Aga Khan Agency for Habitat
India

A Report on Sanitation Technologies for Transforming Urban Settlements

AKAH

Contents

About the Report

The Aga Khan Agency for Habitat (AKAH) India team identified three types of settlements to carry out a desktop research and analysis to identify technically viable, easy Operations and Maintenance (O&M) conceptual technical solutions for the three cases under study and also compile a compendium of proven technologies based on some important parameters. Based on the preliminary site findings and in-depth secondary research, 'A Report on Sanitation Technologies for Transforming Urban Settlements' was formulated.

The report comprises:

Chapter 1

This chapter introduces the topic of urban sanitation in India by briefly explaining sanitation systems. It further elaborates on the right process to choose the most suitable sanitation technology for a particular context. The chapter also states the National Green Tribunal (NGT) standards to be followed for treatment and disposal of the sewage. It concludes by describing 19 proven sanitation technologies through secondary research on important parameters and some successful case studies to illustrate the same.

Chapter 2

This chapter deals with conceptual recommendations for the three different contexts of suburban ward (Oshiwara), transforming rural settlement (Chitravad) and hypothetical greenfield site.

Chapter 3

This chapter concludes that the circular economy model might be the answer to India's water and sanitation crisis, and substantiates the same by presenting two case studies.

Disclaimer

This document is solely for the internal purpose of the AKAH India team only. It will also serve as a guide for selection of appropriate technology based on the context. The contents of the report provide a synthesis of our discussion and insights from the study.

Acknowledgements

This report would not have been possible without the contribution of the AKAH India team.

Foreword

“There is a need to have a clear conceptual understanding of the strengths, weaknesses and opportunities in urban sanitation technologies on offer, in the form of a robust decision-making tool. This would be immensely useful for basic service providers like local administration, community action groups, civil society and others. AKAH India has attempted to develop such a tool to support decision making in identifying the most appropriate technology for similar profile-transforming settlements.”

– Ms. Surekha Ghogale, Chief Executive Officer, Aga Khan Agency for Habitat (AKAH) India

Sanitation Technologies for a Changing Urbanscape

In the fast-changing urban landscape of the country, infrastructural demands of evolving settlements are critical for maintaining good quality of life, but are often overlooked, to the detriment of the habitat. The Aga Khan Agency for Habitat (AKAH) India has been working in the sector of water and sanitation for over three decades now. In rural areas, the work has ranged from rejuvenating and restoring water bodies; securing water sources, community-led water distribution and water harvesting systems; individual and school sanitation infrastructure development and solid waste management. It became quite evident, during our experience, that large villages have started acquiring urban characteristics, whereas peri-urban villages and small towns have begun to merge with larger cities. The drastic growth in population and new changes in administrative and governance structures, coupled with enhanced infrastructure for basic services provisioning, called for new and futuristic technologies to cope with them. Further, changing climatic patterns and the increasing levels of aspirations and attitudes of citizens makes it imperative that these technologies have the capacity to respond, adapt and seamlessly integrate with the needs of the increasing population and unpredictable weather patterns in a sustainable manner, thereby contributing to their resilience.

Sustainable innovations with decentralised liquid waste management systems in peri-urban new housing developments have not only thrown up challenges in maintenance, operations and technology constraints but have also provided opportunities to explore newer technologies to overcome specific challenges. There is a need to have a clear conceptual understanding of the strengths, weaknesses and opportunities in urban sanitation technologies on offer, in the form of a robust decision-making tool. This would be immensely useful for basic service providers like local administration, community action groups, civil society and others. AKAH India has attempted to develop such a tool to support decision making in identifying the most appropriate technology for similar profile-transforming settlements.

The report has been divided into three sections:

- The first section explains various sanitation systems and technologies and provides a decision framework for identifying the most appropriate, context-specific sanitation solution. It explains the standards to be followed for responsible effluent discharge and collates 19 proven urban technologies, along with four successful case studies.
- The second section applies the technologies to transforming settlement contexts for:
  - a) A suburban ward of Mumbai transitioning to formal development planning
  - b) A hypothetical peri-urban greenfield housing project of scale, without access to trunk services
  - c) A rural settlement organically acquiring urban characteristics with increased population and economic growth
- The third section of the report provides an insight to the concepts of circular economy and circular sanitation as the guiding approach for administrators and regional planning authorities.

AKAH India has used the expert services of Water and Sanitation Expert Ms. Priya Iyer to conceptualise this user-friendly compilation for dissemination and reference for planners and implementors alike. We are grateful for her enthusiasm and drive in identifying and validating technology options and documenting them creatively.

1. Urban Sanitation in India

What is sanitation

Sanitation refers to the provision of facilities and services for the safe management of human excreta from the toilet to containment and storage and treatment onsite or conveyance, treatment and eventual safe end use or disposal.

— World Health Organization (WHO)

In simple words, sanitation is defined as safe management of human excreta, including its safe confinement, treatment, disposal and associated hygiene-related practices.

— National Urban Sanitation Policy, Ministry of Urban Development, Government of India

As India is advancing rapidly towards becoming one of the economic superpowers, there is an urgent need to address key issues related to the provision of basic services. There is no doubt that sanitation is critical for any country to prosper sustainably and to significantly improve its people's health and well-being.

Swachh Bharat Mission (SBM) launched in 2014 has initiated a massive transformation in India's sanitation space. It has achieved significant milestones in both the rural and urban front. However, the significant investment in sanitation infrastructure in India, post the SBM, has been primarily focused on traditional sewerage networks, with some efforts also being directed towards sanitation facilities for the economically weaker sections of the society. This has been unable to address the magnanimity of the sanitation challenge in the country.

To improve the sanitation condition in urban India, there needs to be increasing focus on the use and maintenance of the sanitation infrastructure. Along with this, equal importance must be given to related areas such as water supply, drainage and solid waste management.

Vision for Urban Sanitation in India

All Indian cities and towns become totally sanitized, healthy and liveable and ensure and sustain good public health and environmental outcomes for all their citizens, with a special focus on hygienic and affordable sanitation facilities for the urban poor and women.

Broadly speaking, India aspires to transform its urban space into community-driven, completely sanitised, healthy and liveable cities and towns by:

1. Generating awareness about sanitation technologies among communities and institutions
2. Promoting mechanisms to bring about and sustain behavioural changes aimed at adopting healthy sanitation practices
3. Promoting access to households with safe sanitation and waste disposal facilities
4. Prioritising sanitation planning and implementation across national, state, city and local institutions
5. Promoting proper functioning of network-based sewerage systems and ensuring connections of households to them wherever possible
6. Promoting proper disposal and treatment of sludge from onsite installations such as septic tanks, pit latrines, etc.
7. Ensuring that all the human waste is collected and disposed safely after treatment to avoid any hazard to public health or the environment
8. Promoting proper usage, regular upkeep and O&M management of household, community and public sanitation facilities

1.1 Sanitation Systems

A sanitation system aims to protect human health by providing a clean environment that will stop the transmission of disease, especially through the oral-faecal route.

A sanitation system is a context-specific series of technologies and services for the management of these wastes (human excreta and wastewater), i.e. for their collection, containment, transport, transformation, utilisation or disposal.

— The Compendium of Sanitation Systems and Technologies

Types of Sanitation Systems

Sanitation systems can be classified into three categories:

1. **Onsite systems** retain wastes in the vicinity of the toilet in a pit, tank or vault.
2. **Offsite systems** remove wastes from the vicinity of the toilet, for disposal elsewhere.
3. **Hybrid systems** retain solids close to the latrine but remove liquids for offsite disposal elsewhere.

1.2 Definition and Objectives of Sanitation Technologies

Technologies are defined as the specific infrastructure, methods or services designed to contain and transform products, or to transport products to another functional group.

— The Compendium of Sanitation Systems and Technologies

Sanitation technologies aim to improve the quality of sanitation services for millions of people who are currently using non-piped sanitation systems.

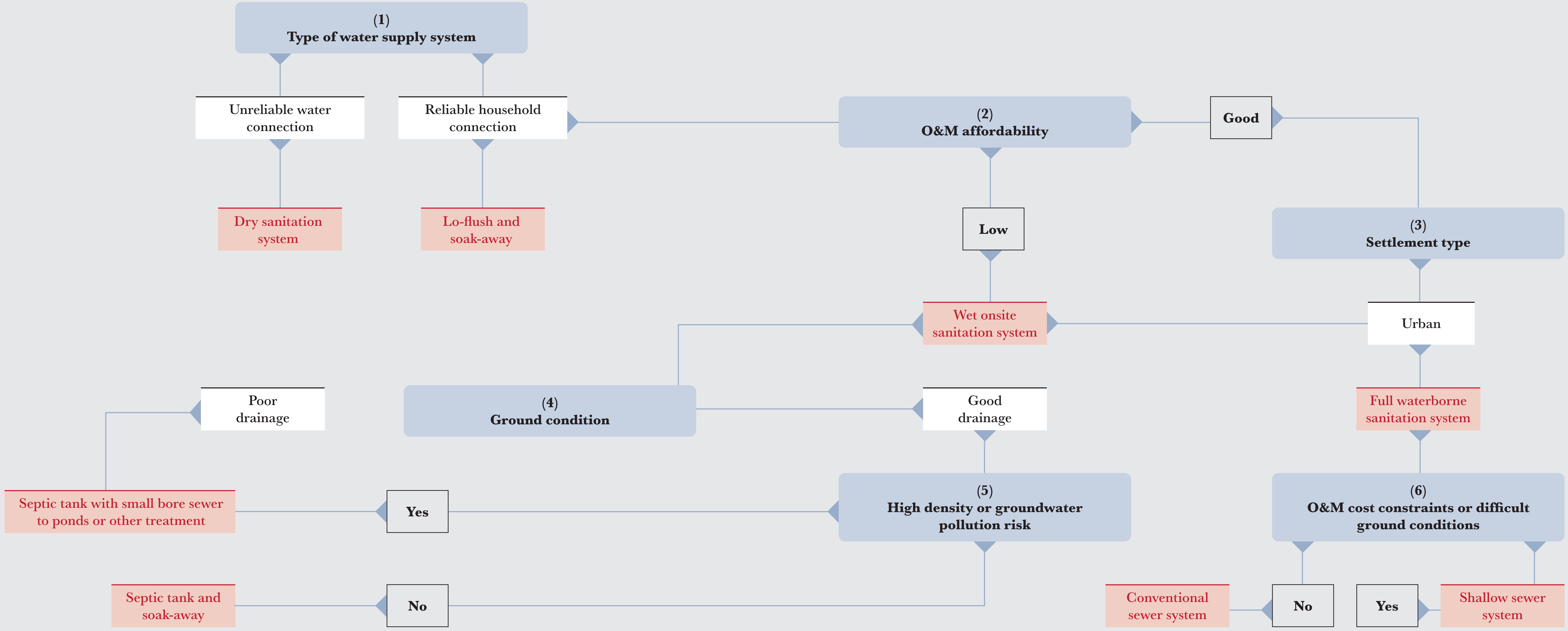
Objectives of sanitation technologies

- Protect public health
- Minimise pollution and environmental impact of poor sanitation
- Make productive reuse of wastewater

1.3 Initial Guide for Selecting Sanitation Solutions

The selection of an appropriate technology from a range of possibilities is the key to the successful and sustainable operation of any facility.

This guide may be used to select two or three possible solutions for a particular application. However, a thorough feasibility study should be undertaken before finalising the selection .



Source: Sanitation Technology Options, Department of Water Affairs and Forestry, Republic of South Africa

1.4 Standards for Effluent Discharge

As India's urban population is increasing, there is a rising need to address the incremental infrastructure needs of a fast-growing urban India. One of the major issues that needs immediate attention is the management of solid waste generation in urban India. Various government bodies have formulated policies and strategies pertaining to different aspects of urban development in India.

National Green Tribunal Guidelines

Scrapping the 2017 notification by the Ministry of Environment, Forest and Climate Change (MoEFCC), which had relaxed standards for upcoming Sewage Treatment Plants (STPs), the National Green Tribunal (NGT) has now ordered stringent norms for all existing and upcoming STPs in the country.

Accepting the report by an expert committee — comprising members from IIT Kanpur, IIT Roorkee, National Environmental Engineering Research Institute (NEERI) and CPCB — the NGT passed an order on April 30, 2019 to junk the 2017 norms and instead follow the more stringent ones proposed in 2015.

The tribunal said the existing STPs should apply these norms without any delay.

Hence, it is recommended to follow the below mentioned norms.

General Sewage Disposal Norms as per the NGT Guidelines

Sr. No.	Parameters	Old Norms of 1986	New Norms from November 15, 2018
1.	Biochemical Oxygen Demand (BOD) (mg/litre)	<30	<10
2.	Chemical Oxygen Demand (COD) (mg/litre)	<250	50
3.	Total Suspended Solids (TSS) (mg/litre)	<100	<20
4.	Total Nitrogen (mg/litre)	<100	<10
5.	Ammonical Nitrogen (mg/litre)	<50	<5
6.	Total Phosphorous (mg/litre)	No limit	No limit
7.	Faecal Coliform MPN / 100 ml	No limit	<100

Source: NGT Order dated April 30, 2019 for sewage disposal norms

1.5 Technical Details of Proven Sanitation Technologies

This chapter will take you through 19 innovative sanitation technologies that have been developed to pave way for a cleaner India.

Diverse Technologies for Specific Applications

Sr. No.	Name of the Technology	Type of System	Contact Firm	Page Reference
1	Aerobic Biodigester Toilet		Stone India Ltd.	8
2	Anaerobic Baffled Reactor (ABR)	Onsite	Ecosan Services Foundation	10
3	Fluidised Media Reactor		Ion Exchange Ltd.	12
4	Tiger Biodigester Toilet		Primemove Infrastructure Development Consultants Pvt. Ltd.	14
5	Soil Biotechnology (SBT)		IIT Mumbai	16
6	Phytorid Technology by National Environmental Engineering Research Institute (NEERI)		National Environmental Engineering Research Institute (NEERI)	18
7	Rotating Biological Contactor (RBC)		Orion Water Treatment Private Limited, Pune	20
8	Sequential Batch Reactor (SBR) Technology for Sewage Treatment	Decentralised	Aquatech	22
9	Membrane Bio Reactor (MBR) for Wastewater		S. S. Eng. Corporation	24
10	Moving Bed Bio-film Reactor (MBBR) Technology for Wastewater		Aquatech	26
11	Decentralised Wastewater Treatment System (DEWATS)		Consortium for DEWATS Dissemination	28
12	Trickling Filter		Ion Exchange Ltd.	30
13	Tiger Bio Filter Technology		Primemove Infrastructure Development Consultants Pvt. Ltd.	32
14	Waste Stabilisation Ponds (WSPs)	Onsite and decentralised	—	34
15	Oxidation Ditch		Eurotek Environmental Pvt. Ltd., Telangana	36
16	Upflow Anaerobic Sludge Blanket Reactor (UASB)	Centralised	Aquatech, Pune & Ion Exchange Ltd.	38
17	Activated Sludge Process		Aquatech, Pune & Ion Exchange Ltd.	40
18	Package Sewage Treatment Plant	Onsite/Offsite	Uniseven Engineering and Infrastructure Private Ltd. Website: adatta@uniseven.in	42
19	Faecal Sludge Management (FSM)		Primemove Infrastructure Development consultants Pvt. Ltd. & Consortium for DEWATS Dissemination	44

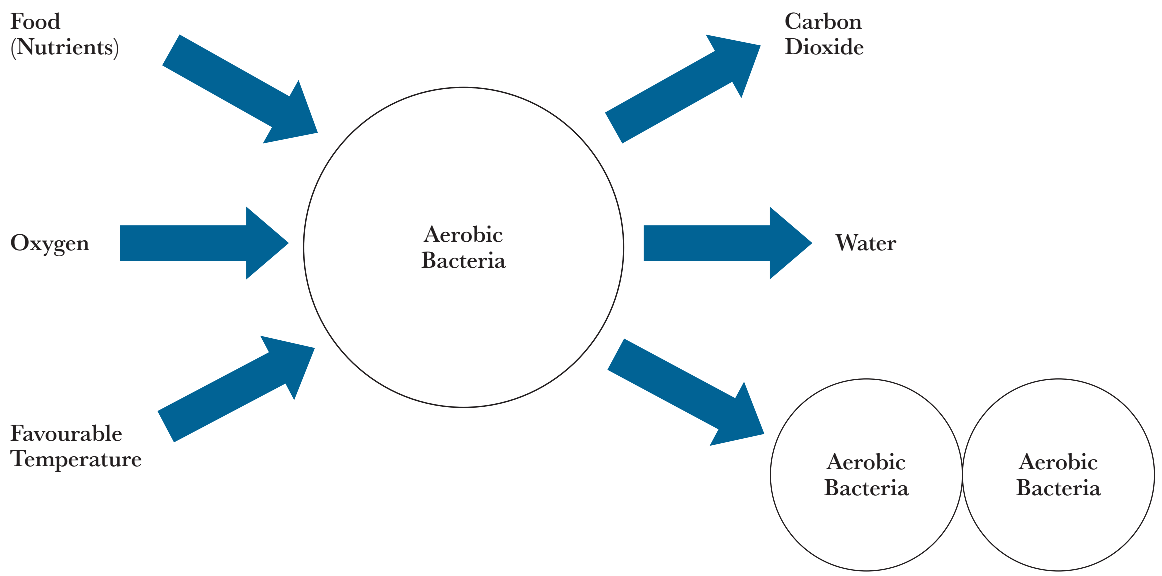
Note:

1. The system augmentation and modular arrangement must be reverified during the detailed design stage by the technology providers.
2. The list of contact firms in the table above is not exhaustive. There are many other technology providers, whose details can be researched.

1 Aerobic Biodigester Toilet

The primary function of the aerobic biodigester toilet is to eliminate open defecation. The biological toilet consists of a purpose-built multi-chambered biodigester tank in which the wastes are stored. The movement of the wastes is slowed down as the wastes flow from one chamber to another by a special process in the biodigester tank. The multi-strain bio media present in the tank toilet system decomposes the waste completely and converts it into water by the bacterial digestion within 24 hours. This resultant water then passes on to the disinfection chamber where it is completely disinfected before it passes out. The biological toilets eliminate the need for septic tanks, sewage lines and any periodic sludge removal.

Representation of Aerobic Biodigester Toilet:



Source: http://www.indiawater.gov.in/misc/InnovationAccrMC_Rep_S.aspx

Specific Design Considerations:

The biological toilets come in portable as well as stationary models, so they can easily be used in construction sites and open spaces.

Sludge Component:

No sludge generation

Land Requirement:

Not applicable

Disposal Standards:

Disposal standards achieved as per the National Green Tribunal (NGT)

Advantages of the Technology:

- Aerobic biodigester toilets use a five-strain aerobic bacterial culture for the digestion process
- The digestion process takes place in a specially designed multi-chambered tank
- The technology conforms to Pollution Control Board (PCB) norms for discharge of effluent in inland surface water
- It does not release banned methane gas like anaerobic bio toilets
- Digestion is much faster than the anaerobic method
- Tank size is much smaller

Disadvantages of the Technology:

The system will not function in the absence of:

- Food/nutrients
- Oxygen
- Favourable environmental conditions such as temperature and pH

Technology Application:

There are different models of this technology:

Model	Description	Key features
Enbiolet Deluxe	It is suitable for construction sites, parks, beaches, fairs, etc.	Compact toilet with an Indian toilet pan
Enbiolet Executive		Spacious toilet with commode and cistern, wash basin, cabinet mirror, cabin fan, exhaust fan and a CFL light
Enbiolet Community	It is suitable for transforming rural areas	Multiple toilet pans combined
Enbiolet Sleek	It is suitable for villages, slums and other CSR projects	Budget bio toilet with an Indian toilet pan
Enbiolet Trailer	Multiple toilet pans on a trailer; can be easily moved from one place to another	Data unavailable

This technology is preferred on construction sites that have a large transient population living in slums without any permanent structures. The average lifetime of this technology is 10 years.

System Augmentation / Modular Arrangement:

Not applicable

List of Installations:

- Shrawani Mela, Deoghar
- Delhi Development Authority Park

Technology at a Glance

ToS

Onsite

LoA

Transforming rural, and peri-urban and urban

CC*#

₹ 25,000-30,000

O&M*

Data to be sourced

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

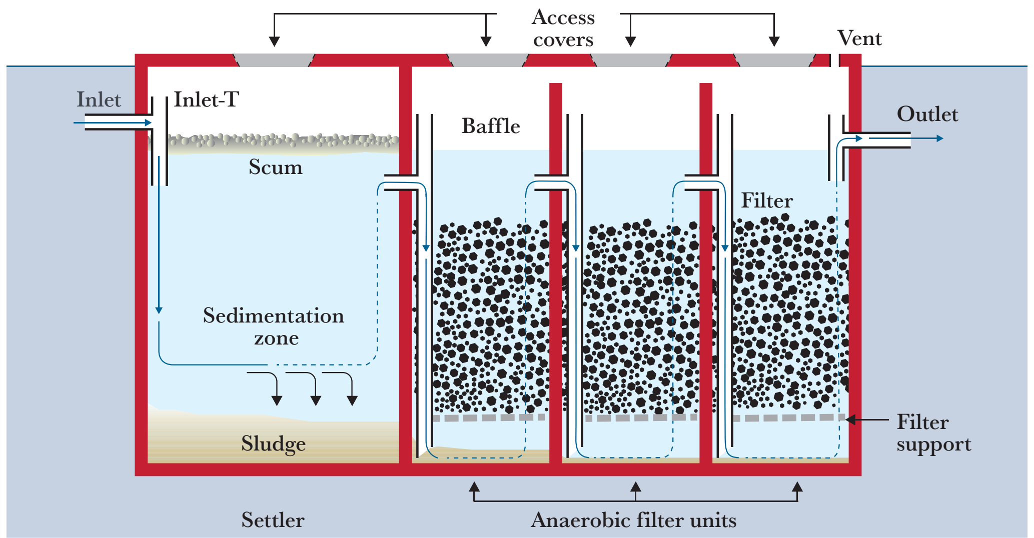
This will be the standard. However, different models and sizes are available. The cost will vary depending on the model being used.

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

2 Anaerobic Baffled Reactor (ABR)

ABR is an improved septic tank with a series of baffles under which the wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment. The upflow chambers provide enhanced removal and digestion of organic matter. BOD may be reduced by up to 90%, which is far superior to its removal in a conventional septic tank.

Representation of ABR:



Source: TILLEY et al. (2014)

Specific Design Considerations:

TThe majority of settleable solids are removed in a sedimentation chamber in front of the actual ABR. Small-scale, standalone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate settler. Designs without a settling compartment are of interest for (semi-) centralised treatment plants that combine the ABR with another technology for primary settling, or where prefabricated, modular units are used.

Typical inflows range from 2-200 m3 per day. Critical design parameters include a Hydraulic Retention Time (HRT) of 48-72 hours, upflow velocity of the wastewater below 0.6 m/hour and the number of upflow chambers (3-6). The connection between the chambers can be designed either with vertical pipes or baffles. Accessibility to all chambers (through access ports) is necessary for maintenance. Usually, the biogas produced in an ABR through anaerobic digestion is not collected because of its insufficient amount. The tank should be vented to allow for controlled release of odorous and potentially harmful gases.

Sludge Component:

Periodic removal of sludge is necessary

Land Requirement:

50 m^2 for 700 KLD

Disposal Standards:

65% reduction in COD and 70% reduction in BOD is achieved

Advantages of the Technology:

- Resistant to organic and hydraulic shock loads
- No electrical energy is required
- Low operating costs
- Long service life
- High reduction of BOD
- Low sludge production; the sludge is stabilised
- Moderate area requirement (can be built underground)

Disadvantages of the Technology:

- Requires expert design and construction
- Low reduction of pathogens and nutrients
- Effluent and sludge require further treatment and/or appropriate discharge

Technology Application:

This technology is easily adaptable and can be applied at the household level, in small neighbourhoods or even in bigger catchment areas. It is most appropriate where a relatively constant amount of black water and grey water is generated. This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. However, a vacuum truck should be able to access the location because the sludge must be regularly removed (particularly from the settler).

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Capacity of 8 m^3/day at Adarsh Vidyaprasarak Sanstha College, Badlapur, Maharashtra

Technology at a Glance

ToS
Onsite

LoA
Peri-urban and urban

CC*
₹ 5,00,000 for 700 KLD

O&M*
₹ 60,000-80,000/year

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

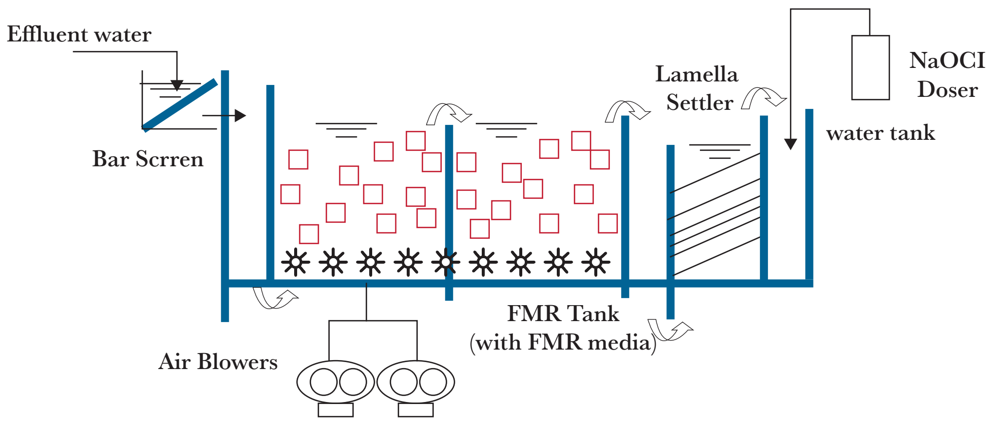
3 Fluidised Media Reactor

The Fluidised Media Reactor (FMR) technology is a simple tank design unit. It comprises the following components:

- A specially designed tank with synthetic media
- A lamella setter
- A chlorine contact tank
- A bar screen

The bar screen removes larger floating matter and suspended particles. Screened sewage flows into the FMR tank, which contains the FMR media. The FMR media significantly increases the surface area for bacterial growth. Air is supplied through fine diffusers. Bacteria oxidise the organic matter present in the wastewater. Oxidised wastewater overflows in the lamella setter. Suspended particles in the treated wastewater settle, with a part of the settled sludge sliding back to the aeration tank. The lamella plates provide larger surface areas, thus reducing the setting tank size. Treated water overflows into a chlorine contact tank, where dosing hypochlorite solution disinfects the treated water through an electronic dosing system.

Representation of Fluidised Media Reactor:



Source: http://www.indiawater.gov.in/misc/Docs/FMR.pdf

Specific Design Considerations:

The FMR carrier material allows biomass concentration of 20-40 kg/m3. The volume of media varies from 6-25% based on the concentration of organic matter (BOD).

Sludge Component:

Sludge is removed in this process once in a day (24 hours) and then dewatered in sludge drying beds.

Land Requirement:

One-third the space of a conventional sewage treatment plant.

Disposal Standards:

Treated Water Quality (Domestic Effluent)

Parameter	After INDION FMR	After Tertiary Treatment (Optional)
BOD	30 ppm	5 ppm
COD	100 ppm	20 ppm
TSS	< 30 ppm	< 5 ppm
Oil and grease	< 10 ppm	< 10 ppm

Advantages of the Technology:

- Significant reduction in space requirement due to the high surface area and loading rate of FMR media
- Reduced power and operating costs
- No sludge recycling
- No moving parts, hence less maintenance

Disadvantages of the Technology:

- **Increased reactor vessel size:** Expansion of the bed materials in the reactor results in a larger vessel than that for a packed bed reactor. This larger vessel means more initial capital cost.
- **Particle entrainment:** The high gas velocities present in the reactor often result in fine particles becoming entrained in the fluid. These captured particles then must be separated, which proves to be difficult and expensive.

Technology Application:

FMR is best suitable when:

- Designing a new wastewater treatment plant when operating cost and space are constraints
- Upgrading existing wastewater treatment plants
- Plants need to be operated in low-temperature areas
- Bulking problems in existing treatment plants need to be reduced

FMR can be used as a decentralised compact sewage treatment plant for housing complexes, hotels, commercial complexes, and industries and in transforming rural communities. The treated water can be used for gardening, toilet flushing and other low-end applications. It is also suitable for industrial wastes such as food and beverage, textile industry, etc.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Data to be sourced

Technology at a Glance

ToS
Onsite

LoA
Peri-urban and urban

CC*
₹ 20-25 lakhs for 150 litres/day

O&M*
Data to be sourced

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

4 Tiger Biodigester Toilet

This technology creates a complete ecosystem in the pit, allowing extremely rapid waste digestion (usually within 24 hrs). Here are some characteristics of this technology:

- Uses natures bio-degradation system by providing a complete soil food chain
- Maintains a completely aerobic environment
- Is odourless
- Worms system operates on a self-regulating basis – the population increases and decreases based on resources
- With an average number of 5 users, it will take 8-10 years for the vermicompost to accumulate

Representation of Tiger Biodigester Toilet:

Source: PriMove Infrastructure Development Consultants Pvt. Ltd.

Specific Design Considerations:

Areas with high water table need to be designed accordingly.

Sludge Component:

Converted to vermicompost in 8-10 years

Land Requirement:

Digester size – 1 m diameter x 1 m depth for a family of 5 users

Disposal Standards:

The waste is converted to vermicompost in 8-10 years.

Advantages of the Technology:

- Eliminates the need for waste handling and faecal recirculation
- Much more effective than twin pit latrines and septic tanks
- Ready-to-install tiger biodigester only requires a pit to be dug for installation
- The rate of waste accumulation is slow – the biodigester tank need not be emptied for up to 10 years
- Odour free

Disadvantages of the Technology:

- Needs to be designed with care in areas of high water table
- Toilet cannot be in disuse for more than a month
- Harsh agents for cleaning of toilets (acids) cannot be used

Technology Application:

- Individual Household Latrines (IHHLs)
- School and community toilets
- Toilets for difficult conditions – high water table / hard rock (above ground digester)
- Conversion of existing twin pit or single pit to tiger biodigester

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

In Chennai slums; Jejuri, Pune; and slum areas of Kolhapur

Technology at a Glance

ToS

Onsite

LoA

Transforming rural, and peri-urban and urban

CC*

₹ 30,000/unit

O&M*

Not applicable for 8-10 years

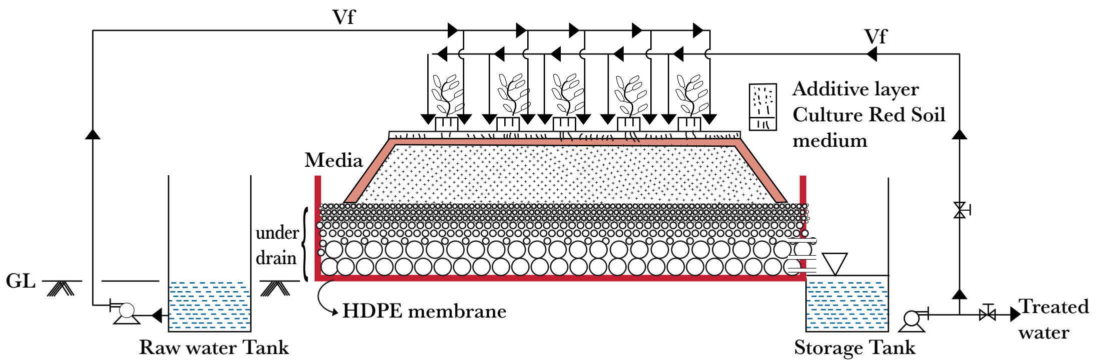
ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

5 Soil Biotechnology (SBT)

SBT is an efficient process of synthesis to completely utilise solids and liquids. A specified additive is added in a predefined proportion. The synthesis process harnesses the energy, carbon and other elements of waste and converts them into precious 'bio-energy' products such as vegetation, energy-rich soil, complete biofertiliser and water. SBT offers bacterial removal of ~99.9%, thus ensuring a healthier environment in a sustained manner without any side effects.

Representation of SBT:



Source: Sugam and IIT Bombay

Specific Design Considerations:

- Operation time for the process is 6-7 hours/day
- Microbial culture is changed every 8-10 years post testing
- The technology works best for quantities less than 5 MLD
- The SBT system bed is dried prior to the next cycle of use
- It requires a temperature between 20-45^{o}C
- No toxic chemicals can be present in the sewage sample
- Wastewater cannot be saline

Sludge Component:

There is no sludge generation due to the complete synthesis of the solids

Land Requirement:

1,500-2,000 m^2 / Million Litres per Day (MLD)

Disposal Standards:

Waste can be treated to disposal standards as per National Green Tribunal (NGT)

Advantages of the Technology:

- Rejuvenation/creation of soil
- Can be utilised for all organic and inorganic molecules present in the effluents
- No requirement of electricity and chemicals (electricity is required only for pumping)
- Generates bioenergy
- Very less space area required – 0.021 m^2 per person (100 litres per day)
- Natural process-based wastewater treatment
- No mechanical aeration involved, yet enough oxygen produced in the bioreactor
- No sludge generation, smell or odour
- Process can be run in both batch and continuous mode
- Overall operating time (wetting cycle) is 6-7 hours
- Capable of handling shock load of 50% over or under design load for a few days automatically
- No skilled labour required for O&M
- Minimal energy consumption (40-50 KWh per MLD to pump wastewater for distribution over the reactor bed)

Disadvantages of the Technology:

- Cannot be used for highly saline and toxic wastes
- Temperature must be in the range of 20-45^{o}C
- Microbial culture needs to be tested and changed once in 8-10 years

Technology Application:

SBT is best suitable when:

- Minimal O&M is required and highly skilled labour is not available
- Space is a constraint
- Electricity is not very reliable

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Capacity of 50 KLD at Naval Dockyard Housing Society, Mumbai

Technology at a Glance

ToS
Decentralised

LoA
Peri-urban and urban

CC*
₹ 1 crore for 1 MLD

O&M*
₹ 15 lakhs/annum for 1 MLD

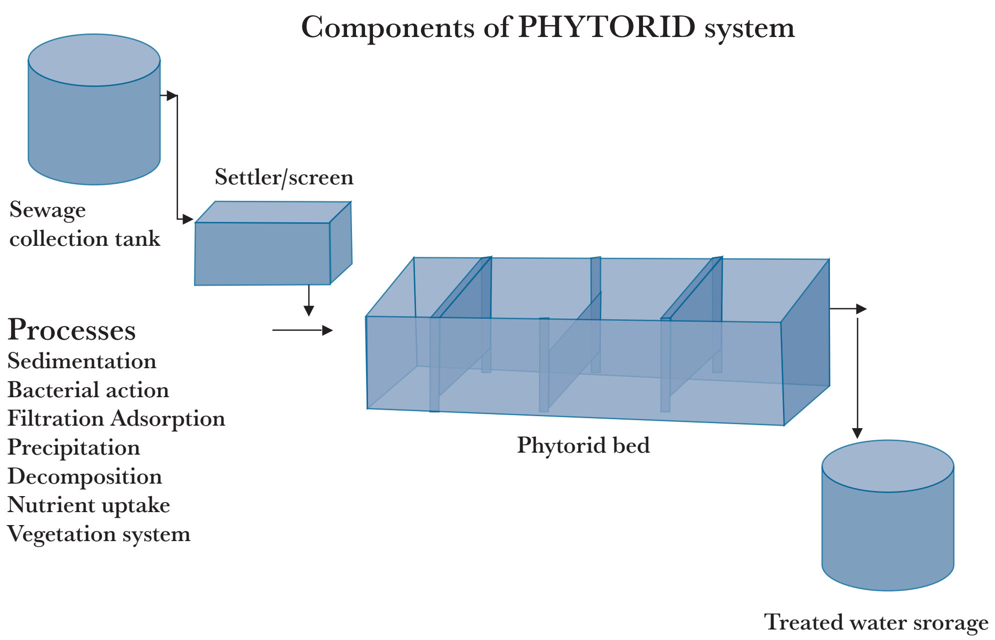
ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

6 Phytorid Technology

Phytorid is a scientifically developed systematic treatment methodology for wastewater. It will consist of a basin or channel with a barrier to prevent seepage, but the systems/cells/beds contain a suitable depth of porous media. A primary treatment facility will also be constructed for effective removal of solids. The porous media also supports the root structure of emergent vegetation. The design of the phytorid system assumes that the water level in the cells will remain below the top of the filter media. The vegetation to be utilised for the said phytorid system is very important. Various species of aquatic plants have been utilised to attain maximum efficiency in the treatment of domestic wastes. These include species such as phramites australis, phalaris arundinacea, glyceria maxima, typha spp., scripus spp., other common grasses, etc.

Representation of Phytorid Technology:



Source: NEERI

Specific Design Considerations:

- Vegetation species utilised for the system are critical
- Maintaining uniform flow across the system through inlet and outlet adjustment is extremely important for the performance of the system

Sludge Component:

Negligible sludge production

Land Requirement:

1 m^3/day will require around 1.5 m^2 area

Disposal Standards:

Performance of Phytorid Technology

Pollutant	Performance (% removal)
TSS	75-95
BOD	70-80
COD	60-75
Total nitrogen	60-70
Phosphate	50-60
Faecal coliform	85-95

Advantages of the Technology:

- Treatment efficiencies of the removal of faecal coliforms, BOD, COD and nutrients are up to 80%, which is greater than the traditional chemical methods
- It is a very cost-effective technology when compared with the traditional wastewater treatment methods
- Since it utilises natural vegetation and rhizosphere microorganisms, it is an eco-friendly method of treating sewage
- An important factor to be considered is the aesthetic improvement that is provided by this methodology
- No mosquitoes and odour nuisance
- The treated water can be used for enhancement of environmental architecture such as roadside fountains
- The quality of treated water is comparable to irrigation standards

Disadvantages of the Technology:

- Vegetation species selected are critical for the system, so dependency on this factor is very high
- Stabilisation of the system initially takes time

Technology Application:

Phytorid is best suitable when:

- Minimal O&M is required and highly skilled labour is not available
- Electricity is not very reliable

It can be used in small towns that have no skilled manpower for O&M.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Capacity of 500 m^3/day at MJP, Nabi Lake, Lonar, Maharashtra

Technology at a Glance

ToS
Decentralised

LoA
Transforming rural and peri-urban

CC*
₹ 30-35 lakhs for 100 m/day

O&M*
₹ 2-3 lakhs/annum

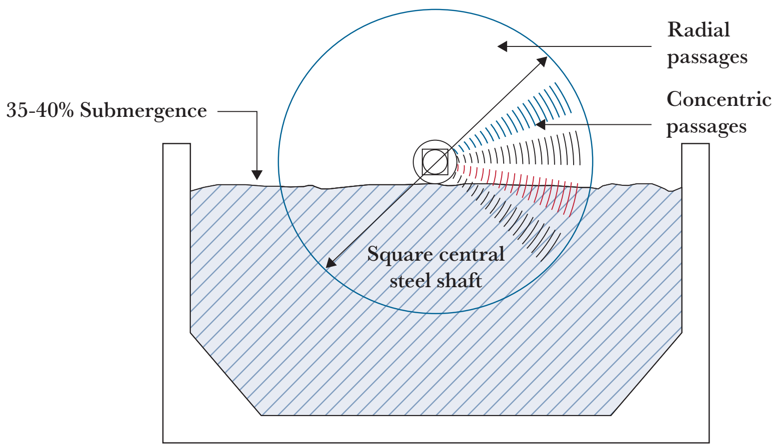
ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obatined through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

7 Rotating Biological Contactor (RBC)

RBC is a biological treatment process used in the treatment of wastewater, following primary treatment. The RBC process involves allowing the wastewater to come in contact with a biological medium to remove pollutants in the wastewater before discharge of the treated wastewater to the environment. Sludge generated in the process is separated in a tube settler type clarifier. Clean water overflows to an intermediate storage tank and sludge is directly disposed to a sludge drying bed at regular intervals. Treated water from the outlet of the sand filter and activated carbon filter is disinfected by chlorination or another equivalent method.

Representation of RBC:



Source: Philippines Sanitation Sourcebook and Decision Aid, WSP-EAP

Specific Design Considerations:

RBCs are usually designed based on hydraulic and organic loadings derived from pilot plants and other full-scale installations. Hydraulic Retention Times (HRTs) generally lie between some hours up to two days.

Sludge Component:

Low sludge production

Land Requirement:

64 m^2 treatment area

Disposal Standards:

BOD reduction is around 95%. Post tertiary treatment from the RBC tank, the treated water can be reused for gardening flushing.

Advantages of the Technology:

- High contact time and high effluent quality (both BOD and nutrients)
- High process stability
- Resistant to shock hydraulic or organic loading
- Short contact periods because of the large active surface
- Low space requirement
- Well-drainable excess sludge collected in the clarifier
- Relatively silent process compared to dosing pumps for aeration
- No risk of channelling
- Low sludge production

Disadvantages of the Technology:

- Continuous electricity supply required (but uses less energy than trickling filters or activated sludge processes for comparable degradation rates)
- Contact media not available in the local market
- High investment as well as O&M costs
- Must be protected against sunlight, wind and rain (especially against freezing in cold climates)
- Odour problems may occur
- Requires permanent skilled technical labour for O&M

Technology Application:

A great variety of applications are known, either as post-treatment for activated sludge processes in conventional domestic wastewater treatment plants or for decentralised application at the level of small to medium-sized communities, industries or institutions. They are mostly adapted for urban areas as land requirements are low, but continuous and consequent energy supply as well as semi-skilled labour are indispensable.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Data to be sourced

Technology at a Glance

ToS

Decentralised

LoA

Peri-urban and urban

CC*

High capital cost

O&M*

High O&M cost

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

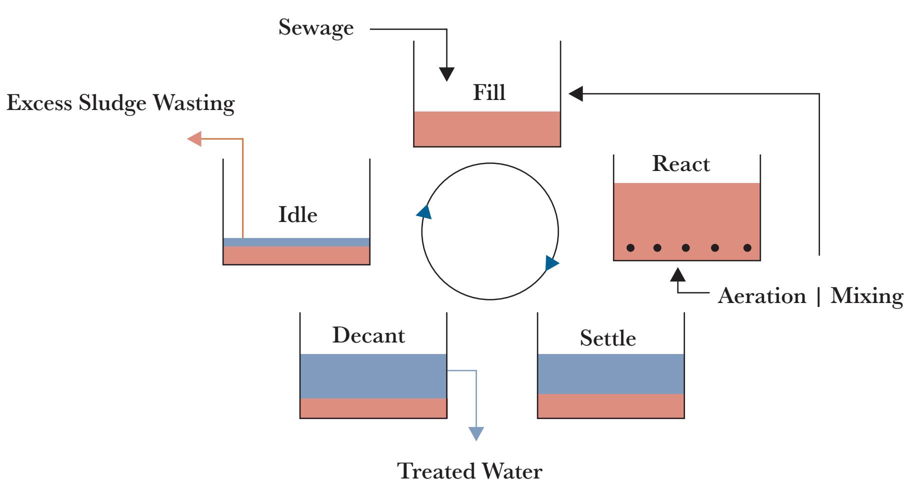
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

8 Sequential Batch Reactor (SBR) Technology for Sewage Treatment

Post pre-treatment, the sewage is taken into an SBR. It provides the highest treatment efficiency in a single-step biological process. The SBR system is operated in a batch reactor mode, which eliminates all the inefficiencies of the continuous process. A batch reactor is a perfect reactor that ensures 100% treatment. Two modules are provided to ensure continuous treatment. No additional settling unit / secondary clarifiers are required. The complete biological operation is divided into cycles. Each cycle runs for a duration of 3-5 hours, during which all treatment steps take place.

Each cycle of operation comprises three phases, viz. aeration, settlement and decanting. Liquid is filled in the SBR basin up to a set operating liquid level. After aeration, the biomass settles and the supernatant is removed from the top using a decanter. Solids are wasted (taken out) from the tanks. The above three phases constitute one cycle, which is then repeated. This technology is suitable where the available land is limited.

Representation of SBR:



Source: Indiamart

Specific Design Considerations:

Once the influent and effluent characteristics of the system are determined, SBR manufacturers will recommend a design. Based on these parameters and other site-specific parameters such as temperature, key design parameters are selected for the system.

Sludge Component:

Sludge component as much as the activated sludge process

Land Requirement:

31.5 m2 treatment area (includes clarification)

They are mostly adapted for urban areas as land requirements are low, but continuous and consequent energy supply as well as semi-skilled labour are indispensable.

Disposal Standards:

For SBRs, the BOD removal efficiency is generally 85-95%. SBR manufacturers will typically provide a process guarantee to produce an effluent of less than 10 mg/litre BOD and 10 mg/litre TSS.

Advantages of the Technology:

- High treatment efficiencies possible for BOD, COD, TSS, nitrogen and phosphate
- High flexibility in operating conditions
- Possibility of producing electric energy from biogas (SBR + anaerobic sludge digestion)
- Less land requirements due to compact tank construction

Disadvantages of the Technology:

- Low pathogen removal
- Requires skilled personnel (particularly SBR with sludge digestion)
- Depends on uninterrupted power supply
- More automation required
- Biogas is an explosive (there is a risk involved in case of improper operation)
- High maintenance requirements
- Almost inevitable dependence on some foreign spare parts
- High capex and opex

Technology Application:

SBRs are typically used at flowrates of 5 MGD or less. As these systems have a relatively small footprint, they are useful for areas where the available land is limited. In addition, cycles within the system can be easily modified for nutrient removal in the future, if it becomes necessary. This makes SBRs extremely flexible to adapt to regulatory changes for effluent parameters such as nutrient removal. SBRs are also cost effective if treatment beyond biological treatment is required, such as filtration.

System Augmentation / Modular Arrangement:

This data must be sourced from the technology provider.

List of Installations:

Capacity of 25 MLD at Sector 50, Noida Authority

Technology at a Glance

ToS

Decentralised

LoA

Peri-urban and urban

CC*

₹ 250-275 lakhs for a capacity of 700 m^3/day/plant

O&M*

₹ 1,27,000/month for a capacity of 700 m^3/day/plant

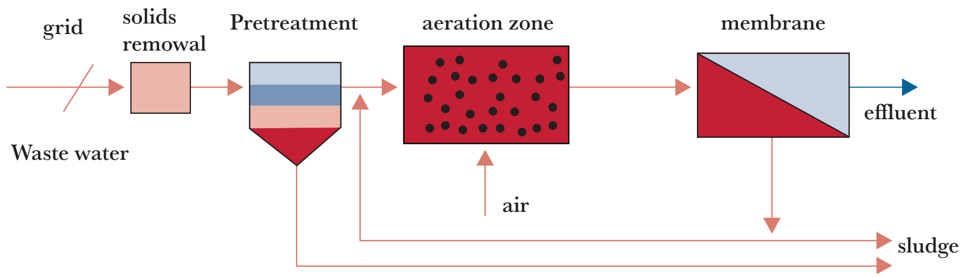
ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

9 Membrane Bio Reactor (MBR) for Wastewater

Sewage treatment plant with MBR technology called as SSEC Membrane Bio Reactor (MBR) can produce good quality water with the highest possible bacterial reduction without adding any chemicals. MBR is the latest technology in wastewater treatment. It has many advantages such as high-quality treated water, small space for installation and easier operation compared to the conventional activated sludge process. The characteristic of the MBR process is the use of revolutionary submerged polymeric hollow fibre membranes in the biological process water tank to produce high-quality permeate from domestic sewage, primary and secondary wastewater, cooling tower blowdown, etc. SSEC MBR is also ideal for retrofitting/augmenting the capacity/quality of existing wastewater plants.

Representation of MBR:



Source: Wikipedia

Specific Design Considerations:

Data unavailable

Sludge Component:

Low sludge yield

Land Requirement:

Low

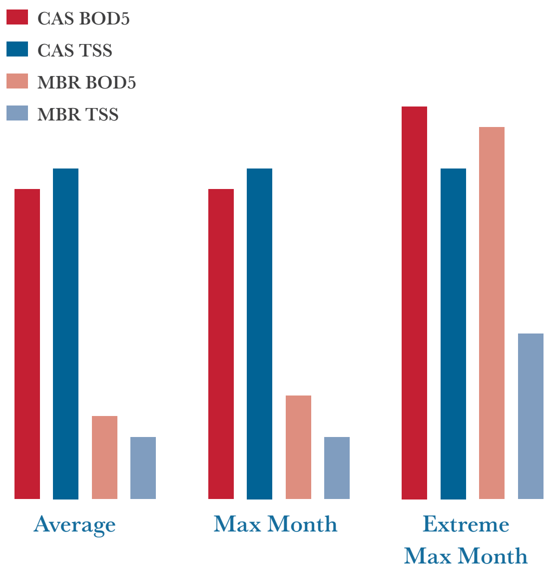
Disposal Standards:

High-quality Treated Water

Parameters	Values
BOD (mg/litre)	<2
TSS (mg/litre)	<1
Ammoniacal nitrogen as NH3-N (mg/litre)	<0.5
Nitrogen as Total Kjeldahl Nitrogen (TKN)*	<1
Faecal coliform count	<2
pH	6.8-7.8

* TKN is the sum of organic nitrogen, ammonia and ammonium in the chemical analysis of soil, water and wastewater

MBR Provides Superior Effluent Quality



MBR Effluent is also Nitrified and Useful for Reclamation

Source: Charu Sharma, M. Tech – Environmental Engineering, Delhi Technological University

Advantages of the Technology:

- It doesn't require a clarifier tank whereas a conventional activated sludge process requires a clarifier, which further adds to the area requirement and cost.
- Biological reaction in MBR can be carried out under the condition of 4-5 times of Mixed Liquor Suspended Solids (MLSS) compared to the conventional activated sludge process. In an aeration tank, MLSS in the range of 8,000-8,500 mg/litre is maintained.

Disadvantages of the Technology:

- High capex and opex due to membrane installation and replacement
- High energy demand
- Fouling of MBR membranes, which leads to frequent cleaning of membranes and hence, more O&M

Technology Application:

MBR systems are being used for treatment of domestic wastewaters from residential townships and group housing complexes. Treated water is reused for gardening and flushing.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

1 MGD plant located near Akshardham temple in Delhi, installed by the Delhi Jal Board, and cities such as Delhi, Panipat and Mumbai

Technology at a Glance

ToS
Decentralised

LoA
Peri-urban and urban

CC*
₹ 340-350 lakhs for a capacity of 700 m^3/day/plant

O&M*
₹ 3,50,000/month for a capacity of 700 m^3/day/plant

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

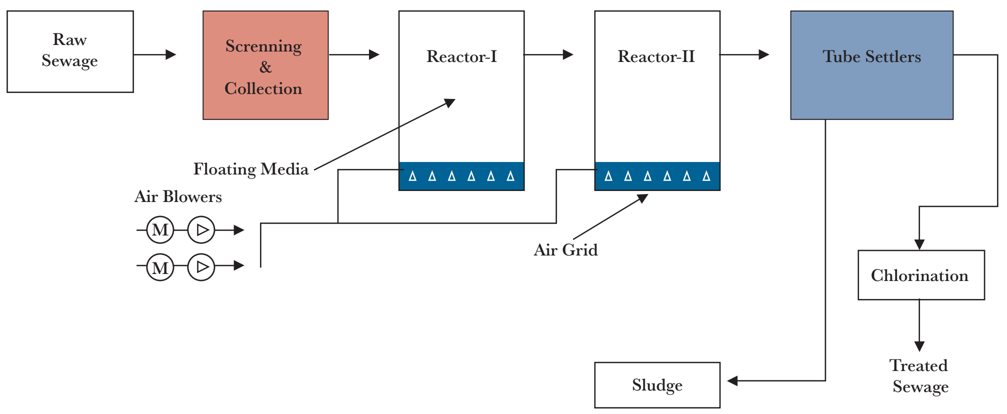
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

10 Moving Bed Bio-film Reactor (MBBR) Technology for Wastewater

MBBR technology employs thousands of polyethylene biofilm carriers operating in mixed motion within an aerated wastewater treatment basin. Each individual biocarrier increases productivity by providing a protected surface area to support the growth of heterotrophic and autotrophic bacteria within its cells. It is this high-density population of bacteria that achieves high-rate biodegradation within the system, while also offering process reliability and ease of operation.

This technology provides cost-effective treatment with minimal maintenance since MBBR processes self-maintain an optimum level of productive biofilm. Additionally, the biofilm attached to the mobile biocarriers within the system automatically responds to load fluctuations.

Representation of MBBR:



Source: Optimus Enviropro

Specific Design Considerations:

- Organic surface loading rate (gram BOD/m2d)
- Protected surface area of carrier (m2/m3)
- The bio media carrier filling fraction
- Temperature

Sludge Component:

Data unavailable

Land Requirement:

8.25 m^2 for treatment area

Disposal Standards:

Removal efficiencies of BOD, COD and NH3-N are ranged between 98.9-99.9%, 97.8-99.9% and 91-100%, respectively

Advantages of the Technology:

- MBBR wastewater systems are compatible with a small footprint, which is almost 1/3rd the space other wastewater systems require
- Improved resilience to load and flow variation
- No operational adjustments
- Only equipment maintenance
- Self-regulating biomass
- Multiple applications
- Cost efficient

Disadvantages of the Technology:

- MBBR reaction tank is prone to having blind corners, and red worms and sewage flies to eat the biofilms, which results in a declined effectiveness of the biological treatment system

Technology Application:

This technology has multiple applications. It can be used for municipal and industrial wastewater treatment, aquaculture, potable water denitrification, and, in roughing, secondary, tertiary and side stream applications. It can also be used in areas where availability of land is an issue.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Supply installation testing and commissioning of modular Sewage Treatment Plant in Rajasthan based on Attached Bio Growth Process with Moving Bed Bio Reactor (MBBR) Technology, 50 KLD, in Ajmer, Rajasthan

Technology at a Glance

ToS

Decentralised

LoA

Urban

CC*

₹ 83 lakhs for a capacity of 700 m^3/day/plant

O&M*

₹ 2,50,000/month for a capacity of 700 m^3/day/plant

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obatined through secondary research and dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

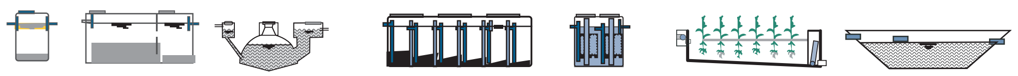
11 Decentralised Wastewater Treatment System (DEWATS)

DEWATS has simple design; is non-dependent on energy; is reliable, long-lasting and tolerant towards inflow fluctuation; and is low in cost. It can treat organic wastewater from domestic and industrial sources. DEWATS is based on different natural water treatment techniques, which are combined according to requirements such as the characteristics of wastewater, desired effluent quality and technical specifications. Settled organic matter is stabilised by anaerobic digestion, while dissolved and suspended matter passes untreated to the next phase. The retention time is around 12 hours (35-40% efficiency).

The following parts comprise DEWATS:

1. **Anaerobic baffled reactor:** The baffle reactor consists of a series of chambers in which wastewater flows upstream. In the bottom of each chamber, activated sludge is retained. During inflow into the chamber, the wastewater is intensively mixed with the sludge whereby it is inoculated with wastewater organisms, which decomposes the contained pollutants. The pathogen reduction is in the range of 40-75%. The baffle reactor is resistant to shock load and variable inflow.
2. **Anaerobic filter:** Anaerobic filters comprise a filter bed for treatment of dissolved organic matter. The treatment is by bringing wastewater in close contact with active bacterial mass. The bacterial mass grows on the filter material (like cinder).
3. **Horizontal planted gravel filter:** The horizontal planted gravel filter is made of reed-planted filter bodies consisting of fine gravel and a polishing pond.

Representation of DEWATS:



Stage	Primary Treatment	Secondary Treatment	Tertiary Treatment
Efficiency	40 - 50%	75 - 90%	95 - 97%
Maintenance	Monthly Inspection Desludging every 2-5yrs	Monthly Inspection Desludging every 2-5yrs	Monthly garden trimming and check/adjust filter

Source: Consortium for DEWATS Dissemination Society (CDD)

Specific Design Considerations:

DEWATS modules are designed and constructed using civil engineering methods. The super surface area of modules can be aesthetically designed and integrated in the landscape requirement. DEWATS treatment modules are designed for mainly organic pollution from both domestic and industrial sources. DEWATS can be designed for wastewater flows from 1-1,000 m³ per day. Modular design of all components can be adapted to changing flows and discharge standards.

Sludge Component:

This system requires desludging regularly. Hence, sludge quantity is high

Land Requirement:

15-20 m² per 1000 litres

Disposal Standards:

Treated water can be reused for gardening, flushing etc.

Advantages of the Technology:

- Treatment of a wide range of wastewater types at affordable prices
- Fulfilment of discharge standards and environmental laws
- Treatment of wastewater flows from 1-1,000 m³ per day
- Tolerance to inflow fluctuation
- Resource efficiency and non-dependence on energy
- Minimal maintenance
- Reliability and longevity
- Reuse of wastewater and its by-products such as biogas and sludge
- Does not require deep sewer line construction
- Can be integrated into the landscape
- Combinations of aerobic and anaerobic treatment process

Disadvantages of the Technology:

- Applicable to flows between 1-1,000 m³/day only
- Certain critical tasks such as weekly removal of leaf litter and harvesting the plants when they are overgrown, monthly sludge level checks and monthly check for algae growth in pond system and its removal if the growth is more, yearly desludging of settler when required, desludging of baffled reactor (2-3 years) and washing filter media of anaerobic filter (2-5 years) are critical for the functioning of the system; hence, O&M is critical

Technology Application:

Disposal of untreated wastewater is a major cause of water pollution in India. Wastewater treatment is often seen as expensive and energy intensive for conventional treatment technologies. DEWATS offers a viable option with reliable long-lasting and affordable techniques. It is applicable in areas where energy is an issue since it involves natural systems. It also involves low maintenance.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Capacity of 15,000 litres per day at Kadi Municipality, Gujarat

Technology at a Glance

ToS
Decentralised

LoA
Peri-urban and urban

CC*
₹ 22,500,000 for a capacity of 700 m³/day/plant

O&M*
₹ 28,000/month for a capacity 700 m³/day/plant

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

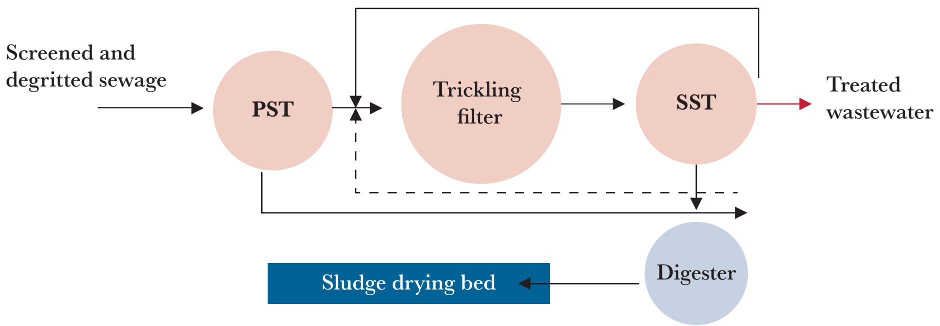
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

12 Trickling Filter

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material.

The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidise the organic load in the wastewater to CO2 and water, while generating new biomass. The incoming pre-treated wastewater is 'trickled' over the filter, e.g. with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass and the inner layers may be anoxic or anaerobic.

Representation of Trickling Filter:



Source: http://www.indiawater.gov.in/misc/InnovationAccrMC_Rep_S.aspx

Specific Design Considerations:

The filter is usually 1-2.5 m deep, but filters packed with lighter plastic filling are 12 m deep. The ideal filter material is low cost and durable, has a high surface-to-volume ratio, is light and allows air to circulate. Whenever it is available, crushed rock or gravel is the cheapest option. The particles should be uniform and 95% of them should have a diameter between 7-10 cm. A material with a specific surface area between 45 and 60 m2/m3 for rocks and 90 to 150 m2/m3 for plastic packing is normally used. Larger pores (as in plastic packing) are less prone to clogging and provide for good air circulation. Primary treatment is also essential to prevent clogging and to ensure efficient treatment.

Adequate air flow is important to ensure enough treatment performance and prevent odours. The underdrains should provide a passageway for air at the maximum filling rate. A perforated slab supports the bottom of the filter, allowing the effluent and excess sludge to be collected. The trickling filter is usually designed with a recirculation pattern for the effluent to improve wetting and flushing of the filter material.

Sludge Component:

Sludge quantity is large.

Land Requirement:

Land requirement is less.

Disposal Standards:

BOD5 Removal Rates for Various Filter Types

Filter type	BOD5 removal rate (%)
Low	80-90
Intermediate	50-70
High	65-85
Roughing	40-65

*The 5-day biochemical oxygen demand, or BOD5, is water quality parameter. BOD5 measures the quantity of biodegradable organic matter contained in water. This biodegradable organic matter is evaluated using the oxygen consumed by the microorganisms involved in natural purification mechanisms. This parameter is expressed as the milligrams of oxygen needed to break down the organic matter contained in a litre of water over five days.

Source: Environmental Engineers' Handbook, 1997

Advantages of the Technology:

- Can be operated at a range of organic and hydraulic loading rates
- Efficient nitrification (ammonium oxidation)
- Small land area required compared to constructed wetlands

Disadvantages of the Technology:

- High capital costs
- Requires expert design and construction, particularly, the dosing system
- Requires O&M by skilled personnel
- Requires a constant source of electricity and constant wastewater flow
- Flies and odours are often problematic
- Risk of clogging, depending on pre-treatment and primary treatment
- Not all parts and materials may be locally available

Technology Application:

This technology can only be used following primary clarification since high solids loading will cause the filter to clog. A low-energy (gravity) trickling system can be designed, but in general, a continuous supply of power and wastewater is required. Trickling filters can be built in almost all environments, but special adaptations for cold climates are required.

System Augmentation / Modular Arrangement:

Data to be sourced from technology provider.

List of Installations:

Data to be sourced

Technology at a Glance

ToS

Decentralised

LoA

Peri-urban

CC*

Data to be sourced

O&M*

Data to be sourced

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

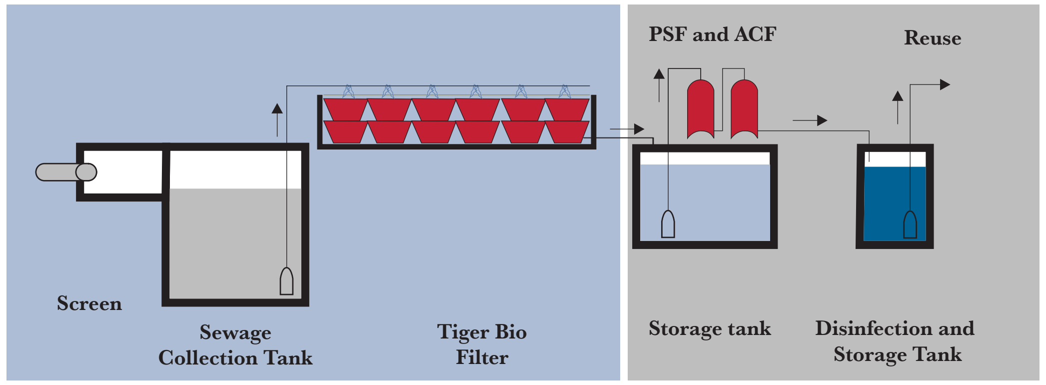
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

13 Tiger Bio Filter Technology

This technology involves a three-stage process:

1. **Primary stage:** A sewage sump where grit and large particles are removed.
2. **Secondary stage:** The bio filter unit consists of a 'bed' of specially bred earthworms and bacteria. Screened wastewater is pumped into the biofilter unit. The trapped organic matter is consumed by earthworms and used for metabolism and reproduction. The thickened sludge spreads to small beds comprising earthworms, bacterial culture and a material suitable to provide a habitat and respiration zone for earthworm growth and reproduction. This tank is used to separate residual solids and liquid stream coming from anaerobic digesters. This tank holds media and earthworms, which helps to further reduce the residual organics from faecal sludge. The trapped solids are consumed by earthworms and converted to vermicompost. The liquid stream leaves the tank from the bottom and is stored in a separate area in the tank.
3. **Optional tertiary stage:** Activated carbon filtration and chlorination is provided to make the treated water safe for reuse.

Representation of Tiger Bio Filter Technology:



Preliminary Units	Secondary Units	Tertiary Units
Existing septic tank/ collection tank can be used.	It can be installed on existing structure or installed separately on ground.	It is an optional treatment for improved treated water quality.

Source: TBF Environmental Solutions Pvt. Ltd.

Specific Design Considerations:

The FMR carrier material allows biomass concentration of 20-40 kg/m^3. The volume of media varies from 6-25% based on the concentration of organic matter (BOD).

Sludge Component:

The trapped organic matter is consumed by the earthworms and hence, there is no sludge formation

Land Requirement:

Data to be sourced

Disposal Standards:

Parameter	Sewage	Treated sewage	CPCB standard
BOD (mg/litre)	80-110	≤ 20	≤ 20 (urban) ≤ 30 (rural)
COD (mg/litre)	250	≤ 50	≤ 50

Advantages of the Technology:

- Low capital cost
- Rapid construction can be erected and commissioned in few weeks
- Modular design can be scaled up rapidly
- Lesser footprint compared to similar technologies; can be stacked vertically
- Odour free
- 75% less electricity consumption
- Natural and eco-friendly technology
- Very less O&M cost
- No need for sludge treatment and handling; by-product is in compost form
- Unskilled labour can operate the plant
- No chemicals used or generated

Disadvantages of the Technology:

- Harsh chemicals in the sewage will prove detrimental for treatment.

Technology Application:

- Decentralised systems that can be used for apartment complexes and small communities
- Range of capacities is from 1,500 m^3/day to 5,00,000 m^3/day

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Pune Sahkar Nagar, 0.5 MLD

Technology at a Glance

ToS

Onsite and decentralised

LoA

Transforming rural, peri-urban and urban

CC*

1,500 m^3/day – ₹ 2.5 crores

O&M*

₹ 7 per 1,000 litres

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

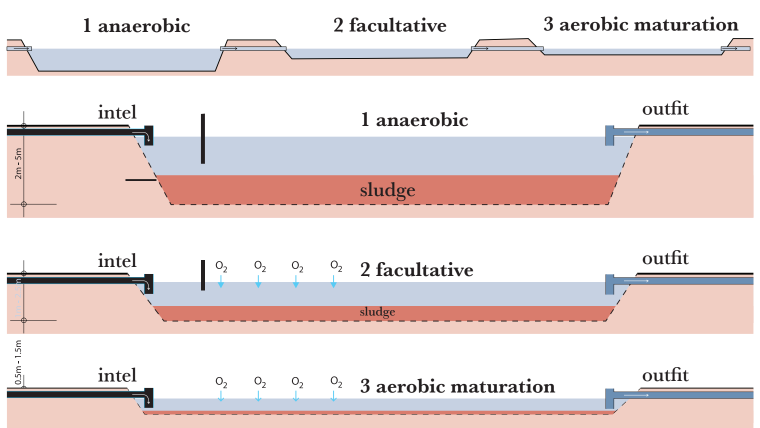
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

14 Waste Stabilisation Ponds (WSPs)

WSPs are large, manmade water bodies. The ponds can be used individually or linked in a series for improved treatment. There are three types of ponds: (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three or more, with effluent flowing from the anaerobic pond to the facultative pond and, finally, to the aerobic pond.

1. **Anaerobic pond:** The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep pond is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the sludge. Anaerobic bacteria convert organic carbon into methane and, through this process, remove up to 60% of the BOD.
2. **Facultative pond:** In a series of WSPs, the effluent from the anaerobic pond is transferred to the facultative pond, where BOD is further removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested at the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.
3. **Aerobic ponds:** An aerobic pond is commonly referred to as a maturation, polishing or finishing pond because it is usually the last step in a series of ponds and provides the final level of treatment. It is the shallowest of the ponds, ensuring that sunlight penetrates the full depth for photosynthesis to occur. Photosynthetic algae release oxygen into the water and at the same time, consume CO_2 produced by the respiration of bacteria. Because photosynthesis is driven by sunlight, the dissolved oxygen levels are highest during the day and drop off at night. Dissolved oxygen is also provided by natural wind mixing.

Representation of WSP:



Source: Wikipedia

Specific Design Considerations:

Anaerobic and facultative ponds are designed for BOD removal, while aerobic ponds are designed for pathogen removal.

Anaerobic ponds are built to a depth of 2-5 m and have a relatively short detention time of 1-7 days. Facultative ponds should be constructed to a depth of 1-2.5 m and have a detention time between 5-30 days. Aerobic ponds are usually between 0.5-1.5 m deep.

To prevent leaching into the groundwater, the ponds should have a liner. The liner can be made from clay, asphalt, compacted earth or any other impervious material. To protect the pond from runoff and erosion, a protective berm should be constructed around the pond using the excavated material. A fence should be installed to ensure that people and animals stay out of the area and that garbage does not enter the ponds.

Sludge Component:

DDesludging every few years is essential.

Land Requirement:

Land requirement is large.

Disposal Standards:

The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.

Advantages of the Technology:

- Resistant to organic and hydraulic shock loads
- High reduction of solids, BOD and pathogens
- High nutrient removal if combined with aquaculture
- Low operating costs
- No electrical energy is required
- No real problems with insects or odours if designed and maintained correctly

Disadvantages of the Technology:

- Requires a large land area
- High capital costs depending on the price of land
- Requires expert design and construction
- Sludge requires proper removal and treatment

Technology Application:

WSPs are among the most common and efficient methods of wastewater treatment around the world. They are especially appropriate peri-urban communities that have large, unused land, at a distance, from homes and public spaces. They are not appropriate for very dense or urban areas.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations

Capacity of 20 MLD at Nandri Jodhpur, Rajasthan, Nagar Nigam Jodhpur

Technology at a Glance

ToS

Onsite and decentralised

LoA

Transforming rural and peri-urban

CC*

₹ 15 lakhs for a capacity 20 m^3/day

O&M*

Data to be sourced

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

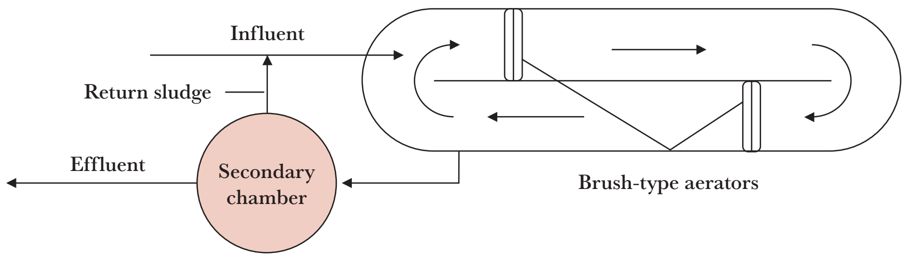
* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

15 Oxidation Ditch

Oxidation ditch is an activated sludge treatment process with a long solids retention time to improve the efficiency of pollutant removal. It typically consists of a single or multichannel configuration within a ring-, oval- or horseshoe-shaped basin. Horizontally or vertically mounted aerators ensure that the wastewater is oxygenated and promote a circular flow of wastewater through the channel.

Long hydraulic retention time and complete mixing reduces the impact of shock loads or hydraulic surges. It produces less sludge than other aerobic treatment processes due to long solids retention times and extended biological activity.

Representation of Oxidation Ditch:



Source: http://www.indiawater.gov.in/misc/InnovationAccrMC_Rep_S.aspx

Specific Design Considerations:

The technology may be preceded by a primary sedimentation tank, but many systems omit primary sedimentation

Sludge Component:

Less quantity of sludge is produced

Land Requirement:

Land requirement is high.

Disposal Standards:

Oxidation ditches achieve BOD, suspended solids, and ammonia nitrogen removal of greater than 90%.

Advantages of the Technology:

- Low operational requirements and O&M cost
- An added measure of reliability and performance over other biological processes owing to a constant water level and continuous discharge, which lowers the weir overflow rate and eliminates the periodic effluent surge common to other biological processes, such as SBRs
- Long hydraulic retention time and complete mixing minimise the impact of a shock load or hydraulic surge
- Produces less sludge than other biological treatment processes owing to extended biological activity during the activated sludge process
- Energy-efficient operations result in reduced energy costs compared to other biological treatment processes

Disadvantages of the Technology:

- Effluent suspended solids concentrations are relatively high compared to other modifications of the activated sludge process
- Requires a larger land area than other activated sludge treatment options; this can prove costly, limiting the feasibility of oxidation ditches in urban, suburban or other areas where land acquisition costs are relatively high

Technology Application:

This technology is very effective in small installations, small communities and isolated institutions because it requires more land than conventional treatment plants

System Augmentation / Modular Arrangement:

Data to be sourced from technology providers.

List of Installations:

Data to be sourced

Technology at a Glance

ToS

Onsite and decentralised

LoA

Transforming rural and peri-urban

CC*

Capital costs (in ₹ 29,400,000)
Plant capacity (m^3/day) 200

O&M*

Annual O&M costs (in₹) 3,43,000
Plant capacity (m^3/day) 200

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

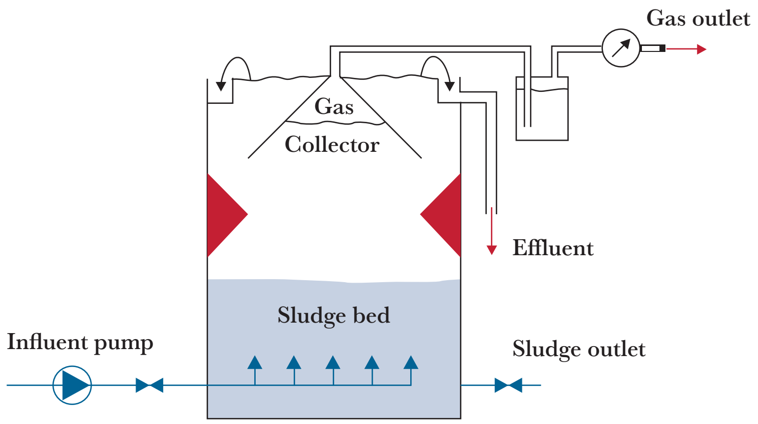
* Most capital and O&M costs have been obatined through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

16 Upflow Anaerobic Sludge Blanket Reactor (UASB)

UASB treats wastewater in the absence of oxygen where the feed enters the tank through the bottom and flows upward as the bacteria present in the sludge digest organic the matter. The sludge blanket consists of microbial granules (1-3 mm in diameter) that are not washed out because of their weight. The microorganisms in the sludge layer degrade organic compounds. As a result, gases (methane and CO_2) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls.

After several weeks of use, larger granules of sludge form, which, in turn, act as filters for smaller particles as the effluent rises through the cushion of sludge. Because of the upflow regime, granule-forming organisms are preferentially accumulated as the others are washed out.

Representation of UASB:



Source: http://www.indiawater.gov.in/misc/InnovationAccrMC_Rep_S.aspx

Specific Design Considerations:

Critical elements for the design of UASB reactors are the influent distribution system, the gas-solids separator and the effluent withdrawal design. The gas that rises to the top is collected in a gas collection dome and can be used as energy (biogas). An upflow velocity of 0.7-1 m/hour must be maintained to keep the sludge blanket in suspension. Primary settling is usually not required before the UASB. Temperature is also a key factor affecting the performance.

Sludge Component:

Sludge production is low

Land Requirement:

Low requirement of land.

Disposal Standards:

Potential to produce higher quality effluent than septic tanks, in a smaller reactor volume. The technology typically removes 80-90% of COD. ata unavailable

Advantages of the Technology:

- High reduction of BOD
- Can withstand high organic and hydraulic loading rates
- Low sludge production (and thus, infrequent desludging required)
- Biogas can be used for energy (but usually requires scrubbing first)

Disadvantages of the Technology:

- Treatment may be unstable with variable hydraulic and organic loads
- Requires O&M by skilled personnel; difficult to maintain proper hydraulic conditions (upflow and settling rates must be balanced)
- Long start-up time
- A constant source of electricity is required
- Not all parts and materials may be locally available
- Requires expert design and construction
- Effluent and sludge require further treatment and/or appropriate discharge

Technology Application:

UASB is not appropriate for small or transforming rural communities without a constant water supply or electricity. It is often used for brewery, distillery, food processing, and pulp and paper waste since the process typically removes 80-90% of COD. Where the influent is low-strength or where it contains too many solids, proteins and fats, the reactor may not work properly. Temperature is also a key factor affecting the performance of this technology.

System Augmentation / Modular Arrangement:

It is possible in this technology, but requires expert design inputs.

List of Installations:

- Most preferred technology at the Yamuna Action Plan, Phase I (YAP-I), accounting for 83% of the total installed treatment capacity of 722 MLD
- Capacity of 34 MLD at Sector 54, Noida

Technology at a Glance

ToS

Centralised

LoA

Urban

CC*

₹ 2.5-3.6 million for 1 MLD

O&M*

₹ 0.08-0.17 million/MLD/year

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

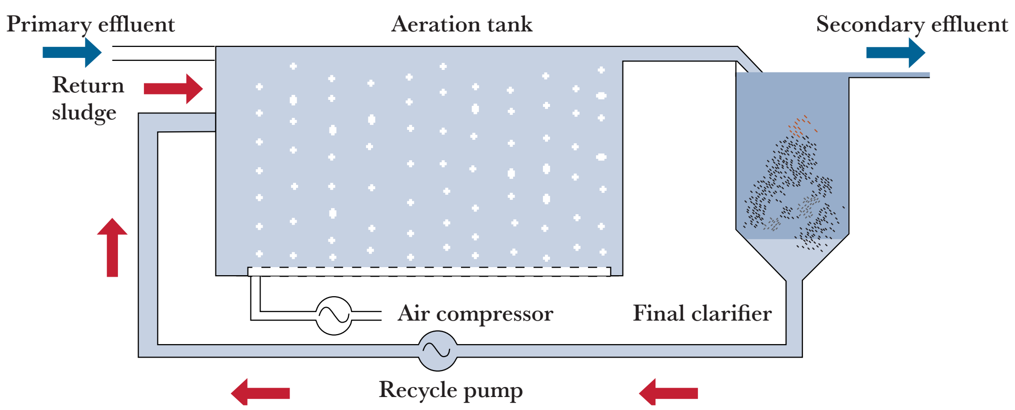
17 Activated Sludge Process

An activated sludge process refers to a multi-chamber reactor unit that uses highly concentrated microorganisms to degrade organics and remove nutrients from wastewater to produce a high-quality effluent. To maintain aerobic conditions and to keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required.

Different configurations of the activated sludge process can be employed to ensure that the wastewater is mixed and aerated in an aeration tank. Aeration and mixing can be provided by pumping air or oxygen into the tank or by using surface aerators. The microorganisms oxidise the organic carbon in the wastewater to produce new cells, CO_2 and water. Although aerobic bacteria are the most common organisms, facultative bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment and wastewater characteristics.

The flocs (agglomerations of sludge particles), which form in the aerated tank, can be removed in the secondary clarifier by gravity settling. Some of this sludge is recycled from the clarifier back to the reactor. The effluent can be discharged or treated in a tertiary treatment facility, if necessary, for further use.

Representation of Activated Sludge Process:



Source: http://www.indiawater.gov.in/misc/InnovationAccrMC_Rep_S.aspx

Specific Design Considerations:

The design must be based on an accurate estimation of the wastewater composition and volume. Treatment efficiency can be severely compromised if the plant is under- or over-dimensioned.

The excess sludge needs to be treated to reduce its water and organic content and to obtain a stabilised product suitable for end-use or final disposal. It is important to consider this step in the planning phase of the treatment plant.

Sludge Component:

A large amount of sludge is generated, which needs to be stabilised before disposal

Land Requirement:

Land requirement is less.

Disposal Standards:

High reduction of BOD and pathogens (up to 99%) and hence, treated water can be reused post tertiary treatment

Advantages of the Technology:

- Resistant to organic and hydraulic shock loads
- Can be operated at a range of organic and hydraulic loading rates
- High reduction of BOD and pathogens (up to 99%)
- High nutrient removal possible
- Can be modified to meet specific discharge limits

Disadvantages of the Technology:

- High energy consumption – A constant source of electricity is required
- High capital and operating costs
- Requires O&M by skilled personnel
- Prone to complicated chemical and microbiological problems
- Not all parts and materials may be locally available
- Requires expert design and construction
- Sludge and effluent require further treatment and/or appropriate discharge

Technology Application:

An activated sludge process is only appropriate for a centralised treatment facility with a well-trained staff, constant electricity and a highly developed management system that ensures that the facility is correctly operated and maintained. Because of economies of scale and less fluctuating influent characteristics, this technology is more effective for the treatment of large flow volumes. An activated sludge process is appropriate in almost every climate. However, treatment capacity is reduced in colder environments.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Most preferred technology at the Ganga Action Plan Phase I (GAP-1)

Technology at a Glance

ToS
Centralised

LoA
Urban

CC*
₹ 237 lakhs for 700 m³/day

O&M*
₹ 3,20,000/month

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and are dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

18 Package Sewage Treatment Plant

The sewage purifier includes anaerobic, anoxic, aerobic, sedimentation, filtration and return sludge. Package sewage treatment plant is an innovative and truly versatile system for the effective treatment of wastewater, including nutrient removal. They can be configured for BOD reduction, suspended solids reduction, ammoniacal and/or total nitrogen reduction and phosphorus reduction. The membrane bio reactor's features have been built into the single packaged plant to create the physical-biological tertiary treatment with water recycling.

Specific Design Considerations:

Design capacity is 2.5 – 100 m^3/hour

Sludge Component:

Sludge is recycled and excess sludge needs to be disposed

Land Requirement:

Less area requirement

Disposal Standards:

Treated water can be recycled.

Advantages of the Technology:

- Proven technology that always offers reliable performance
- Meets the standards for emission of pollutants set by the government and avoids heavy penalty
- Simple and easy installation
- Less land space
- Less manual labour
- Reduces risk to public health and the environment

Disadvantages of the Technology:

- Design capacity is limited. The technology can treat between 2.5 -100 m^3/hour.

Technology Application:

Applicable in areas where land is an issue and less labour is available.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

Hindustan Zinc Ltd., Pantnagar

Technology at a Glance

ToS

Offsite/onsite

LoA

Peri-urban

CC*

₹ 20,00,000 for a minimum capacity of 2 m^3/day

O&M*

₹ 25,50,000/year

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

* Most capital and O&M costs have been obtained through secondary research and dated. Hence, during finalisation of technology, these costs must be revisited and rechecked with the technology providers.

19 Faecal Sludge Management (FSM)

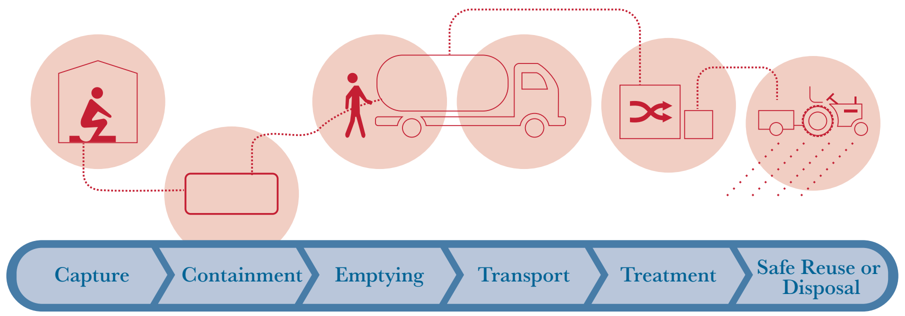
FSM provides sanitation service within the service area in the form of faecal management system in the most cost-effective, healthy and environmentally responsive way. FSM includes emptying, transportation, treatment and use or disposal of faecal sludge from an onsite sanitation technology (like a pit latrine or septic tank).

Septic Tank	Transporation	Plant Drying Beds: De-watering of Liquid Sluge
Treated water used for irrigation	Horizontal planted gravel filter for treatment of water pollutions	Integrated setter and Anaerobic Filter (AF) for primary treatment by sedimentation of solids and AF anaerobic degradation of organic matter

The FSM Process:

1. **Plant Dying Beds (PDBs):** Sludge is transported to the PDBs. Layers of sludge are dewatered and stabilised through multiple biological and physical mechanisms.
2. **Integrated settler and Anaerobic Filter (AF):** The percolate from PDBs is subjected to treatment in the integrated settler and AF. The settler is a primary technology for wastewater. The AF consists of three chambers in which pipes enable water to reach at the tank's bottom where the suspended solids undergo anaerobic degradation.
3. **Horizontal Planted Gravel Filter (HPGF):** It's a tertiary treatment unit where the pollutants are degraded aerobically. HPGF is made up of planted filter materials consisting of graded gravel bed. It's necessary to remove the odour and colour to enrich wastewater with oxygen.
4. **Stabilisation reactor:** Its objective is to allow the sludge to digest anaerobically, which leads to reduction in organic load.
5. **Sludge dying beds:** They are permeable beds filled with several drainage layers. They percolated leachate and allow the sludge to dry by percolation and evaporation.
6. **Settler:** This is a rectangular tank in which faecal sludge is discharged into an inlet at the top of one side and the effluent leaves through an outlet on the opposite site. The solids settle at the bottom of the tank.
7. **Vertical planted gravel filter:** This technology is appropriate where trained mechanical staff, constant power supply and spare parts are available. A vertical flow constructed wetland is a planted filter bed for secondary and tertiary treatment.

Representation of FSM:



Source: Clean India Journal

Land Requirement:

The land required will depend on the different processes involved and also on the specific technology provider.

System Augmentation / Modular Arrangement:

It is possible in this technology.

List of Installations:

A first-of-its-kind FSM plant was set up in Devanahalli, Bangalore, to treat 6,000 litres of faecal sludge a day by CDD Society and the Devanahalli Town Municipal Corporation

Technology at a Glance

ToS

Offsite/onsite

LoA

Transforming rural and peri-urban

CC

₹ 1 crore for a capacity of 10 KLD

O&M

Data to be sourced

ToS - Type of System
LoA - Level of Application
CC - Capital Cost
O&M - Operations and Maintenance Cost

1.6 Four Successful Case Studies

Chapter 1.5, *Technical Details of Proven Sanitation Technologies* on PAGE NO. 7, demonstrated some proven technologies for sustainable sanitation systems. Several states in India and abroad have taken a step towards better sanitation by incorporating technologies that best suit their needs and locations.

1. Faecal Sludge Management at Wai, Maharashtra

Source: https://swachh.maharashtra.gov.in/Site/Upload/Pdf/Road-map-to-success-wai-CEPT-160915.pdf

(Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies*: *19. Faecal Sludge Management (FSM)* on PAGE NO. 44)

Background

Wai is a town in Satara district in the state of Maharashtra. The city is situated on the Krishna River and is surrounded by the mountainous region of the Sahyadris. The town having a population of ~43,000 faced the challenge of human waste disposal. Due to lack of conveyance to transport the waste and absence of treatment facilities, the human waste was dumped into the Krishna River or thrown along with solid waste.

Location

Satara, Maharashtra

Area

Peri-urban (town)

Objective of the Assignment

The objective of the project was to prevent people from dumping human waste in the Krishna River by providing the district with an appropriate sewage treatment method, which would reduce the deterioration of the river quality. It would also treat water so that it can be reused for other non-potable purposes.

Technology Used

Faecal Sludge Management (FSM)

What Was Done

Here is a stepwise account of how this issue was addressed.

1. Faecal Sludge and Septage Management (FSSM) Resolution

First, the Wai Council signed a resolution for FSSM.

What is FSSM?

FSSM is the collection, transport and treatment of faecal sludge from pit latrines, septic tanks or other onsite sanitation systems. Faecal sludge is a mixture of human excreta, water and solid wastes (e.g., toilet paper or other anal cleansing materials, menstrual hygiene materials, etc.) that are disposed of in pits, tanks or vaults of onsite sanitation systems. Faecal sludge that is removed from septic tanks is called septage.

Faecal sludge collection services can be made available on a scheduled basis or on an on-demand basis. The collected faecal sludge should preferably be processed at dedicated Faecal Sludge Treatment (FST) plants, instead of being co-treated with sewage in municipal sewage treatment plants, unless these plants are able to take the additional load, and facilities to separate liquids and solids are available.

Source: Wikipedia

The FSSM Agenda

- Use FSSM to dispose human waste across the town
- Involve the private sector
- Ensure timely cleaning
- Obtain land for setting up the treatment facility
- Levy taxes to ensure the plant's O&M

Wai became the first town to pass such a resolution for sanitation.

2. Scheduled Emptying of Septic Tanks

Irregular cleaning of septic tanks and pit latrines can result in harmful wastewater seeping into the groundwater, wells and local habitats. This is a health concern for people, domestic livestock, pets and wildlife. It can also pollute local rivers, lakes or other recreational areas, making them unusable and unsafe.

The Wai Council decided to shift from a consumer-complaint system of demand-based emptying to a regular service-oriented emptying system. It developed a plan for scheduled septic tank emptying. A legislation was passed to empty all tanks once every three years and two trucks were assigned to desludge ~2,000 septic tanks annually.

Wai became the first town to start scheduled emptying of septic tanks.

3. Faecal Sludge Treatment Plant (FSTP)

Wai constructed a FSTP for treatment and safe disposal of collected septage. The Wai Municipal Council allocated land near the solid waste processing site for the construction of the FSTP.

The construction of the FSTP and its subsequent operation was undertaken by Tide Technocrats (Bangalore) and Bill and Melinda Gates Foundation funded the project. The FSTP uses pyrolysis technology.

Sanergy, a company in Kenya dedicated to providing better sanitation solutions, also used pyrolysis technology. For more details, refer to *Chapter 3, Conclusion and Way Forward: 1. Sanergy, Kenya* on PAGE NO. 65)

Pyrolysis is a thermal decomposition process that occurs in the absence of oxygen. In general, pyrolysis of organic substances produces volatile products and leaves a solid residue enriched in carbon, char.

Source: Wikipedia

4. Private Sector Participation

The Council engaged a private operator for scheduled the emptying of the septic tanks. A tender was floated on the MahaTenders website* and selection was done through a transparent bidding process. An Escrow account was created for payments to eliminate the risk of late payment.

*Through the website, tenderers can download the tender schedule free of cost and then submit their bids online.

5. Financing through Sanitation Tax

A minimal sanitation tax was levied for financing scheduled emptying operations. This amount is less than what citizens were paying as charge for each cleaning. Surplus from property tax collection is also used for maintaining the FSTP.

6. Citizen Awareness

To apprise the people of Wai of the importance of FSSM and of FSTP, awareness campaigns were undertaken. Pamphlets were distributed, informative WhatsApp videos were circulated and door-to-door knowledge-sharing visits were undertaken.

Today, Wai is ODF+ after the implementation of the FSSM Plan. More than 80% of the households have individual household toilets, while the rest have access to well-maintained community toilets.

The ODF+ protocol says that a city, ward or work circle could be declared ODF+ if, at any point of the day, not a single person is found defecating and/or urinating in the open, and all community and public toilets are functional and well-maintained.

Challenges and Issues Faced

- Septic tanks had to be cleaned regularly instead of relying on a consumer-complaint based system.
- The ULBs of Wai had to be equipped with adequate infrastructure required for cleaning the tanks.
- Bringing people on board to understand the importance of a good sanitation system needed much effort.
- It was challenging to build a sustainable financial model for the sanitation system.

Impact

- After the installation of the FSTP, there is reduction in the usage of potable water for non-potable purposes.
- Biochar is used for landscaping and plantation and can be used for agriculture in future.
- Employment opportunities for semi-skilled local citizens were created.
- Various water-borne diseases such as diarrhoea, dysentery, cholera, jaundice, typhoid, etc. were prevented.

2. Moving Bed Bio-film Reactor (MBBR) Technology at Hindustan Zinc Limited (HZL), Udaipur

Source: Case study by Indian Sanitation Coalition

(Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 10. Moving Bed Bio-film Reactor (MBBR) Technology for Wastewater* on **PAGE NO. 26**)

Background

HZL, a Vedanta Group company, is India's largest and the world's second-largest zinc and lead miner. The Company wanted to treat and recycle the sewage collected from Udaipur city and use the recycled sewage in various process applications, thereby saving potable water resources.

Udaipur city generates ~70 million litres of sewage per day and cleaning it has been a challenge. Most of the sewage was finding its way to the lakes leading to contamination of water.

HZL, in association with the Government of Rajasthan, has invested ~170 crore to treat 20 million litres of sewage daily in Udaipur by constructing the first Public Private Partnership (PPP) Sewage Treatment Plant (STP) in the city.

Location

Udaipur, Rajasthan, 2014

Areas

Urban

Objective of the Assignment

The aim of the project was to scale up the STP project in Udaipur and take a step further towards making Udaipur a smart city.

Technology Used

Moving Bed Bio-film Reactor (MBBR) Technology and Sequential Batch Reactor (SBR)

What Was Done

HZL implemented the MBBR technology and commissioned a 20 MLD STP in Udaipur in 2014. It later commissioned an additional 40 MLD, taking the total capacity of the STP to 60 MLD. The construction of the plants was based on Sequencing Batch Reactor (SBR) process and they have a provision for reuse of 50% treated water for Udaipur city.

Challenges and Issues Faced

- Selecting the appropriate location for the wastewater treatment plant, close to the city, was the greatest challenge.
- It was crucial to obtain the necessary approvals for laying down the pipe network in busy urban and touristic areas. The developer of the plant worked in close alliance with the government to ensure all the approvals are in place.
- There were reliability and optimisation issues, as well as challenges related to inconsistent incoming wastewater quality.
- Further, there were challenges switching from freshwater to a treated effluent water quality that had higher TDS. The problem was resolved by marginally modifying the treatment process.

Impact

- The project has a provision for reuse of 50% treated water for Udaipur city.
- 20 million litres per day of freshwater is conserved every day.
- Outlet water quality is fit for process application.
- O&M of the plant is simple.
- The plant consumes less power.
- Wastewater previously disposed into the lakes (30% of city's wastewater) is now collected and treated effluent is used for industrial production.
- Water quality has improved in the Ahar River, and Pichola and Udai Sagar lakes due to reduced volume of wastewater discharges.

3. Decentralised Wastewater Treatment System (DEWATS) in the Kolding Pyramid, Denmark

Source:

- Compendium of Global Good Practices, Urban Sanitation, Peer Experience and Reflective Learning
- https://www.researchgate.net/figure/Block-Scale-Biological-Sewage-Treatment-Kolding-Denmark-The-Fredensgade-blocks_fig1_292939651

[Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 11. Decentralised Wastewater Treatment System (DEWATS)* on **PAGE NO. 28**]

Background

The Municipality of Kolding is a mid-sized Danish town consisting of ~60,000 inhabitants, with a strong political interest in supporting sustainable development. The Kolding Pyramid Project is a top-down, large-scale, integrated project with emphasis on documentation. The project aimed at establishing varied ways of limiting the use of non-renewable resources. It was carried out from 1993-1997 and is one of the pilot demonstration projects.

The project was based on:

- Reduced consumption of energy and water
- Reduction of waste by sorting for recycling and composting
- Use of environment-friendly materials in the construction of the project

Location

Denmark, northern Europe

Area

Urban

Objective of the Assignment

The aim of the project was to build a STP based on reclaiming resources specially designed to target geographical areas with insufficient wastewater treatment infrastructure and/or scarce supply of water.

Technology Used

Decentralised Wastewater Treatment System (DEWATS)

What Was Done

A variety of ecological and energy conservation measures were used while deploying the DEWATS technology at Kolding. The Bioworks, a glass pyramid in the centre of the block, is used to treat sewage, grow fish and cultivate ornamental plants. Rainwater is collected from roofs, stored in a pond and cistern, and used for toilets. Water is treated by algae ponds, ultraviolet light and ozone before circulating to a fish nursery. Effluent circulates to outdoor reedbed wetlands and a seepage pond, finally returning to the ground.

Challenges and Issues Faced

- Operationally, the largest problem is odour, which is a serious nuisance to the inhabitants. The aeration pond is an open system, and continually smells like sewerage, the strength of which varies from day to day depending upon the weather.
- When rainwater was reused, inhabitants complained of dirty water after a long period of no rain due to the dust that settles on the roofs. The solution is further filtration of the rainwater before use. During the driest part of the year, the rainwater must be supplemented with drinking water.

Impact

- The cost of treating wastewater is less expensive compared to the municipal wastewater treatment plant. In the process, it reclaims 98% of the organic material for fertilisation of plants.
- The project has contributed to raising awareness and inspiring decision makers, technicians and private people in Denmark and abroad.

4. Sanitation Program in Kampala, Uganda

Source: Compendium of Global Good Practices, Urban Sanitation, Peer Experience and Reflective Learning

[Refer to *Chapter 2.2, Conceptual Recommendations for Suburban Ward (Oshiwara), Transforming Rural Settlement (Chitravad) and Hypothetical Greenfield Site* on **PAGE NO. 56**]

Background

Increased urbanisation and industrialisation in Uganda led to an increase in the city's population and development of informal settlements. The population doubled during the day due to the influx of the labour force that worked within the city but resided in the neighbouring districts.

In Kampala, sanitation services were inefficient. Untreated effluent was discharged into lakes that supplied drinking water to the population. The impact of poor sanitation facilities, coupled with lack of hygiene knowledge and practices, led to an increase in sanitation-related diseases. This indicated the need for urgent improvement to match the socio-economic and environmental needs of the people.

Location

Kampala, Uganda, Africa in 2010

Area

Peri-urban and urban

Objective of the Assignment

The aim of the project was to improve the health and living standards of the urban poor in informal settlements in Kampala through improved management of sludge from domestic sanitation facilities and provision of hygiene-related education. The project also aimed to improve environmental sustainability of the Lake Victoria basin by reducing the pollution entering the lake through the Nakivubo channel.

Technology Used

A combination of sanitation services such as expansion of sewer networks, septic tanks and services tailored to the urban poor

What Was Done

A comprehensive programme was designed to address the issue of sanitation in Kampala. It included expansion of the sewer network and improved collection of sludge from pit latrines and septic tanks. The project was intended to establish sanitation services tailored to the needs of the urban poor in the low-income community, with special focus on excreta management at both household and communal levels. Ecological sanitation, a concept where the nutrients in human excreta are sanitised and safely reused as biological fertiliser, would be promoted.

Challenges and Issues Faced

- A variety of community-related concerns had to be considered before providing sanitation solutions to ensure environmental sustainability.
- Lack of enforcement of existing planning and sanitation regulations due to scanty resources and political interference was another crucial issue.

Impact

- Reduction in morbidity and mortality caused by sanitation-related illnesses among the urban poor population
- Improved quality of effluent of Nakivubo channel resulted in increase in the efficiency of the water treatment processes and reduction in chemicals used reduced the O&M costs of the National Water and Sewarage Corporation (NWSC)
- Reduction in distance and time spent to obtain safe water and improve sanitation

2. Conceptual Recommendations for Three Different Contexts

This section gives conceptual recommendations for the three identified contexts – suburban ward (Oshiwara), transforming rural settlement (Chitravad) and hypothetical greenfield site – based on preliminary site visit, secondary research data and consultations with AKAH India team members.

The three contexts have been elaborated through the following parameters:

• Current context description and observation	• Current issues

Brief Explanation of the Three Contexts

The Three Contexts	Suburban Ward (Oshiwara)	Transforming Rural Settlement (Chitravad)	Hypothetical Greenfield Site
	Parameters		
Current Context Description and Observation	• The context ward area is 0.98 sq. km and the Oshiwara river system forms an important part of the context area. • Its current population is 55,820. • The area has 17 community toilets, 8 municipal toilets and ~200 individual household toilets. • The slums in the area get water from 7 a.m. to 10 a.m. and have individual household taps. • There are no visible septic tanks or any other mode of treatment for sewage in the context area. The untreated sewage flows directly into the Oshiwara nallah through disposal points along the entire context area stretch. • There are several wood polishing and metal industries in the context area. • There are three cattle sheds in the area.	• It is a transforming rural settlement, a part of the Talala taluka. • The context area is 36.76 hectares. • Its current population is 3,537 and has ~685 households. • The context area has minimal infrastructure. • Source of water is a dug well near Hiran river. • The village has one Elevated Service Reservoir (ESR) with a capacity of 50,000 litres. • There is zone-wise distribution of water supply in the village. • Soil profile is hard murum and soft murum. • There is no sewerage network existing in this region. • More than 90% of the households have leach pits (single-pit – 5 feet X 5 feet) for the toilet waste. There are only 40 households having twin-pit latrines. • Through the 24-hour Jyotigram scheme, the village has electricity all day. • Individual taps exist in every household. • Few households have soak pits for the grey water from the kitchen/bathrooms. • There are no community toilets and septic tanks in the context area. • There is a box drain on the main arterial road. However, there is no existing Storm Water Drain (SWD) in the context area. **Assumptions for the transforming rural settlement in Chitravad** • No. of households • Population • Water supply system as per the new scheme of Water and Sanitation Management Organisation (WASMO), which is being implemented • Sewage technology as per conceptual recommendations given below	• This context area is assumed to have 1,000 households in a peri-urban settlement. • A greenfield project is one that lacks constraints imposed by prior work. The analogy is to that of construction on greenfield land where there is no need to work within the constraints of existing buildings or infrastructure (Source: Wikipedia).

The Three Contexts	Suburban Ward (Oshiwara)	Transforming Rural Settlement (Chitravad)	Hypothetical Greenfield Site
	Parameters		
Current Issues	• Untreated solid waste, sludge and garbage can be observed along the riverbed, creating blockage during monsoons and leading to water logging. • There is no existing sewerage system. • Untreated discharge of cow dung is seen along the context area. • Untreated industrial effluents are discharged directly into the nallah. • Community toilets are not connected to septic tanks. • Water supply lines run parallel to the SWDs, which carry untreated sewage. This could pose a grave health risk in case of leakage. • The colour of the water varies from brown to black and emits a foul odour in the context area stretch.	• Grey water disposal is an issue; only a few households have soak pits. The rest of the households discharge in the open. This leads to health risks. • A few existing soak pits are overflowing since they are not designed properly. • There are no existing SWDs. • There is no structured solid waste collection and disposal mechanism.	Not applicable

2.1 Common Criteria to Be Followed During Planning and Design of the Sewerage System

Planning for selection of technology

Evaluation of the STP technologies

Evaluation of the STP site

Planning for selection of technology

Data collection

Primary data

1. **Topographical and geotechnical survey of the context area**

   Topographical survey: Survey of India's topographical maps and Google GIS maps, followed by any survey done through contractors to corroborate the secondary data. Sometimes, the municipal bodies also have this data, especially if they are planning for a sewage treatment plant.

   Geotechnical study: Conducted by an engineering contractor and/or information is sourced from Urban Local Bodies (ULBs)

2. **Domestic sewage and industrial (in case of any industries) analysis**

   Domestic sewage: pH, temperature, oil and grease, suspended solids, TDS, BOD, COD, phosphates, nitrates, total coliforms and e-coliforms. Ideally, the sample should be analysed across all three seasons and the average should be considered for design

   The guidelines to be followed are as per the NGT on PAGE NO. 6.

   Industrial waste: Depending on the type of industry waste, specific toxic chemicals/compounds will have to be analysed in addition to the parameters mentioned above for domestic sewage.

   Institutes like IIT Bombay and National Accreditation Board for Testing and Calibration Laboratories (NABL Laboratories) conduct these tests.

   NABL Laboratories: Dhttps://www.nabl-india.org/nabl/file_download.php?filename=201903011005-NABL-400-doc.pdf

3. **Random sampling of ward/context area, household survey, community toilets and industry data (if any)**

   The data to be collected for this is enclosed in *Annexure 1, Data Sheets for the Context Area* on PAGE NO. 69. This data can be collected by interns to further corroborate secondary data (if available) for the details needed.

Secondary data

Existing details of the context area, including maps, etc., through ULBs, secondary research, consultants and contractors, and any other relevant information on the context area

The inputs received from stage 1 will be used to evaluate the STP technologies in stage 2.

ii Evaluation of the STP technologies

Parameter	Analysis	Decision
Primary and secondary data of stage 1	While collecting primary data, sewage analysis is critical for selection of technology	Technology selection to be based on data collected
Final use of treated sewage	• Disposal to drain • Reuse for either flushing or gardening	• Secondary level of treatment for disposal to drain • Primary, secondary and tertiary treatment for reuse
Land availability	• End use of treated sewage • **Type of settlement:** Transforming rural, peri-urban and urban	If the treated wastewater is going to be reused, land requirement will generally be more. Hence, technology will have to be selected as per the above criteria.
Energy availability	• Electricity dependability • Any other form/source of energy possible	Settlements where electricity is dependable can consider technologies in which continuous supply of electricity is an important component. This will also help in selection of technologies in areas where electricity is an issue, and hence, alternative sources of energy like solar can also be considered. Energy-intensive technologies can be avoided where costs must be considered
Capital cost	**Capital cost includes:** • Civil items • Electrical items • Mechanical items • Piping	
O&M cost	**O&M cost includes:** • Power cost (₹/litre) • Manpower/labour cost (per person/day) • Chemical and renewables cost (lumpsum/month or lumpsum/year)	Most technologies will give a lumpsum cost. When evaluating, it is good to get a breakup of the capital cost as given under Analysis. Selection can then be done appropriately*.
		O&M is a very important criteria for selection of technology since it is recurring. Ideally, technologies that are not O&M intensive work better in the long run. When evaluating, please ask for this breakup*.

*Land is specifically not considered in both these costs. Ideally, land is provided by the ULBs/government/community.

The next step is the evaluation of the STP site.

iii Evaluation of the STP site

Parameter	Analysis
End use of treated effluent	Location of the site should be selected keeping in mind the following factor: In case reuse of effluent is the aim, then to avoid escalation of costs due to treated water conveyance, a site close to the reuse site should ideally be located. However, this is not always possible, especially in urban areas, where the land cost is quite high.
Future expansion	Land is always selected such that in case there is an increase in the number of people in the project area and hence more usage of the sanitation system is required, expansion of the existing sewage system in the adjacent area is possible.
All-weather access site	Sewage treatment technologies generate sludge, screenings, grit, etc. Removal of this from the site to the designated landfills is essential. Good O&M entails movement of trucks and manpower to take care of the above waste at all times. Hence, ease of access to site is important.
Minimum land resettlement issues	Government-owned land is better to avoid as the chances of land resettlement issues is high. It might lead to escalation in costs, time and resources.
Minimum sewage conveyance	If land is closer to the actual project site, pumping costs and piping costs will reduce, which in turn will reduce the capital cost of the technology.

2.2 Conceptual Recommendations for Suburban Ward (Oshiwara), Transforming Rural Settlement (Chitravad) and Hypothetical Greenfield Site

These recommendations are based on a preliminary site visit to the suburban ward (Oshiwara) and transforming rural settlement (Chitravad), and secondary data received from the AKAH India team. Assumptions have been made in all three cases. During detailed design, it is recommended that the above three stages be followed in detail to arrive at the right solution.

1

Conceptual recommendations for suburban ward (Oshiwara)

- **For the existing community and municipal toilets**
  - **Option 1:** Sewage collection tank with a tiger bio filter unit
  - **Option 2:** Anaerobic Baffled Reactor (ABR)
- **Individual toilets**
  - **Option 1:** Tiger toilet
  - **Option 2:** Tiger biodigester tank
  - **Option 3:** Enbiolet sleek toilets developed by Stone India Ltd.
- **Cattle sheds**
  - An anaerobic digester followed by a tiger bio filter
- **Industrial effluent from metal polishing and wood furniture**

For the existing community and municipal toilets

Option 1: Sewage collection tank with a tiger bio filter unit

The following are our assumptions:

Parameters	Units
No. of community toilets	17
No. of municipal toilets	8
Population considered	35,000
Water consumer per person per day	20 litres (we have considered a higher amount of water consumption)
Capacity of the sewage collection tanks	28,000 litres/day
No. of sewage tanks to be constructed	Depends on actual site conditions such as the distance between two toilets, etc.
No. of tiger bio filters and tertiary systems	

Sewage can be pumped from the sewage collection tanks to the tiger bio filter unit/units (depending on actual site conditions) for the community and municipal toilets. Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 13. Tiger Bio Filter Technology* on **PAGE NO. 32**.

Based on the desired end use, the waste can either be discharged into the nallahs or undergo further treatment in the polishing units and be reused as flush water.

Option 2: Anaerobic Baffled Reactor (ABR)

The following are our assumptions:

Parameters	Units
No. of community toilets	17
No. of municipal toilets	8
Population considered	35,000
Water consumed per day	20 litres (we have considered a higher amount of water consumption)
Capacity of the sewage storage tanks	28,000 litres/day
No. of ABRs constructed	Depends on actual site conditions

Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 2. Anaerobic Baffled Reactor* on **PAGE NO. 10**.

Individual toilets

Option 1: Tiger toilet

The following are our assumptions:

Parameters	Units
No. of individual toilets that exist	200
No. of persons per family	4 or 5

A slum design for tiger toilets can be developed. Wastewater can be collected from households, which have individual toilets (which generate black water) and moris (which generate grey water) can be collected in a storage tank. From here, it can be pumped into a small tiger bio filter. This will cover the waste generated from individual toilets.

Option 2: Tiger biodigester tank

The following are our assumptions:

Parameters	Units
No. of individual toilets that exist	200
No. of persons per family	4 or 5
Dimension of the tiger biodigester system	1 m X 1 m

Individual house toilets can be connected to tiger biodigester tanks. The tanks create a complete ecosystem in the pit, allowing extremely rapid waste digestion. It uses nature's biodegradation system by providing a complete soil food chain. With an average number of five users, it will take 8-10 years for vermicompost to accumulate.

Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 4. Tiger Biodigester Toilet* on **PAGE NO. 14**.

Option 3: Enbiolet sleek toilets developed by Stone India Ltd.

The following are our assumptions:

Parameters	Units
No. of individual toilets that exist	200
No. of persons per family	4 or 5

TThe R&D team at Stone India has developed an aerobic biodigester toilet (Enbiolet) in which human waste is completely digested by the bio media present in the biodigester tank and converted into non-toxic water and gas. It is an aerobic biodigester toilet and uses a five-strain aerobic bacterial culture for the digestion process. The digestion process takes place in a specially designed multi-chambered tank.

These toilets have been installed in several areas in India. To evaluate this further, a visit to one of their sites is essential.

Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 1. Aerobic Biodigester Toilet* on **PAGE NO. 8**.

Cattle sheds

The following are assumptions:

Parameters	Units
No. of existing cattle sheds	3
No. of cattle in the project area	100-900

Not much information is available at present regarding the amount of dung produced, dung sold and dung remaining. Hence, the capacity of the anaerobic system or any other system can only be decided after significant data is collected.

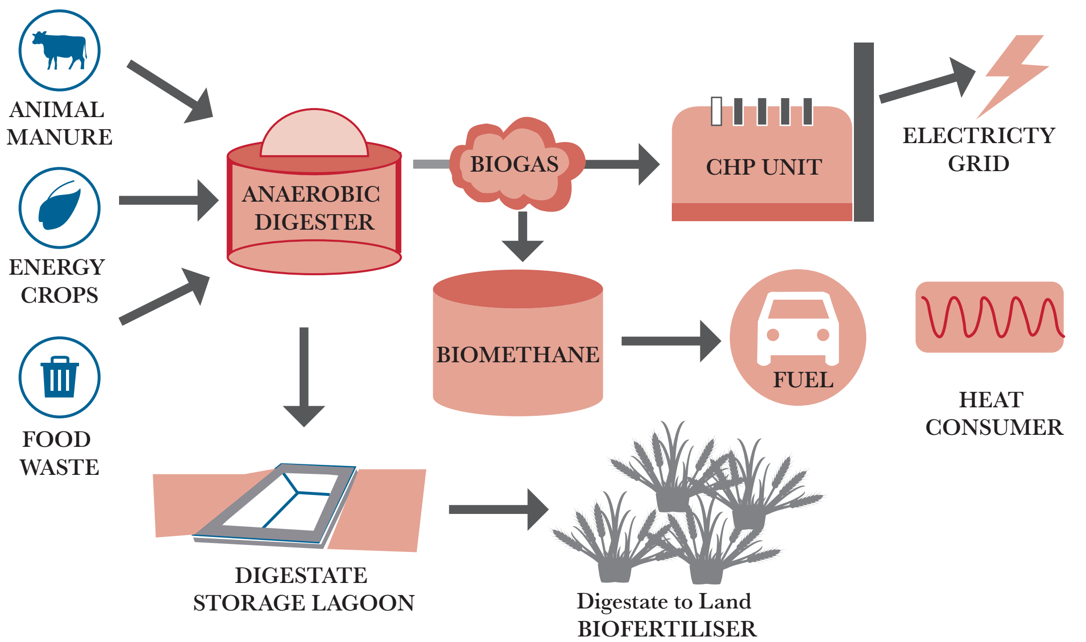
Anaerobic digestor and tiger bio filter

A natural process called anaerobic digestion creates biogas. Anaerobic digesters are closed systems that harness this natural process to produce biogas and other useful co-products. These systems also reduce odours, pathogens and waste.

The effluent from this process can be sent to a tiger bio filter for further treatment and reuse. The sludge can be used as fertiliser/ manure.

Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 13. Tiger Bio Filter Technology* on **PAGE NO. 32**.

Representation of Anaerobic Digester



Source: Geoline Ltd.

Industrial effluent

The following are our assumptions:

Parameters	Units
Type of industry	Metal and wood polishing
Location of discharge of wastewater	Directly into the nallahs through outfalls
Possible discharge pollutants	Metal filings, oil and grease, rinse water and metals in solution in acid/ alkaline formulations

The industrial effluents from all these units must be segregated and tested for, following which the mode of treatment can be finalised. This effluent may have toxic elements, which will need a different kind of treatment. This can also be considered as an enforcement issue to be handled by the pollution board and municipal authorities.

2

Conceptual recommendations for transforming rural settlement (Chitravad)

Option 1A:

Individual black water treatment by tiger biodigester toilets

Option 1B:

Decentralised system for grey water, which can be reused

Option 2:

Decentralised system for treatment of black and grey water for 350 m^3/day

The following are our assumptions:

Parameters	Units
Total population of Chitravad as per census data 2011 (www.census2011.co.in)	3,954
Growth rate (as per census data 2011 and Wikipedia)	1.13%
Projected population in the year 2031 calculated as per above assumptions	4,975
Projected population in the year 2041 calculated as per above assumptions	5,567
Population considered for the year 2041 for calculation purposes	6,000
Water consumption in litres/capita/day	70 lpcd
Quantity of sewage	6,000 X 70 = 4,20,000 litres/day. 80-85% is released as sewage 4,20,000 X 0.8 = 3,36,000 litres/day or 336-350 m^3/day
Energy status	Available most of the time

Option 1A: Individual black water treatment by tiger biodigester toilets

The following are our assumptions:

Parameters	Units
No. of households in 2041	1200
No. of individual toilets with tiger biodigester toilets	1200
No of persons per family	4-5
Water consumer per person per day for toilet use	10 litres (considered on a slightly higher side)
Size of the biofilter	1 m diameter X 1 m depth

Sewage can be pumped from the sewage collection tanks to the tiger bio filter unit/units (depending on actual site conditions) for the community and municipal toilets. Refer to *Chapter 1.5, Technical Details of Proven Sanitation Technologies: 13. Tiger Bio Filter Technology* on **PAGE NO. 32**.

Based on the desired end use, the waste can either be discharged into the nallahs or undergo further treatment in the polishing units and be reused as flush water.

Option 1B: Decentralised system for grey water, which can be reused

Based on the sample analysis of the grey water and actual quantity of water being used in the moris and bathroom out of the 70 lpcd, a small and simple decentralised system can be considered.

Depending on the width of the road, distance between the houses and quantity of grey water generation, collection tanks to store the grey water can be constructed. Though the tanks can be constructed for 20-25 households, the final decision must be made based on actual site conditions.

The following are grey water system components for reuse:

1. Screening
2. Oil and grease removal
3. Equalisation
4. Gravel filtration
5. Activated carbon filtration
6. Chlorination

Name of the process	Function
Screening	Floating matter and suspended matter
Oil and grease removal	Oil and grease
Equalisation	Removal of settleable solids
Gravel filtration (sand and gravel)	Turbidity, suspended filter solids and some amount of BOD
Activated carbon filter	Colour, odour and some amount of BOD
Chlorination/disinfection	Bacteria and odour removal

Grey Water Management System

Grey water → Screening (grease trap) → Froth removal and equalisation → Gravel filtration → Sand filtration → Reuse in flushing/ gardening

Option 2: Decentralised system for treatment of black and grey water for 350 m^3/day

Ideally, the design of this system should refer to the zoning system implemented for water supply by WASMO. Based on the WASMO scheme, the decentralised sewage systems can be planned in terms of location and design.

Sewage will be collected in a sewage collection tank designed to the optimum capacity. From here, it can be pumped to a decentralised sewage system.

The plant will consist of primary (screening and equalisation), secondary (biological, aerobic or anaerobic system) and tertiary treatment (pressure sand filter, activated carbon filter and disinfection) so that the water may be reused for gardening or flushing. Refer to the various options given in *Chapter 1.5, Technical Details of Proven Sanitation Technologies* on **PAGE NO. 7** for decentralised treatment systems. The final selection of the technology option will depend on many factors, which have been enumerated in the same chapter, and in the design considered by WASMO for the water supply system.

3

Conceptual recommendations for the hypothetical greenfield site

Option 1:
In case water supply is equal to or greater than 135 lpcd

- **Centralised treatment:** A sewer collection network to bring the waste to one point
- Will involve primary (screening and equalisation), secondary (biological, aerobic and/or anaerobic treatment) and tertiary treatment (polishing units) for reuse

Option 2:
In case water supply is less than 135 lpcd (@100 lpcd and less)

- Decentralised system for treatment
- Combined streams of black and grey water for further treatment. This will also involve primary, (screening and equalisation), secondary (biological, aerobic and/or anaerobic treatment) and tertiary treatment (polishing units)

Option 1: In case water supply is equal to or greater than 135 lpcd

Centralised treatment: A sewer collection network to bring the waste to one point

The following are our assumptions:

Parameters	Units
Type of settlement	Peri-urban and urban
No. of households	1,000
No. of persons per households	4
Population considered	4,000
Electricity	Available during most times
Water consumed per person per day	135 lpcd
Individual toilets/bathrooms	In all households
Quantity of sewage	4,000 X 135=5,40,000 litres/day 80-85% is released as sewage – 5,40,000 X 0.8 = 4,32,000 litres/day or 450 m^3/day

The sewage from the households will need to be collected via a sewer network and brought to a central location. The capacity, as given above, works out to around 450 m^3/day.

The plant can consist of primary (screening and equalisation), secondary (tiger bio filter) and tertiary (pressure sand filter, activated carbon filter and disinfection) treatment so that water can be reused for gardening or flushing.

The secondary system can be selected from the various technology options given in *Chapter 1.5, Technical Details of Proven Sanitation Technologies* on **PAGE NO. 7**.

Option 2: In case water supply is less than 135 lpcd (@100 lpcd and less)

Decentralised system for treatment

The following are our assumptions:

Parameters	Units
Type of settlement	Peri-urban and urban
No. of households	1,000
No. of persons per households	4
Population considered	4,000
Electricity	Available during most times
Water consumed in litres/person/day	70
Individual toilets/bathrooms	In all households
Quantity of sewage	4,000 X 70 = 2,80,000 litres/day 80-85% is released as sewage – 2,80,000 X 0.8 = 2,24,000 litres/day or at 225-240 m^3/day

In this case, the sewage will be collected in a sewage collection tank designed to the optimum capacity. From here, it can be pumped to a decentralised sewage system.

The plant can consist of primary (screening and equalisation), secondary (biological, aerobic or anaerobic system) and tertiary treatment (pressure sand filter, activated carbon filter and disinfection) so that water can be reused for gardening or flushing. Refer to the various options given in *Chapter 1.5, Technical Details of Proven Sanitation Technologies* on **PAGE NO. 7** for decentralised treatment systems.

3. Conclusion and Way Forward

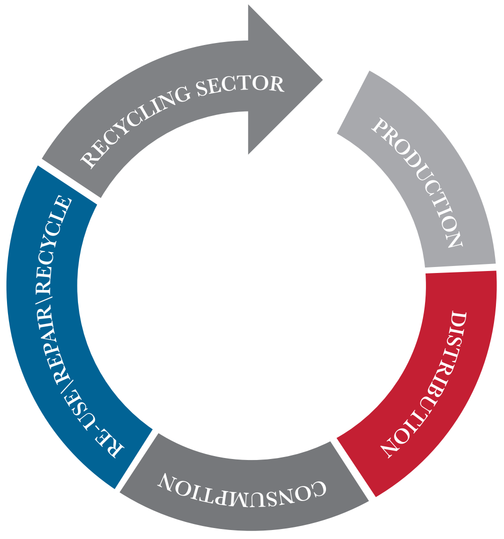
Given the huge financing deficit in urban sanitation in India and the considerable investment required for sewerage systems, a systems approach needs to be taken. There needs to be stringent focus on all aspects of every step in the sanitation chain, encompassing perspectives on technology, management and planning.

Research now suggests that the circular economy model might be the answer to India's water and sanitation crisis.

> Circular economy is the concept in which products, materials (and raw materials) should remain in the economy for as long as possible, and waste should be treated as secondary raw materials that can be recycled to process and reuse.
>
> **— Circular Economy in Wastewater Treatment Plant– Challenges and Barriers**

Circular economy aims to keep products, components and materials at their highest utility and value at all times.

Circular Economy Model



Source: Ellen Macarthur Foundation

To transition to a circular economy, it is important to anticipate, respond to and influence the external and internal factors that enable a circular economy. They include:

- Consumers
- Industry
- Environmental regulations
- Infrastructure
- Economy

Circular Economy – The Future

The following table shows the wastewater treatment plants of today and the intelligent wastewater treatment system of tomorrow. This futuristic system will not only treat wastewater efficiently, allowing effluent reuse, but also generate energy and produce fertilisers.

Wastewater Systems Today	Wastewater Systems Tomorrow
Wastewater treatment and removal of biogenic* compounds	• Change of priorities – Preserving natural resources for future generations • Minimisation of the water footprint • The use of treated wastewater as process water in the wastewater treatment plants • Recovery of raw materials from the wastewater
Disposal of sewage sludge	• Recovery of raw materials from sewage sludge • Energy production from sewage sludge • Disposal of industrial waste
Utilisation of biogas energy	• Self-sufficient wastewater treatment plants (heat and electrical energy generated to run the plant from the waste itself) • The surplus energy can be used to supply external urban facilities

*A biogenic substance is a product made by or of life forms. The term encompasses constituents, secretions and metabolites of plants or animals.

Here are two case studies that showcase how different companies are using the circular economy model to improve sanitation services in different regions.

3.1 Sanergy, Kenya

Background

In Kenya, loss of productivity due to illness costs the country 1% of its GDP every year and at current rates, complete sanitation coverage will take 150 years. Sanergy provides cheap non-sewered sanitation solutions for all urban residents. The Sanergy model was introduced to improve unhealthy sanitation practices in Kenya where residents were forced to rely on unsanitary options such as flying toilets and pit latrines that release untreated human waste into the environment.

Sanergy introduced affordable and high-quality sanitation facilities. Residents who purchase and operate these sanitation facilities are called Fresh Life Operators (FLOs). They become franchise partners who are provided with Fresh Life Toilets (FLTs), training, access to financing, ongoing operational and marketing support, and a daily waste collection service by Sanergy. Its working model includes:

- **Waste collection** – Waste from the toilets is collected daily.
- **Treatment** – The collected waste is converted into useful products such as organic fertilisers, insect-based animal feed and renewable energy.
- **Marketing of recycled products** – The recycled products are transferred to East Africa due to the high demand for such products.

Stakeholders of the Sanergy model

- The operators
- The Sanergy team
- Environment
- Sanergy supporters
- The community

Location

Kenya

Area

Urban

Objective of the Assignment

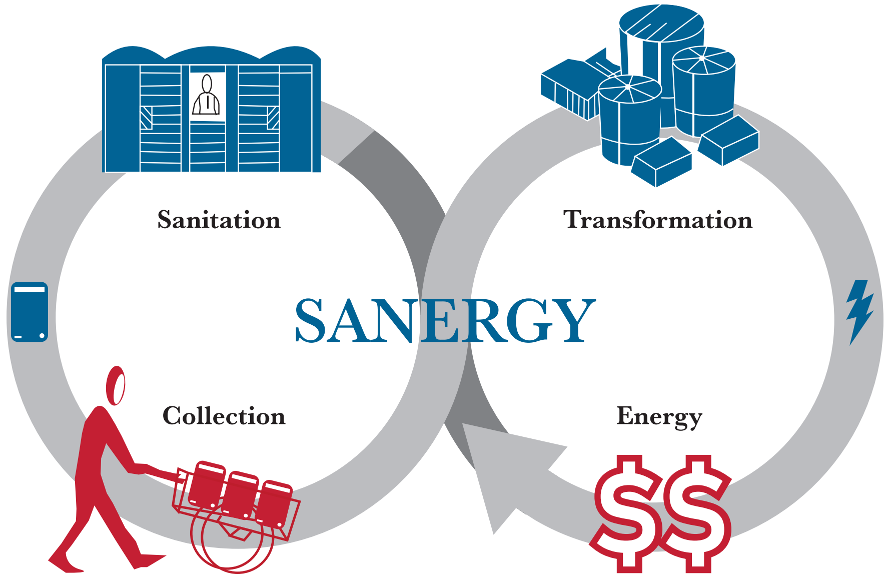
The aim of the project was to provide people access to healthy sanitation services in Kenya.

What Was Done

The Sanergy model not only provides clean toilets, but also uses the human waste to produce energy. The model is designed in a way to create a solution that is clean, sustainable and economic every step of the way.

The model has three parts:

- Create a network of low-cost, robust sanitation centres to provide people with access to clean toilets and showers, either on a pay-as-you-go or subscription basis
- Collect the waste, store it in air-tight containers and transport it to a centralised processing centre with an optimised distribution network
- Process the waste with an anaerobic digester to generate biogas for producing electricity; the remaining solid waste of the biogas generation will then be used as high-quality fertiliser



Source: https://wattnow.org/2011/06/sanergy-building-sustainable-sanitation-in-urban-slums/

Approach of the Sanergy Model

Build
Over 2,827 FLTs serving 1,13,080 residents per day

Sanergy provides FLTs that are high-quality, low-cost sanitation units. With a urine-diverting squat plate, they source-separate solid and liquid waste, making collection and conversion safe and easy. Amenities include a handwashing station with soap, water and a bin for feminine hygiene products.

Collect
7,400 tonnes of waste safely removed from the community every year

Handcarts and trucks are used to remove waste from the community.

Convert
Selling high-quality farm inputs to over 1,000 Kenyan farmers

Waste is converted into valuable end products, such as organic fertilisers and insect-based animal feed, at a centralised facility. Third parties test the end products to ensure their compliance with international standards.

Expand
City wise is Sanergy's consulting arm that helps cities develop and deliver safe, cost-effective sanitation for residents of urban slums

City wise offers four critical services:

- **Assess:** Understand the magnitude of the city's sanitation need
- **Advise:** Evaluate options for technology, service delivery and treatment
- **Assist:** Design an affordable, appropriate and actionable plan, customised for the city under consideration
- **Implement:** Build and operationalise a sustainable sanitation delivery network

Challenges and Issues Faced

- Educating people about the functioning of the Sanergy model and convincing them to use the toilets was a major hurdle.
- Another challenge was promoting the Sanergy model as a solution to Kenya's sanitation troubles.
- It was also crucial to build a sustainable business model.

Impact

Sanergy not only succeeded in setting up 1,134 active FLTs in informal settlements, but has also created over 900 jobs.

Being in harmony with local community, the Sanergy model has tackled unhealthy sanitation conditions successfully in the slums of Kenya. It has also ensured livelihood generation by adopting a circular economic path.

Source: Developing a Circular Economy Model for Rural Sanitation, research plan submitted by Ms. Amruta Khairnar

3.2 Sanivation in Naivasha, Kenya

Background

According to the United Nation's 2014 report, only 30% of Kenyans had access to sanitation services and 13% of the population had to defecate in open spaces due to lack of sanitation facilities. The numbers increased up to 80% in several rural areas. In 2006, the World Bank cited lack of sanitation infrastructure to be at the top of the list of pressing issues in Nairobi. As of 2010, a Guardian report found that only 25% of the households had access to private toilets, while 68% used shared toilets and another 6% defecated in plastic bags that were tied and flung away. Nearly two-thirds of the households disposed human waste through pit latrines, while others had running water or composting toilets within their homes.

In June 2015, Naivasha, a small town in Kenya, was severely affected by a cholera outbreak. Most of the sufferers were from an informal settlement that relied heavily on shallow water wells. Tests run on the water in the wells showed that it was contaminated with human waste. The reason for the contamination was the lack of sanitation facilities in the pre-urban, low-income area, which forced people to defecate in the open or near water bodies. The case of Naivasha was no different from that of hundreds of slums in East Africa where the poor in urban areas were deprived of even the basic hygiene needs.

To address the deteriorating condition of the urban poor and the environment, in 2011, Emily Woods and Andrew Foote, Georgia Institute of Technology (Georgia Tech) grads came forward to start a social enterprise – Sanivation.

Location

Naivasha, Kenya; 2015

Area

Peri-urban

Objective of the Assignment

To help the growing need to process waste coming from septic tanks and pit latrines, and improve the overall dignity, health and environment of urbanising communities in East Africa by delivering clean, safe and efficient sanitation services.

What Was Done

Sanivation partners with local governments to help meet the growing waste processing need from septic tanks and pit latrines. It designs, builds and operated treatment plants to transform faecal sludge into biomass fuels. The revenue from the sale of fuel covers operational costs. Sanivation also works with partners to design, build and train local staff on how to manage improved sanitation services that meet the environmental constraints and cultural aspirations of specific localities.

Objectives of Sanivation

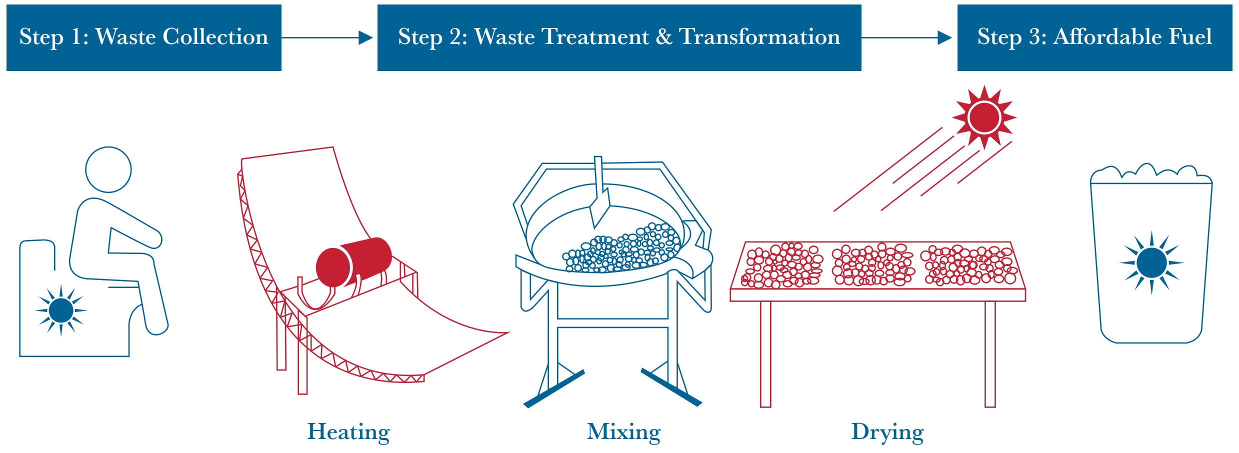
- Apply sustainability models in any business setup, covering the three spheres of sustainability — economic, social and environmental — in a real-life situation
- Analyse the challenges faced by the social entrepreneurs
- Suggest ways to address the cultural barrier for using human excreta as fuel in the household
- Prepare a roadmap to scale up the enterprise
- Transform human waste into a safe and clean alternative to charcoal

Sanivation's Business Model – Relentless Innovation

Sanivation's business model focuses on converting human waste to fuel. The company first collects faecal waste from latrines in a huge container and uses thermal treatment to sanitise the waste and remove any harmful pathogens.

Team members collect waste from each home toilet twice a week and treat it through a solar thermal process. The sanitised sludge is then mixed with carbonised waste, such as charcoal dust or plant waste from nearby plantations, to form briquettes that can be burned as cooking fuel. These briquettes have lower carbon monoxide emissions compared to traditional charcoal and they do not produce smoke. The entire process from collection to finished briquette takes only about four days.

Sanivation's waste treatment system uses a solar concentrator to heat up faecal matter. Primary components include the Scheffler dish reflector (mirrored surface), the beige hopper to load the faecal matter and the large-bore-pipe heat exchanger. A glass and steel parabolic disk with an area of about 5 m^2 acts like a solar concentrator. When the sun's rays hit the disk, it reflects the light and focuses it onto the glass side of an approximately 13 X 13 cm receiver containing the waste. The waste starts warming up to about 60° C. The other sides of the receiver prevent the heat from escaping because they are insulators: cement or fiberglass. Once the human waste gets hot enough, pathogens disappear. This dried human waste is then mixed with charcoal dust or saw dust. Faeces have high fibre content. So, when cooled and dried after heat treatment, a hard and solid briquette forms.



Source: https://medium.com/impact-engineered/waste-not-addressing-the-sanitation-and-fuel-need-235f09b45696

Sanivation's agglomerator* acts like a cement mixer to combine ingredients and apply tumbling pressure to the faeces binder and the carbonised agriculture waste.

Sanivation introduced a new continuous-flow system in which the waste heats up for about five to 10 minutes. It is then routed via pipes to insulating cement and fiberglass containers, where it sits for a total of three hours before moving into the briquette production stage. Sensors throughout the container monitor the temperature.

*A device that causes material to gather into rounded balls

Challenges and Issues Faced

Sanivation states that its solution to Kenya's sanitation problem 'is not a one-size-fits-all'. Saivation is, therefore, working towards customising solutions as per the needs of various communities.

All the projects undertaken by Sanvation have started small. The challenges to scale up and become sustainable are many.

Impact

Sanivation is hoping to replicate their model more rapidly by opening three more branches and expanding to 15,000 households in urban communities of more than 100,000 people. By 2020, they aim to have nine waste-treatment sites and license their model to over 10 refugee camps, reaching over a million people in the process.

Annexure 1

Data Sheets for Suburban Ward (Oshiwara), Transforming Rural Settlement (Chitravad) and Hypothetical Greenfield Site

General Information

Parameter	Details
Ward area	
Total population as per latest census data	
Floating population	
No. of households	
Any topographical and soil profile of context area	
Source of potable water for the households	
Quantity of water being supplied per day	
How many times in a day do the households get water?	
Water distribution system details	
Are there any water meters?	
Any existing sewerage system	
No. of households served by the sewerage network	
No. of households not served by the sewerage network	
No. of community toilets in the context area	
No. of household toilets in the context area	
No. of times a day the households get water	
Septic tank details, if any	
Any form of treatment given to sewage currently?	
Current mode of disposal of black water / grey water	
SWDs laid (length in km)	
Width of the SWDs	
High flood level	
Land availability for setting up of a sanitation system	
Energy situation in the context area	
Skilled labour available /not available in the context area	

Industries Data

Parameter	Details
Kind of industry and details of the process	
Raw water source	
Wastewater treatment and disposal details	

Cattle Shed Data

Parameter	Details
No. of cattle sheds and cattle	
Raw water source for cattle	
Disposal method for cattle waste	

Community Toilets (If Any)

Parameter	Toilets built by the community (within the slums)	Toilets constructed by the municipality
No. of toilet blocks		
No. of seats per block		
Over Head Tank (OHT) capacity		
No. of times the OHT is filled		
Presence of septic tank		

Household Survey – Alleys

Parameter	Typical residential alley	Typical industrial alley
No. of family members		
No. of units per alley		
No. of family members / labourers per unit		
Do they have a mori/bathroom		
Do they have individual taps? If yes, how many?		
Raw water tank capacity		
No. of times the tank is filled in a day		
Do they have an individual toilet?		

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Glossary

1. **Aerobic wastewater treatment** – Aerobic wastewater treatment is a biological process that takes place in the presence of oxygen. Aerobic wastewater treatment encourages the growth of naturally occurring aerobic microorganisms as a means of renovating wastewater.
2. **Anaerobic wastewater treatment** – Anaerobic wastewater treatment is the biological treatment of wastewater without the use of air or elemental oxygen. The organic pollutants are converted by anaerobic microorganisms to biogas, which contains methane and carbon dioxide (CO2).
3. **Baffle** – A water baffle is a type of curtain used to control sediment in water bodies and acts as part of a system to affect water flow.
4. **Biochemical Oxygen Demand (BOD)** – BOD is the amount of oxygen consumed by bacteria while decomposing organic matter under aerobic conditions.
5. **Biofilm** – A biofilm is formed when microorganisms irreversibly attach to and grow on a surface and produce extracellular polymers that facilitate attachment and matrix formation.
6. **Black water** – Black water is a mix of urine, faeces, flush water and nitrogen of the sewage along with the water used to cleanse oneself and/or any dry cleaning materials that might be used for cleansing. Blackwater contains pathogens that must decompose before they can be released safely into the environment.
7. **Brown water** – Brown water is a mixture of faeces and flush water. It does not contain urine. Brown water is generated by Urine-Diverting Flush Toilets (UDFTs). Such toilets have two sections so that the urine can be separated from the faeces. The waste may also include cleansing water or dry cleansing materials.
8. **Centralised system** – When sewage is collected and transported by a network of pipes and pump stations to a municipal treatment plant, it is called a centralised system.
9. **Chemical Oxygen Demand (COD)** – COD is the amount of oxygen required for the oxidation of total organic matter in water.
10. **Combined sewer** – A combined sewer is an underground sewage collection of pipes designed to collect domestic sewage, industrial wastewater and stormwater runoff in a centralised treatment facility. Such sewage systems are mostly found in urban areas and do not require onsite pre-treatment or storage of the wastewater. All the wastewater is transported to a wastewater treatment plant, where it is treated before being discharged into water bodies.
11. **Community-led Total Sanitation (CLTS)** – CLTS is an innovative methodology used to bring communities together to completely eradicate open defecation. It empowers communities to take stock of the situation related to open defecation in their villages and take the necessary steps to become Open Defecation Free (ODF).
12. **Compost** – Compost is produced when microorganisms decompose the biodegradable waste components. The result is an earth-like, odourless, brown or black material. Compost has excellent nutritional properties and can be added to soil for plant growth.
13. **Decentralised system** – When sewage can be treated close to where it is generated, it is called a decentralised or onsite system.
14. **Dry toilet** – A dry toilet is one that operates without flush water. It normally has a raised pedestal on which the user can sit or a squat pan over which the user can squat. In both cases, the faeces fall though a drop hole into a pit dug for this purpose.
15. **Effluent** – Effluent is a common term used for liquid that is remaining after black water or sludge has undergone a solid-separation treatment or any other type of treatment. Depending on the type of treatment, the effluent may be completely sanitised or may require further treatment before it can be reused or disposed of.
16. **Excreta** – Excreta consist of urine and faeces that is not mixed with any flush water.
17. **Faeces** – Faeces refers to semi-solid excrement that is not mixed with urine or water.
18. **Grey water** – Grey water is the total quantity of water generated from activities such as washing food, clothes or dishware, and bathing, but not from the toilet. It may contain traces of excreta (e.g., from washing diapers) and, therefore, also pathogens. Grey water accounts for approximately 65% of the wastewater produced in households with flush toilets.
19. **Improved sanitation facility** – A sanitation facility that hygienically separates human excreta from human contact is considered an ‘improved’ sanitation facility.
20. **Lamella settler** – Lamella settler, also called Inclined Plate Settler (IPS), is a device designed to remove particulates from liquids.
21. **Microbiological culture** – A microbiological culture, or microbial culture, is a method of multiplying microbial organisms by letting them reproduce in predetermined culture medium (a solid, liquid or semi-solid designed to support the growth of microorganisms) under controlled laboratory conditions.

22. **Open defecation** – Open defecation is when people go out in fields, bushes, forests, open bodies of water, or other open spaces rather than using the toilet to defecate.

23. **Open Defecation Free** (**ODF**) – An area, village, state or country is ODF when there are no visible traces of faeces found in the environment and when every household and public/community institution uses the accurate technology for safe disposal of the faeces.

24. **Pit latrine** – A latrine with a pit for collection and decomposition of excreta is called a pit latrine. Liquid from the excreta gets absorbed by the surrounding soil in the pit.

25. **Semi-centralised system** – A semi-centralised system has enough treatment capacity for small villages, communities or districts of about 1,000–10,000 people. The system is connected to sewer systems.

26. **Septage** – Septage is the partially treated wastewater stored in a septic tank or, less commonly, in a pit latrine. It is a by-product of the pre-treatment of household wastewater in a septic tank where it accumulates over time.

27. **Sewage** – Sewage, also called domestic wastewater or municipal wastewater, is produced by a community of people. It consists mostly of grey water, black water, soaps and detergents, and toilet paper. Sewage usually travels from a building's plumbing either into a sewer, which will carry it elsewhere, or into an onsite sewage facility.

28. **Sludge** – Sludge is a mixture of solids and liquids, containing mostly excreta and water, in addition to sand, grit, metals, trash and/or various chemical compounds. There are two types of sludge:

- Faecal sludge: It comes from onsite sanitation technologies and has not been transported through a sewer. It is the solid or settled contents of pit latrines or septic tanks.
- Wastewater sludge: It originates from sewer-based wastewater collection and (semi-) centralised treatment processes.

The composition of the sludge will determine the type of treatment required and the possibilities of end use.

29. **Stormwater** – Stormwater is the general term for the rainfall runoff collected from roofs, roads and other surfaces before flowing towards low-lying land. It is the portion of rainfall that does not infiltrate into the soil.

30. **Vermicompost** – Vermicompost is the product of the composting process using various species of worms. It contains water-soluble nutrients and is an excellent, nutrient-rich organic fertilizer and soil conditioner. It is used in farming.

31. **Wastewater** – Used water from households, communities, farms and businesses contains large quantities of harmful materials, enough to damage the water's quality. Such water is called wastewater. It includes both domestic sewage and industrial waste from manufacturing sources.

Source:

- Water and Sanitation Program, *A Guide to Decisionmaking: Technology Options for Urban Sanitation in India*
- The International Water School, *Compendium of Sanitation Systems and Technologies* (2nd Edition)

Aga Khan Agency for Habitat
India
405A/407, Jolly Bhavan No. 1, 10, New Marine Lines, Mumbai - 400 020, India

/Design at AICL (hello@aicl.in)