all types of human excreta collected from onsite sanitation systems, including wet and dry systems, and private or public toilets.

Sewage vs septage

Sewage is untreated wastewater which contains faeces and urine, this wastewater gets conveyed through the sewerage system. Generally, grey water from the kitchen and bathroom also becomes part of sewage. The biochemical oxygen demand (BOD) of sewage ranges from 150–350 mg/l and all sewage treatment plants are designed for this load. Septage is slurry, it is emptied out of septic tanks and is much more concentrated than sewage; for example, BOD of septage ranges from 1,000–20,000 mg/l.

Faecal sludge

It is the solid or settled contents of pit latrines and septic tanks. It is raw or partially digested, slurry or in a semisolid form, it results from the collection, storage or treatment of combinations of excreta and black water, with or without grey water. It differs from sludge produced in municipal waste water treatment plants. The characteristic of faecal sludge can differ widely from household to household, city to city, and country to country. The physical, chemical and biological qualities of faecal sludge are influenced by the duration of storage, temperature, soil condition, and intrusion of groundwater or surface-water in septic tanks or pits, performance of septic tanks, and tank-emptying technology and pattern.[14]

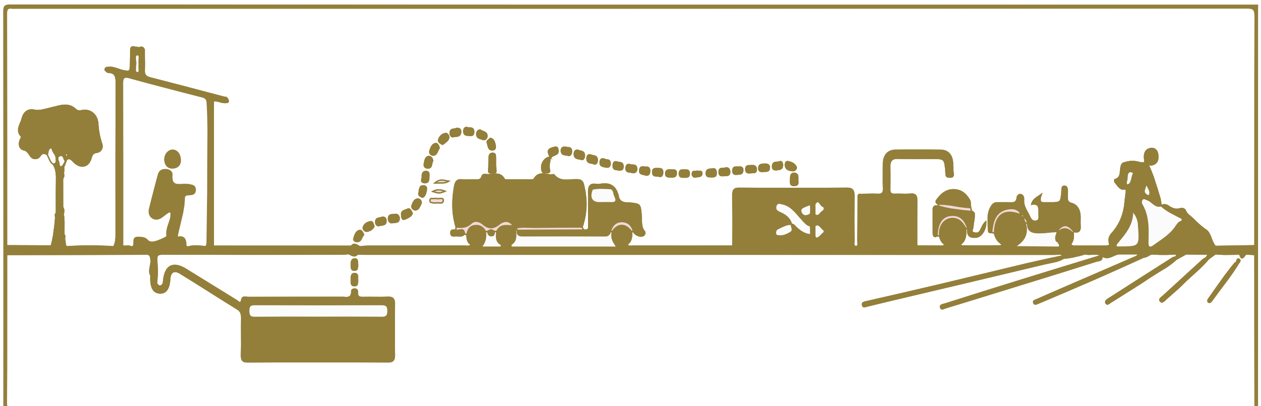
2.1 Characteristics of septage

The factors which influence the characteristics of septage are the design of the OSS, food habits of users, the performance of septic tanks, tank-emptying technology and pattern, the intrusion of groundwater, temperature, admixtures to septage like grease, kitchen, or solid waste, and the storage duration, which can last from months to years. These characteristics have practical implications for treatment. For example, septage which is still rich in organic matter and has not undergone significant degradation is difficult to dewater. Conversely, septage that has undergone significant anaerobic degradation such as from septic tanks or anaerobic baffled reactors (ABRs)—in other words, which is stabilized—is more easily dewatered. All these factors influence the characteristics of faecal sludge. Septage is a very variable material. Consequently, management systems need to be designed on a case-by-case basis. *Table 2: Characteristics of septage* compares characteristics of septage from onsite sanitation facilities and wastewater sludge.

2.2 What is septage management?

Sanitation often focuses only on the provisioning of physical infrastructure—toilets or latrines—in order to increase the 'coverage of toilets', or to look at the epitome of sanitation: ODF cities. But in order to provide tangible and sustainable sanitation, there is a need to focus on the entire 'sanitation chain' (see *Figure 5: Sanitation chain*). In simple terms, a sanitation chain (the term 'sanitation chain' is often used interchangeably with 'service chain',[15] or 'sanitation value chain',[16] but in this study 'sanitation chain' is preferred) is an outline for understanding how faecal waste flows through each system.[17] It sets out interlinked steps vital to manage septage and effluent from generation to disposal or end use, thereby summarizing the city-level outcomes and current status of the same.

Figure 5: Sanitation chain



	Containment	Emptying and transport	Treatment	Disposal and end use
Definition	An onsite sanitation system into which a user interface discharges	Manual or motorized removal and transportation of faecal waste from the containment system	Process of converting faecal sludge into a product that is safe for end use	Disposal or utilization of output products derived from sanitation systems
Examples	Septic tanks, soakpits and cesspools	Vacuum trucks or carts	FSTPs, constructed wetlands and dewatering	Manure

Source: Compiled by CSE, 2016

Table 2: Characteristics of septage

Parameter	Septage source		WWTP sludge	Reference
	Public toilet	Septic tank		
pH	1.5–12.6			USEPA (1994)
	6.55–9.34			Kengne et al (2011)
Total solids, TS (mg/l)	52,500	12,000–35,000		Koné and Strauss (2004)
	30,000	22,000		NWSC (2008)
		34,106		USEPA (1994)
	≥ 3.5%	< 3%	< 1%	Heinss et al. (1998)
Total volatile solids, TVS (as percentage of TS)	68	50-73		Koné and Strauss (2004)
	65	45		NWSC (2008)
COD (mg/l)	49,000	1,200–7,800		Koné and Strauss (2004)
	30,000	10,000	7-608	NWSC (2008)
	20,000–50,000	<10,000	500–2,500	Heinss et al (1998)
BOD (mg/l)	7,600	840–2,600		Koné and Strauss (2004)
			20-229	NWSC (2008)
Total nitrogen, TN (mg/l)		190–300		Koné and Strauss (2004)
			32-250	NWSC (2008)
Total Kjeldahl nitrogen, TKN (mg/l)	3,400	1,000		Katukiza et al (2012)
NH_4-N (mg/l)	3,300	150–1,200		Koné and Strauss (2004)
	2,000	400	2-168	NWSC (2008)
	2,000–5,000	< 1,000	30-70	Heinss et al (1998)
Nitrates, NO_3 (mg n/l)		0.2–21		Koottatep et al (2005)
Total phosphorus, TP (mg p/l)	450	150	9-63	NWSC (2008)
Faecal Coliform (cfu/100 ml)	$1x10^5$	$1x10^5$	$6.3x10^4$–$6x10^5$	NWSC (2008)
Helminths eggs (numbers/l)	2,500	4,000–5,700		Heinss et al (1994)
	20,000–60,000	4,000	300–2,000	Heinss et al (1998)
		600–6,000		Ingallinella et al (2002)
		16,000		Yen-phi et al (2010)

Source: *Faecal sludge management*, IWA, 2014

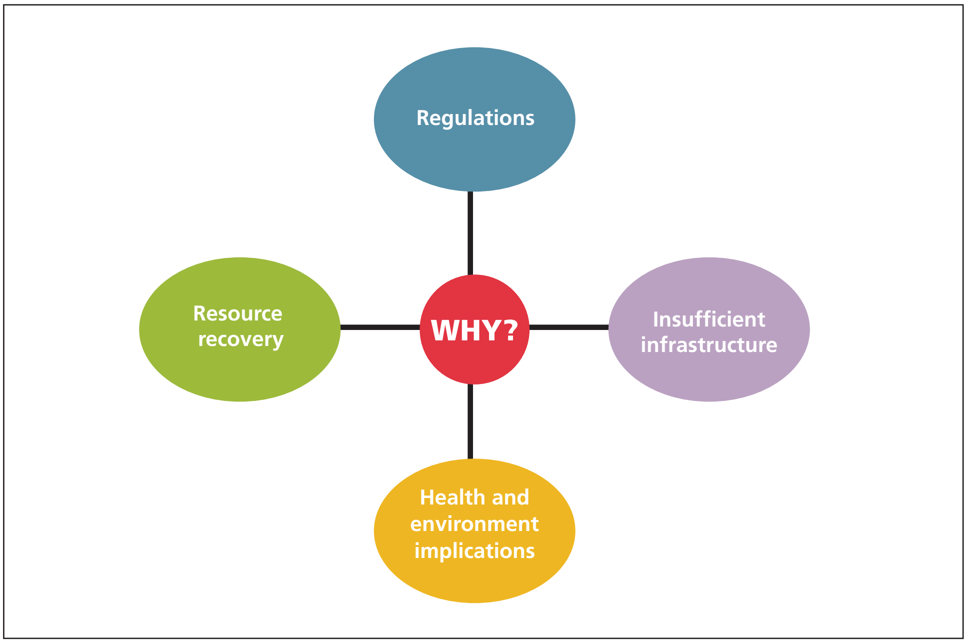
2.3 Why manage septage

There are many reasons to manage septage. This guide broadly lists four main reasons (see *Figure 6: Why manage septage*).

Insufficient infrastructure

The challenge with respect to sanitation infrastructure is not unknown to India. As described already, only 40 per cent of Indian population having toilets are connected to sewerage networks, while another 48 per cent are connected to OSS, therefore, infrastructure does not pose a challenge only in the form of lack of sewerage network lines, but also in the case of emptying of OSS and treatment of effluent let out by them.

Figure 6: Why manage septage



Source: CSE, 2016

One of the objectives of SBM is construction of toilets and connecting these toilets to sewerage lines available within 30 metres of the user interface. In the absence of a sewerage line, the toilets are to be connected to twin pits or other OSS. This objective will lead to an ODF India. Achieving this objective in the context of the aforementioned statistics means the need to have emptying solutions for OSS will increase, which will either be catered through manual cleaning or through the use of vacuum tankers.

Another important point to realize here is that in the absence of designated disposal sites, private operators often discharge collected septage into drains, waterways, open land and agricultural fields, which in turn poses a larger threat to the environment and health.

Regulations

The legislative framework in India has adequate provisions at the national-, state- and city-level to protect water and environment. Public health and sanitation is a part of the 'constitutional responsibility' of the municipalities under the 12th schedule of the Constitution (74th Amendment, 1992). Some of the key provisions in different laws and regulations that deal with septage management are given in *Table 3: Legislative and regulatory provisions for septage management*. Municipal acts and regulations normally refer to management of solid and liquid waste, but do not provide detailed rules for septage management. Inadequacy in the implementation and enforcement of regulations worsens the problem. We need a better regulatory framework focused on septage management as well as more robust implementation.

In February 2017, MoUD issued the National FSSM Policy. The policy aims to set the context, priorities, and direction for, and to facilitate nationwide implementation of, FSSM services in all ULBs such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town and city in India.[18]

Table 3: Legislative and regulatory provisions for septage management

Policy	Existing key focus	Provision for septage management
National Urban Sanitation Policy (NUSP), 2008	Prioritizes state-wide sanitation strategy (SSS) and CSP with a focus on service-level benchmarking. The policy envisages a city sanitation task force.	Provision for septage management exists, but is not part of the service-level benchmarking.
Advisory Note on Septage Management, 2013	Development of a septage management sub-plan as part of CSP.	Recommends septage management as an essential component for citywide sanitation
National Urban Faecal Sludge and Septage Management Policy, 2017	Recognition of faecal sludge and septage management as a sanitation solution.	Focused on areas with no sewers, emphasis on onsite and offsite sanitation systems need to exist in tandem.
Plan		
Swachh Bharat Mission, 2014	Prioritizes ODF, and also emphasizes upon provisions of containment system with proper dimensions.	Focus on ending open defecation with a little focus on the treatment of septage and wastewater.
Pradhan Mantri Awas Yojna, 2015	Provision of houses with a toilet, with no focus on any of the components of the sanitation value chain.	No mention of integration of standard designs for OSS.
Guidelines		
Environment Impact Assessment (EIA), 1994	Clearance for scheduled development projects that are likely to result in significant environmental effects.	Key sources of pollution like wastewater and septage are not considered.
Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, 2014	Proposed land use for the bifurcation of different urban centres.	Provides a relatively wide scope under the CSP by talking about septage management and wastewater.
Model building by-laws, 2016	Tool used for construction and design aspects of buildings in a development area.	Clearance by ULBs, with standards reference from the BIS codes.
Act		
The Water (Prevention and Control of Pollution) Act, 1974 and Environment Protection Act, 1986	Provides provisions for prevention and control of water pollution and for maintaining or restoring wholesomeness of water in the country.	No dedicated mention of septage management.
Agency for defining standards		
Bureau of Indian Standards (BIS)	Provides standards for building materials and their components.	Provides the standards for building of a septic tank along with user interface description.

Source: Compiled by CSE, 2017

Resource recovery

Faecal sludge has always been considered a social taboo. So the conventional thinking has been to dispose it of as quickly and secretly as possible. But there is another way of looking at septage. It can be seen as a resource containing nutrients such as nitrogen and phosphorus and, in some cases, varying amounts of micro-nutrients such as boron, copper, iron, manganese, molybdenum and zinc.[19] Urine contains 90 per cent nitrogen, 50–60 per cent phosphorus and 50–80 per cent potassium, which are very valuable in agricultural applications. Septage can reduce reliance on chemical fertilizers and in combination with them, it can meet the requirements of nutrients for crop production. In some

Table 4: Characteristics of septage in tropical countries

Parameter	Faecal sludge from public toilets	Septage from household septic tanks
Characterization	Highly concentrated, mostly fresh faecal sludge, stored for only a few weeks at maximum	Faecal sludge of low concentration, usually stored for several years, more stabilized than faecal sludge from public toilets
COD mg/l	20–50,000	< 15,000
COD/BOD	5:1 to 10:1	5: 1 to 10: 1
NH_4-N mg/l	2–5,000	< 1,000
TS mg/l	≥ 3.5 %	< 3 %
SS mg/l	≥ 30,000	7,000 (approximately)
Helminths eggs no./l	20–60,000	4,000 (approximately)

Source: Policy Paper on Septage Management in India, CSE, 2011

experiments, septage has also been used to generate energy through biogas systems and bio-methanization process. The methane thus produced can be used as fuel for cooking or for generation of electricity. Resource recovery has been highlighted in *Section 4.7* of this report.

Health and environment implications

Septage contains elements that may produce bad odour, risk public health and create serious environmental hazards. Since septage is highly concentrated, discharging it into a water body may cause immediate depletion of dissolved oxygen and increase nutrients levels in the water, leading to eutrophication and increase in the number of pathogens, thus creating risk of health hazards. Knowledge of septage characteristics and variability is important in determining acceptable disposal methods. In the absence of adequate information on septage characteristics in India, typical characteristics of the septage in tropical countries like Argentina, Ghana (Accra), Philippines (Manila) and Thailand (Bangkok) may be useful (see *Table 4: Characteristics of septage in tropical countries*).[20] Septage from both septic tanks in households and public toilets is highly concentrated and hazardous for water bodies.

3. Septage management: How to start?

Septage management is a process and requires attention at every stage of the sanitation chain. It needs to be comprehensive and requires a step-wise approach, beginning from systematic planning to ensuring availability of infrastructure and human resources for collection, transportation and treatment of septage (see *Figure 7: Steps for planning septage management*). It has to be sustainable and must take into consideration the socio-economic aspects of the region. Safe disposal or end use in a scientific manner is the main goal of septage management.

3.1 Stakeholder identification and engagement

All interested parties, be they individuals, groups, organizations or entities, are stakeholders. Relevant stakeholders like representatives of ULBs, public health and engineering departments and pollution control boards, as well as sanitary inspectors, masons, vacuum truck operators, media, farmers etc. should be identified for the target area. Once identified, stakeholders are supposed to be analyzed based on the interest and influence chart, as shown in *Figure 8: Stakeholder engagement strategy*. The analysis includes understanding their profile, their interests, their position (for or against), and their ability to influence septage management practices. Stakeholders are then engaged through different strategies.

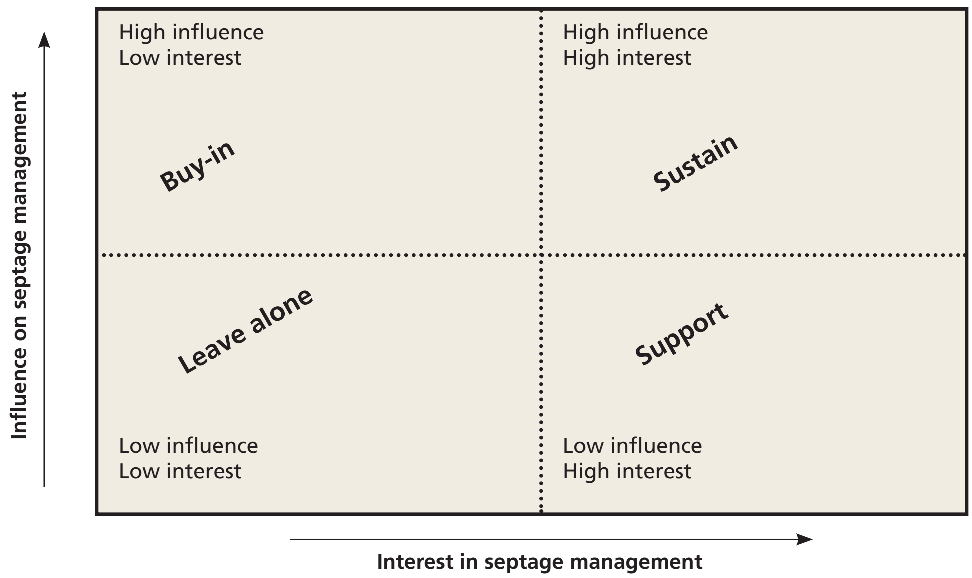
Stakeholder engagement is a key prerequisite for successful implementation of septage management. If the city already has a sanitation task-force, as notified in NUSP, then it should deliberate about septage management, starting with collection and analysis of baseline data. The 'stakeholder analysis tool' can be used to identify, analyze and understand possible ways of engaging a particular category of stakeholders. This tool can be downloaded from http://www.fsmtoolbox.com/stakeholder_analysis_tool/.

Figure 7: Steps for planning septage management

- Define the issue
- Identify the key stakeholders
- Stakeholder engagement
- Collect baseline information
- Analyze collected data
- Design strategy for each stage
- Implement
- Monitor

Source: CSE, 2016

Figure 8: Stakeholder engagement strategy



Source: CSE, 2016

Figure 9: Stakeholder analysis tool webpage

Source: http://www.fsmtoolbox.com/stakeholder_analysis_tool

3.2 Assessment of baseline information

The next stage of septage management is collection of baseline data from secondary sources like Census, state surveys, detailed project reports of previous projects and primary surveys, wherever necessary, for spatial information. It is important to understand how many households are using OSS. Spatial distribution of the houses in the area should be qualitatively mapped. Preliminary surveys of households that are depended on the onsite sanitation system must be done to prepare comprehensive management plans. *Table 5: Essential baseline data to plan septage management* enlists the basic but crucial information needed to plan septage management.

Table 5: Essential baseline data to plan septage management

Baseline data	Details and possible source of data
Base maps of the target area	Available with government agencies. Can also be prepared using Google Earth software.
Water supply	Information on source of water supply, level of groundwater, and per capita water supplied is essential.
Spatial distribution of households dependant on the OSS	Secondary data sources like Census, surveys by NGOs, and published reports. This might not be available for small- or medium-sized towns and cities and, therefore, primary surveys are essential.
Type of OSS	Information on type of OSS—with their average capacity, desludging frequency, fate of liquid waste (effluent) that is overflowing from the OSS
Mode of emptying the OSS and transporting the produce	Whether emptying services are provided by government or private operators. Information on the number of service providers, infrastructure like number of trucks and labourers
Treatment and disposal of septage	Whether there is any treatment of the septage collected, where is it disposed of

Source: Compiled by CSE, 2016

'Sanitab' is an android-based application which assists in performing a household- or property-level sanitation survey for creating a database on OSS. This tool can be used by city councils and can be downloaded from http://www.fsmtoolbox.com/sanitab/.

Once the baseline data is in place, the next step is assessment of the initial situation of the target area, i.e., community, ward, zone or city. There are several tools available to help the practitioner analyze the collected data. One such tool is called an excreta or shit flow diagram (SFD). It is an easy-to-understand advocacy and decision-support tool that summarizes and presents what happens to the excreta of the whole city or town through the sanitation chain. *Figure 12: Shit flow diagram of a sample city* clearly shows that there is dependence on onsite systems and the septage generated is not being treated,

Figure 10: Sanitab webpage

Source: http://www.fsmtoolbox.com/sanitab/

What is an SFD?

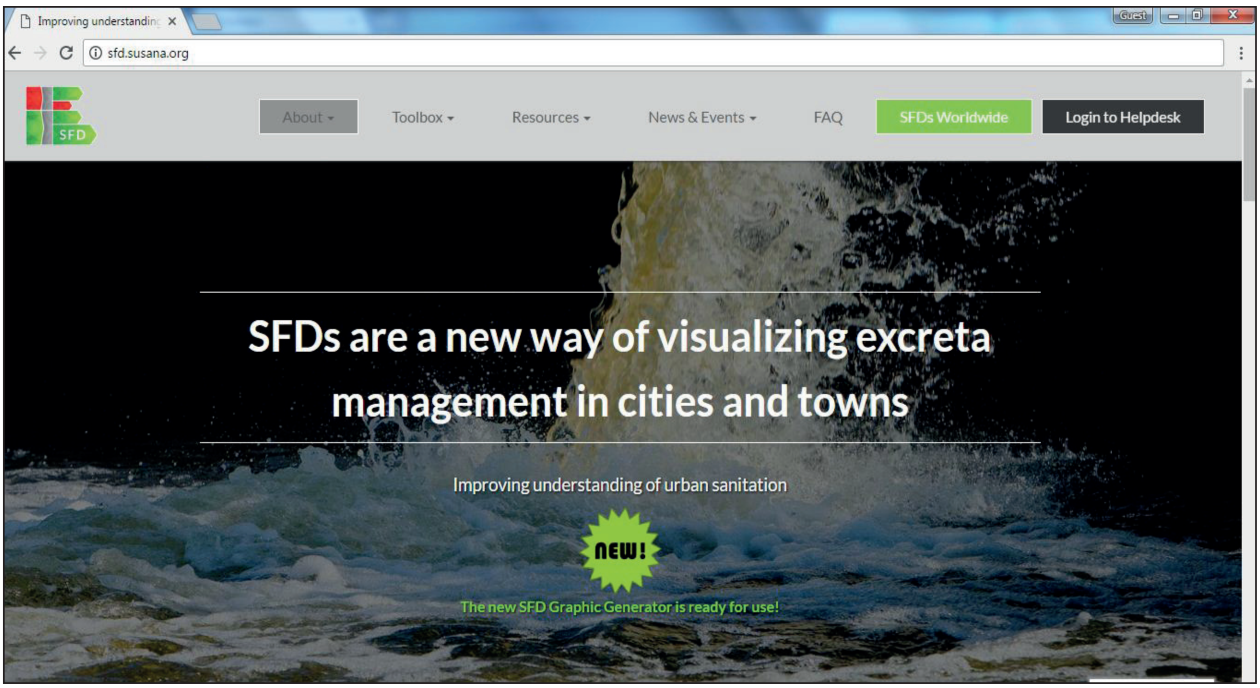
An excreta flow diagram or SFD is a tool to readily understand and communicate visualizing how excreta physically flow through a city or town. It shows how excreta is or is not contained as it moves from the point of defecation to disposal or end-use—thus the fate of all excreta generated. An accompanying report describes the service delivery context of the city or town.

IT IS	IT IS NOT
• A tool for engineers, planners and decision-makers • Based on contributing populations and an indication of where their excreta (septage or sewage) goes • A representation of public health hazard • An effective communications and advocacy tool • An overview from which to develop sanitation priorities	• Based on actual volumes/mass – these are determined by other related factors • A representation of public health risk (risk = hazard x behavior) • A precise scientific analytical tool

hence excreta of 64 per cent population is not being managed safely. The SFD turns out to be a good advocacy and monitoring tool. To learn how to make an SFD visit www.sfd.susana.org.

There is another tool that can be used for situation assessment. This tool is an excel-based data entry form which contains questionnaires reflecting institutional, regulatory, financial, technical, advocacy, capacity-building, and monitoring aspects of septage management along the service delivery pathway, i.e. containment, emptying, transportation, treatment and end-use. This tool can be accessed from http://www.fsmtoolbox.com/sattool/.

Figure 11: SFD susana website



Source: www.sfd.susana.org

Figure 12: Shit flow diagram of a sample city

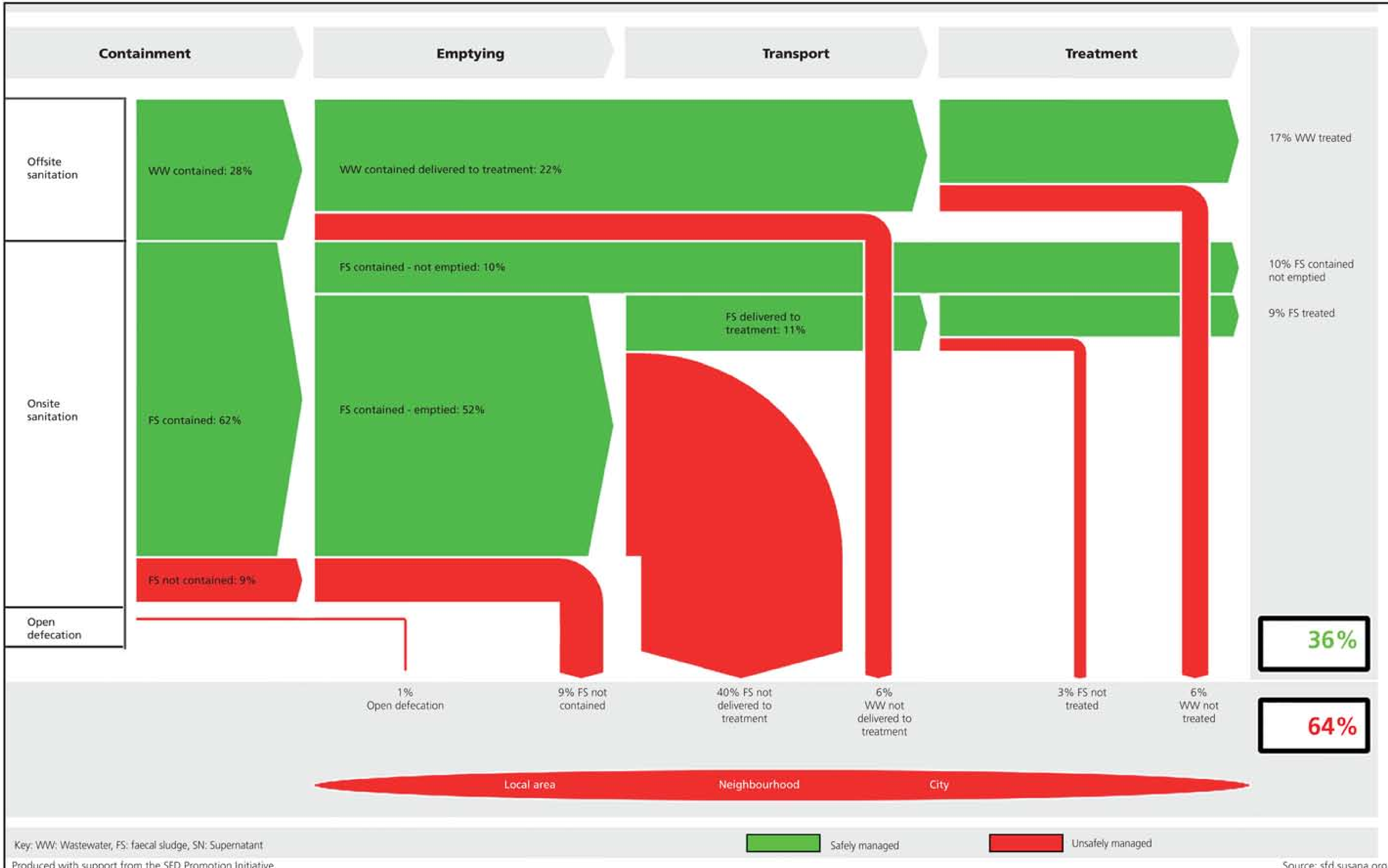


Table 6: Roles and responsibilities of institutions in the development of FSSM plans

Institution	Lead role towards septage management	Supportive role
Ministry of Urban Development	Technical and planning support to states and ULBs	Formulation of state- and city-level FSSM strategies and implementation plans
Ministry of Drinking Water and Sanitation	Technical and planning support to peri-urban and rural areas	Formulation and implementation of plans for rural India
Ministry of Environment, Forest and Climate Change	Enforce compliance of the relevant environmental laws and rules during the collection, transport, treatment, and disposal of faecal sludge and septage	Support and build capacity of state pollution control boards towards enforcement of relevant laws and rules
Ministry of Social Justice and Empowerment	National-level awareness campaign through monitoring and evaluation	Help states and ULBs eliminate manual scavenging and rehabilitate manual scavengers
Ministry of Women and Child Development	----	Gender mainstreaming in information, education and communication (IEC) material for FSSM across the country
State governments	Develop state level FSSM strategy and implementation plan	• Technical, financial and administrative support to ULBs • Encourage coordination and cooperation among ULBs • Regulate and help ULBs set up systems to ensure financial sustainability in provision of FSSM services • Implement municipal by-laws.
Urban local bodies	Design, develop, plan and implement ULB level FSSM strategy	Create enabling environment for NGOs and private initiatives to achieve safe and sustainable FSSM
Households	Maintenance of septic tanks through scheduled desludging regular maintenance and monitoring of septic tanks	Engage with decision-makers at state and ULB level to ensure that they receive good quality FSSM services

Source: Compiled by CSE, 2017

3.3 Suggested institutional framework

In India, there are few institutions at the city- and state-level which take care of septage management. This section enumerates the suggestions under the National Urban FSSM Policy, which highlights that each state and city needs to formulate its own FSSM strategy and integrate the same in their respective state and city sanitation plans in overall conformity with the national policy (see Table 6: *Roles and responsibilities of institutions in the development of FSSM plans*; a more detailed table on the roles and responsibilities has been provided in the *Appendix 3*).

3.4 Current economics and business model

3.4.1 Current economics behind septage management

In the present scenario, septage management is primarily in the hands of private operators. The operators charge for emptying services provided to different stakeholders. Emptying points can be individual households, residential colonies, commercial establishments, institutions, toilet complexes, offices etc. Generally, the operators are called for emptying only when the containment is full. The fee for emptying varies widely. Due to absence of dedicated disposal sites, private emptiers practice illegal dumping of septage into water bodies, utterly disregarding the threat posed to health and environment. They run their business without paying any fees to government authorities which means that despite high charges collected from the customers, no revenue is generated by government authorities from the emptying business. Farmers in whose fields the collected septage or faecal sludge is disposed of also pay the private operators.

Case study 1: Sewerage Act, 1993—Malaysia

Background

Until 1990, the predominant containment systems in Malaysia were bucket latrines and emptying was handled by local authorities. Sludge collected was not treated and directly deposited in open land or water bodies. To overcome this issue, the government of Malaysia formulated the Sewerage Services Act, 1993 (Act 508).

Septage management

In 1994, Malaysia moved towards privatization using the new Act. The government adopted a new process and employed Indah Water Konsortium (IWK), a private service provider, for 28 years to regulate the septage sector. Regulations under the Act prioritized 1. Public health, 2. Protection of water resources, and 3. Environment

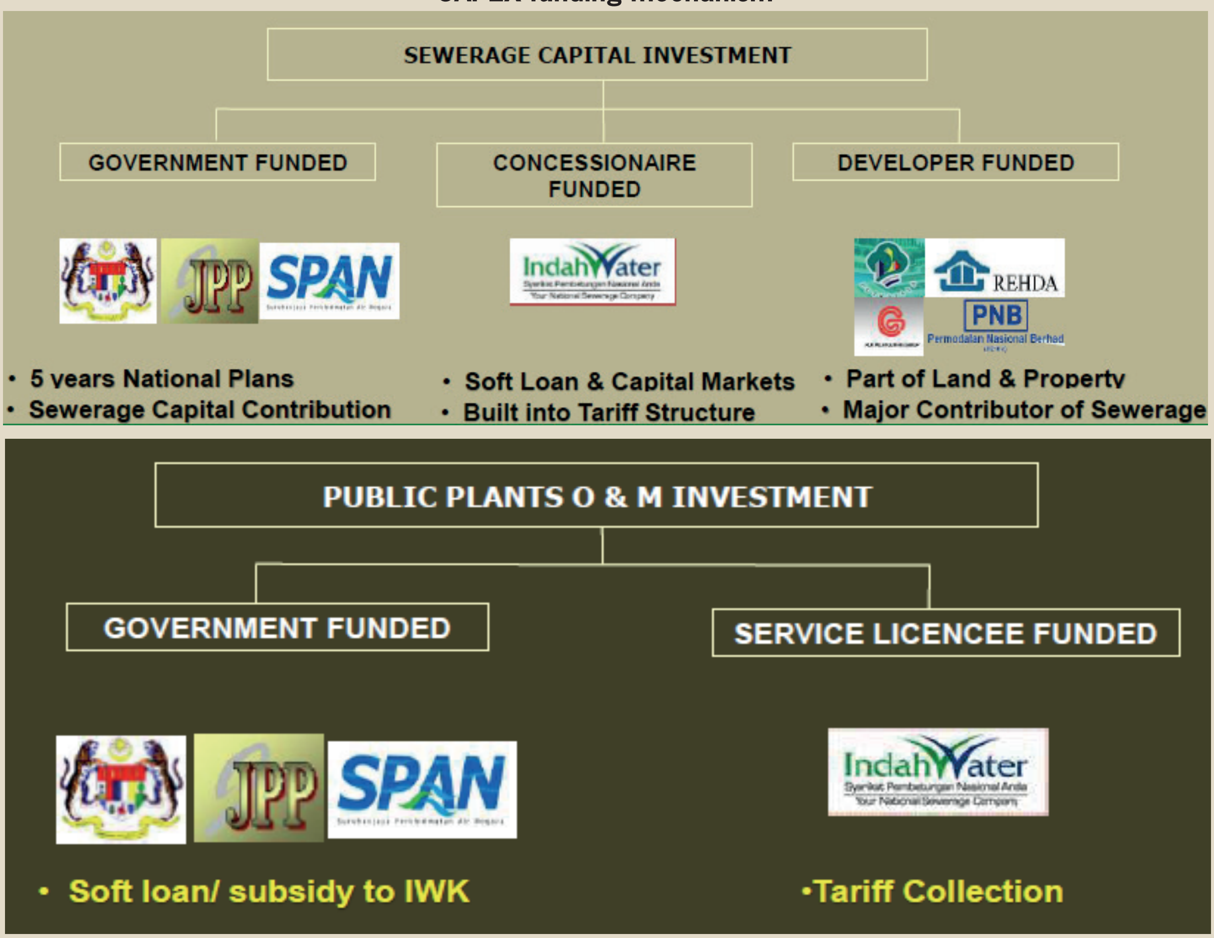
Provisions under the Act:

- Federalization and privatization of sewerage and septage management
- Investment in refurbishment and upgradation of operations
- Catchment planning and reservation
- Developer guidelines and specifications to be compiled
- Ensuring that containments are as per standards and are inspected

Role of private organizations:

IWK provides sewerage services in 87 out of the 144 local authorities in Malaysia. IWK is responsible for providing sewerage services, operating and maintaining over 5,605 public sewage treatment plants, and 14,700 km networks of sewerage pipelines, as well as the desludging and septage management of one million individual septage tanks. IWK covers most parts of Malaysia for operation and maintenance whilst providing technical expertize to the remaining non-serviced areas.[21]

CAPEX funding mechanism



Source: Indah Water Konsortium, 2017

Case study 2: Warangal—India

Background

Greater Warangal Municipal Corporation (GWMC) addressed the need of introducing FSM regulation and septage management guidelines for an effective monitoring process in compliance with national level guidelines and regulations. The objective of the initiative was to promote a comprehensive and integrated approach to septage management covering the entire sanitation chain.

Septage management

a. Operative guidelines adopted for septage management:

1. Designing and construction of septic tanks
2. Conversion of insanitary latrines into sanitary latrines
3. Septic tank pumping and desludging every three years
4. Septage transportation
5. Treatment, disposal and end use of septage
6. Information, education and communication
7. Training programmes
8. Record keeping and reporting
9. Helpline for septage management (s-line)
10. Operationalizing the FSM regulations

b. Sanitation-line or S- line: A helpline setup by GWMC to support citizens on all aspects of septage management (such as request for new toilets, septic tank designs, approval process, methods of construction, contact details of masons and desludging operators).

1. Information, education and communication: Provision of printed material on design of toilets—three-chamber septic tanks for households, advanced septic tanks and decentralized wastewater treatment (DWWT) systems.
2. Extensive promotion of the s-line
3. Consultation meetings with members of resident welfare associations to educate them about the importance and legal requirements related to scheduled desludging
4. Establishment of a formal process for empanelment of desludging operators and issuance of license to operate (five-year validity, with yearly renewal)
5. Fitting global positioning systems (GPS) in licensed trucks used for monitoring by GWMC

Innovative processes such as support call centres and co-treatment as examples from Warangal are being scaled up in the entire state of Telangana.[22]

Case study 3: Manila—Philippines

Background

Philippines is one of the few countries in Asia that has a national policy on septage management under the mandate of local governmental units (LGUs) and water service providers under the Clean Water Act, 2004.

Septage management

- Maynilad Water Services Inc works in the west zone of Manila, Philippines.
- It is involved in performing desludging activities.
- The Clean Water Act of 2004 makes it compulsory for LGUs and water districts to build septage management programmes in those areas which are deficient in sewerage systems.
- Private service providers in the metro city of Manila also participate in the collection and treatment of septage for profit.
- The city has adopted a decree of septage management and constructed septage treatment facilities (oxidation ponds) with a capacity of 450 cum per day.[23]
- Manila Water Company works on the east zone of Manila, Philippines
- The company has 78 vacuum trucks and is involved in the empting and treatment of septage

3.4.2 Business model

A business model is a reflection of not only the financial spending of an institution towards better septage management, but also illuminates the return on investments. A business model consists of four interlocking elements.[24]

- Customer value proposition: Products that create value for a target customer
- Cost structure: All costs incurred in operating the business model
- Profit formula: Revenue streams from each component
- Key resources: Most critical activities required for the business

For a business model of any institution working in the spectre of septage management, the four elements mentioned above should create and provide value to customers. The value propositions can be divided into multiple segments, but in this guide, we are enumerating only five types as follows:

- Value proposition 1—Access to toilets and treatment for end use: Providing an improved sanitation service to communities through access to toilets and recovery of nutrients or energy through treatment of FS.
- Value proposition 2—Emptying and transportation of FS: Providing a timely sanitation service for emptying pits and septic tanks at an appropriate frequency.
- Value proposition 3—Treatment of FS for disposal: A healthier and safe environment through appropriate treatment of FS.
- Value proposition 4—End use through nutrient recovery: Producing high-quality compost as a soil conditioner.
- Value proposition 5—End use through energy recovery: Improving access to energy.[25]

Depending on the value proposition offered by the business, its customer segment will vary. For a business providing emptying and transportation services, the customer segment is individual households, community toilet, and institutions. A generic business model canvas is described in *Appendix 4*. The government could charge for the following activities by private operators and septic tank owners to generate revenue for sustainably-run septage management programmes.

a. Permits and their renewal for private operator through a registration process.
b. Charges to repair the faulty design through registered masons or plumbers.
c. Fine on defaulters (private operators or containment owners) for not following instructions of government agencies.

3.5 Monitoring and grievance redressal systems

At each stage of the sanitation chain, monitoring is essential. Any lapse in monitoring means avoidable delays in achieving the goals of the programme and, in extreme cases, may result in the goals of the programme not being achieved (see *Table 7: Monitoring septage programmes*).

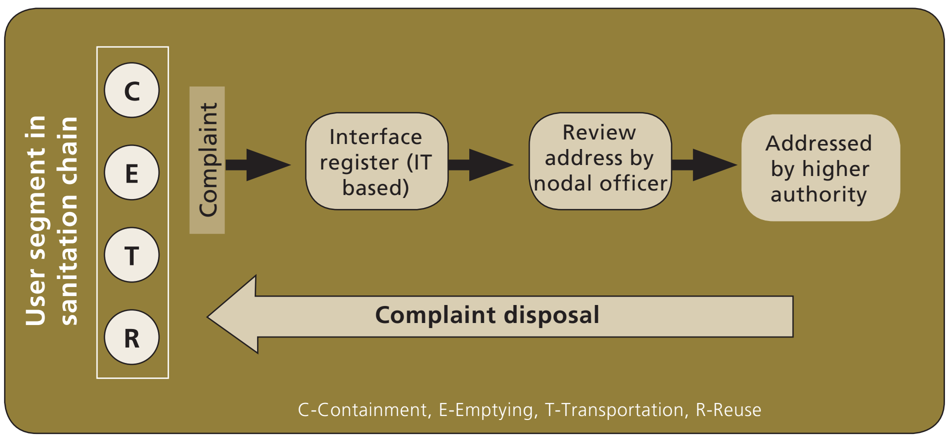
When any services are offered, there are always some issues and challenges associated with them. Customer satisfaction should be the main objective of service providers. In septage management, many stakeholders and beneficiaries are involved. It may not be possible to ensure that every one of them is satisfied with the services. Therefore, for appropriate disposal of the complaints with septage management, a complaint redressal system must be put in place before the services are offered. The mode of the redressal system should vary according to the size of the target area, from a simple register to complex information technology-based systems. Nodal officers must be appointed to dispose of the complaints for each stage of septage management.

Table 7: Monitoring septage programmes

Stage	Monitoring
Containment	• Construction as per prescribed standards by BIS or CPHEEO • Construction of the containment by licensed masons and plumbers • Overflow from containment is not diverted in open areas or drains • Census of the OSS and retrofitting of faulty containment is done. If not done within a timeline, defaulters should be charged
Emptying	• Safety standards are followed • Legislative provisions like Manual Scavenging Act, 2013 are followed • Fixed charges are collected by private or government operators
Transportation	• Vehicles are registered with ULBs with transparency • Vehicles are well-maintained • All vehicles are GPS-enabled so that the route followed and point of disposal can be monitored • Septage is disposed in designated disposal or treatment sites
Treatment	• Septage characteristics are determined to design the treatment system • In case of co-treatment at STPs, design parameters to take additional septage load is checked • Effluent resulting from dewatering is treated as per discharge standards • Independent septage treatment plants have adequate provisions for vehicle parking • Sludge drying beds are emptied regularly
Disposal and end use	• Legislative provisions like water pollution and environment protection acts are followed • Defaulters are charged or fined as per provisions • Quality checks of end products is done before end use • Rates of end products are reasonable • Treated wastewater overflowing from containment meets prescribed standards of end use for designated purposes

Source: Compiled by CSE, 2017

Figure 13: Flowchart of complaint redressal system for septage management



Source: Compiled by CSE, 2017

Nodal officers should review the complaint and take appropriate action. However, in case the complaint is not addressed or the user is not satisfied, there should be provisions to take the complaint to higher authorities or institutions (e.g. pollution control boards) for appropriate action (see *Figure 13: Flowchart of complaint redressal system for septage management*).

4. Stages of septage management

Septage management is a process that requires attention at every stage of the sanitation chain, as explained in *Section 2.2*. Safe disposal or end use in a scientific manner is the main goal of septage management. The important calculations in septage management can be understood through an example of a sample City X.

Example 1—City X

Assuming example of City X which has following characteristics
- Population: 150,000
- No. of households: 30,000
- No. of household dependent on onsite sanitation systems: 20,000
- Average volume of a household containment system: 3,000 litres
- No. of community toilets and public toilet blocks: 40
- Average volume of containment systems of community toilets and public toilets: 10,000 litres

4.1 Containment system

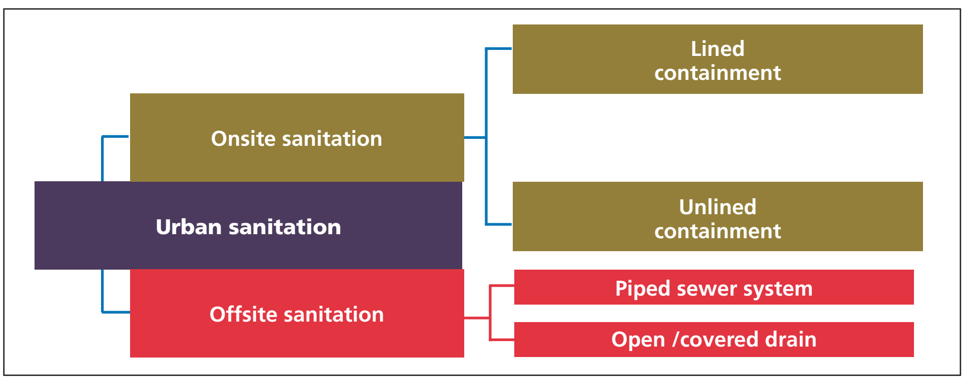
Two main types of systems exist in urban areas for the management of faeces: 1. Offsite sanitation systems, which carry the wastewater collected from user interfaces to a single point of collection and treatment or outlet to water bodies. 2. Onsite sanitation systems (OSS), where faecal waste is collected in a containment system and may or may not be treated. As this is a guide on septage management, our focus is on OSS. *Figure 14: Sanitation systems in India* elucidates the difference between the two systems.

The terms OSS and containment systems have been used interchangeably in this document. Prevalent OSS or containment systems have been explained in the following sections.

4.1.1 Scenario in India

India, like any other developing country, significantly depends on OSS. Prevalent and upcoming urban onsite sanitation systems have been highlighted in *Table 8: Urban containment systems in India*, along with the required

Figure 14: Sanitation systems in India



Source: CSE, 2017

Table 8: Urban containment systems in India

Urban sanitation systems				
Type of system	**Containment system type**	**Containment system used**	**System name as per 2011 Census of India**	**Standards to be followed**
Onsite sanitation system	Lined containment	Septic tank with soakpit	Septic tank	Bureau of Indian Standards
		Septic tank without soakpit		
		Collection tank		
		Bio-toilet	Other technology	Defence Research Development Organization (DRDO) and SBM
		Bio-digester		
	Unlined containment	Pit latrine or ventilated improved pit	Pit latrine	SBM containment guidelines
		Twin-pit latrine		

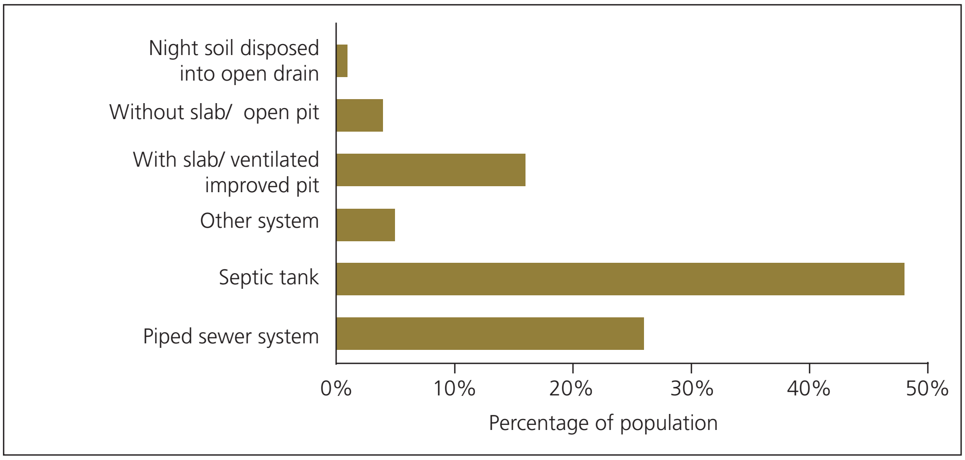
Source: Compiled by CSE, 2017

standards. *Figure 15: Sanitation technologies and corresponding percentage of population* addresses the distribution of containment systems in India as per the 2011 Census. Lined tanks with open bottoms should be considered unlined containment systems.

Description of containment technologies prevalent in India

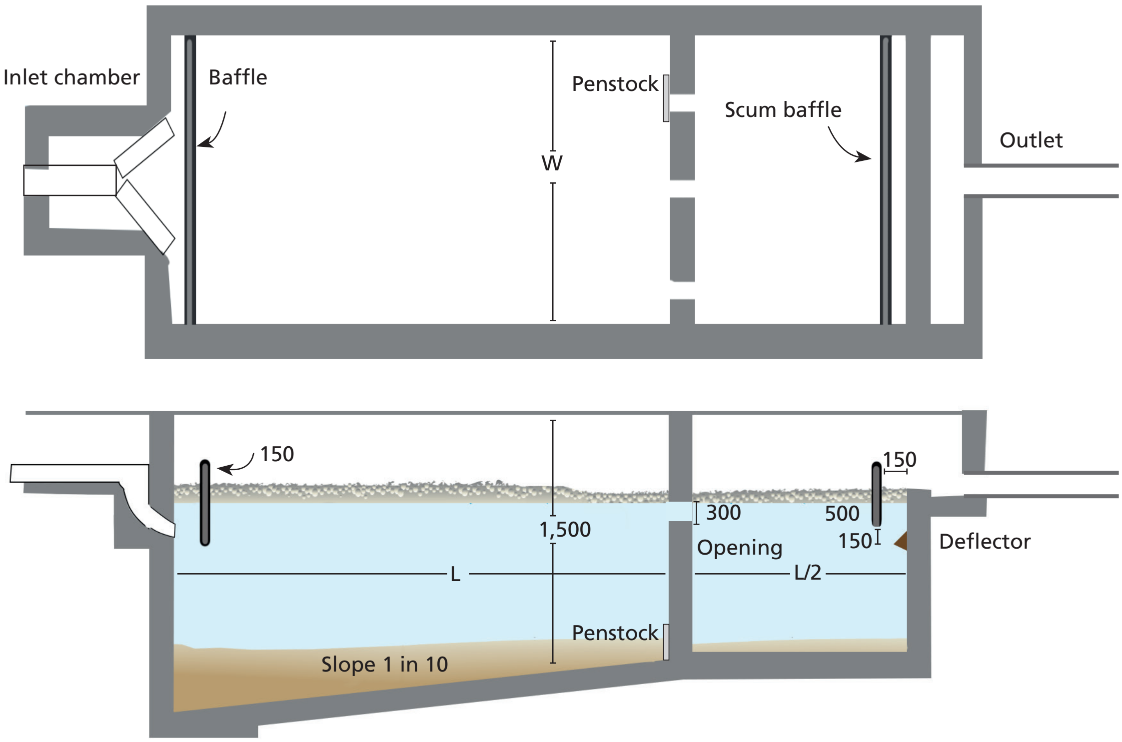
In practice, the septic tanks are not constructed according to the Indian Standard (IS) code and, hence, the efficiency of the system is not up to the mark. This also affects the emptying frequency and quality of effluent and septage recovered from these tanks. These systems are generally constructed by local masons according to the space available and the financial status of the user. The masons often create bigger pits than required. Often, the bottom of the tanks is not lined, to decrease the frequency of emptying. See *Table 8: Urban containment systems in India* for an overview of the ongoing containment practices in India. Refer to *Appendix 5* for a brief description of containment systems prevalent in India and also the output expected from such systems.

Figure 15: Sanitation technologies and corresponding percentage of population



Note: Public toilets are assumed to be connected to septic tanks.
Source: Census of India, 2011

Figure 16: Standard septic tank design



All measurements in millimetres (mm)
Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

4.1.2 Septic tank

BIS provides a code of practice for installation of septic tanks (IS-2470 Part-1, 1985). It illustrates design criteria to construct septic tanks based on certain assumptions. It provides details to design installations for small and large areas considering the population. Comprehensive design standards on OSS are provided in part-A of the *Manual on sewerage and sewage treatment* published by CPHEEO, the research wing of MoUD. The standard designs for prevalent and safe onsite sanitation technologies have been described in the section (see *Figure 16: Standard septic tank design*).

Table 9: Recommended sizes of septic tank

No. of users	Length (m)	Breadth (m)	Liquid depth (cleaning interval of) (m)	
			One year	Two year
5	1·5	0·75	1·0	1·05
10	2·0	0·90	1·0	1·40
15	2·0	0·90	1·3	2·00
20	2·3	1·10	1·3	1·80

Note 1: The size of septic tanks is based on certain assumptions (liquid discharge), while choosing the size of septic tanks, exact calculations shall be made. For information on the same, please refer to BIS: 2470 (Part 1), 1985.
Note 2: A provision of 300 mm should be made for a free board.
Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012.

Specifications of a septic tank

- Rectangular: Length to breadth ratio—2:1 to 3:1
- Depth: Between 1.0 to 2.5 m
- If two-chambered: First chamber two-thirds of the total length
- If three-chambered: First chamber half of the total length
- Manholes above each chamber
- A watertight, durable and stable tank

Capacity of a septic tank

The capacity of the tank helps calculate the duration for desludging. Following are some key points useful to measure the capacity of a septic tank:

- Sedimentation: An area of 0.92 m^2 is required for every 10 l/min peak flow rate to support adequate sedimentation of suspended solids. Generally, the depth of the sedimentation zone is 0.3 m.
- Sludge digestion: The capacity of the digestion zone works out to be 0.032 m^3 per capita.
- Sludge and scum storage: For an interval of one year of sludge cleaning, storage capacity of $(2 \times 10^{-4}) \times 365 = 0.073$ m^3/capita is required.
- Free board: At least 0.3 m

Types of septic tanks

Septic tanks are classified according to the number of chambers, intensity of treatment, and complexity of the system.

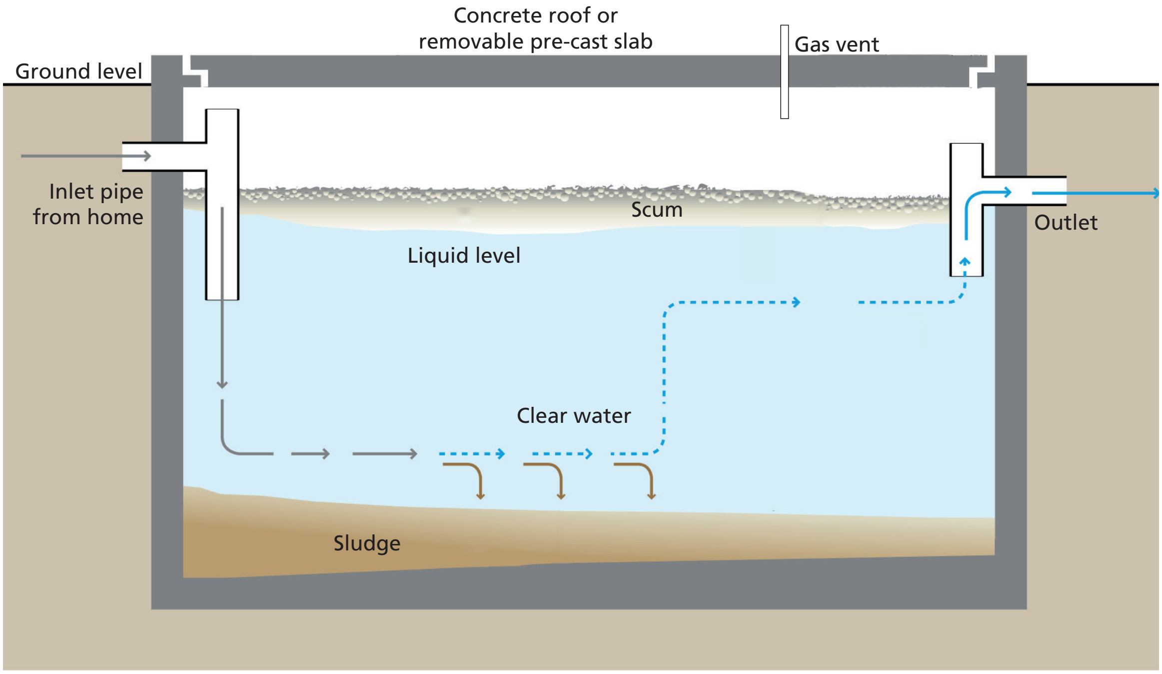
Conventional system

a) Single-chambered septic tank
b) Two- or three-chambered septic tank

Improved system

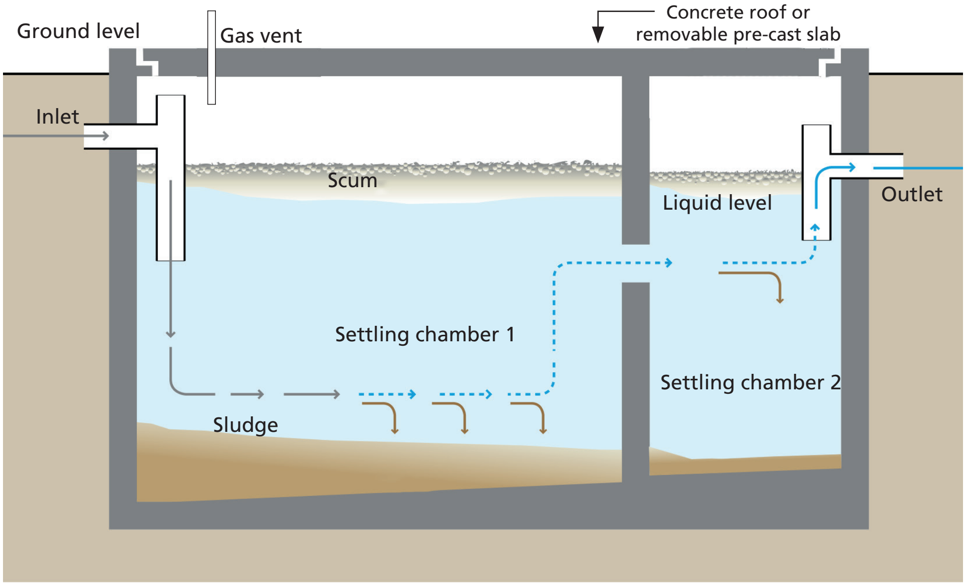
a) Two-chambered septic tank with filter
b) Anaerobic baffled reactor with filter

Figure 17: Single chambered septic tank



Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

Figure 18: Two-chambered septic tank



Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

Conventional system

a) Single-chambered septic tanks

Single-chambered septic tanks are tanks in which anaerobic digestion takes place. This type of OSS requires frequent emptying as the rate of digestion of solids is comparatively low. This conventional type of septic tank is not suggested as an OSS because of its low efficiency and high maintenance requirements (see *Figure 17: Single-chambered septic tank*).[26]

b) Two-chambered septic tanks

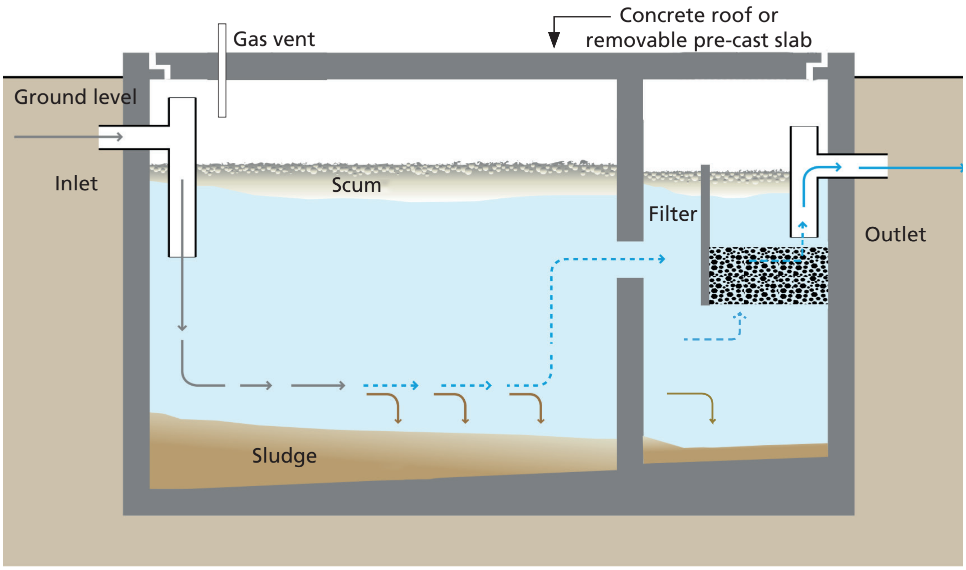
Two-chambered septic tanks have two chambers. The first chamber is at least twice the size of the second chamber. Maximum solids settle down in the first chamber and the partition between the chambers prevents scum and solids from escaping with the effluent. A T-shaped outlet pipe further reduces the amount of scum and solids that are discharged. Generally, these septic tanks have to be emptied every three years (see *Figure 18: Two-chambered septic tank*).[27]

Improved system

a) Two-chambered septic tanks with filter

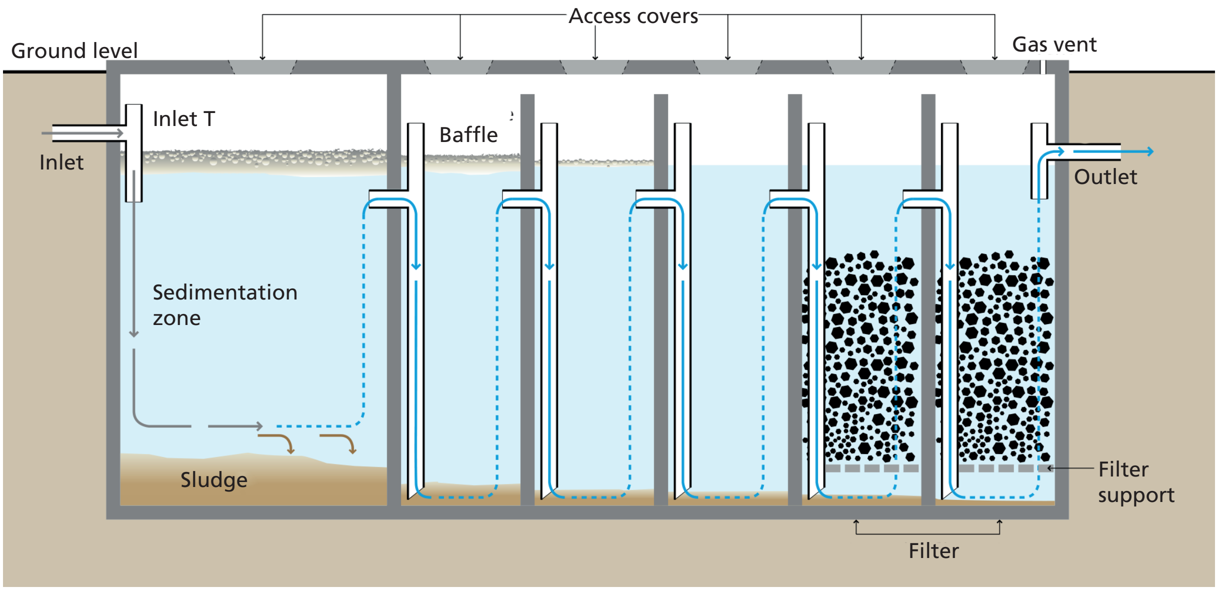
This type of system incorporates two chambers with a single filtration chamber resulting in improved treatment (see *Figure 19: Two-chambered septic tank with filter*). As wastewater flows through the filter, particles are trapped and organic matter is degraded by the active biomass that is attached to the surface of the filter material. Commonly used filter material includes gravel, crushed rocks, cinder, or specially manufactured plastic pieces. Typical filter material sizes range from 12–55 mm in diameter. Ideally, the material will provide between 90–300 m^2 of surface area per m^3 of reactor volume. By providing a large surface area for the bacterial mass to work, there is increased contact between the organic matter and active biomass, effectively degrading the organic matter. Suspended solids and BOD removal can be as high as 85–90 per cent, but is typically between 50–80 per cent. Nitrogen removal is limited, and normally does not exceed 15 per cent total nitrogen.[28]

Figure 19: Two-chambered septic tank with filter



Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

Figure 20: Anaerobic baffled reactor with filter



Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

b) Anaerobic baffled reactors with filter

An ABR with filter is an improved septic tank (see *Figure 20: Anaerobic baffled reactor with filter*). ABRs incorporate one or more baffles which force the sewage to flow from the bottom to top until it starts to flow into the next chamber. The upflow chambers catalyze the sedimentation of solids and digestion of organic matter.[29] BOD may be reduced by up to 90 per cent, which is far higher a percentage than a conventional septic tank. The filter chambers typically remove 50–80 per cent BOD as sewage flows through them.[30]

Table 10: Specifications for designing of a twin-pit

Type of pit	Number of users					
	Five		Ten		Fifteen	
	Diameter	Depth	Diameter	Depth	Diameter	Depth
Dry pit	900	1,000	1,100	1,300	1,300	1,400
Wet pit	1,000	1,300	1,400	1,400	1,600	1,500

Note: Depth from bottom of pit to invert level of incoming pipe or drain (all dimensions in mm)
Source: Manual on sewerage and sewage treatment part A : Engineering. CPHEEO; 2012.

4.1.3 Twin-pit system

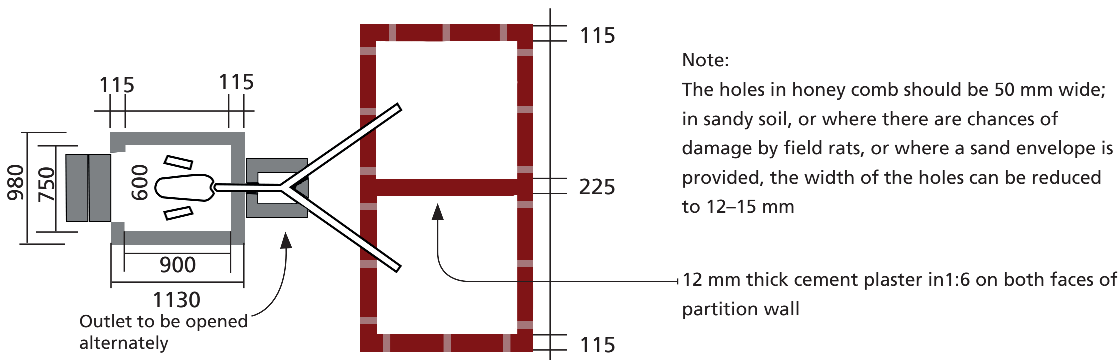
It consists of a superstructure (toilet) and treatment units (two chambers). The two underground chambers (pits) are provided to hold faecal sludge. There are two alternating pits generally connected to a pour-flush toilet. Only one pit is functional at a time while the other is allowed to rest as the liquid leaches out of the pit. Pathogenic germs are absorbed into the soil while solids dry inside the pit.

Specifications for designing a twin-pit

Twin pits are normally offset from the toilet and should be at least 1 m apart from each other. A single pipe leads from the toilet to a small diversion chamber, from which separate pipes lead to the two underground chambers. The pits should be lined with open jointed brickwork. Each pit should be designed to hold at least 12 months' accumulation of faecal sludge. Wastewater is discharged to one chamber until it is full of faecal sludge. Discharge is then switched to the second chamber. Just before the second chamber is full of faecal sludge, the contents of the first pit are dugout, which have been reduced by an anaerobic process. Sizes of twin pits as per size of family and number of users have been provided in *Table 10: Specifications for designing of a twin-pit* (see *Figure 21: Latrine with twin-pits*).

The capacity of a twin pit is guided by the sludge accumulation rate (see *Table 11: Sludge accumulation rate*). Sludge accumulation rate is a function of a wide range of variables, including water table, pit age, water and excreta loading rates, microbial conditions in the pit, temperature and local soil conditions,

Figure 21: Latrine with twin-pits



Source: Manual on Sewerage and Sewage Treatment—Part A: Engineering. CPHEEO, 2012

Table 11: Sludge accumulation rate

Material used for anal cleansing	Effective volume in cum per capita per year*		
	Pit under dry conditions	Pit under wet conditions	
		With successive desludging intervals	
		Two years	Three years
Water	0.04	0.095	0.067
Soft paper	0.53	0.114	0.8

*Effective volume is the volume of the pit below the invert level of pipe or drain.
Source: Manual on Sewerage and Sewage Treatment–Part A : Engineering. CPHEEO, 2012.

and the type of material used for anal cleansing.[31] The SBM guidelines may be referred for the further understanding at http://www.Swachhbharaturban.in:8080/sbm/content/writereaddata/sbm_guideline.pdf

4.1.4 Bio-digester (anaerobic)

Bio-digesters advocated by the SBM are widely used to provide 80 per cent treatment of black water from individual and cluster households, or institutional buildings where there is no sewerage network (see *Figure 22: Working of a bio-digester*).[32] The technology has been developed by DRDO.

Specifications of a bio-digester

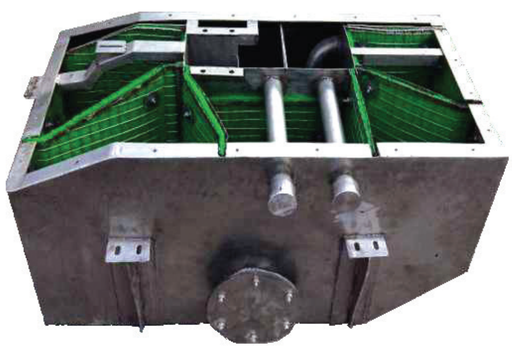
The bio-digester technology has two key components:

- Anaerobic microbial consortium
- Specially designed fermentation tank

The microbial consortium has been created by acclimatization, enrichment and bio-augmentation of cold active bacteria collected from Antarctica and other low-temperature areas. It is composed of four clusters of bacteria belonging to hydrolytic, acidogenic, acetogenic and methenogenic groups with high efficiency of bio-degradation. A fermentation tank made of metal or fiber glass-reinforced polymer (FRP) has the capacity to immobilize bacteria in large numbers. A bio-digester's construction has the following specifications:[33]

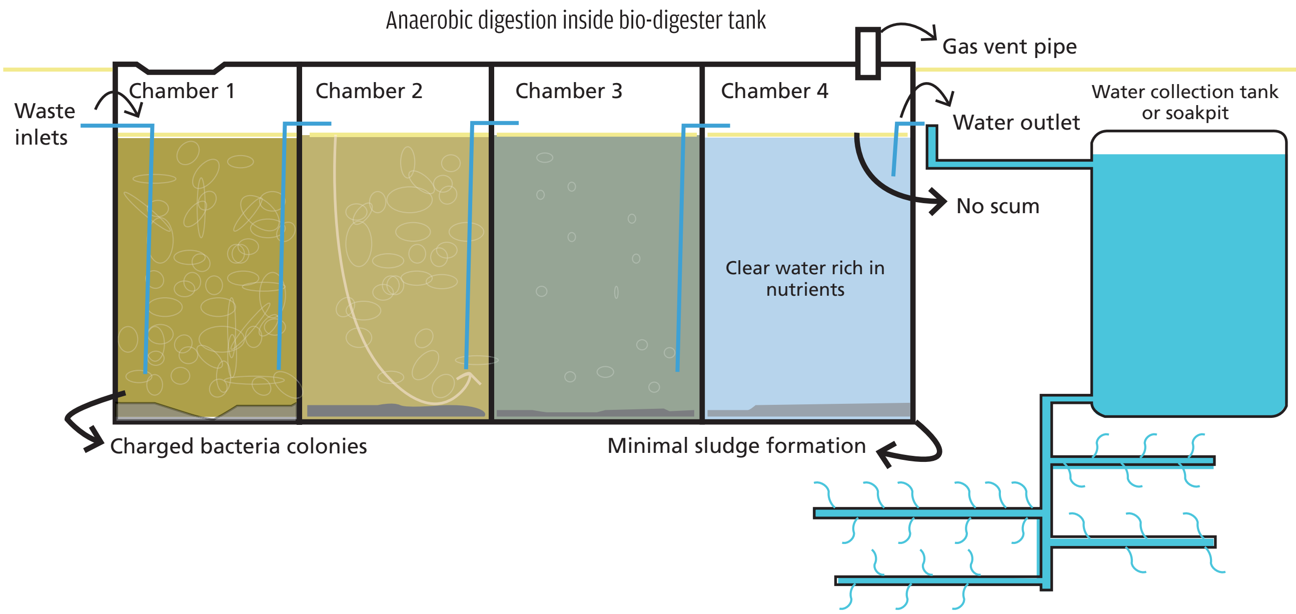
- Land requirement—25 sq ft
- Internal dimensions of the tank—1,336 mm x 1,036 mm x 900 mm
- Diagonal partition walls of 8 mm thickness (adequately stiffened by ribs)
- The tank is buried 600 mm deep and anchored by 300 mm long stainless steel (SS-316) anchor bolts at the corners
- FRP tanks are of 8 mm thickness

Image of a bio-digester



Source: DRDO Zero waste. Available at http://dbma.org.in/About_BioToilet_BioDigesters.aspx

Figure 22: Working of a bio-digester



Source: DRDO Zero waste. [Internet]. available from: http://dbma.org.in/About_BioToilet_BioDigesters.aspx

Capacity of a bio-digester (for five or six users):

- Total capacity: 700 litres (1,000 mm x 700 mm and 1,000 mm depth). Where space is a constraint, the depth of the tank can be increased to 1.5 m
- Volume of the anaerobic compartment (30 per cent total capacity): 210 litres

Tank can also be constructed with masonry.[34]

4.1.5 Bio-toilet (aerobic)

Bio-toilets make use of aerobic digestion involving multiple strains of bacteria that break down waste matter through oxidization (see *Figure 23: Bio-toilet representation*).

Specifications of bio-toilets

Bio-toilets are constructed with a multi-chambered bio-tank for the storage of waste. The waste is slowed down as it flows from one chamber to another by a special process in the bio-tank, such that the multi-strain bio-media present in the tank can digest the waste and convert it fully into non-toxic neutral water.[35]

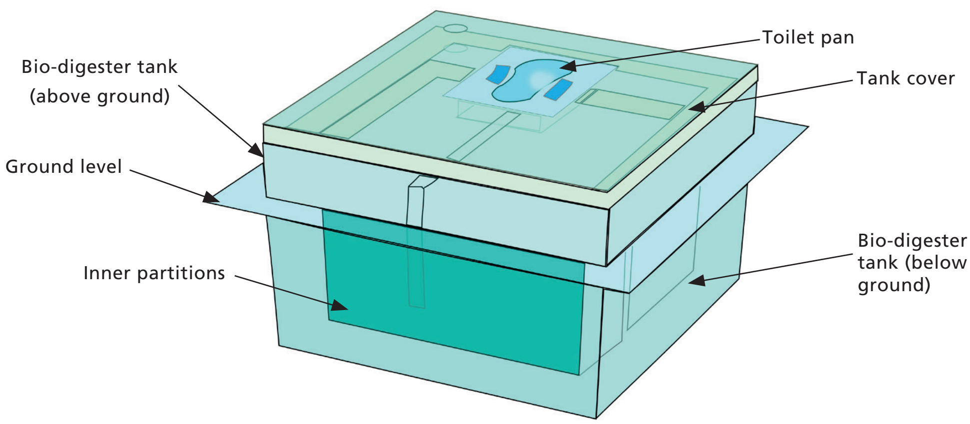
The bio toilet system consists of:

- Bio-digester tank (bricks and mortar or FRP or steel)
- Superstructure (bricks and mortar or FRP)
- Indian pan or WC
- Size: 4 x 4 ft tank base, 4 ft high tank, 6 ft high superstructure
- Maximum usage recommended: 30 defecations per day per bio-toilet (no limit on urination)
- Land requirement: 16 sq ft

Site suitability of the containment system

Before choosing a containment system, it is necessary to assess the physiological conditions of the site (see *Table 12: How to choose a suitable containment system*).

Figure 23: Bio-toilet representation



Source: Swachh Bharat Mission Guidelines—Delhi: Ministry of Urban Development, Government of India, 2014

Table 12: How to choose a suitable containment system

Various possibilities	Ground water table is shallow (less than 10m)	Ground water table is deep (more than 10m)	Soil strata –- permeable (sandy, silty etc.)	Soil strata – low permeability (rock, clay etc.)	Preferred containment system
Option 1	√		√		Any lined containment, without soakpit and effluent conveyed to nearest treatment plant through shallow sewers
Option 2	√			√	Same as above
Option 3		√		√	Same as above
Option 4		√	√		Twin pit latrines(in case of pour flush) or lined containment with soakpit

Note: The soakpit/soak away/twin pit should be located at least 8 m away from drinking water source if connected to pour flush toilets and 20 m if connected to flush toilets
Source: Compiled by CSE, 2017.

4.1.6 Suggested action

Census of OSS*:* It is essential that a census of OSS is carried out for target areas by the technical staff responsible for the sanitation management. It is essential to ensure that the OSS constructed is best suited to the local condition of the target area.

Enforcement of bye-laws: Municipal bye-laws for construction of containment systems should be enforced for new constructions. Penalty should be accrued upon defaulters.

Retrofitting of faulty systems*:* The relevant agencies must provide sufficient time and support to retrofit OSS with faulty design. Households willing to upgrade faulty systems can be provided financial incentives.

Capacity building of masons and plumbers: Construction of containment is mainly done by masons and plumbers. Only skilled and experienced labourers can construct functional systems. Training and capacity building of workforce can prove to be a significant contribution towards improved septage management.

Effluent needs further treatment: The effluent or supernatant from a septic tank needs further treatment only if construction of a soakpit or soak-away is not a feasible option. The effluent can be conveyed through small bore or solid-free sewer to the nearest trunk sewer line, if there is any STP in the town with spare capacity. If there is no STP, then the effluent should be conveyed to the nearest decentralized wastewater treatment (DWWTs). Different types of DWWTs are discussed in detail in *Section 4.6*.

4.2 Septage quantification

Quantum of septage generated depends on a number of factors including number of users, number of toilets connected to a septic tank, the volume of water used for flushing and ablution. The tank cleaning frequency increases if other sources of wastewater are connected to the septic tank (kitchen, bathrooms etc.). In general, the capacity of a septic tank in India ranges from 1–4 m^3 for houses; 5–15 m^3 for septic tanks of community or public toilets; and 10–100 m^3 for commercial places. There are two ways to calculate the septage generation rate for a given city.

- Septage production method
- Septage collection method

Septage production method: There is no study of septage generation rate in India yet, but we have data from the United States Environmental Protection Agency (USEPA) manual. An estimate based on septic tank design mentioned in IS code suggests 100–120 litres per capita per annum considering the septic tank is periodically de-sludged. *Table 13: Estimate of septage generation* summarizes quantum of septage that can be expected from household with an average size of five.

Septage collection method: The volume of septage that is collected by private operators or government vehicles can be mapped to calculate the quanta of septage that is collected from a particular region. Another method to perform the calculation is by collecting data like average capacity of containment systems and average frequency of desludging, which would eventually help us to calculate the average volume of septage that should be collected every day. The volume calculated by this method is more realistic. The calculations based on this method can be understood with an example.

Table 13: Estimate of septage generation

Septage generation	230 litres per year per capita (based on USEPA manual)	120 litres per year per capita (based on the IS code)
Average household size	Five members	Five members
Septage generation per household	1,150 litres or 1.15 cum per year	600 litres or 0.6 cum per year

Source: Compiled by CSE. 2017

Example 2

Question: Calculate the total septage to be collected per day from the city considering household septic tanks (onsite sanitation systems) are emptied once in every three years and the community toilets and public toilet septic tanks are emptied once in three months. Assume the emptying service is provided for 285 days in a year and septage generated per day from non-house establishments would be 5 per cent of the septage generated from households.

Answer:
Volume of septage generated from household septic tank (V_1):

$V_1 = ((HH_{OS} * V_{HH})/(3*285))$

$= (20000*3000)/(3*285)$
$= 70175$ litres or 70.175 KLD

Volume of septage generated from CTPT (V_2):
$V_2 = ((PT * V_{PT} * 365)/(90 * 285))$

$= ((40*10000*365)/(90*285))$
$= 5692$ litres or 5.7 KLD

Volume of septage generated from non-house establishments (V_3):
$V_3 = 0.05*V_1$

$= 3509$ litres or 3.509 KLD

Total Volume of septage to be collected per day (V_D)
$V_D = V_1 + V_2 + V_3$

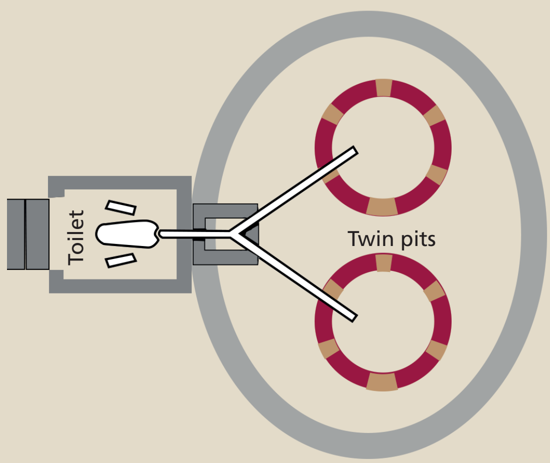
$= 70175 + 5692 + 3509$
$= 79376$ or 79.38 KLD

Case study 4: Black gold, Sulabh International, New Delhi—India

Background
Seepage pits are unlined pits where accumulated effluent seeps into the soil and only sludge in retained. These may be a direct source of groundwater pollution in many areas. Sulabh International studied the risks of contamination and offered design innovations that were accepted by CPHEEO. Their innovation is the cheapest septage management option available, provided it is designed for suitable locations (taking into consideration soil, groundwater level etc).

Septage management
The effluent seeps out through the walls of the seepage pit while the sludge remains inside. After a while, almost all pathogens—viruses, bacteria, protozoa and Helminths eggs— die off in the seepage pit or in the surrounding soil, but not Ascaris Lumbricoides (the large human round-worm), particularly if the leach pit is wet. In a little more than a year, it becomes safe to use the contents of the pit as manure. Sulabh International designed the twin-pit system such that the pit is filled in three years and can be used alternately. One pit is used at a time for a duration of three years while the other pit is left undisturbed. During this time, the excreta in the other pit degrades to form an odourless, pathogen-free compost that can be dug out and used as manure. The manure so formed is termed as "Black Gold" by the organization's workforce.[36]

Twin-pit design proposed by Sulabh International



Source: SBM Guidelines, 2015

4.3 Emptying

Emptying of containment systems is done both mechanically and manually. At the end of a fixed time period, ideally two–three years, a containment system should be emptied of septage. The scheduled emptying should be done in order to facilitate treatment of faecal matter in the OSS. There are many benefits of regular desludging of OSS. These include:

1. Increased efficiency—septic tanks perform well when detention time in the tank is maximized. As accumulated sludge reduces available tank volume, the resulting decrease in detention time impacts the tank's function and ability to separate heavier solids from lighter fats and oils.[37]

2. Better discharge quality—septage has a much higher concentration of pollution constituents than septic tank effluent. The concentration of BOD and total suspended solids is much lower in effluent compared to sewage or septage. The quality of the effluent reduces with time.

4.3.1 The scenario in India

In India, a prevalent practice is to construct a large containment system to avoid frequent emptying. The focus is on saving money needed for emptying. Outlet pipes connect the containment systems to open drains or sewerage network, wherever present. Once the effluent enters the open drains, it poses a serious environmental and health hazard.

The Prohibition of Employment of Manual Scavengers and their Rehabilitation Act, 2013 prohibits employment or engagement of manual scavengers, however many locations which are inaccessible to mechanical emptying continue to employ manual scavengers.[38]

Other than manual emptying, mechanized methods include use of vacuum tanker or tractor-mounted vacuum tankers. These are used for emptying of containment systems. Mechanized systems are usually accompanied by a driver and a helper (sometimes two helpers). No personal protective equipment (PPE)

Unsafe practices during emptying operations—placing the suction pipe with bare hands exposes workers to septage

Amrita Bhatnagar / CSE

Need for the use of PPE—use of PPE helps in preventing workers from direct contact with septage

Anil Yadav / CSE

is used by the operators while emptying the tanks or pits, posing a health risk. Private emptying operators lack proper knowledge of the business, and sometimes presume that it is a relatively easy business requiring only the acquisition of a couple of trucks and half a dozen labourers. This lack of information is worsened by the absence of a regulatory framework. Charges for emptying vary between Rs 500–3,000 across the country. The wide variance in rates is due to the informal nature of the sector.

4.3.2 Procedure for emptying

1. Check vehicle (vacuum truck or tanker mounted on a tractor) and equipment
   a. Check engine oil
   b. Check air pressure in tyres
   c. Check pumping equipment
2. Check PPE
   All employees should carry PPE such as gloves, boots, a hard hat and face masks. Use of bare hands should be strictly prohibited by the governing authority.
3. Have the service requester take the crew to the OSS. Open the access covers and inspect the interior and exterior of the tank and check:
   a. The level of water or sludge up to the flow line of the outlet pipe—a water level below the flow line of the outlet pipe indicates leaks.
   b. Tank construction to look for cracks in the concrete. Use of a mirror on a long rod can help inspect the interior of the tank.
   c. If there is more than one compartment, locate and remove lids from all compartments. Each compartment will require pumping out.
   d. Seek information from local sources about the water table. Be cautious when pumping out material from tanks because if the water table is high, an unsecured tank may crack.

4) Position the truck near the building with safety cones, stoppers and hand-break to avoid any friction during to pumping pressure.
5) Check hoses for cracks, and wear and tear:
   Proper fitting is required for operation, therefore twine, tyre tube and plastic should not be used for hose connections as they may cause leaks. Hoses, clamps and fittings should be used to connect the main hose to the tanker and the hoses to each other are critical for proper suction and pressure operations.
6) Check the depth of the tank with the help of the hose. This will provide a fair indication on the volume of the sludge and time it will take to empty

Bhitush Luthra / CSE

Incorrect connecting of a hose— cloth and twine are not appropriate friction busters, as they might come off, spilling septage on the workers and posing as a health hazard

Friction fitting—Clamp fitting should be used to screw in the pipe, which also helps in avoiding breaking of pipe during breaking of hardened solids in case of back pressure

David Robbins

it. This can be done by slowly lowering the hose in the tank; as it moves down, and it becomes harder to push it further, the sludge viscosity can be estimated.

7) Connect the hose to the truck tank. In case of hardened sludge, back pressure may be required to break the sludge mass. Clamp fittings should be screwed in such cases. The fitting might come off due to high pressure, and expose the workers to safety hazards.
8) Engage the pump or vacuum equipment. The operator will:
   a. Make sure there is suction and that the pump is operating
   b. Use the hose to break up sludge and scum masses as much as possible.
   c. The operator should closely monitor the level gauge on the vehicle. In case, there is less space, the operator should monitor level gauge closely.
   d. Check for water flowing back from outlet pipe, this is indicative of a clogging problem and should be reported to the building owner or requester
9) Upon completion of emptying through the suction system, the operator should check if there are rocks or clogged mass which needs to be broken or can be pumped out. This can be done either by pumping 200–300 litres of septage back into the tank. Fresh water can also be pumped in instead of septage.
10) Never pump out the entire contents of a tank during periods when the water table is high. If the groundwater is higher than the bottom of the tank, the tank may float out of the ground. In such conditions, leave enough contents in the tank to serve as a stabilizer.
11) Upon completion of emptying, wash the pipes with water directed to OSS.
12) Replace clean hoses back in the truck toolbox and place lids over the tank.
13) Spills should be cleaned and disinfected using lime or bleach.[39]

Septage spills should be disinfected using lime or bleach

Amrita Bhatnagar / CSE

Precautions to be taken during emptying

- Proper PPE should be used to avoid transmission of pathogens to the operator providing desludging services.
- Some amount of septage or sludge should be left in the septic tank to ensure retention of necessary micro-organisms responsible for anaerobic digestion.
- Due to anaerobic digestion processes, flammable gases are formed in septic tanks. While opening the chambers for desludging, they escape into the atmosphere. Hence, it is recommended not to light a fire nearby.
- Because of the sensitivity of septic systems due to presence of bacteria that speeds up anaerobic digestion process, care should be taken not to clean the septic tank using strong chemicals which may kill the bacteria.

4.3.3 Suggested action

Fixed charges for emptying*:* The charges to empty septage vary widely across the country, according to the urgency shown by the customer to get the containment emptied. ULBs should fix the fees charged by private operators, taking into consideration fuel costs, salary, and profit for the operator, with provisions of revising the fees as and when required.

Regulating and licensing of private emptiers: ULBs should regulate private emptiers by licensing them, which would help in streamlining of the process and checking faulty septic tanks, as well as inhibit environmental pollution.

Awareness campaigns: Awareness about the need to empty containments regularly is very essential. Frequent advisories on appropriate use of chemicals and detergents in cleaning the bathrooms and toilets should be provided to the owners of OSS. Benefits of regular desludging should be conveyed through mass awareness campaigns, IEC material distribution, electronic media etc. NGOs operating in a city should be consulted or hired for the awareness campaigns.

Sensitization of private operators: Most private operators in this business are not aware about adverse impacts of unsafe disposal of the septage. To limit illegal and unsafe disposal of septage, local authorities should train private operators on correct transportation and disposal methods, and understand challenges faced by them so that they can be addressed properly.

Record keeping: Keeping accurate records regarding tasks and volume pumped is important for billing compliance and forms an integral part of any comprehensive septage management programme.

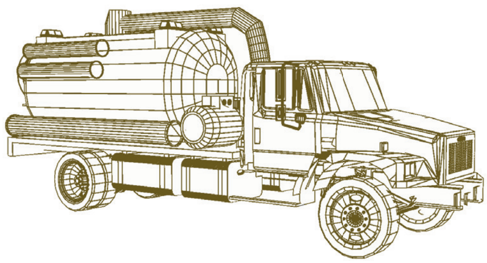
Scheduled desludging: ULBs should ensure that containment systems are desludged as per schedule.

4.4 Transportation

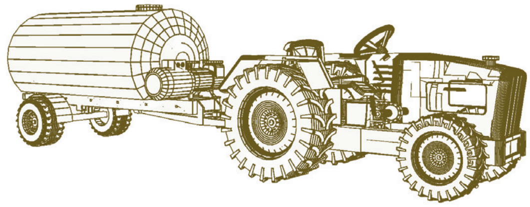
Transportation is a very vital stage in the sanitation value chain and so are safety measures involved in it. Vehicles that carry septage act as mobile sewer networks for OSS. Ideally, an ultimate discharge point of collected septage is an STP or septage treatment plant.

The two main types of vehicles used in India are:
1. Truck-mounted vacuum tankers
2. Tractor-mounted tankers

A truck-mounted vacuum tanker



Tractor-mounted vacuum tanker



Graphic: Sunny Gautam / CSE

Truck-mounted vacuum tankers
These trucks have vacuum pumps with sizes based on lift elevation, pumping distance, volume of sludge to be removed, and volume of the tank. Their capacity varies between 3,000–10,000 litres.

Tractor-mounted vacuum tankers
These vehicles are locally made across India, but their capacity is similar to that of vacuum trucks. The motor, the tank and the tractor are assembled according to the complimenting capacity of each module.

4.4.1 The scenario in India

As mentioned in *Section 4.1.1*, there is a high percentage of OSS in India, generating demand for both private and public emptiers. Predominantly, mini-trucks, tractors and indigenously developed vehicle mounted with pumps are used. The capacities of tanks attached to transportation vehicles, mostly indigenously made, vary from 500–10,000 litres. The vehicles cost between Rs 5–20 lakh each. Vacuum trucks are rare in India due to insufficient funds and lack of manpower to operate them. Private emptying services dominate in cities. They run informal businesses and use factory-fitted tractor-mounted vacuum tankers. At present, no safety standards or traffic rules are followed by these vehicles and they ply on the roads at all times.

4.4.2 Suggested action

Calculating the number of vehicles required: It is essential to determine the number of vehicles required to cater to the needs for transporting sludge in a target area. The advisory issued by the MoUD on septage management in urban India provides a calculation sheet to arrive at the number of vehicles required to fulfil the requirements in a given area.

Route planning for transportation: One of the important issues in the transportation of septage is the cost of fuel. Most private operators illegally discharge septage at the nearest point, they can, from the point of collection. Routes to be taken should be fixed to reduce the cost of transportation as well as minimizing the effects on health and environment. It should be ensured that transporters follow these fixed rules. Appropriate fines should be slapped on violators. The money thus collected can be used by the ULBs to fund the sustainable septage management programme.

The following points need to be considered for safe transportation of septage:

- Registration of septage transportation vehicles with ULB.
- Schedule for cleaning OSS and shortest routes for septage transportation to be determined by responsible organizations.

Tanker on tempo having 1,000 litre capacity (Puducherry)

Vacuum tanker with 3,000 litre capacity (Alwar)

Vacuum tanker with 5,000 litre capacity (Trichy)

Photographs: Bhitush Luthra / CSE

Case study 5: Call center—Senegal

Background

In 2011, the National Sanitation Office of Senegal (ONAS) decided to restructure the mechanical empyting sector with new technical and administrative organizational forms to be adopted in an inclusive and participatory manner. To this end, development of a call center was seen as an effective method for improving services by facilitating better a relationship between clients and service providers. The process of developing and designing the call center took two years, as care was taken to ensure the participation of all relevant stakeholders.

Septage management

- ONAS engaged with Water and Sanitation for Africa and Innovations for Poverty Action for technology interventions.
- Initially, a pilot project was launched to assess the viability of the plan.
- An awareness campaign on the launch of call center was launched.
- Training of truck operators was performed.
- Geo-referencing of trucks was done.
- The call center provides each requirement for emptying as an auction which is sent through SMS as an update.
- The business from call center applies to each truck and not individual businesses.
- Trucks have been segregated area-wise, therefore, bids are sent to the individual trucks plying in that area.
- When an auction is provided, it calls for bids from individual trucks.
- At the end of the bidding period, the lowest bidder is notified.
- In the event that a customer reports on poor quality of service, the relevant operator is penalized in future bids, whereby the offer made is marked up with a fixed penalized amount of CFA Francs 2,000 (US $3.5), which would make the offer less competitive.

Progress of the initiative

- In July 2014, the call center had 138 trucks registered and it had emptied 499 septic tanks.
- The call center model has resulted in a significant decrease in emptying fees. For example, in the Commune of Sicap Mbao, between July 2013 and December 2014, emptying fees had declined by 14 per cent (from US $57 to US $49). The call center service has expanded to the entire city and, on an average, the emptying fee is about CFA francs 24,047 (US $50), with a minimum fee of CFA francs 16,500 (US $35).
- Since the launch of the call center, there has been an increase in the volumes of sludge delivered to treatment plants.
- The model could support, in particular, low-income households struggling with emptying fees, while high-income households might continue personally contracting emptiers, to control who is entering their premises.[40]

Example 3

Question:

In City X, 70 per cent of households dependent on onsite systems are accessible by medium-sized (5,000 litres) vacuum trucks but 30 per cent of households are inaccessible to such trucks, hence smaller Vacutugs (1,000–2,000 litres) or gulpers are required. The utility needs to buy vehicles of two sizes 1,000–2,000 and 4,000–5,000. Calculate the minimum number of trucks needed for each size only to provide service to the household septic tanks. Assume one truck is able to do three trips a day and Vacutugs are able to do four trips a day and the emptying service is provided 285 days a year.

Answer:

Volume of septage generated or to be collected from households (V_1) = 70,175 litres/day.

Assuming 70 per cent of the septage can be collected by the 5,000 litres capacity truck

Number of 5,000 litres capacity trucks = (V_1* 70)/(100 * Average volume of septic tank * number of trips)
= (70,175 * 70) /(100* 3,000 *3)
= 5.45 or six trucks

Rest 30 per cent of the septage would be collected by the 2,000 litres capacity Vacutug.

Number of 2,000 litres capacity Vacutugs
= (V_1* 30 * Number of trips per septic tank)/ (100* Average volume of septic tanks * number of trips)
= (70,175*30*2)/(100 * 3,000 * 4)
= 3.508 or 4 Vacutugs

Example 4

Question

For septic tanks of commercial places and public or community toilets, calculate the number of vacuum trucks of 10,000 litres capacity required in City X?

Answer:

Volume of septage generated or to be collected:

V_2 = 5,692 litres per day

V_3 = 3,509 litres per day

Since the minimum size of the septic tank is 10,000 litres, scheduled desludging of public toilets can be done every alternate day, and for commercial places it needs to be done every third day, hence if the utility can buy two trucks, there will always be a backup for emergency.

Case study 6: Septage collection service by Mysuru City Corporation, Mysuru—India

Background

Mysuru City Corporation (MCC) is active in providing services related to septage collection, which serves as an initial step in septage management. This case study depicts an example of active participation by the municipal authorities to manage septage and avoid the menace that it may cause.

Septage management

- MCC undertakes cleaning of septic tanks; it is done mechanically using suction pumps.
- MCC clears septage by engaging vacuum tankers on request, with a fixed fee of Rs 500 per hour. For this, it provides a dedicated helplines called civil service centre.
- The sewage systems in all wards within the limits of MCC are being maintained by Vani Vilas Water Works and Karnataka Urban Water Supply, and include all work like periodical repair of collapsed manholes, cleaning blocked manholes etc.
- There are three vacuum tankers with the MCC for septage removal, which is disposed of in the existing STPs. The sludge is transported to an STP for further treatment and used for manufacturing compost. The sludge is sun dried in an open area after which it is used as manure in agricultural fields.
- The interval of cleaning is two–three years, but in some cases the cleaning is done once every five years. It is estimated that around 750 septic tanks get cleaned every year.[41]

- All safety procedures must be followed.
- Vehicles transporting septage should be able to ply on the roads only during select hours of the day.

4.5 Septage treatment

Septage collected from various points in the city needs to be disposed of at an appropriate treatment facility. The treatment methods can be conventional or non-conventional. Non-conventional improved methods are recommended for countries where septage management is non-existent. Effluent from septic tanks as well as septage needs treatment.

4.5.1 The scenario in India

In India, septage treatment is not given due attention. Septage is often disposed of untreated in storm-water drains, nullahs, canals, vacant plots, and agricultural fields. Untreated septage is harmful for environment and adversely affects the health of people who come in contact with it.

India has experimented with treatment of septage. A few pilot projects have been tried. Some attempts, like the faecal sludge treatment at Devanahalli, Bengaluru, have succeeded while others, like the one at Musiri, Tamil Nadu

Case study 7: Private emptying service, Bengaluru city—India

Background

In absence of a sewerage network in the conurbation areas, the green belt and rural areas in Bengaluru, OSS, like septic tanks, are common.[42] Due to lack of regulations and resources, the municipal authorities are unable to meet the demand of septage collection or management. This is where the private service providers and farmers in Bengaluru step in to provide an economical model for septage management.

Septage management

A private mechanized truck for emptying septic tanks charges Rs 1,500 per trip and can do five trips a day. One truck can service a population of 20,000, assuming a two year pit emptying cycle. Farmers in Bengaluru provide land (compost pits dug by them) to these private trucks for disposal, and in lieu get free compost in three months.[43]

Land application of septage at the outskirts of Bengaluru

Photographs: S. Vishwanath

Case study 8: Innovative desludging vehicle (Vacutug), Dhaka—Bangladesh

Background

WaterAid, Bangladesh introduced a pilot project in December 2000 for collection and transportation of septage in Dhaka.

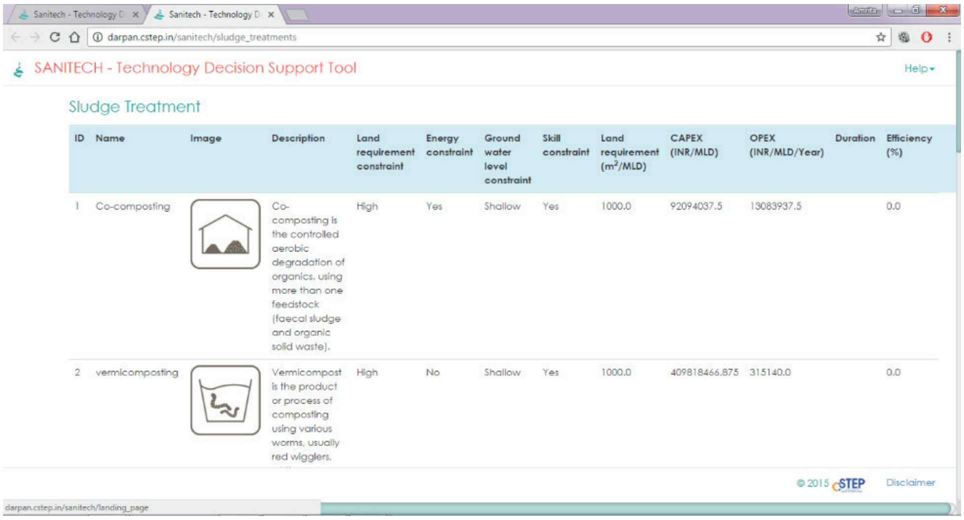
Septage management

- The responsibility of operation and management was delegated to a regional partner Dushtha Shasthya Kendra, which is also responsible for establishing a partnership with the Dhaka Water and Sewerage Authority for the discharge of collected faecal sludge into the main sewer line.
- Vacutug system, that was first used in Kenya, was redesigned and manufactured locally to offer flexibility and mobility without losing the capacity to collect a substantial volume of faecal sludge within one operation. A larger 1,900 litre and a small tank of 200 litre capacity were manufactured. This new Vacutug system was mounted on wheels and could be attached to other vehicles. It became operational in July 2001.[44] The tank takes 10–20 minutes to fill. One complete operation is completed in 90 minutes, which includes preparation and cleaning of the Vacutug after use.
- The Vacutug system garnered interest from other areas as well. Apart from providing services to households in slums and squatter settlements, the facility also responds to demands from households in middle and higher income neighbourhoods, schools and other institutions and factories that are located in other parts of the city.

As a result, within a few months after the commencement of the project, the monthly revenue generated from the Vacutug services was enough to cover the staff salary and maintenance expenses.[45]

have failed due to local socio-economic issues. Land spreading is another method that is practiced in India. Septage is disposed on farm lands for sun drying and the compost prepared is either used locally or sold to other farmers. In the following section, the focus would be on septage treatment. Effluent

Figure 24: Sanitech tool—treatment technologies webpage



Source: http://darpan.cstep.in/sanitech/

separated from septage after dewatering and from septic tanks should be treated further, as discussed in *Section 4.6*. Septage can be treated in various ways, e.g., it can be co-treated with sewage, treated at a dedicated septage treatment plant, or co-composted with municipal solid waste.

4.5.2 How to choose the best treatment?

To choose the best combination of technologies, the existing scenario of a city has to be discussed among the stakeholders. Variables like population density, water usage, type of OSS common in the city, soil strata, water table, land availability, and topography of the city, as well as characteristics of the septage, demand for the end product, capital and operation costs should be considered before deciding on the combination of technologies to be used. A decision-making tool called sani-tech can be used to identify the most suitable combination. This tool can be accessed at http://darpan.cstep.in/sanitech/. It also provides a rough estimate of the costs involved in the implementation of various technologies (see *Figure 24: Sanitech tool—treatment technologies webpage*).

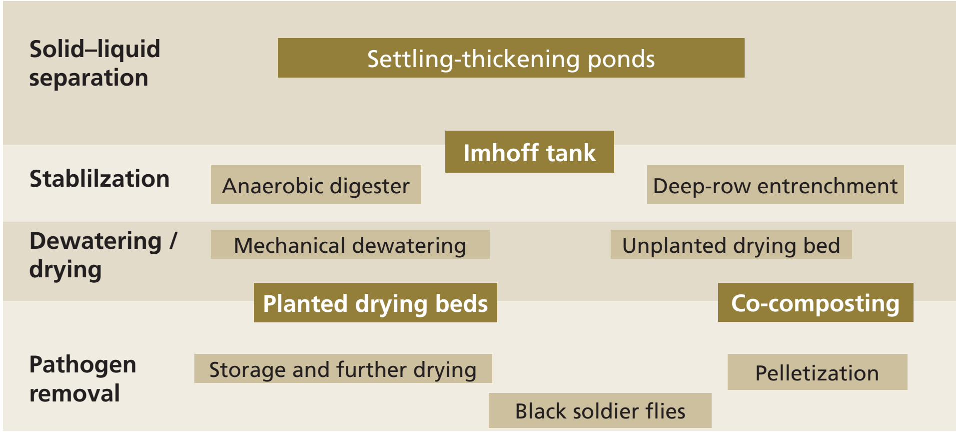
4.5.3 Co-treatment with wastewater

Co-treatment simply means treating septage along with wastewater at a wastewater treatment plant. It is an option which can be considered in India, provided the characteristics of the septage are known, it is diluted with sewage to avoid shock load, and the STP has enough capacity to take the extra load. Broadly, co-treatment can be carried out in two ways:

1. Septage directly mixed with sewage
2. Septage treated with the sludge of an STP

Septage directly mixed with sewage flows: Since most STPs are underutilized, adding septage into existing STPs can be a quick solution to the safe management of septage. Septage can be added to the trunk sewer line either through sewage pumping stations or through a sewer hole adjacent to the STP. Septage can also be mixed with incoming sewage at the STP, right before the screening. The following aspects must be considered while thus mixing faecal sludge or septage:

Figure 25: Different treatment technologies based on their function



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

a) The quality, and not just the quantity, of the sludge, must be evaluated. Most biological wastewater treatment plants are designed and operated based on solid content, BOD, COD and pH.
b) It must be ascertained beforehand whether the septage and sludge contain any toxic chemicals that can destroy biological communities. The presence of trash, grit, and trade and industrial sludge can be toxic and impact biological processes.
c) Consistent compliance of STPs might be an issue.

Septage co-treated with STP sludge: This is a better option because most STPs have land for sludge drying and dewatering. Sludge dewatering sites needs to be improved a bit by designing proper sludge drying beds. Geobags to dewater the septage or sludge can be developed as an alternative option to sludge drying bed. The liquid fraction from sludge or septage can be directed to the STPs. This is a much better option than directly mixing septage into the liquid stream of STPs. Septage, after dewatering, and sludge from STPs can be treated together through co-composting, pyrolysis etc. This solution is feasible only in STPs in the vicinity of the target city, otherwise, sludge transportation cost will be prohibitive.

4.5.4 Septage treatment plant

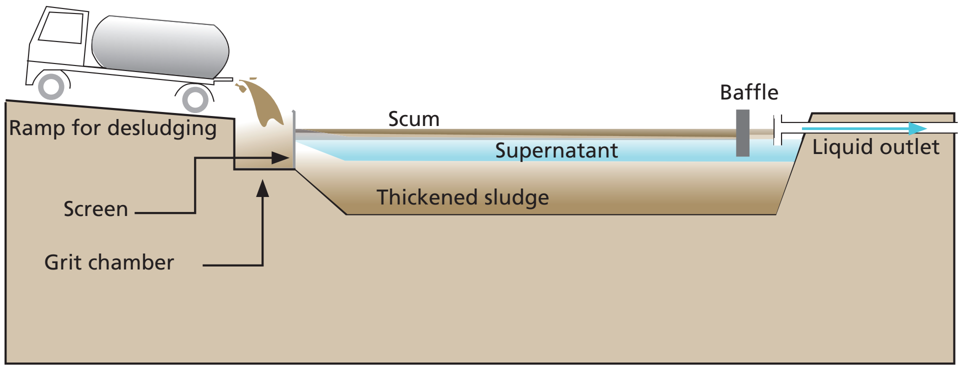
The four main functions of septage treatment are: the solid–liquid separation, stabilization, dewatering or drying, and pathogen reduction (see *Figure 25: Different treatment technologies based on their function*). Potential end-uses are in fertilizers, as fuel (biogas) etc. Collected septage can be passed through a screen to remove unwanted solid wastes which might interrupt in the treatment process.

It is important to understand that in order to achieve complete treatment, a combination of two or three technologies is ideal. A brief description of the technologies is given as follows.[46]

Settling-thickening (solid–liquid separation)

Settling-thickening technologies thicken and dewater septage. Solids settle to the bottom as the septage flows from one end of the pond or tank to the other (see *Figure 26: Settling-thickening pond*). The liquid (effluent) flows through the outlet and requires further treatment. Some solids (for example, fats, oil and grease) float to the top and form a layer of scum. Examples of these technologies

Figure 26: Settling-thickening pond



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

include settling-thickening tanks or ponds, settlers, Imhoff tanks and septic tanks. Settling-thickening technologies operate semi-continuously. They often include two lined ponds or tanks, while one is in operation, sludge thickens in the other. Septage is then pumped out for further treatment. Septage is removed every month to every few months. Other than pumping, settling-thickening technologies require low amount of energy.[47]

Mechanical dewatering

Mechanical dewatering technologies include belt-filter press, frame-filter press, screw press and centrifuge. Mechanical forces dewater septage (for example, centrifugal force). Conditioners are often added to the septage before mechanical dewatering. Conditioners are products that help dewater the sludge more efficiently. Mechanical dewatering is fast (takes only minutes or a few hours) and requires less space, but it uses large amount of energy.[48]

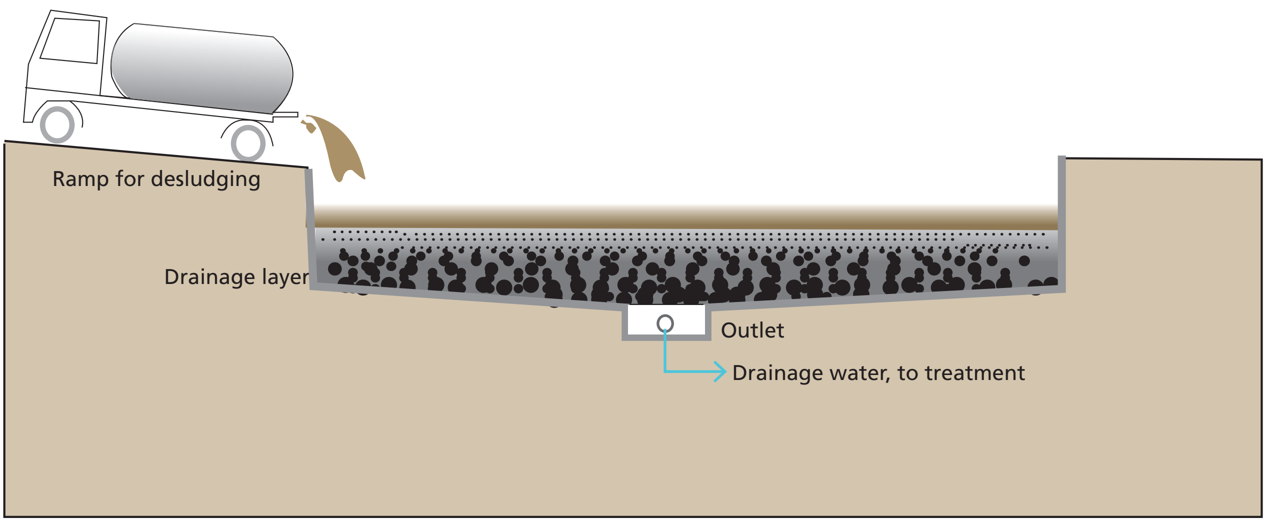
Deep-row entrenchment (stabilization)

Deep-row entrenchment is a method of disposal and soil modification which consumes little energy. Its design and operation ensure that groundwater is not contaminated. The length and depth of a trench depends on the highest groundwater level and quantity of faecal sludge. A trench can be lined with clay and other material to reduce the risk of groundwater contamination. Entrenchment is done in batches. Untreated faecal sludge is placed in trenches and covered with soil. Trees can be planted on top or next to the trench.[49]

Anaerobic digester (stabilization)
Input sludge undergoes solid–liquid separation beforehand. The stabilized (digested) sludge needs further drying and pathogen removal. There is a solid retention time of about 10–15 days. Organic matter is thus converted into biogas. This process ensures effective sludge digestion and stabilization. Removal of accumulated solids from the digester remains a challenge.[50]

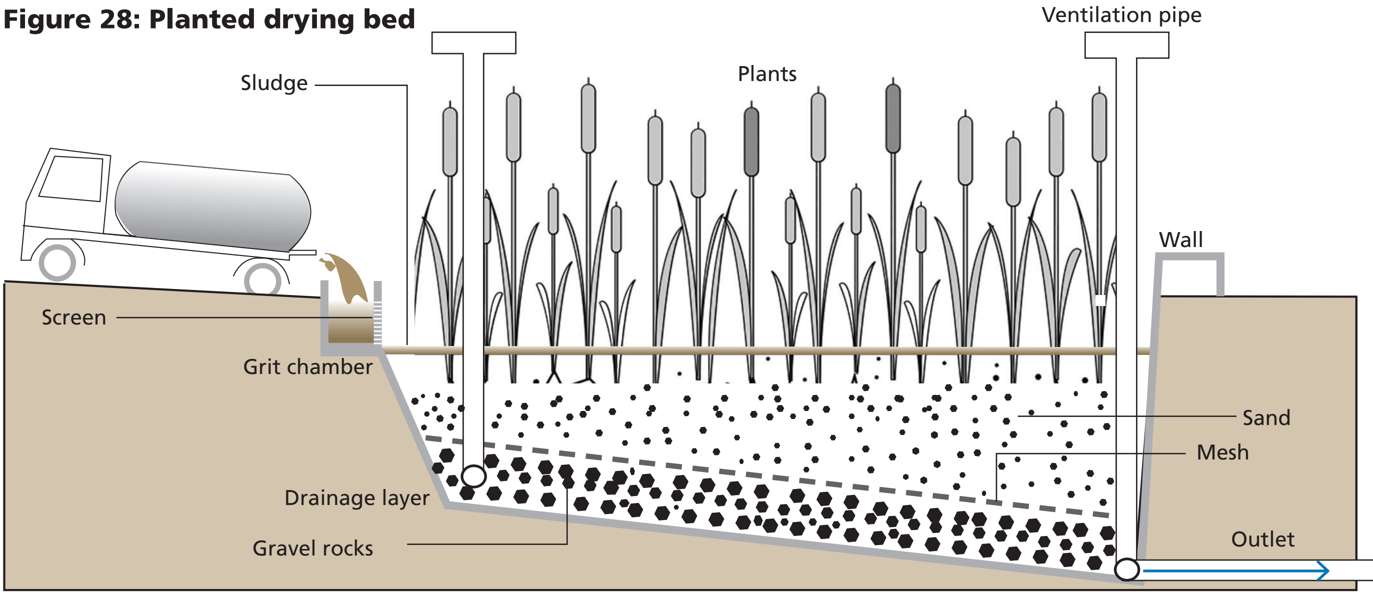
Unplanted drying bed (dewatering)
The main objective of the energy-saving unplanted drying bed method is dewatering. The bed is filled with filter material, usually gravel at the bottom and sand on top. The bottom is sloped and lined with perforated pipes to drain away the effluent. Unplanted drying beds are operated in batches. Sludge is placed on the surface of the bed and the liquid flows through the sand and gravel for a period of days. The majority of the solid portion of the sludge stays on the surface. The remaining water in the sludge is removed by evaporation. The dewatered sludge is then removed from the surface manually or mechanically, once every few weeks or months.[51]

Figure 27: Unplanted drying bed



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

Figure 28: Planted drying bed



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

Planted drying bed (dewatering and stabilization)

The main objective of the energy-saving planted drying bed method is dewatering and stabilization. The bed is filled with filler material, usually gravel at the bottom and sand on top. Plants selected for a specific climate grow in the filter media. The bottom of the bed is sloped and lined with perforated pipes to drain away the effluent.

Planted drying beds operate semi-continuously. Faecal sludge is placed on the surface of the bed and the liquid flows through the sand and gravel. The majority of the solid portion of the sludge stays on the surface. Some of the remaining water in the sludge is removed by evapo-transpiration. Sludge can be loaded on the beds without removal for a period of one–three years. Dewatered sludge is stabilized. Dewatered sludge is removed every few months to years. Plants are harvested according to their growth cycle.[52]

Lime stabilization

Lime stabilization is the process by which hydrated lime (calcium hydroxide) is added to septage to form a product that can be disposed of on land for use as a fertilizer. The process requires approximately 12–20 kg of hydrated lime for every 4,000 litres of septage. Once the lime and septage are mixed, the pH is raised to 12 and kept thus for a minimum of 30 minutes. This kills any pathogens present. The material can then be more easily handled for final disposal. Several readings of pH during the mixing process must be taken to determine the exact amount of hydrated lime required.[53]

There are two common ways to perform lime stabilization:

1. Adding lime directly to a vacuum truck. Lime can be added either before or after the septage is pumped out. The pump in the truck can then be used to mix the lime and septage. This method only works in case of stainless steel tanks.
2. Adding lime to the septage pit daily or weekly. The frequency of adding lime depends on the quantity of septage; if it is under 20,000 litres per week, adding lime weekly is sufficient; if it is over 20,000 litres per week, lime should be added daily.

A simple earthen pit works well for lime stabilization. Typical pits are 4 x 3 x 1.5 m (height, width and depth), and have a capacity of 40,000 litres. Two pits are recommended for a long-term operation, to be used alternatively. Typically, the pits would be lined, but if the soil contains sufficient amount of clay, it may be compacted to prevent seepage and save the cost of lining.

Composting

Composting is a popular method of treating septage. Composting may be defined as the stabilization of organic material through the process of aerobic, thermophilic decomposition. During the composting process, organic material undergoes biological degradation to form a stable end product. Approximately 20–30 per cent organic solids are converted to carbon dioxide and water. As the organic material in the septage decomposes, the compost heats to temperatures in the range of 50–70°C and harmful pathogens are destroyed. The resulting humus-like material is suitable as a soil conditioner and source of nitrogen and phosphorus.[54]

Septage can be composted directly. The basic procedure for composting is as follows:

1. Septage or wastewater solids are mixed with a bulking agent, (e.g. wood chips, sawdust) to decrease the moisture content of the mixture, increase porosity, and assure aerobic conditions during composting.
2. The mixture is aerated either by the addition of air (aerated static pile) or by mechanical turning (agitated) for about 28 days.

The most common agitated method is windrow composting in which the mixture of septage or wastewater solids and bulking agent is pushed into long parallel rows called windrows, about 1–2 m high and about 2–4.5 m wide at the base. The cross-section is either trapezoidal or triangular. The mixture is turned over several times a week. Although specialized equipment has been developed for windrow composting, it is possible to use a front-end loader to move, push, stack, and turn the mixture.

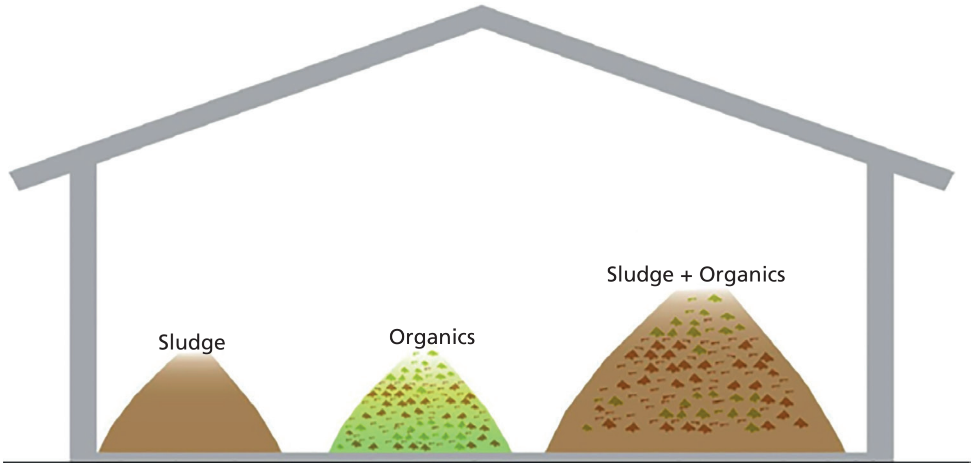
Factors affecting the composting process include moisture (40–60 per cent) and oxygen (5–15 per cent) content; temperature (must reach 55–65°C); pH (6–9); and carbon–nitrogen ratio (30:1).

For the operation to be smooth, there should be sufficient laboratory equipment to monitor these parameters during the compost process. Moisture can be added and turning can be increased based on monitoring results. The operator should measure temperature at least once every day by placing a thermometer into the mixture at various locations. Maintaining temperatures of 50–60°C for the compost period assures destruction of pathogens.

Co-composting

Co-composting is composting of septage along with the organic fraction of municipal solid waste (see *Figure 29: Co-composting of septage with organic waste*). The organic fraction includes food waste, paper, yard waste (e.g. leaves and branches) cut or removed during landscaping. Co-composting is done in batches. Septage and other organic material are placed in piles or rows. Various parameters need to be controlled to ensure an optimal composting process, including temperature, moisture, carbon–nitrogen ratio and oxygen concentration. Co-composting takes several months and needs low amount of energy. The process produces compost, a dark, rich soil-like material which can be used as a soil conditioner.[55]

Figure 29: Co-composting of septage with organic waste



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

Aishwarya Varadharajan / CSE

Black soldier fly larvae

Black soldier fly larvae eat septage, and in doing so they reduce the volume and stabilize the sludge. Black soldier fly larvae are rich in fat and protein. They are fed to livestock as a source of protein. Black soldier fly larvae treatment is done in batches or semi-continuously. Septage is placed in a container with black soldier fly eggs or larvae. Other organic waste streams can be added as well to be co- treated. The larvae are harvested periodically to be fed to livestock. Larvae digest septage in days. The technology needs low amount of energy.[56]

Black soldier fly larvae

Source: http://farmerfredrant.blogspot.in/2010/06/what-are-those-bugs-in-my-compost.html

Pelletizing

Dewatered sludge is processed into pellets by pressing it through a nozzle or plate. Pellets are dense, consistent in composition, and relatively easy to store, transport and market. Pelletizing can be used to enhance drying, for example, with the bio-burn process that can process pellets at 50 per cent moisture that can dry to 90 per cent without additional thermal energy. Pelletizers dewater or dry sludge when they are combined with other technologies, such as thermal dryer in the LaDePa technology. Other pelletizing technologies require that the sludge is first dried, and then compressed into pellets with a binder. Pelletizing takes seconds and requires a low amount of energy, which varies with the technology used.[57]

Lagoon
The simplest septage treating lagoon consists of two earthen basins arranged in series (see *Figure 30: Lagoon technology*). The first or primary lagoon (may or may not be lined, depending on the local geological conditions) receives raw septage. The supernatant liquid from the primary lagoon, which has undergone some clarification and possibly anaerobic digestion, is transferred into the second lagoon, or percolating pond, where it is allowed to infiltrate into the ground. It is also possible to have multi-celled lagoon systems with either surface discharge or land application of effluent.[58]

Geotube bags
Geotubes, containers and bags are made from porous tubular containers fabricated with high strength woven geo-textiles (polyethylene material) mainly used for dewatering sludge. Geotubes have high durability, low maintenance, low energy or fuel consumption, and they do not require additives. These bags are all-weather and environment-friendly and trap all solids in FS.[59] The solids collected can then be transported to a landfill site for disposal or sent for recovery of nutrients and then used as a soil conditioner. Geotubes significantly reduce the operation and maintenance costs.[60] A list of possible technologies, with reference to requirement of land, money, energy and performance is attached as *Appendix 6*.

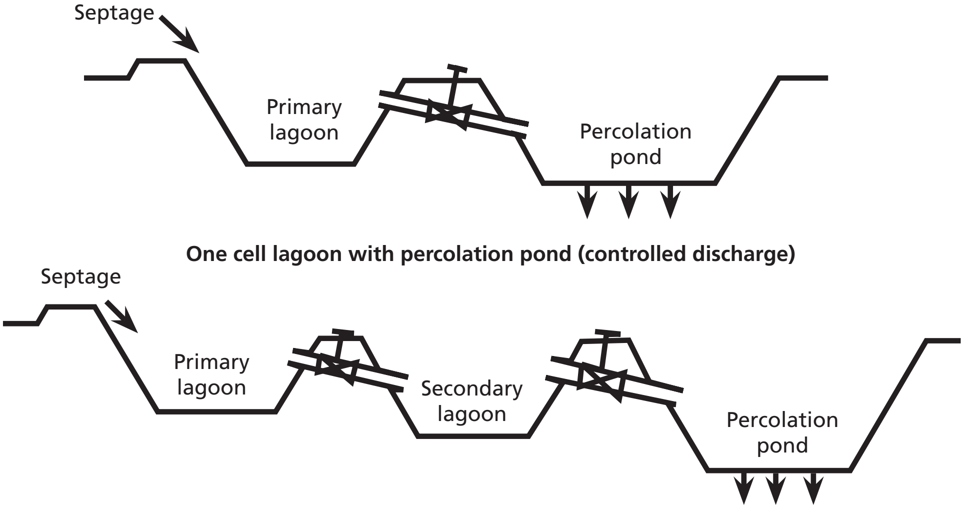
4.5.5 Suggested actions

Septage characterization: Currently, there is negligible information about the characteristics of septage desludged from containment systems of different agro-climatic regions of India. Academic research institutions or accredited

Pelletization—dewatered slugde broken down into smaller pieces as shown in the picture are used as fuel, compost etc. These are light in weight and easy to transport

Source: JAEE, 2002

Figure 30: Lagoon technology



Source: USEPA, Handbook: Septage treatment and disposal, 1994

laboratories in India should be consulted to determine septage characteristics. This will help in selecting the appropriate technological option that suits the local and regional conditions.

Site selection and land allocation: Instead of one big piece of land, smaller pockets should be identified for establishment of decentralized septage treatment plants**.** The sites should be selected considering the spatial spread of OSS in the city. One of the main objectives is to reduce the distance covered by vacuum trucks and, eventually, the cost of conveyance.

Pilot projects: ULBs can take up pilot projects under various programmes sanctioned by the government of India. Pilot projects should be implemented by ULBs with minimum support from consultants. ULBs should own these

Geotube bags—these bags are extremely useful in dewatering of sludge, as shown below a geotube bag bloated with septage

Source:http://www.tencate.com/apac/geosynthetics/product/dewatering-technology/dewatering-container.aspx

Case study 9: Treatment system at Bansberia, West Bengal—India

Background

The project was initiated by a concerned citizen of Bansberia city located in West Bengal, India. The main aim was to handle septage which was being discharged into River Ganga. The project is a joint venture between Bansberia Municipality and Greenery Biocompost and Animal Farming Pvt Ltd. The private company receives septage from the entire city and then converts it into poultry waste through bio-composting.

Septage management

Capacity of the treatment plant: 1,500 metric tonnes per year
Area of the facility: 2.75 hectares
Technology used: Sludge drying beds
Daily septage received: 12,000 litres
Treatment process:

Step 1: Septage is spread on sludge drying beds and dried for two–three weeks until maximum water evaporates. This excreta consists of 1 per cent nitrogen. In order to increase the nitrogen content, poultry excreta (with 3 per cent nitrogen content) is mixed with it.

Step 2: Lime is added to the sludge in order to kill the pathogens and increase the rate of composting. It takes around three weeks to dry this sludge. Once dried, it is stored in bags for two weeks.

Step 3: This dried sludge is then spread out in a small area and kept for it to receive rainfall for at least a year. Due to its high nitrogen content, it becomes suitable for plant growth and the plants help in maintaining the pH of the sludge at around 6.5–7.

Step 4: A three layer compost is prepared to form one half of the bio-compost. The above mentioned dried sludge forms the first layer. Leather ash forms the next layer on top of this. Leather ash, which is high in nitrogen and potassium is the remnant which is formed after boiling slaughterhouse leftovers such as animal skin.

Step 5: "Kheri", as it is called in Hindi, forms the third layer on top of the leather ash. Animal blood from slaughterhouses and coconut peel mixed with husk forms Kheri. This layer is rich in iron, calcium and nitrogen. All three layers are mixed well and kept aside. This forms the faecal compost.

Step 6: Alongside the faecal sludge treatment, Vermicomposting of cow dung and kitchen waste also takes place separately. Vermicompost is mixed with faecal compost and is sieved well. The final product is called bio-compost. In order to enhance the quality of the biocompost, neem seed powder may be added to it. Each biocompost sack (weighing 50 kg) sells at Rs 850.

Septage management pictures depicting composting process at Bansberia

Photographs: Aishwarya Varadharajan / CSE

projects. The implementation and results should be systematically documented for up-scaling the implementation and replicate it in other parts of country.

Pre-feasibility studies, including EIA: Pre-feasibility studies and an EIA should be performed before setting up a septage treatment plant.

4.6 Effluent treatment

There are two types of effluents:
1. The effluent or supernatant which drains out of the septic tank.
2. The effluent which is separated out from the septage after dewatering.

Case study 10: Gravity-based biological septage treatment plant, Devanahalli—India

Background

Devanahalli town has a population of around 23,406 people. Most households depend on septic tanks and soakpits for sewage disposal. There are about 5,110 septic tanks as per the municipal council. There is neither an underground sewerage connection nor any organized septage treatment facility in the area, which leads to washing of septage into existing open drains. The objective of this project was to establish a pilot independent septage treatment unit and treat sewage as per the prescribed standards.

Septage management

Gravity-based biological treatment technology in an area of 650 sq m has been used. The plant is mostly underground, completely covered and odourless. For treatment, septage passes through five different units: 1. A feeding tank with a screen chamber is the first unit which traps large solids. Screened septage enters the biogas settler (BGS), where it gets settled and liquid supernatant is formed on the top. 2. Sludge accumulated in the BGS moves to a stabilizing tank and the stabilized sludge is disposed of into sludge drying beds for dewatering. This dried sludge can be used as a soil conditioner. 3. The liquid supernatant from the BGS moves to a DWWT system which consists of two chambers of a settler, five chambers of an anaerobic baffled reactor, and one chamber of an anaerobic filter. After this, it is finally treated through a planted gravel filter bed. This treated liquid can be end used for gardening.[61]

Devanahalli septage treatment plant

Photographs: Bhitush Luthra / CSE

Case Study 11: Nonthaburi septage treatment facility—Thailand

Background

The Nonthaburi septage treatment facility is an example for its public outreach as a service provider, spreading awareness in the community about the facility, and generating revenues by selling fertilizer.

Source: USAID, 2010

Nonthaburi septage treatment facility

Septage management

- The septage collected from the septic tanks first undergoes anaerobic digestion, after which the digested sludge goes to a drying bed. The liquid portion filters through sand beds from the sludge drying beds and goes into an oxidization pond.
- The treated septage (both liquid and solid) is then used as a fertilizer in the city's public parks and surrounding green areas.
- The plant also has its own collection vehicles.
- There is a growing demand for both septage collection and fertilizer in the area which has influenced Nonthaburi to expand its facilities.
- The Ministry of Public Health has formulated policy and technical guidelines to collect and treat septage.
- The Public Health Act (1992) has commissioned local government authorities for septage management.[62]

Case study 12: Dumaguete—Philippines

Background
Dumaguete's Septage Management System demonstrates what small cities with good governance can do to protect their groundwater resources through low cost and simple technologies in the absence of a sewerage system.

In 2006, the city government of Dumaguete, with technical assistance from the USAID adopted a septage management programme in a joint venture with the Dumaguete City Water District, the local water utility company.

To legitimize the proposed programme, the government adopted an ordinance mandating the establishment of a city-wide septage management system with provisions on the proper design, maintenance, regular de-sluding of septic tanks, treatment of septage and 'user fee' to recover capital and operating costs.

Site picture, Dumaguete, Philippines

Source: Local government financed city-wide septage management system, Philippines

Septage management
The city has constructed a septage treatment plant which uses stabilization ponds composed of anaerobic, facultative and maturation ponds. A planted gravel filter and wetland is used for polishing operations.

At first, the incoming septage passes through a set of anaerobic lagoons, where majority of BOD and total suspended solids (TSS) are removed. The anaerobic lagoon is 3 m deep and provides a 60 day detention period, thereby removing 60–75 per cent BOD and TSS.

Next, the effluent flows into the facultative lagoon where both aerobic and anaerobic bacteria consume much of the remaining organic material present.

The final lagoon cells provide effluent polishing so that the effluent can be directly discharged into the Ocoy River. Although sewage lagoons are relatively inexpensive to construct and operate, they require more land than mechanized septage treatment facilities. Hence, in areas where land is abundant and inexpensive, sewage lagoons can be considered a good option for septage management.[63]

Case study 13: Integrated septage treatment facility—Indonesia

Background
An integrated septage treatment facility has been constructed with the assistance of the Bremen Overseas Research and Development Authority in Aceh, Indonesia. The treatment system became operational on 22 June 2006, and it treats up to 60 cum of septage sludge every day and receives most of the waste from the cities of Banda Aceh and Aceh Besar with a total population of 250,000.

Septage management
This treatment facility combines and utilizes several technologies such as anaerobic digestion, biogas generation, sludge drying and constructed wetlands for septage treatment and end use.

There are a series of steps followed to treat the septage sludge. The first step involves extraction of biogas from the waste. This gas is utilized for cooking.

The second step involves the sludge passing through drying beds. A large amount of this sludge is converted into compost, which is sold and used for farming. The remaining effluent is treated in a series of anaerobic reactors, through a gravel filter followed by a maturation pond. The final effluent can be safely discharged into the sea.[64]

Example 5

Question:
Assuming that the peak load of septage in City X any given day is less than 80 m^3. Calculate the number of treatment plants and design one treatment plant with unplanted drying beds, providing the size and number of beds required, given that average total solids content of septage is 20 g/l and maximum height of septage in one bed cannot exceed 30 cm.

Answer:
The number of treatment plants, their capacity and site location is a site-specific question. The treatment plants should be strategically located so that the distance from the area with onsite sanitation dependence is minimized.

If we assume that onsite systems are prevalent all over the city, three treatment plants of 30 KLD each should be enough.

To design a plant based on unplanted drying bed, we should understand the sludge load and average total solids content of the septage.
SL = TS x Q x N
Where,
SL is sludge load (in kg TS/year)
TS is average total solids content (in kg/m^3)
Q is incoming septage per day (m^3/day)
N is number of delivery days (days/year)
SL= 20 x 30 x 285
= 171,000 Kg TS/year

Sludge loading rate (SLR) of 200 kg/m^2/year is recommended
Hence total area required for drying bed would be:
Total bed area = SL/SLR = 171,000/200 = 855 m^2

Volume of septage delivered is 30 m^3 and maximum depth allowed is 0.3 m.
Area of one bed assuming all the load for one day would be discharged in one bed only.
Area of 1 bed = 30/0.3 = 100 m^2
Total no. of beds required = 855/100 = 8.55 or nine beds

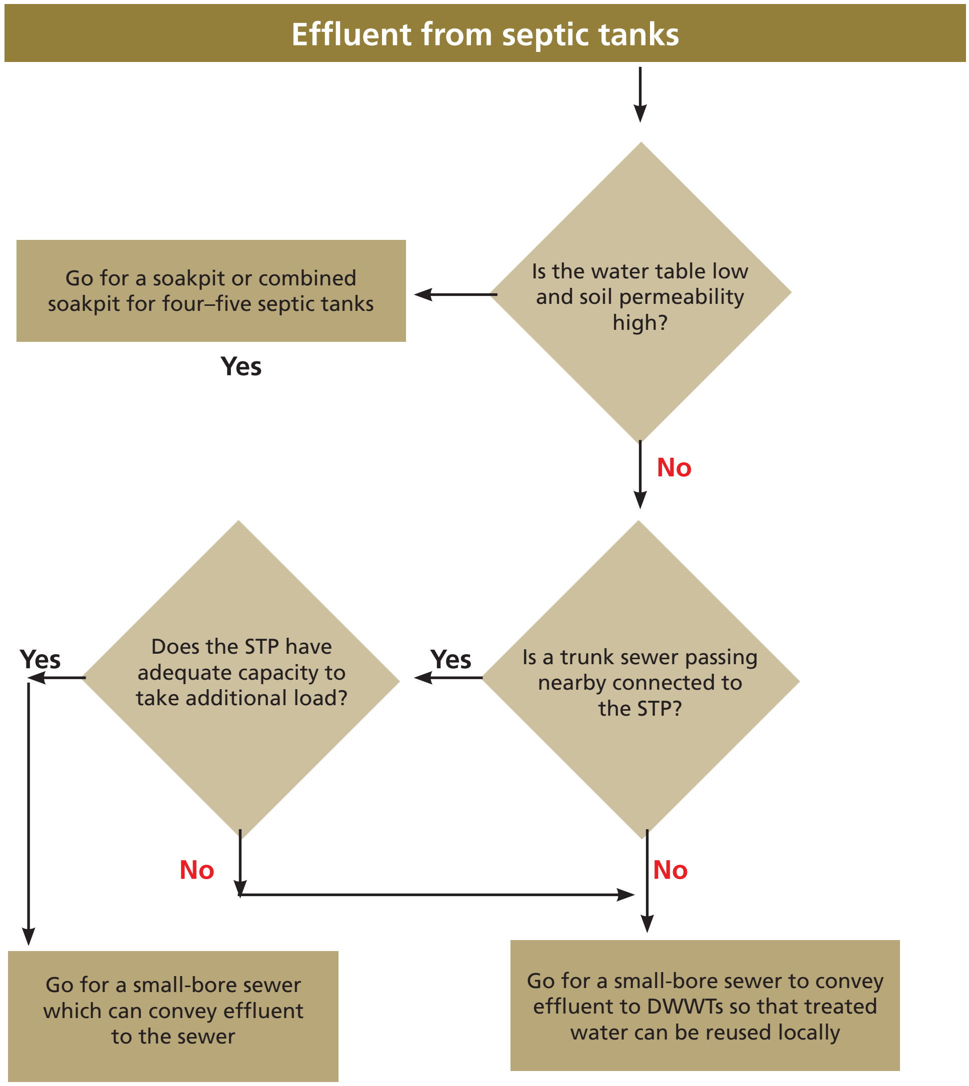
If the septage is delivered five days a week and the time taken in dewatering is approximately two weeks, then it would be better to have ten beds of 100 m^2 each with a working depth of 30 cm, so that 30 m^3 of septage can be discharged to one bed every day. The dewatered sludge should be removed for further processing.

Both types of effluent need further treatment to meet the end use or discharge standards. The former can be tackled in following three ways:

a) **Discharged into a soakpit or soak-away**: This option can only be used if there is enough land available at the household level and the water table is low (more than 10 m deep) throughout the year. Four or five septic tanks can be connected to a common soak pit as well.
b) **Conveyed to the nearest trunk sewer via small bore or solid free sewer**: Effluent from septic tanks of a community or society can be conveyed using a small bore or solid free sewer to the nearest trunk sewer. This option can only be used if there is an existing STP with spare capacity.
c) **Conveyed to the DWWTs**: Effluent from septic tanks of a community or society can be conveyed using a small bore or solid-free sewer to a decentralized wastewater treatment plant. The treated water can be end used for horticulture, toilet flushing, car wash etc.

To decide on the type of effluent treatment to be undertaken, see *Figure 31: Flowchart to select suitable effluent disposal method*.

Figure 31: Flowchart to select suitable effluent disposal method

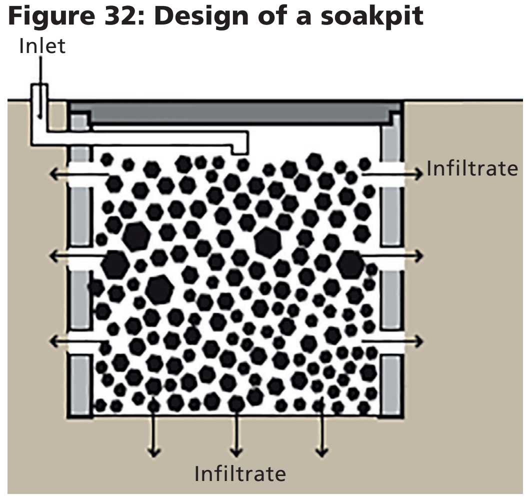


Source: Compiled by CSE, 2017

4.6.1 Soakpit or soak away

A soakpit, also known as soak away or leach pit, is a covered, porous-walled chamber that allows water to slowly soak into the ground (see *Figure 32: Design of a soakpit*).[65] Effluent from septic tanks is discharged into an underground chamber from where it infiltrates into the surrounding soil. These pits can be lined with semi-permeable walls or can be unlined and filled with rocks.

Figure 32: Design of a soakpit



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

4.6.2 Small-bore sewer

A small-bore or solids-free sewer is a network of small-diameter

Example 6

Question: Designing a soakpit

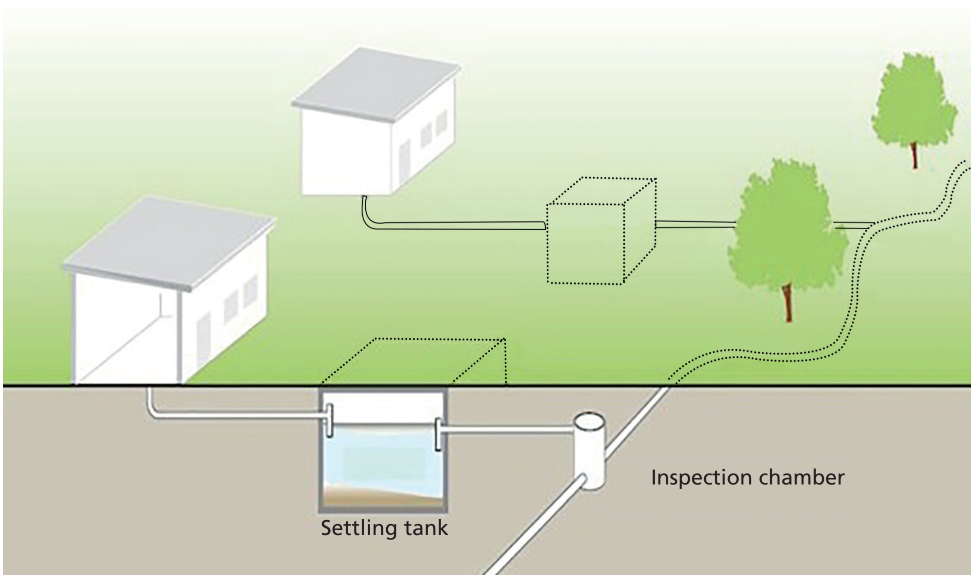
Answer:
To calculate the area of the soakpit that does not include the base.
WA = DF / SIR
e.g. WA = 540 L / 50 L/m^2 = 10.8 m^2
WA = Wall area
DF = Daily flow
SIR = Soil infiltration rate

To calculate pit dimensions below inlet pipe.
D = WA / π x PD
e.g. D = 10.8 / 3.14 x 1 = 3.4 m
D = Depth in meters
PD = Pit diameter in meters.
π = 3.14

Add depth of inlet pipe or 0.5m whichever is the highest.[66]

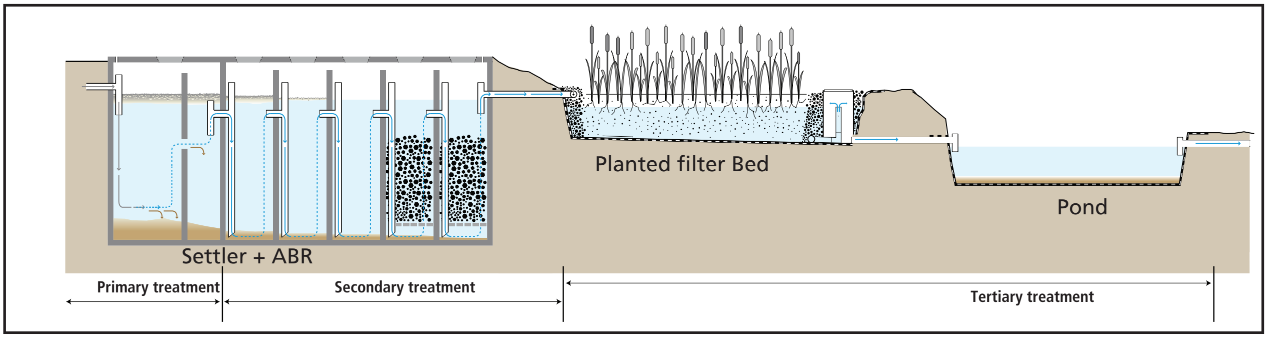
pipes that conveys pre-treated and solids-free wastewater (such as septic tank effluent) to a treatment facility for further treatment, or to a discharge point (see *Figure 33: Solids-free sewer or small-bore sewer*). As solids are removed, the diameter of the sewers can be much smaller than for conventional sewers, the recommended pipe diameter is 75 to 100 mm. They can be installed at a shallow depth, at least 300 mm, and do not require a minimum wastewater flow or slope to function. Thus, construction costs are lowered. Solids-free sewers can be built for new areas or where soil infiltration of septic tanks effluents (e.g. via leach fields) is not appropriate anymore (i.e., densely populated areas or clogging of sub-surface). Although solids-free sewers require a constant supply of water, less water is needed compared to conventional sewers because self-cleansing velocity is not required.[67] The differences between small-bore systems and large-bore systems have been enumerated in *Appendix 7*.

Figure 33: Solids-free sewer or small-bore sewer



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

Figure 34: Decentralized wastewater treatment system



Source: Toolkit on Decentralized Wastewater Management, CSE, 2013

Septic tanks have to be emptied periodically so that no solids enter the small-bore sewer. The network should also be flushed once a year for smooth operation of the sewers.

4.6.3 Decentralized wastewater management

Instead of having one big conventional STP in the outskirts of a city, many small STPs can be developed within the city. Grey water can also be treated along with the effluent from septic tanks. The main advantage of such an approach is that sewage is not supposed to be conveyed or pumped to long distances and the possibility of end use of treated water increases manifold. The level of end use should decide the level of treatment. These systems generally range from a capacity of 5 KLD to 1 MLD and should be installed at septage treatment units as well, to take care of the effluent after dewatering. Details of case studies can be found at http://CSEIndia.org/node/3798.

Decentralized wastewater treatment system

DWWTS is a combination of different systems such as a settler or biogas digester, anaerobic baffled reactor, planted gravel filter bed (horizontal or vertical) and polishing pond or vortex system (see *Figure 34: Decentralized wastewater treatment system*). These systems are based on natural wastewater treatment techniques and are designed in accordance with different parameters such as the characteristics of wastewater, quality of treated wastewater to be achieved, and site and technical specifications. In these systems, both aerobic and anaerobic treatment processes occur. DWWTS applications are based on four basic treatment processes:

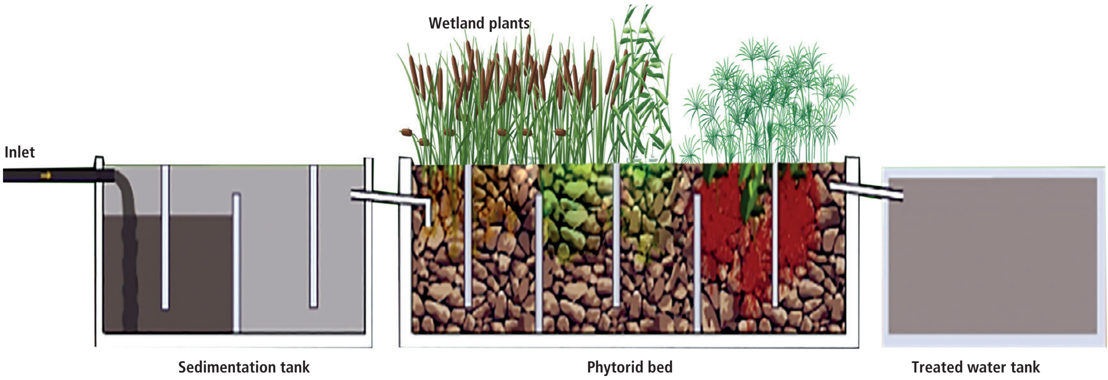
1. Primary treatment includes pre-treatment and sedimentation in settlers or septic tanks
2. Secondary anaerobic treatment in baffled reactors
3. Tertiary aerobic or anaerobic treatment in planted gravel filter beds
4. Aerobic treatment in polishing ponds

Refer to *Case Studies 14* and *15*.

Phytorid wastewater treatment technology

The phytorid treatment system, developed by National Environmental Engineering Research Institute (NEERI), is a sub-surface flow type in which wastewater is discharged into a cell or system filled with porous media such as crushed bricks, gravel and stones (see *Figure 35: Phytorid treatment technology*). The hydraulics are maintained such that the wastewater does not rise to the surface by retaining a free board at the top of the filled media. The

Figure 35: Phytorid treatment technology



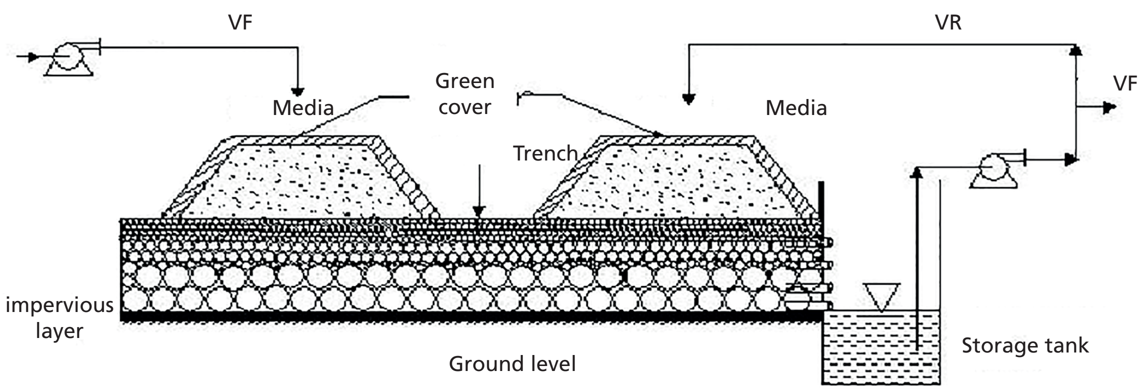
Source: NEERI, 2016

system consists of the following three zones: (i) an inlet zone comprising of crushed bricks and different sizes of stones, (ii) a treatment zone consisting of the same media as the inlet zone with plant species, and (iii) an outlet zone. The reduction in the treated effluent for the TSS varies from 70–80 per cent, BOD from 78–84 per cent, nitrogen from 70–75 per cent, phosphorus from 52–64 per cent, and faecal coliform from 90–97 per cent. The treated effluent can be used for irrigation, horticulture and in fountains. The total area required for a system with a capacity of 20 KLD is approximately 35 sq m.[68]

Soil biotechnology

Soil biotechnology (SBT) is a terrestrial system for wastewater treatment which is based on the principle of trickling filter (see *Figure 36: Schematic of an SBT plant*). This technology has been developed by Indian Institute of Technology, Mumbai. SBT engages three fundamental processes of nature: photosynthesis, respiration and mineral weathering. Suitable mineral constitution, culture containing native micro-flora and bio-indicator plants are the key components of the system. It is also known as constructed soil filter. SBT systems are constructed from reinforced cement concrete, stone-masonry or soil bunds. It consists

Figure 36 : Schematic of an SBT plant



Source: Toolkit on Decentralized Wastewater Management, CSE, 2013 of a raw water tank, a bioreactor containment, a treated water tank, piping and pumps.[69]

Electro-mechanical or packaged sewage treatment plants
Space constrained ULBs can go for energy-intensive small-scale STPs, based on up-flow anaerobic sludge blanket (UASB), sequential batch reactor (SBR), membrane bioreactor (MBR), moving bed biofilm reactor (MBBR), activated sludge process (ASP), etc. Generally, these systems are able to meet discharge standards. These systems occupy less space but are capital-intensive. Their operation costs are also high because they consume large quantities of energy.

Constructed wetland
A constructed wetland is a large gravel and sand-filled horizontal or vertical sub-surface channel that is planted with aquatic vegetation (see *Figure 37: Horizontal flow constructed wetland*). As wastewater flows through the channel, the filter material sieves out particles and attached micro-organisms degrade organic material. The water level in a horizontal sub-surface flow constructed wetland is maintained at 5–15 cm below the surface to ensure sub-surface flow.[70] Horizontal flow constructed wetlands (CW) are relatively inexpensive to build where land is affordable and they can be easily maintained by the local community as they require no high-tech spare parts, electrical energy or chemicals. It has been established that a horizontal filter bed area of about 2

Case study 14: Decentralized waste water treatment system at Banker's Colony, Bhuj, Gujarat—India

Background
The Banker's Colony in Bhuj, Gujarat lies below the level of the main sewer line passing near the area. Therefore, it was not possible to connect the sewer line of the colony to the main line.

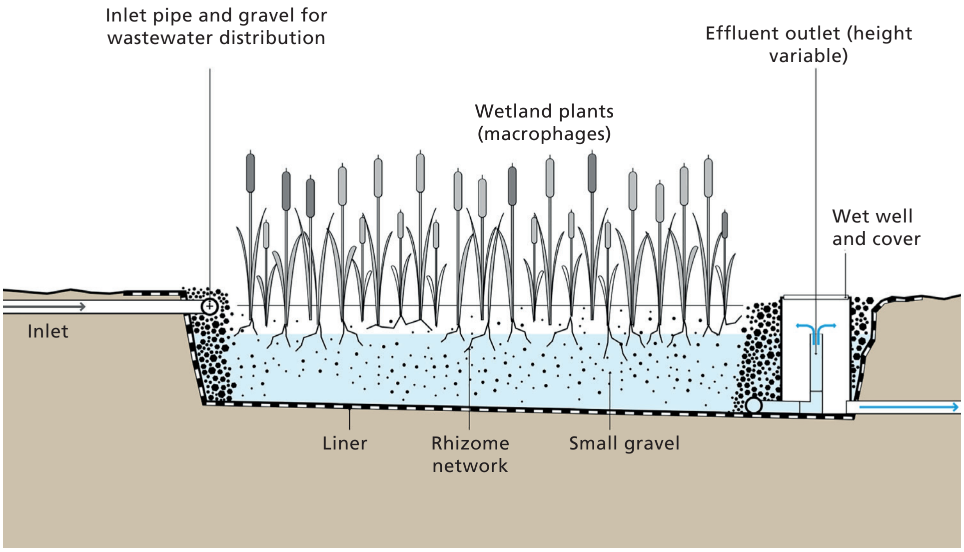
Banker's Colony site photograph

Source: https://www.flickr.com/photos/indiawaterportal/sets/72157603997548941/

Wastewater management

- A 30 KLD DWWT was constructed in 2006. The treated wastewater is used to irrigate a green belt in the colony. With support from the Bhuj Municipality, Hunarshala Foundation, in association with Kachchh Navnirman Abhiyaan, undertook this project to implement the system.
- The system has been designed keeping in view optimized use of space. Overflow from the system is diverted to a storm-water drain and ultimately discharged into the city lake called Hamirsar, in the centre of the city.
- Controlled discharge of treated wastewater from the colony, which was otherwise not possible due to local topographical constraints, has been achieved.
- Reduction in concentration of key indicators in the treated water: BOD—91 per cent, COD—81 per cent; and TDS—98 per cent.[71]

Figure 37: Horizontal flow constructed wetland



Source: Compendium of sanitaiton systems and technology, EAWAG, 2014

m² per person equivalent is sufficient for the complete secondary and tertiary treatment of wastewater, including the removal of pathogenic germs.[72]

4.7 Resource recovery

Goal 6.3 of Sustainable Development Goals encourages to increase recycling and safe end use globally. Goal-6.3 is interlinked to the Goal 2.3 which talks about increasing agricultural productivity.[73] The safe use of septage or faecal sludge and wastewater in agriculture (i.e. implementing Goals 6.3 and 2.3) would help in meeting "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability". The use of excreta in agriculture can help communities grow more food and decrease use of precious water and nutrient resources. However, it should be done safely to maximize public health gains and environmental benefits. In 2006, the World Health Organization (WHO) provided guidelines on safe end use of wastewater, excreta and grey water.[74]

Case study 15: Decentralized wastewater treatment system at Varunalaya, Delhi Jal Board—India

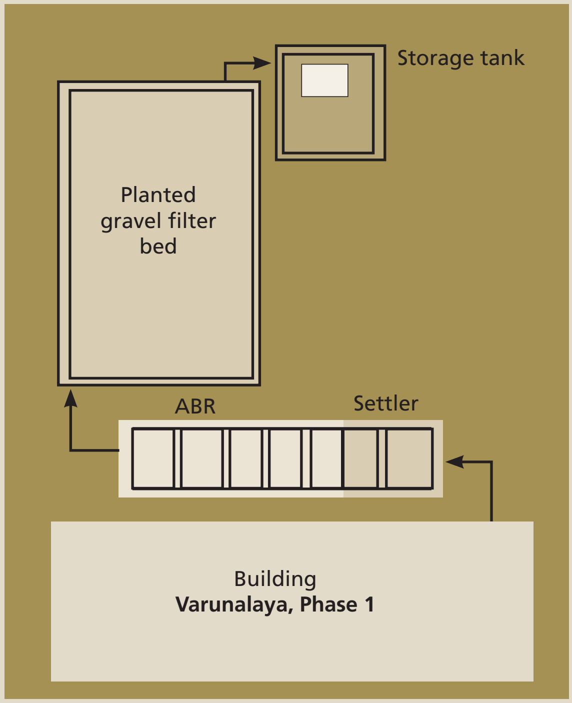
Background

The DWWTs at Delhi Jal Board's head office is a model project that showcases treatment of wastewater to obtain reusable water. Inaugurated in 2015, the DWWTs has been designed to treat 8,000 litres per day to cater to horticultural requirements inside the campus.

Wastewater management

- Toilet waste from Phase-I office building is treated through various treatment units that include a settler, an anaerobic baffled reactor and a planted filter bed.
- Treatment technology:
  - Wastewater enters a two-chambered settler for removal of suspended solids, and then flows into an ABR
  - The ABR at the site is five-chambered, facilitates anaerobic degradation of organic impurities, and reduces about BOD and COD levels by 60–70 per cent.
  - The treated water is further improved as it passes through the planted gravel filter (PGF) bed. The PGF at the site has Canna and Typha plantations. Treated water is stored in a collection tank.
  - The system does not require any electricity for the treatment process as it is designed to have a natural gravity flow, thereby reducing cost of operations.

Schematic of DWWTs at DJB



Source: CSE, 2016

Performance

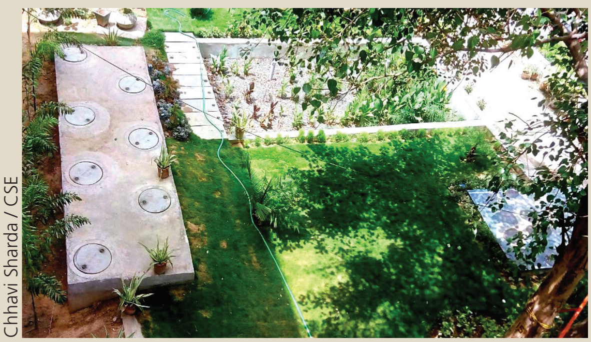
8,000 litres of wastewater is treated and end used every day. The quality analysis result show that the efficiency of the system is about 80 per cent in terms of BOD and COD removal. Various water quality parameters tested before and after treatment are shown in the table below:[75]

Treatment efficiency of the DWWTs

Parameters	Before	After
pH	7.4	7.5
BOD (mg/L)	110	23
COD (mg/L)	344	96
Total suspended solids (mg/L)	376	97
Ammonia (mg/L)	30	20
Phosphate	Traces	Nil
Faecal coliform (per 100m)	3,600	93

Source: CSE, 2016

DJB DWWT site



Chhavi Sharda / CSE

End use of septage refers to the safe and beneficial use of human excreta, i.e. faeces and wastewater from OSS. Considering the nutrients, organic matter and energy contained in septage, it can be used as a soil conditioner or fertilizer in agriculture, gardening, aquaculture or horticultural activities (see *Figure 38: Closing the loop*). Other uses include use as a fuel source, building material or for protein food production. Closing the loop would not only help in reducing fresh water and chemical fertilizer demand but also prove to be a source of

Case study 16: Soil biotechnology at Naval civilian housing colony in Mumbai, Maharashtra—India

Background

Naval Civilian Housing Colony is a residential housing neighbourhood for officers and their families situated in Kanjurmarg, Mumbai, India. The colony has 20 blocks of buildings with residential facilities, a mess, a hospital, a sports complex, a market area and administrative offices. The SBT-based DWWTs treats wastewater generated from seven residential building blocks—each building having 24 apartments.

Waste water and effluent management

SBT is a green technology for water purification using a natural and novel high-efficiency oxidation process at competitive costs. Features:

Natural processes-based wastewater treatment with a capacity to treat 50 KLD.

Minimal energy consumption (40–50 kWh per MLD to pump the wastewater for distribution over the reactor bed)

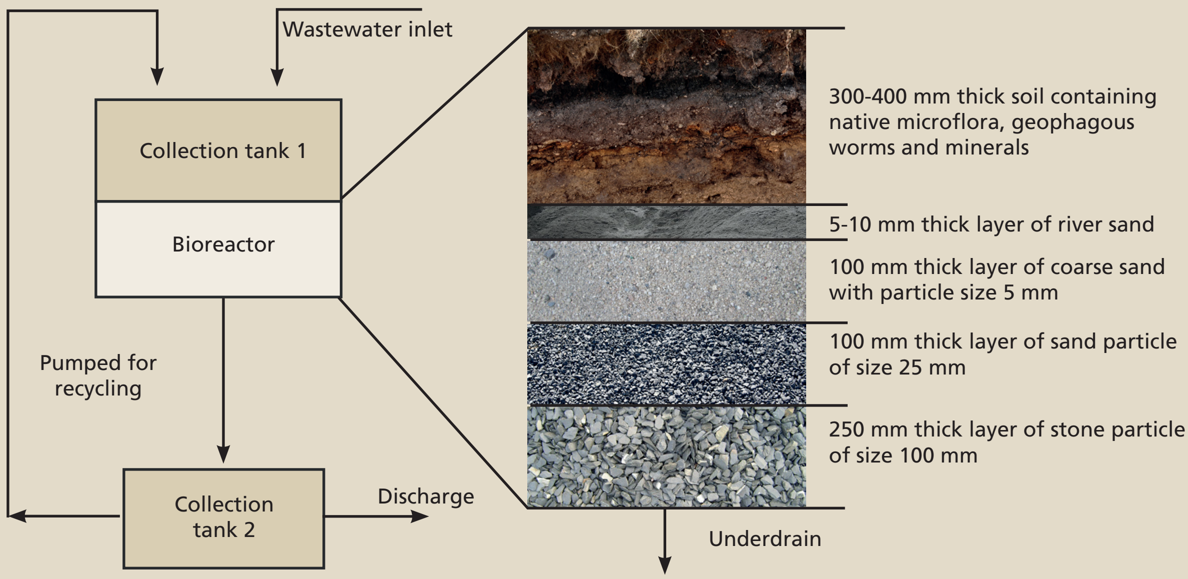
The DWWTs creates an alternate resource of water that is used to maintain the green area inside the residential premises.[76]

Raw water collection tank: Raw sewage, after screening, is collected in the tank from where it is directed towards the trench filled with gravel.

Soil filter bioreactor: Sewage is then pumped and distributed over the reactor bed.

Effluent collection tank: The treated sewage gets collected in this tank and is (re)circulated in order to achieve the desired quality of treated wastewater.

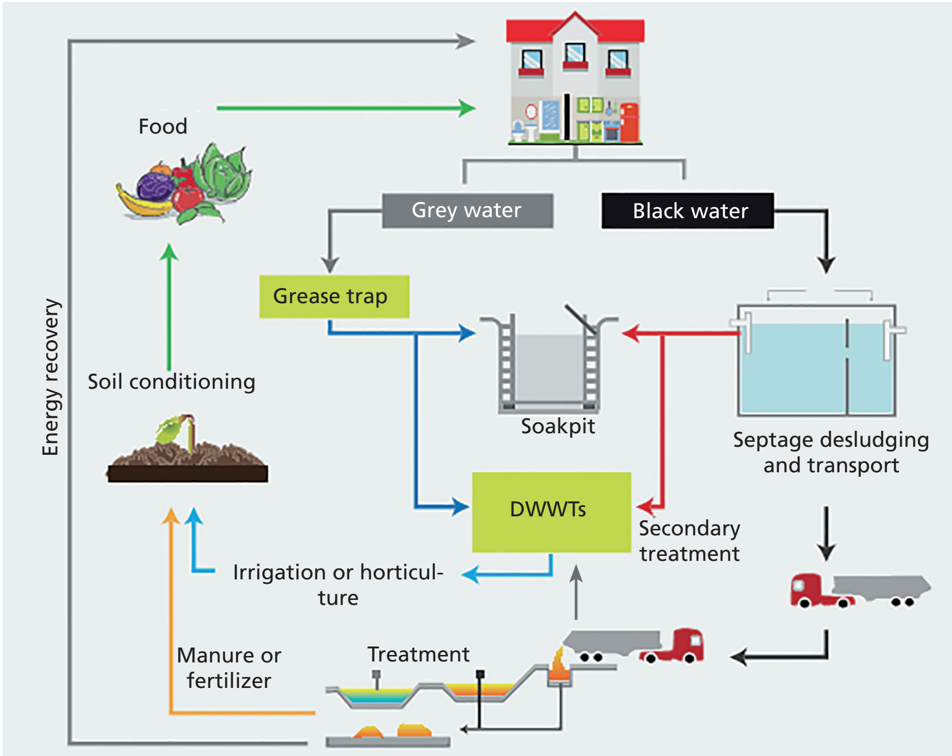
Schematics of SBT and the bioreactor showing different layers of filter materials



revenue, in other words, an all-round improved business model.

Septage contains nutrients such as nitrogen, phosphorus and potassium as well as micronutrients like sulphur and organic matter that can be recovered. Septage and domestic wastewater (sewage) have traditionally been used in agriculture. They are still being used in agriculture to this day, but the practice is often carried out in an unregulated and unsafe manner in developing countries.

Figure 38: Closing the loop



Source: Introduction to preparation of CSP, GIZ-CSE, 2016

End use should decide level of treatment

WHO's 2006 guidelines established a framework on how end use can be done safely by following a 'multiple barrier approach'.

"No higher quality of water should be used for a purpose that can tolerate a lower grade"—UN Council Resolution 1958

The type of end use should decide the level of treatment. The degree of treatment required for excreta-based fertilizers before they can be safely used in agriculture depends on a number of factors; a number of barriers may be necessary. Such barriers are selecting a suitable crop, farming method, method of applying the fertilizer, education and so forth.[77] However, health concerns are a major challenge for such approaches. Proponents operate in fragmented and hostile policy environments that are often weakly linked to health. They also need to overcome negative public perceptions about the risks associated with the use and disposal of human waste. A tool by WHO, Sanitation Safety Planning (SSP) can help sanitation system operators maximize health benefits and minimize health risk of their system.[78] SSP takes into consideration all steps of the chain, from sanitation waste generation (e.g. in the toilet) to the waste's final use or disposal. For end use in agriculture, which produces a food product, SSP goes from 'toilet to farm to table'.

The National Water Policy of 2012 recognizes end use of reclaimed water as an important factor for meeting environmental objectives and suggests preferential tariff to incentivize reclaimed water over freshwater. The National Policy on

Application of compost made from septage

Source: SuSana website: http://www.susana.org/

FSSM, 2017 emphasizes maximum end use of treated sludge as fertilizer in farmlands, parks, gardens and other such venues, treating wastewater to produce energy, wherever feasible, and end use for any other productive uses.[79] Atal Mission for Rejuvenation and Urban Transformation, a national flagship programme of MoUD, has implied service-level benchmarking that at least 20 per cent of the wastewater generated in ULBs should be recycled.[80] This has also been recommended by the NUSP, 2008.

For dewatered septage or sludge to be used as a fertilizer in agriculture applications, it should satisfy the criteria of Class-A bio-solids of USEPA: A faecal coliform density of less than 1,000 Maximum Probable Number (MPN)/g total dry solids. Helminths egg concentration of < 1/g total solids and E coli of 1,000/g total solids in treated septage for use in agriculture.[81]

Central Pollution Control Board has prescribed standards for wastewater end use in irrigation, which is notified under [Schedule-VI] General Standards for Discharge of Environmental Pollutants Part A: Effluent (see *Appendix 8: General standards for discharge of environmental pollutants Part-A : Effluents*). According to these rules, the effluent or supernatant generated from OSS and after dewatering septage should be treated further to comply with the general standards and should be end used. CPHEEO has detailed a few case studies in its Manual on Sewerage and Sewage Treatment Systems on end use of sewage. In order to ensure safe application of compost, Municipal Solid Wastes (Management and Handling) Rules, 2016 can be followed for the application of compost prepared from dried sludge.

In India, end use of treated septage is currently unregulated, but the 2006 WHO guidelines and 2016 SSP tool for safe use of excreta, wastewater and grey water provide a comprehensive framework for managing health risks associated with the use of human wastes in agriculture and aquaculture. The guidelines and the manual are eminently suitable for application in Indian conditions and may be adopted.[82]

End use of treated septage

If septage is properly treated, it can be used for agricultural purposes, but should not be used on food crops intended to be eaten raw, unless stringent controls are in place. The Department of Health Regulations of Philippines has put in place the following regulations for reusing septage as compost for food crops:

According to USEPA guidelines for bio-solid treatment processes that significantly reduce pathogens, if land application for food crops is to be practiced, one of these methods must be used:

- Aerobic digestion between 40 days at 20°C and 60 days at 15°C.
- Anaerobic digestion between 15 days at 35–55°C and 60 days at 20°C.
- Air drying for at least three months, at least two months should have daily temperatures above freezing levels
- Compost with temperatures greater than 40°C for five days. The temperature must be greater than 55°C for four hours every day.
- Lime stabilization by adding sufficient hydrated lime to raise the pH to more than 12 for 30 minutes.

Testing to verify the appropriate pathogen reduction is required if agricultural end use is intended. These methods have been recognized to reduce the number of Helminths eggs to levels that are determined to be acceptable by the WHO for land application purposes for food crops. While a standard for the concentration of Helminths eggs in bio-solids has not been codified into law by the Philippines Department of Health, WHO guidance on acceptable limits of these parasitic organisms exist, as follows:

WHO 1989 guidelines of one nematode egg per litre of treated wastewater (or septage) used for vegetable irrigation, and an average manuring rate of two–three tonnes per hectare per year should be followed. Testing for nematode eggs is a relatively simple procedure that should be used to check the treatment efficiency and acceptability of bio-solids prior to land application. This should become an integral component of any bio-solids programme that end uses the treated product as a soil amendment or conditioner for agricultural purposes.

Catalytic fast pyrolysis

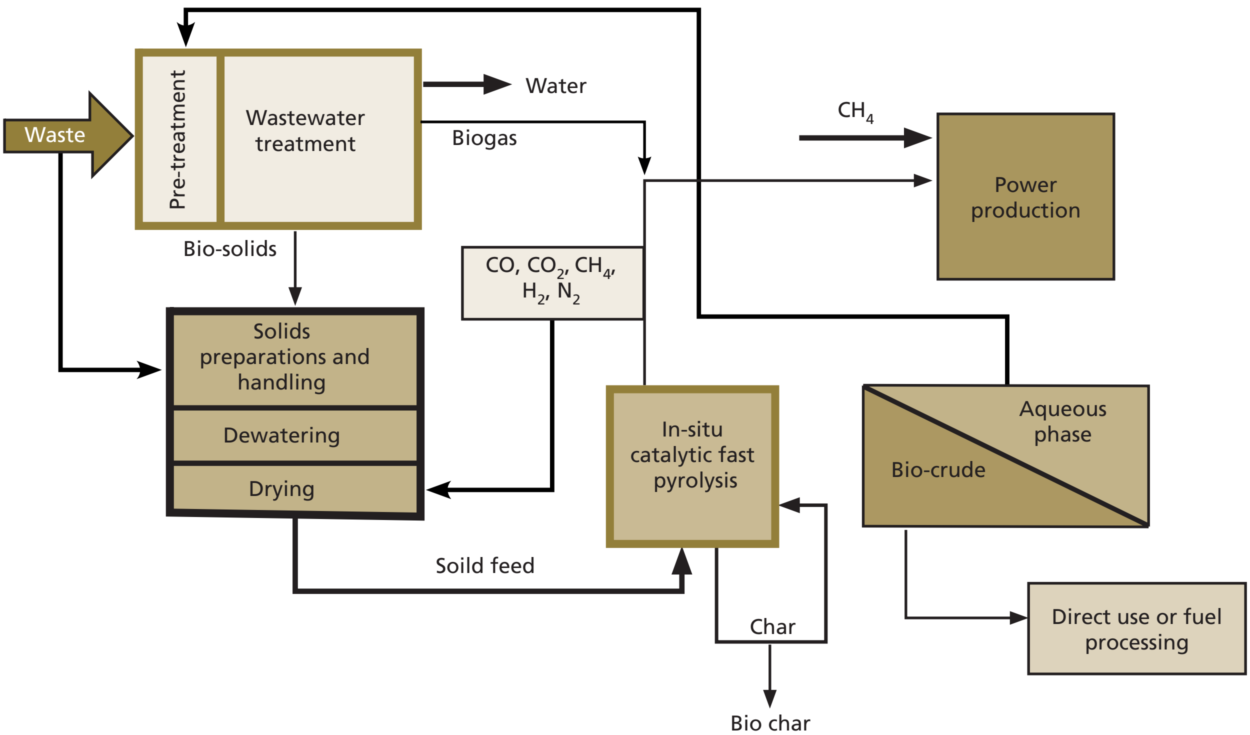
One of the emergent end uses of septage is as biofuel. Biofuel can be obtained using catalytic fast pyrolysis, in which septage enters the wastewater treatment system, where the waste is dewatered, while solids are separated and dried in a different unit. This dried waste or bio-solid is sterilized with high temperature, which produces methane, bio-crude and char (see *Figure 39: Catalytic fast pyrolysis*). The methane can be used for production of power, while bio-crude can be processed further. The char produced from this technology can also be processed further and converted into bio-char.[83]

Septage to electricity using omni-processor

The omni-processor developed by Janicki under the Bill and Melinda Gates foundation undertakes the process of combining three different standard procedures—solid fuel combustion, steam power generation and water treatment. The three aspects or steps of the technology are described as below:

1. Solid fuel combustion: Bio-solids, wet waste (sludge or solid waste) enters a dryer where moisture is evaporated and trapped. The dried waste is transferred to burn in a very controlled fashion, reducing the solids to dry flyash. The exhaust from the fire is conditioned and filtered to meet regulatory emission standards before being released into the environment. This process is extremely energy-intensive.
2. Steam power generation: Heat generated during the burning of dried waste is used to heat water in the boiler pipes to create steam. This steam is then fed to steam engines, which runs the generator to produce electricity. The

Figure 39: Catalytic fast pyrolysis



Source: Catalytic pyrolysis of human faeces for biofuel production, Jeff Piscik, 2017

electricity thus produced can be used to power the entire omni-processor and the surplus can be old or used for other purposes. Heat from the engines is trapped and transferred back to heat the incoming wet waste or the point where solid fuel combustion takes place.

3. Water treatment: It is the final step of the procedure. The moisture obtained from burning the wet waste is filtered, condensed and distilled and may be used in the omni-processor. Depending on the type of wet waste, there may be excess water which can be further treated and made potable.[84]

The way forward

This practitioner's guide demonstrates why it is important to manage septage generated in urban centres of the country and how to do it. It examines the issues and challenges at each step and suggests the most suitable ways forward.

Key message from *Excreta Matters: Seventh State of India's Environment Report*

For a water-sewage secure future, cities have to think differently. Spend less to get water to cities. Use less water so there is less to treat and dispose. Cut costs of sewage and septage transportation and treatment. Use a mix of technology to treat sewage as a resource for agriculture and industry.

To find a sustainable solution to this persistent problem, resource recovery and end use is the need of the hour. It is important to close the loop and not to consider it as a chain any more. Decentralized septage management (including effluent treatment) will help in closing the loop by utilizing end use potential of both treated septage and effluent.

Each state should develop a septage management policy and guidelines, where funding provisions and stringent regulations for each stage of sanitation loop are suggested and enforced. Cities can use this guide to develop their septage management sub-plan and incorporate the same in their CSP.

The SMPs should clearly indicate short-, medium- and long-term plans for managing septage. Implementing SMPs in a time-bound manner will definitely help in improving sanitation of cities, including for the urban poor.

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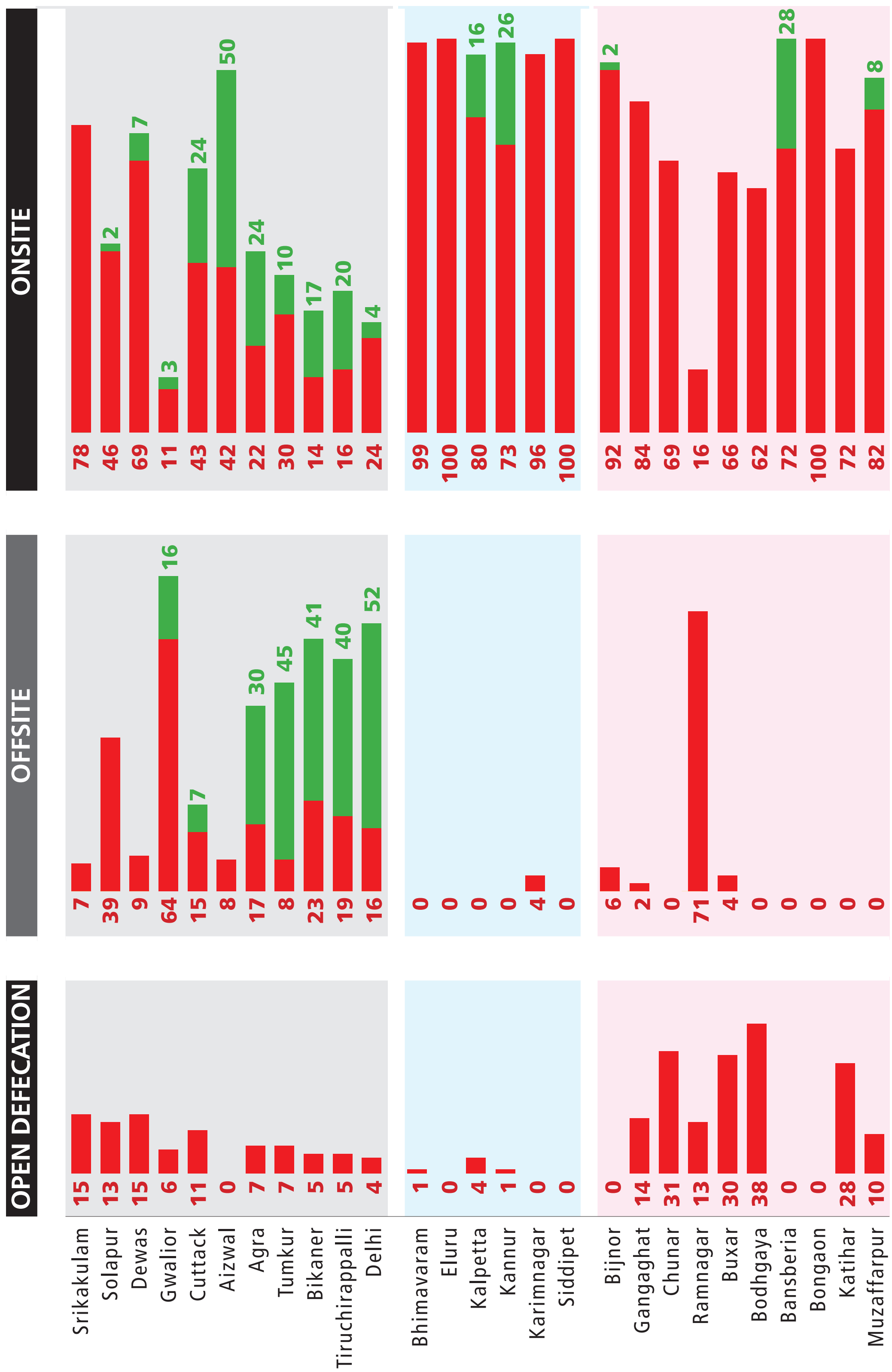
Appendix 1: Excreta management of 27 cities from different agro-climatic

regions



NOTE: **The numbers above represents excreta in terms of contributing percentage of population**

Source: Poster presentation by CSE at FSM-4 conference, Chennai, 2017

Appendix 2: Revised Service Level Benchmarks for sanitation proposed in FSSM policy

Current SLB indicators (Sewerage System)	Proposed Sanitation Benchmark (Sewerage + Onsite systems)
1. Coverage of sewerage network services	**1. Coverage of adequate sanitation system**
Total number of properties with individual connections to sewerage network as a percentage of total number of properties in the city.	Percentage of households with individual or group toilets connected with adequate sanitation systems (sewer network/ septic tank / double pit system) to total households in the city
2. Collection efficiency of sewerage network	**2. Collection efficiency of sanitation system**
Quantum of sewage collected at the intake of the treatment plant to the quantity of sewage generated (as per CPHEEO, 80% of water consumed is generated as sewage)	Weighted average of collection efficiency of each sanitation system, weighted by share of households dependent on each sanitation system
3. Adequacy of sewage treatment capacity	**3. Adequacy of treatment capacity of Sanitation System**
Adequacy is expressed as secondary treatment capacity available as a percentage of normative wastewater generation.	Weighted average of adequacy of treatment plant capacity available for each sanitation system, weighted by share of households dependent on each sanitation system.
4. Quality of sewage treatment	**4. Quality of treatment of sanitation system**
Quality of treatment is measured as a percentage of WW samples that pass the specified secondary treatment standards, that is, treated water samples from the outlet of STPs are equal to or better than the standards lay down by the GoI agencies for secondary treatment of sewage.	Weighted average of quality of treatment of each sanitation system, weighted by share of households dependent on each sanitation system.
5. Extent of reuse and recycling of sewage	**5. Extent of reuse and recycling in sanitation system**
Quantity of sewage that is recycled or reused after secondary treatment as a percentage of quantity of sewage received at the treatment plant.	Weighted average of extent of reuse of treated wastewater and sludge after adequate treatment as a percentage of sewage and sludge received at the treatment plant, weighted by share of household dependent on each sanitation system.

Source: National Policy on FSSM, MoUD, 2017

Appendix 3: Roles and responsibilities of institutions in the development of FSSM plans

Agency	Role	Responsibility
Ministry of Urban Development	• Technical and planning support to states and ULBs • Training and capacity-building of state level officials and those from select ULBs • Funding through specific schemes and plans • National level awareness and behaviour change campaign • Support research and capacity building in the sector • Create enabling environment for participation of the private sector, NGOs and CBOs in provision of FSSM services including to the poor and marginalized households and areas • National-level monitoring and evaluation	Formulation of state- and city-level FSSM strategies and implementation plans
Ministry of Environment, Forest and Climate Change	Enforce compliance of the relevant environmental laws and rules during the collection, transport, treatment and disposal of faecal sludge and septage	Support and build capacity of state pollution control towards enforcement of relevant laws and rules
Ministry of Social Justice and Empowerment	• Elimination of manual scavenging and rehabilitation of manual scavengers • Monitor and evaluate progress at the national level • National-level awareness campaign	Help states and ULBs eliminate manual scavenging and rehabilitate manual scavengers
Ministry of Women and Child Development		Gender mainstreaming in IEC material for FSSM across the country
State Governments	• Develop state-level FSSM strategies and implementation plans • Develop operative guidelines on FSSM • Training and capacity-building of ULB officials and others engaged in provision of FSSM services • State-level awareness and behaviour change campaign • Create enabling environment for participation of the private sector, NGOs and CSOs in provision of FSSM services including to the poor and marginalized households and areas • Funding through specific schemes and plans • Support research and capacity-building in the sector • State level monitoring and evaluation	• Technical, financial and administrative support to ULBs • Encourage coordination and cooperation among ULBs • Regulate and help ULBs set up systems to ensure financial sustainability in provision of FSSM services • Implement municipal by-laws.
Urban local bodies	• Design, develop, plan and implement ULB-level FSSM strategies • Set up and ensure operation of systems for 100 per cent safe and sustainable collection, transport, treatment and disposal of faecal sludge and septage • Develop expertize, in-house and outsourced, to provide safe and effective FSSM services • Awareness and behaviour change campaigns to engage diverse stakeholders • Develop training programmes for masons to build requisite skills in the construction of quality septic tanks as per IS codes • Set up systems to ensure financial sustainability in provision of FSSM services • Achieve objectives of FSSM policy in a time-bound manner • Design and implement plans to eliminate manual scavenging and rehabilitate manual scavengers • Funding through specific schemes and plans • Monitor and evaluate FSSM strategies and implementation plans • Implement municipal by-laws	Create enabling environment for NGOs and private initiatives to achieve safe and sustainable FSSM
Households	• Timely and regular emptying of septic tanks through approved entities • Regular maintenance and monitoring of septic tanks • Timely payment of user fee and charges, if any, towards FSSM services • Practice building by-laws for construction of OSS	Engage with decision-makers at the state- and ULB-level to ensure they receive good quality FSSM services

Source: Compiled by CSE, 2017

Appendix 4: Generic business model for septage management

Key partners	Key activities	Value propositions	Customer relationships	Customer segments
• Municipal corporation and local authorities • Technology suppliers • Financial institutions • Community-based organizations • Research and development institutions (e.g., local university)	• Toilet provision • Waste collection	• VP1: Access to toilet and increased revenue from end use	• Direct sale of toilet	• Community • Businesses
	• FS collection	• VP2: Timely emptying and transportation of FS	• One-on-one service provision • Contracts with municipality • Direct or through contracts	• Households • Businesses
	• FS treatment	• VP3: FS treatment for healthy and safe environment	• Direct compost sales	• Municipality
	• Organic waste and FS collection • Compost production • Compost – Sales & marketing	• VP4: High-quality compost (soil ameliorant)	• Distributors • Direct energy sale	• Farmers • Municipal park department • Agriculture department • Agroforestry • Fertilizer industry
	• Biogas production • Biogas sale	• VP5: Reliable and renewable energy service	• Power purchase agreement	• Households • Community • Small businesses
	• Customer relationship management			• Public sector (e.g., municipality, ministry, etc.) • Institutions
	Key resources		Channels	
	• Appropriate technology and equipment • Labor • Finance • License and contracts for collecting waste		• Direct • Municipality • Word-of-mouth • Brochures and other media communications • Distributors and extension agents	

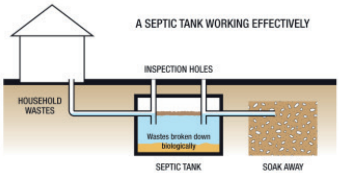
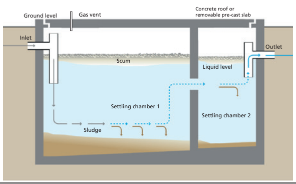
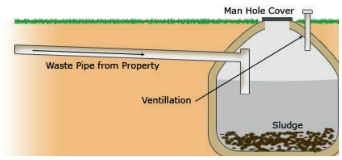
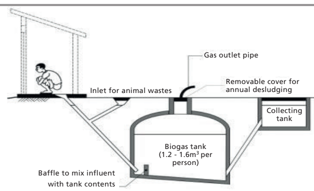
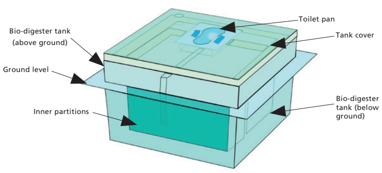
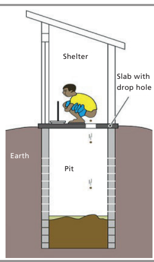
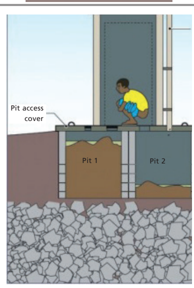
Cost structure		Revenue streams	
• Fixed investment cost (construction, trucks, equipment, etc.) • Operation and maintenance cost (labour, raw material input, utilities, sales and marketing, license, etc.) • Interest payments	• Emptying fees and, in some instances, FS delivery fees	• Sale of toilet and end use products • Sale of compost	• FS disposal fees, sanitation tax and O&M budget support
		• Sale of Energy	

Social and environmental costs	Social and environmental benefits	
• Potential health risk for those in direct contact with FS (can be mitigated with the use of protective equipment) • Improper FS treatment and disposal causing environmental and health risks for citizens • Improved energy security	• Reduced pollution of water bodies and soils • Reduced human exposure to untreated faecal sludge • Job creation	• Improved soil and agricultural productivity

Note: Colours indicate relevance to corresponding value proposition (VP). Beige is applicable to all VPs

Source: Krishna C. Rao, 2016 Business models for fecal sludge management, IWMI

Appendix 5: Types of containment systems

<table>
<tr><th>Containment system</th><th>Description</th><th>Output</th></tr>
<tr><td>
</td><td>A septic tank with soak pit, is a decentralized wastewater treatment system. It is basically a sedimentation tank with chambers, which has settling and anaerobic processes to reduce solids to organics, which lets out the effluent content to flow into a soak pit, from where it infiltrates into water. (EAWAG, 2014)</td><td>Septage found within the septic tank</td></tr>
<tr><td>
</td><td>A septic tank without soak pit has a same function as a septic tank with a soak pit. The only difference between the two is that effluent is let out on ground/water body or open drains. (EAWAG, 2014)</td><td>Septage found within the septic tank and effluent let out in the open drains</td></tr>
<tr><td>
</td><td>A reservoir or a closed tank for collection of wastewater, with no intent to treat or discharge any of its components. (WTE, 2014)</td><td>Slurry from mixture of faeces and water</td></tr>
<tr><td>
</td><td>Bio-digester is a decomposition mechanical toilet which decomposes waste water in the digester tank using specific high graded bacteria further converting it into methane and water, discharged further to the desired surface. (CSE, 2013)</td><td>Pathogen-free water which can be used for agriculture purposes</td></tr>
<tr><td>
</td><td>This technology is evolved around aerobic digestion - which involves a different multi-strain of bacteria which breaks down the waste matter through oxidization.</td><td>Digested septage</td></tr>
<tr><td>
</td><td>Defecation into pits dug into ground for the reception of night soil directly without flushing are reckoned as pit latrines.
(Census of India, 2011)</td><td>Faecal sludge</td></tr>
<tr><td>
</td><td>This type of system may be lined or unlined. It consists of two identical pits, which are used alternatively, where pit is closed upon the filling up, where anaerobic digestion of the faecal waste takes place. (Ministry of Urban Development, 1992)</td><td>Faecal sludge</td></tr>
</table>

Appendix 6: Comparison of systems with respect to various parameters

System number	System name	Type of system	System Life time	Applicability of system	Land availability	Performance of the system	Energy requirement	CAPEX	OPEX
System 1	Twin-pit system	Onsite system	Twin-pit, 10 years	Household level	5 m^2 per household for pit + toilet	-	Not required	Rs 4,500 per household for pit	Rs 400 per household per year
System 2A	UDB + WSP + co-composting + chlorination	Decentralized system	Septic tank, 50 years; soakpit, three-five years, UDB or WSP, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; WSP, 6,000 m^2/ MLD	BOD, 75–85 per cent; COD, 74–78 per cent; TSS, 75–80 per cent; TN, 70–90 per cent; TP, 30–45 per cent; coliform, 60– 99.9 per cent	WSP, 5.7 kWh/d/MLD	IST, Rs 75,000 per household; WSP: Rs 23,00,000/MLD; UDB: 3,00,00,000/MLD	IST, Rs 1,500 per household year; UDB, Rs 50,00,000/MLD/ year; WSP, Rs 2,00,000/MLD/ year
System 2B	AD + co-composting + chlorination	Decentralized system	Septic tank, 50 years; soakpit, three–five years, AD, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; AD, 600 m^2/MLD	BOD, 60–90 per cent; COD, 60–80 per cent; TSS, 60–85 per cent	AD, 60 kWh/d/ MLD	IST, INR 75,000/HH; AD, INR 5,00,00,000/ MLD	IST, INR 1,500/ HH/year; AD, INR 30,00,000/ MLD/year
System 2C	Centrifugation + ASP + vermicompostin g + ozonation	Decentralized system	Septic tank, 50 years; soakpit, three-five years, UDB or WSP, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; ASP, 900 m^2/MLD	BOD, 85–92 per cent; COD, 93–94 per cent; TSS, 75–80 per cent; TN, > 90 per cent; TP, > 90 per cent; coliform, 60– 90 per cent	ASP, 185.7 kWh/d/MLD; Centrifugation: 20–300 kWh per metric tonne of solid	IST, INR 75,000/HH; ASP, 68,00,000/MLD	IST, INR 1,500/ HH/year; ASP, INR 7,00,000/ MLD/year
System 2D	Centrifugation + SBR + co-composting + chlorination	Decentralized system	Septic tank, 50 years; soakpit, three-five years, SBR, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; SBR, 450 m^2/MLD	BOD, 95 per cent; COD, 90 per cent; TSS, 95 per cent; TN, 70–80 per cent	SBR, 153.7 kWh/d/ MLD; Centrifugation: 20–300 kWh per metric tonne of solid	IST, INR 75,000/HH; SBR, INR 75,00,000/ MLD	IST, INR 1,500/ HH/year; SBR, INR 6,00,000/ MLD/year
System 2E	Centrifugation + MBR + co-composting + ozonation	Decentralized system	Septic tank, 50 years; soakpit, three-five years, MBR, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; MBR, 450 m^2/MLD	BOD, 95 per cent; COD, >90per cent; TSS, >90 per cent; TN, >90 per cent; TP, >90per cent	MBR, 302.5 kWh/d/ MLD; Centrifugation: 20–300 kWh per metric tonne of solid	IST, INR 75,000/HH; MBR, INR 30,000,000 /MLD	IST, INR 1,500/ HH/year; MBR, INR 9,00,000 / MLD/year

System number	System name	Type of system	System lifetime	Applicability of system	Land availability	Performance of the system	Energy Requirement	CAPEX	OPEX
System 3A	MD + AF + CW + co-composting + chlorination	Decentralized system	Treatment plant life, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet	BOD, 50–90 per cent; TSS, 50–80 per cent	AF, 34 kWh/d/MLD	BD, INR 60,000/HH	BD, INR 1,400/HH/year
System 3B	MD + WSP + co-composting + chlorination	Decentralized system	Treatment plant life, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet	BOD, 75–85 per cent; COD, 74–78 per cent; TSS, 75–80 per cent; TN, 70–90 per cent; TP, 30–45 per cent; coliform, 60– 99.9 per cent	WSP, 5.7 kWh/d/MLD	IST, INR 75,000/HH; WSP, INR 23,00,000/MLD	IST, INR 1,500/HH/year; WSP, INR 2,00,000/MLD/year
System 4	ASP + reed bed + sludge drying bed + co-composting	Networked system	Sewer and treatment plant life, 50 year	Ward-, city-, or cluster-level	ASP, 900 m^2/MLD	BOD, 90–95 per cent ; COD, 85–90 per cent; TSS, >90 per cent; TN, >60 per cent; coliform, 90– 99.9 per cent	ASP: 185.7 kWh/d/MLD	ASP, INR 68,00,000/MLD	ASP, INR 7,00,000/MLD/year
System 5	IT + CW + sludge drying bed + co-composting + chlorination	Decentralized system	Septic tanks, 50 years; Individual toilet, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; IT, 900 m^2/MLD	BOD, 30–50 per cent; TSS, 50–70 per cent.	IT, 45 kWh/d/MLD	IST, INR 75,000/HH; IT, INR 5,00,00,000/MLD	IST, INR 1,500/HH/year; IT, INR 30,00,000/MLD/year

System number	System name	Type of System	System Lifetime	Applicability of system	Land availability	Performance of the System	Energy Requirement	CAPEX	OPEX
System 6A	ABR+ sludge drying bed + co-composting	Networked system	Treatment plant life, 50 years	Ward-, city-, or cluster-level	ABR, 1,000 m^2/ MLD	BOD, 70–95 per cent; TSS, 80–90 per cent; coliform, 20– 30 per cent	ABR, 34 kWh/d/MLD	ABR, INR 5,00,00,000 INR/MLD	ABR, INR 30,00,000/MLD/ year
System 6B	AF+ sludge drying bed + co-composting	Networked system	Treatment plant life, 50 years	Ward-, city-, or cluster-level	-	BOD, 50–90 per cent; TSS, 50–80 per cent	AF, 34 kWh/d/ MLD	AF, US$350 to US$500 per cu.m for a treatment capacity of 10 cu.m, if the AF is used in combination with other treatment modules (e.g., in DEWATS) [39	-
System 7	Belt filter press + CW + lime stabilization + chlorination	Decentralized system	Septic tank, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet	-	22 kWh/d/MLD	-	-
System 8	UASB + sludge drying bed + co-composting	Networked system	> 50 years	Ward-, city-, or cluster-level	UASB, 1,000 m^2/ MLD	BOD, 75–85 per cent; COD, 60–80 per cent; TSS, 75–80 per cent; TN, 10–20 per cent.	UASB, 34 kWh/d/MLD	UASB, INR 68,00,000 /MLD;	UASB, INR 6,00,000/MLD/ year
System 9	MD + WSP + solar drying + chlorination	Decentralized system	Septic tank, 50 years; WSP, 50 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; WSP, 6,000 m^2/ MLD	BOD, 75–85 per cent; COD, 74–78 per cent; TSS, 75–80 per cent; TN, 70–90 per cent; TP, 30–45 per cent; coliform, 60– 99.9 per cent	WSP, 5.7 kWh/d/MLD	IST, INR 75,000/ HH; WSP, INR 23,00,000MLD	IST, INR 1,500/ HH/year; WSP, INR 2,00,000/ MLD/year

System number	System name	Type of system	System lifetime	Applicability of system	Land availability	Performance of the System	Energy Requirement	CAPEX	OPEX
System 10	PDB + CW + shallow trenches + chlorination	Decentralized system	Septic tank, 50 years; trenching site, five–10 years	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet	-	-	IST, INR 75,000/HH	IST, INR 1,500/ HH/year
System 11	Geo-bags + WSP+ chlorination	Decentralized system	Septic tank, 50 years; geo-bag, six–12 months	Ward-, city-, or cluster-level	7 m^2 per household for storage + toilet; WSP: 6,000 m^2/ MLD	BOD, 75–85 per cent; COD, 74–78 per cent; TSS, 75–80 per cent; TN, 70–90 per cent; TP, 30–45 per cent; coliform, 60– 99.9 per cent	WSP, 5.7 kWh/d/MLD	IST, INR 75,000/HH; WSP, INR 23,00,000/ MLD	IST, INR 1,500/ HH/year; WSP, INR 2,00,000/ MLD/year
System 12	ABR + CW + sludge drying bed + co-composting + chlorination	Decentralized system	> 50 years	Ward-, city-, or cluster-level	ABR, 1,000 m^2/ MLD	BOD, 70–95 per cent; TSS, 80–90 per cent ; coliform, 20– 30%	ABR, 34 kWh/d/MLD	IST, INR 75,000/HH; ABR, INR 5,00,00,000 /MLD;	IST, INR 1,500/ HH/year; ABR, INR 30,00,000/ MLD/year

ABR = Anaerobic baffled reactor, AD = Anaerobic digester, AF = Anaerobic filter, ASP = Activated sludge process, BD = Biogas digester, BOD = Biological oxygen demand, COD = Chemical oxygen demand, CW = Constructed wetland, HH = Household, INR = Indian rupee, IST = Improved septic tank, IT = Imhoff tank, kWh = Kilowatt hour, MBR = Membrane bio-reactor, MD = Mechanical dewatering, MLD = Million litres per day, PDB = Planted drying bed, SBR = Sequence batch reactor, ST = Septic tank, TN = Total nitrogen, TP = Total Phosphorous, TSS = Total suspended solid, UASB = Upflow Anaerobic sludge blanket, UDB = Unplanted drying bed, WSP = Waste stabilization pond

Source: Technology options for the sanitation value chain, CStep, 2016

Appendix 7: Small-bore sewer

Cost of installing small-bore sewer with a treatment plant

S. No	Sewerage scheme	Cost (in lakh Rs)				Population		Cost per capita	
		Pipe sewer	STP	Maintenance cost	Total	Present (2012)	Prospective (2027)	Total (2012)	Sewer (2012)
1	Abiana Kalan and Abiana Khurd, Ropar	123.5	73.16	19.75	216.41	2,131	2,557	9,232	5,798
2	Boje Majra, Ropar	91.8	59.28	17.30	168.38	1,166	1,399	12,959	7,872
3	Chitamali, Ropar	127.5	82.56	19.57	229.63	1,415	1,699	14,838	9,008
4	Bhajouli, Mohali	61.5	61.49	15.20	138.19	1,161	1,393	10,808	5,295
5	Singhpura, Mohali	88.0	55.85	15.14	158.99	822	986	17,497	10,703
6	Jaula Kalan, Mohali	127.0	59.80	17.59	204.39	1,852	2,223	10,083	6,854

Source: Innovation for scaling up to citywide sanitation, CEPT, 2012

Conventional vs small-bore sewers

S. No.	Parameter	Conventional sewers	Solids-free sewers	Effect
1	Excavation	Deep	Shallow	+ ve for solids-free
2	Water supply	More (125–135 per capita LPD) required for self-cleansing	Less (40 per capital LPD) is sufficient	+ ve for solids-free
3	Capital cost	High	Low	+ ve for solids-free
4	Individual septic tanks	Not required	Required	+ ve for conventional
5	Operation and maintenance cost	Very high	Very low	+ ve for solids-free
6	People's perception	Preferred	Less preferred	+ ve for conventional

Source: Innovation for scaling up to citywide sanitation, CEPT, 2012

Appendix 8: General standards for discharge of environmental pollutants

Part-A: Effluents

Parameter	Standards
Odour and colour	All efforts should be made to remove colour and unpleasant odour as far as practicable
Suspended solids mg/l, Max.	200
pH value	5.5 to 9.0
Oil and grease (mg/l, max.)	10
Biochemical oxygen demand [3 days at 27 °C] mg/l max.	100
Arsenic (as As), mg/l, max.	0.2
Cyanide (as CN) mg/l Max.	0.2
(a) Alpha emitter micro curie/ml.	10^{-8}
(b) Beta emitter micro curie/ml.	10^{-7}
Bio-assay test	90% survival of fish after 96 hours in 100% effluent

Source: General standards for discharge of environmental pollutants, 1993

Appendix 9: Important weblinks

Topic	Weblink
National FSSM Policy	http://amrut.gov.in/writereaddata/FSSM_Policy_Report_23Feb.pdf
Advisory note on septage management	http://moud.gov.in/upload/uploadfiles/files/Advisory_SMUI06.pdf
Operative guidelines for septage management for local bodies in Tamil Nadu	http://www.tn.gov.in/dtp/gorders/maws_e_106_2014_Ms.pdf
Guidelines for septage management in Maharashtra	https://swachh.maharashtra.gov.in/Site/Upload/GR/Septage_Management_Guidelines_UDD_020216.pdf
Standard operating procedure for FSM in Gujarat	http://umcasia.org/UserFiles/umc/file/FSM%20SOP.pdf
Chapter on onsite sanitation from CPHEEO Manual	http://cpheeo.nic.in/WriteReadData/Cpheeo_Sewarage_Latest/PartA-HighResolution/Chapter%209.pdf
Swachh Bharat Mission guidelines	http://www.swachhbharaturban.in:8080/sbm/content/writereaddata/SBM_Guideline.pdf
IS code for designing septic tank	https://archive.org/details/gov.law.is.2470.1.1985
How to make an SFD	http://sfd.susana.org/toolbox/how-to-make-a-sfd
Technology options for sanitation value chain	http://cstep.in/uploads/default/files/publications/stuff/CSTEP_Technology_Options_for_the_Sanitation_Value_Chain_Report_2016.pdf
FSM toolbox	http://www.fsmtoolbox.com/
FSM book	http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Book/FSM_Book_LowRes.pdf
Case studies of various decentralized treatment systems in India	http://cseindia.org/node/3798

Source: Compiled by CSE, 2017

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