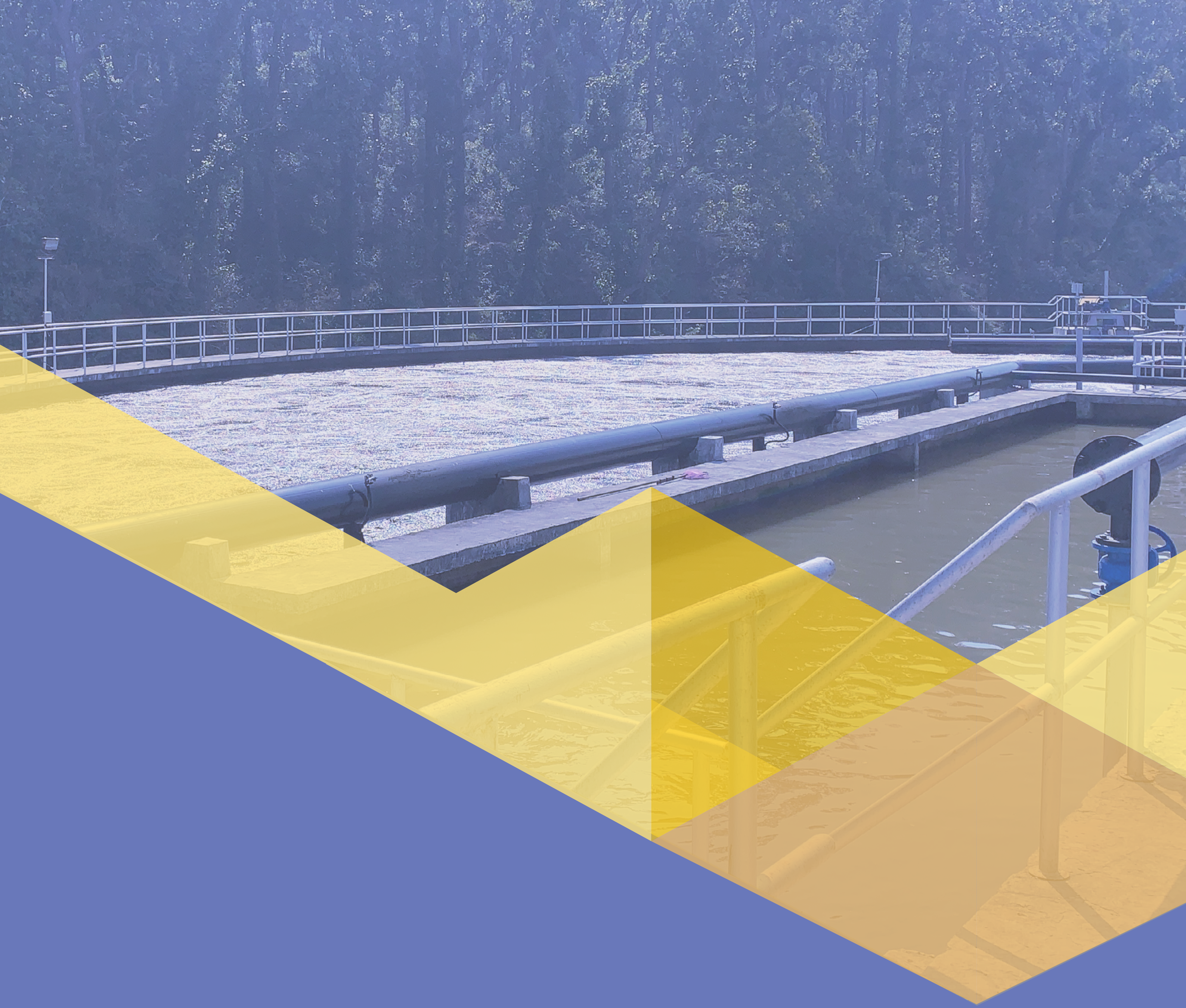

INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT
PLANNING MODULE

PART B: LEARNING NOTES

National Institute of Urban Affairs

NFSSM Alliance

ECOSAN SERVICES FOUNDATION

TITLE
Integrated Wastewater and Septage Management- Planning Module (Part: B Learning Notes)

PUBLISHER
National Institute of Urban Affairs, New Delhi

RESEARCH PROJECT
Sanitation Capacity building Platform (SCBP)

GRAPHIC DESIGN
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Year of Publishing: 2021

CONTENT
The module has been developed with the collaborative effort of NFSSMA partner organisations under Training Module Review Committee (TMRC) anchored by NIUA.

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INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT- PLANNING MODULE

PART: B

LEARNING NOTES

Collaborative Effort Under Training Module Review Committee (TMRC)

Foreword

Acknowledgements

ABOUT NATIONAL FAECAL SLUDGE AND SEPTAGE MANAGEMENT ALLIANCE (NFSSMA)

The ‘NFSSM Alliance’ was formed with a vision to “Create an enabling environment which amplifies scaling of safe, sustainable and inclusive FSSM through knowledge, partnerships and innovative solutions by 2024”.

Convened by Bill and Melinda Gates Foundation in 2016, the Alliance is a voluntary body that aims to:

- Build consensus and drive the discourse on FSSM at a policy level, and
- Promote peer learning among members to achieve synergies for scaled implementation and reduce duplication of efforts.

The Alliance currently comprises 32 organizations across the country working towards solutions for Indian states and cities. The Alliance works in close collaboration with the Ministry of Housing and Urban Affairs (MoHUA) and several state and city governments through its members to support the progress and derive actions towards mainstreaming of FSSM at state and national level. The NFSSM Alliance works on all aspects of city sanitation plans including regulatory and institutional frameworks across the sanitation value chain. The NFSSM Alliance working in collaboration with MoHUA has been instrumental in the passage of India’s First policy on FSSM launched in 2017. This has resulted in the adoption of FSSM guidelines and policies by 19 states in India.

The strength of the Alliance lies in its diverse membership, which includes research institutes, academic institutions, think-tanks, quasi-government bodies, implementing organizations, data experts, consultants and intermediaries. This enabled a multi-disciplinary view of urban sanitation, with members building on each other’s expertise. The Alliance has had enormous success in championing FSSM as a viable solution to the Government of India by broadly focussing on:

1. Influencing and informing policy.
2. Demonstrating success through innovation and pilot projects.
3. Building capacities of key stakeholders across the value chain.

The Alliance continues to work towards promoting the FSSM agenda through policy recommendations and sharing best practices which are inclusive, comprehensive, and have buy-in from several stakeholders in the sector.

NFSSM Alliance

▪ ASCI	▪ CSTEP	▪ EY	▪ NIUA	▪ USAID
▪ Athena Infonomics	▪ CDD	▪ GIZ	▪ PSI	▪ WASHi
▪ BBC Media Action	▪ CPR	▪ IIHS	▪ RTI International	▪ Water Aid
▪ BMGF	▪ CFAR	▪ ISC	▪ Tide Technocrafts	▪ World Bank Group
▪ Borda	▪ CSE	▪ IWMI	▪ UMC	
▪ CEPT University	▪ Dasra	▪ KPMG	▪ UNICEF	

ABOUT TRAINING MODULE REVIEW COMMITTEE (TMRC)

To ensure quality control in content and delivery of trainings and capacity building efforts, a **Training Module Review Committee (TMRC)** was formed with the collaborative effort of all the Alliance partners. TMRC, which is **anchored by the National Institute of Urban Affairs (NIUA)**, has the following broad objectives:

- Identification of priority stakeholders and develop training modules for capacity building accordingly
- Development of a normative framework for capacity building at state level
- Standardization of content for priority training modules with flexibility for customization based on state context
- Quality control of trainings by defining the criteria for ensuring minimum quality of training content and delivery
- Strategy for measuring impact of trainings and capacity building efforts

About the Training Module

Title	Integrated Wastewater and Septage Management - Planning Module (Part A: Presentation Slides)
Purpose	The module introduces a city/town perspective of an integrated planning approach to managing wastewater and septage including methods and technological options for treatment. With the announcement of SBM-U 2.0 and AMRUT 2.0, continuation of NMCG and the recommendations of the 15th Finance Commission, this course provides participants a holistic understanding of wastewater and septage management approaches, which is a key component in these national missions.
Target Audience	Decision-makers, technical and planning officials from state governments and ULBs with a basic understanding and professional experience in wastewater and septage management.
Learning Objectives	1. Gain in depth knowledge of wastewater and septage management principles and approaches 2. Understanding of different sanitation systems and technologies with a focus on wastewater and septage conveyance technologies 3. Gain knowledge about the different treatment principles and technologies available for wastewater and septage management
Format of the Module	The training module is based on case methodology where the sessions are combined with exercises based on real-life cases. This helps the trainee to apply the knowledge grasped during the session and reinforce it further. The module is divided into three parts: Part A: This contains the slides used during the session in the presentation format. **Part B: This is a comprehensive compilation of the all the session briefs and further reading material which helps to strengthen the learning.** Part C: This contains the exercise developed for training based on the real-life cases.
Duration	In a face to face training format, this training is conceptualized for 3 days without site visits and can be adopted for including the site visits depending upon the city where it is being conducted.

GLOSSARY

Anaerobic Digestion	It is a process wherein the degradation and stabilization of organic compounds by microorganisms in the absence of oxygen occurs, leading to production of biogas.
Biogas	It is the common name for the mixture of gases released from anaerobic digestion. Biogas comprises of methane (50 to 75%), carbon dioxide (25 to 50%) and varying quantities of nitrogen, hydrogen sulphide, water vapour and other components. Biogas can be collected and burned for fuel (like propane).
Biomass	It refers to plants or animals cultivated using the water and/or nutrients flowing through a sanitation system. The term biomass may include fish, insects, vegetables, fruit, forage or other beneficial crops that can be utilized for food, feed, fibre and fuel production.
Blackwater	It is the mixture of urine, faeces, and flushwater or anal cleansing materials. It contains the pathogens and organic matter of faeces as well as the nutrients of urine.
Collection and Storage/Treatment	This describes the ways of collecting, storing, and sometimes treating the products generated at the user interface or containment level. The treatment provided by these technologies is often a function of storage and is usually passive (e.g., requiring no energy input). Thus, products that are 'treated' by these technologies often require subsequent treatment before reuse and/or disposal.
Conveyance	It describes the transport of products from one functional group to another. Although products may need to be transferred in various ways between functional groups, the longest and most important gap is between user interface or collection and storage/treatment and (semi-) centralized treatment. Therefore, for the sake of simplicity, conveyance only describes the technologies used to transport products between these functional groups.
Dewatering	The process of reducing the water content from sludge or slurry is termed as dewatering. Dewatered sludge may still have a significant moisture content, but it typically is dry enough to be conveyed as a solid (e.g., shovelled).
Effluent	Generally, it refers to the a liquid that leaves a technology, typically after blackwater or sludge has undergone a basic form of treatment like solid-separation. Effluent originates either the collection and storage/treatment step or at the outlet of (semi-) centralized treatment technology. Depending on the type of treatment, the effluent may be completely sanitized or may require further treatment before it can be used or disposed of.
Excreta	It consists of urine and faeces that is not mixed with any form of water. Excreta is relatively small in volume, but concentrated in both nutrients and pathogens. Depending on the quality and quantity of the faeces, it has either a soft or runny consistency.
Faecal sludge	It is the raw or partially digested wastewater, in a slurry or semi-solid form, found in the collection, storage or treatment unit. It mainly contains a mixture of excreta and blackwater, with or without greywater.
Faeces	It refers to (semi-solid) excrement that is not mixed with urine or water. Depending on diet, each person produces approximately 50 L per year of faecal matter. Fresh faeces contain about 80% water. Of the total nutrients excreted, faeces can contain about 12% N, 39% P, 26% K and have 107 to 109 faecal coliforms in 100 ml.
Flushwater	The water discharged into the user interface to transport the content into the conveying system and/or clean it. Freshwater, rainwater, recycled greywater, or any combination of the three can be used as a flushwater source.

Greywater	The total volume of water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets. It may contain traces of excreta (e.g., from washing diapers) and, therefore, some pathogens. Greywater accounts for approximately 65% of the wastewater produced in households with flush toilets.
Nutrient	It refers to any substance that is used for growth. Nitrogen (N), phosphorus (P), and potassium (K) are the main nutrients contained in agricultural fertilizers. N and P are also primarily responsible for the eutrophication of water bodies.
Sanitation	It is the means of safely collecting and hygienically disposing of excreta and liquid wastes for the protection of public health and the preservation of the quality of public water bodies and, more generally, of the environment.
(Semi-) centralized treatment	This refers to treatment technologies that are generally appropriate for large user groups (i.e., neighbourhood to city level applications). The operation, maintenance, and energy requirements of technologies within this functional group are generally higher than for smaller-scale technologies at the collection and storage/treatment level.
Septage	It is the liquid and solid material that is collected from a septic tank, cesspool, or such onsite treatment facility after it has accumulated over a period of time.
Septic tank	It is generally an underground tank that treats sewage by a combination of solids settling and anaerobic digestion. The effluents may be discharged into soak pits or small-bore sewers, and the solids have to be pumped out periodically.
Sewage	It is the wastewater containing human body waste matter (faeces and urine etc), either dissolved or undissolved, discharged from toilets and other receptacles intended to receive or retain such human body wastes. The effluent coming out of septic tanks or any such facility is also termed as sewage.
Sewerage system	The underground conduit for the collection of sewage is called sewer. A network of sewer appurtenances intended for the collection and conveyance of sewage from the source to a sewage pumping station for pumping to sewage treatment plant for further treatment and disposal is called sewerage system.
User interface	It refers to the type of toilet, pedestal, pan, or urinal with which the user comes in contact; it is the way by which the user accesses the sanitation system. In many cases, the choice of user interface will depend on the availability of water. Note that greywater and stormwater do not originate at the user interface, but may be treated along with the products that originate from it.
Use and/or Disposal	This refers to the methods by which products are ultimately returned to the environment, either as useful resources or reduced-risk materials. Furthermore, products can also be cycled back into a system (e.g., by using treated greywater for flushing).

LIST OF ABBREVIATIONS

C&T	Collection and Transport
IHHT	Individual Households Toilet
IWSM	Integrated Wastewater & Septage Management
ABR	Anaerobic Baffled Reactor
CAPEX	Capital Expenditure
DTS	Decentralised Treatment System
ESF	Ecosan Services Foundation
FSS	Faecal Sludge and Septage
FSSM	Faecal Sludge and Septage Management
FSTP	Faecal sludge and Septage Treatment Plant
HCW	Horizontal Constructed Wetlands
LCC	Life Cycle Cost
NIUA	National Institute of Urban Affairs
O&M	Operation & Maintenance
OPEX	Operational Expenditure
UDDT	Urine Diverting Dry Toilet
UDFT	Urine Diverting Flush Toilet
STP	Sewage Treatment Plant
SCBP	Sanitation Capacity Building Program
SeTP	Septage Treatment Plant
UASB	Up-flow Anaerobic Sludge Blanket Reactor
ULB	Urban Local Body
VCW	Vertical Constructed Wetlands
WSP	Waste Stabilization ponds

INTEGRATED WASTEWATER & SEPTAGE MANAGEMENT (IWSM)

Planning Module

AGENDA

Time	Session Title
	Day 1
10:00 –10:30	Registration
10:30 – 11:00	Introduction- Round of Introduction; Setting ground rules; Understanding expectations, aims & objectives
11:00 – 11:45	Sustainable Sanitation & Water Management
11:45 – 12:00	**Tea and Coffee Break**
12:00 – 12:10	Missions and Programs
12:10 – 12:40	Sanitation Systems
12:40 – 13:30	**Lunch Break**
13:30 – 14:30	Sanitation Technologies
14:30 – 15:00	Building Sanitation Systems- Activity Session (F2F)
15:00 – 15:45	Liquid Waste Management
15:45 – 16:00	**Tea and Coffee Break**
16:00 – 17:00	Mapping the City- Activity Session (F2F)
17:00 – 18:00	Decentralised Wastewater Management – Exercise

Time Duration (Hours)	Session Title
	Day 2
09:30 – 10:15	Feedback & Quiz
10:15 – 11:15	Aspects of Decentralised Wastewater Management
11:15 – 11:30	**Tea and Coffee Break**
11:30 – 12:15	Understanding Faecal Sludge & Septage Management
12:15 – 13:00	Faecal Sludge & Septage Management Planning – Exercise
13:00 – 14:00	**Lunch Break**
14:00 – 15:00	Stakeholders Management
15:00 - 15:45	Faecal Sludge & Septage Treatment
15:45 – 16:00	**Tea and Coffee Break**
16:00 – 16:45	Financial Aspects of Faecal Sludge & Septage Management
16:45 – 17:30	Operation & Maintenance Cost for Faecal Sludge & Septage Management – Exercise
17:30 – 18:00	Conceptualizing Sewage Treatment Plant- Activity Session (F2F)

Time Duration (Hours)	Session Title
Day 3	
10:00 – 12:30	Site Visits
12:30 – 13:30	**Lunch Break**
13:30 – 14:15	Feedback & Quiz
14:15 – 15:15	Wastewater Treatment Principles
15:15 – 15:30	**Tea and Coffee Break**
15:30 – 16:15	Wastewater Treatment Technologies
16:15 – 16:45	Case Studies of STPs & FSTPs in India
16:45 – 17:00	Feedback & Wrap Up Session

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Session

01

Sustainable sanitation & water management

1. Sustainable sanitation & water management

1.1 Learning objectives

- To understand the concept of environmental health, environmental sanitation and environmental services needed to maintain the balance in the environment
- To understand various types of liquid waste products and their flow
- To understand the basis of ecological sanitation and its extension
- To understand urban challenges faced at various levels of sanitation and water management

1.2 Session plan

Duration - 45 minutes

Topics	Time	Material/Method
Introduction to environmental health	5 min	Power point presentation
Environmental sanitation	5 min	Power point presentation
Liquid waste products	5 min	Power point presentation
EcoSan- Ecological Sanitation	10 min	Power point presentation
Urban challenges	10 min	Power point presentation
Q&A	10 min	Discussion

1.3 Key facts

- Good health presupposes that the water we drink, the air we breathe and the food we eat are free from contaminants and pathogens, and that facilities, services and hygienic behavior provide for a clean environment in which to live, with measures to break the cycle of disease and contamination
- Waste should be considered a resource, and its management should be holistic and form a part of integrated water resources, nutrient flows and waste management processes
- In line with sound governance principles, decision-making should involve the participation of all stakeholders, especially the consumers and service providers

1.4 Learning notes

1.4.1 Introduction to environmental health and its components

Environmental health is broader than hygiene and sanitation; it encompasses hygiene, sanitation and many other aspects of the environment such as global warming, climate change, radiation, gene technology, flooding and natural disasters. It also involves studying the environmental factors that affect health.

> The World Health Organization (WHO) defines environmental health as follow:
>
> Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health

It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behaviour not related to environment, as well as behaviour related to the social and cultural environment, and genetics. It is an international discipline, although practices vary from country to country, as do the people and organizations undertaking the work.

Figure 1: Components of environmental health

Environmental health has been responsible for improving our life expectancy and quality of life. Practitioners have been instrumental in reducing air pollution, improving standards in housing and food safety, and mitigating infectious disease and effects of disasters. The components that make up environmental health can be grouped as follows:

Table 1: Components of environmental health

Description	Concerns
Personal hygiene	Hygiene of body and clothing
Water supply	Adequacy, safety (chemical, bacteriological, physical) of water for domestic, drinking and recreational use
Human waste disposal	Proper excreta disposal and liquid waste management
Solid waste management	Proper application of storage, collection, disposal of waste. Waste production and recycling
Vector Control	Control of mammals (such as rats) and arthropods (insects such as flies and other creatures such as mites) that transmit disease
Food hygiene	Food safety and wholesomeness in its production, storage, preparation, distribution and sale, until consumption
Healthful housing	Physiological needs, protection against disease and accidents psychological and social comforts in residential and recreational areas
Institutional hygiene	Communal hygiene in schools, prisons, health facilities, refugee camps, detention homes and settlement areas
Water pollution	Sources, characteristics, impact and mitigation

Anyone changing the natural or built environment has an impact on environmental health. To achieve good environmental health, one should

- Maintain a natural environment free from undue hazards
- Ensure a built environment free from undue hazards
- Provide essential environmental services to households and communities in order to achieve good individual and community health

Figure 2: Natural and Built Environment (Source: Eawag, Sandec (2008))

The natural and built environment with its natural resources water, air and soil (blue) along with all services and facilities required to keep the environment clean and protect health (green). In this module, focus will be on water supply and environmental sanitation services, facilities and human behaviour (inside yellow line).

Interventions to reduce people's exposure to disease by providing a clean environment and measures to break the cycle of disease. It involves both behavior and facilities, which jointly work together to form a hygienic environment. (Simpson-Hebert and Woods, 1998)

This comprises of:

- access to a safe supply of water for domestic use;
- access to water for washing and hygiene practice;
- safe management of human excreta and wastewater; and
- solid waste management and (storm water) drainage.

1.4.2 Environmental sanitation

Environmental sanitation is defined as activities aimed at improving or maintaining the standard of basic environmental conditions affecting the well-being of people. These conditions include: (1) clean and safe water supply, (2) clean and safe ambient air, (3) efficient and safe animal, human, and industrial waste disposal, (4) protection of food from biological and chemical contaminants, and (5) adequate housing in clean and safe surroundings.

Waterborne or excreta related diseases are still significant and they cause mortality and morbidity in many developing countries. The transmission routes of these and the health risk factors involved are important, in order to design and implement or modify excreta use schemes so that the transmission of these diseases are reduced (see also health risk management). The pathogens of concern for environmental transmission through faeces mainly cause gastrointestinal symptoms such as diarrhoea, vomiting and stomach cramps. Several pathogens may also cause symptoms involving other organs and severe sequels or be an interrelated factor for malnutrition. This mechanism works through a variety of routes, as shown by the "F-diagram".

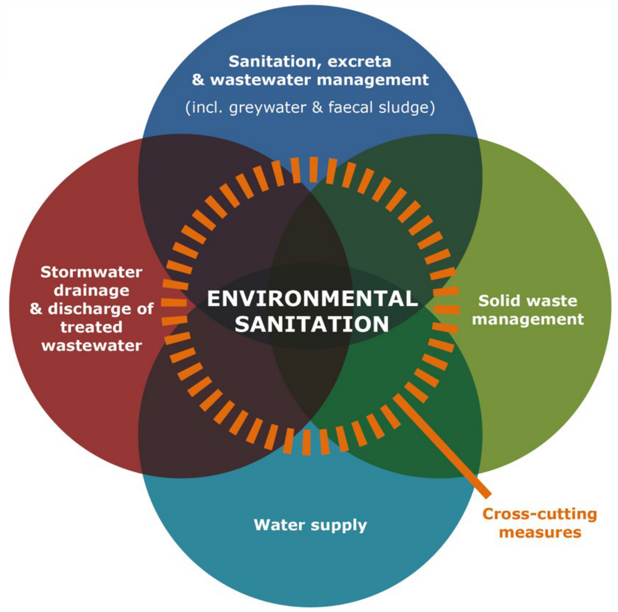

Figure 3: Components of environmental sanitation

The figure below shows the factors that are essential for diarrhoea transmission.

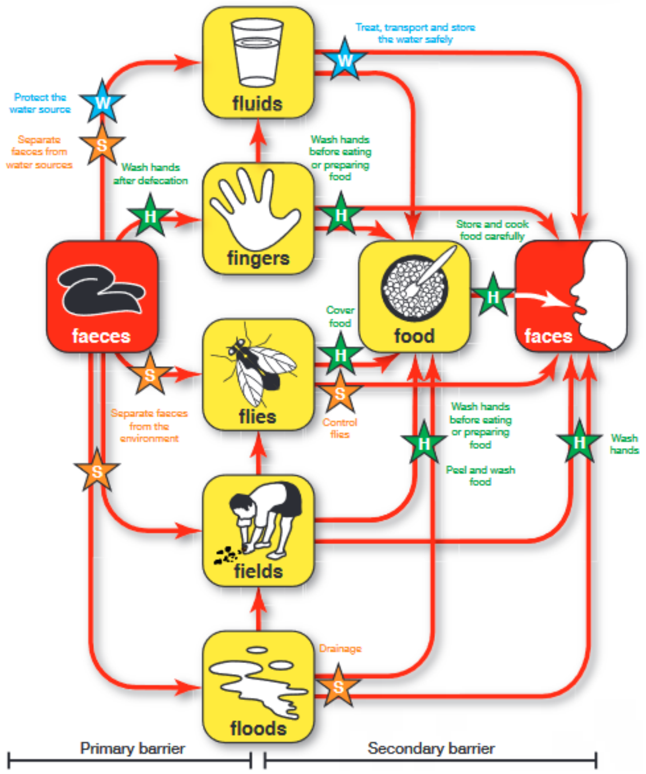

Figure 4: The F-diagram (Source: WEDC)

If you understand the pathway of the disease, then you can design an intervention for the disease that targets the source, environment or the host. An intervention is a way of stopping the disease from being transmitted. The stars in different colours, in the figure above, indicate the possible interventions for the prevention and control of diarrhoea. Some of these interventions are described in the table below.

Table 2: Possible health interventions to prevent diseases

Intervention strategies	Activities
Intervention at the source	Avoid open defecation Install a latrine Always use a latrine to bury feces and urine
Intervention in the environment	Use safe drinking water Handwashing Vector control and management Proper refuse and liquid waste management Provision of food safety Healthful housing
Intervention at the host	Hygiene promotion through hygiene education and community mobilization Vaccination (if available) Healthy living

1.4.3 Resources and waste management systems

The large number of people worldwide still lacking access to adequate water, sanitation, drainage, and solid waste disposal services provides sufficient evidence that conventional approaches to environmental sanitation are unable to make a significant dent in the existing service backlog. At the same time, the world's natural supply of freshwater is subject to increasing environmental and economic pressure. Unless determined action is taken, the situation is likely to worsen dramatically. Population growth and increasing per capita water demand fuelled by rapid industrialisation in the developing world will further contaminate and deplete the finite water sources already over-exploited in many countries.

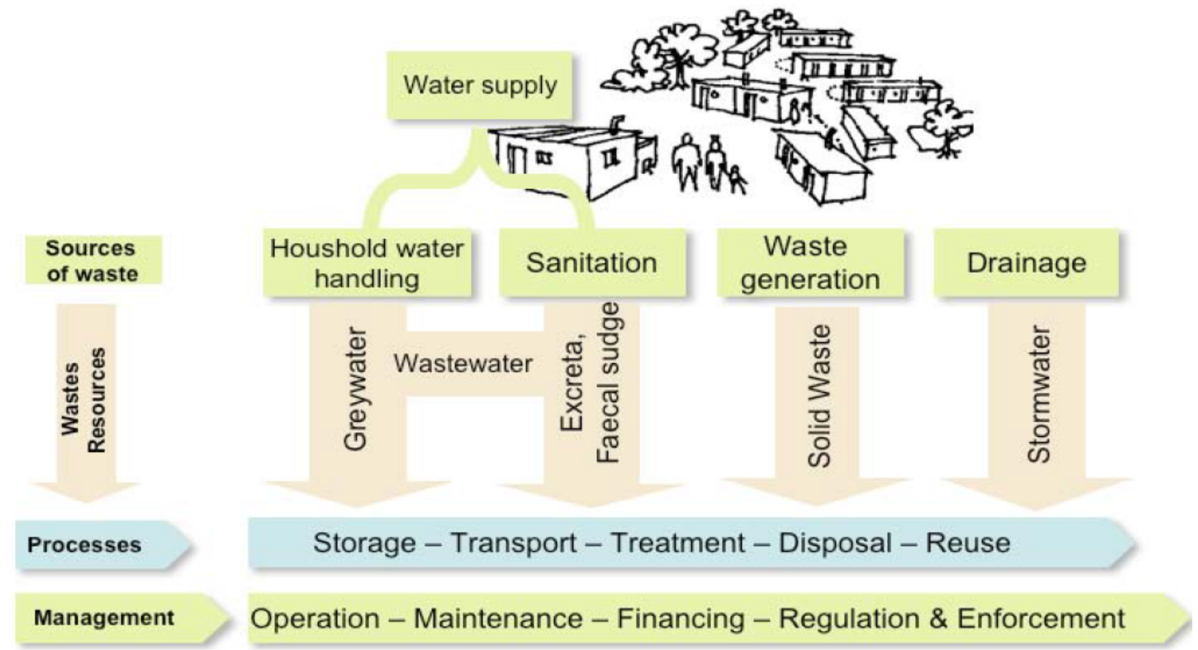

Figure 5: Waste and resource flow (Source: Eawag, Sandec (2008))

The figure above shows the sources of waste in the household and neighbourhood (green) and the waste and resource flows (brown). All waste and resource flows require an integrated management (green) within a settlement: regulatory system and its enforcement, as well as operation and maintenance for safe transport, treatment, safe disposal, and/or reuse (blue).

A well-planned and well-managed city will be able to meet the double challenge of demographic change and the massive transformations taking place in the global economy. It is a priority for city governments and administrations to anticipate these trends and to grasp the opportunities presented by the new roles for cities and their governments. The situation is urging for new planning approaches to overcome the serious lack of sanitation services, causing illnesses and stunting economic progress for hundreds of millions of people in developing countries.

Sanitation planning

A system approach to environmental sanitation, which extends from the point of generation to the point of disposal/discharge or reuse – from the cradle to the grave is urgently needed, both at the planning and implementation stages. The sanitation systems are often only considered partially during these stages. For example, on-site based sanitation solutions (latrine or septic tank-based) frequently do not include excreta and faecal sludge emptying, transport or treatment services and facilities. Additionally, local business opportunities, as well as demand and potential use of waste resources, such as water, nitrogen or biosolids, are given little attention. Failures or unsustainable solutions put a substantial financial burden on municipalities.

Excreta and septage management

In cities of developing countries, large amounts of excreta and faecal sludge collect in on-site sanitation facilities, such as private or public toilets, and septic tanks. As opposed to industrialised countries, where excreta are disposed of via water flush toilets, city-wide sewerage systems and central wastewater treatment plants, all of which are widespread technologies in industrialised countries but unaffordable or inappropriate in developing countries. If faecal sludge is collected at all from on-site sanitation technologies, they are mostly disposed of in an uncontrolled manner without prior treatment, thus, posing severe health risks and polluting the environment.

1.4.4 Liquid waste products

The urban water cycle is one of the key processes connecting human activity to natural systems. The health and well-being of both human population and environment is therefore dependent on the integration of urban water systems with the natural systems. The generation of liquid waste from human activities is unavoidable. However, not all humans produce the same amount of liquid waste. The type and amount of liquid waste generated in households are influenced by behaviour, lifestyle and standard of living of the population as well as by the governing technical and juridical framework. (Henze and Ledin, 2001)

The different sanitation systems generate the following products:

- Blackwater is the mixture of urine, feces and flushing water along with anal cleansing water (if anal cleansing is practiced) or dry-cleaning material (e.g. toilet paper)
- Greywater is used water generated through bathing, hand-washing, cooking or laundry. It is sometimes mixed or treated along with blackwater
- Urine is the liquid not mixed with any feces or water
- Brown water is blackwater without urine
- Excreta is the mixture of urine and feces not mixed with any flushing water (although small amounts of anal cleansing water may be included)
- Fecal sludge is the general term for the undigested or partially digested slurry or solid resulting from the storage or treatment of blackwater or excreta
- Septage is the term for the completely digested sludge collected from on-site sanitation system such as septic tank or ABR etc.
- Domestic wastewater comprises all sources of liquid household waste: blackwater and greywater. However, it does not include stormwater
- Sewage sludge is the term for the sludge generated during treatment of domestic wastewater at the sewage treatment plant.
- Stormwater in a community settlement is runoff from house roofs, paved areas and roads during rainfall events. It also includes water from the catchment of a stream or river upstream of a community settlement.

1.4.5 Parameters to characterise wastewater

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants.

The characteristics can be mainly divided into three categories; physical parameters, chemical parameters and biological parameters.

Solids

Solids can be classified into various categories depending upon the size of the particles.

- TS- Total Solids
- TSS-Total Suspended Solids

If the particle size is very small and is completely dissolved in the solution, we call it as dissolved solids. If the particle size is in between 0.01 micrometer to 1 micrometer, they are colloidal solids. These colloidal solids are very stable and will not settle down in the liquid or water, so it is very difficult to remove them especially from water and wastewater.

Suspended solids are those solids that do not pass through a 0.2 micrometer filter. About 70% of those solids are organic, and 30% are inorganic. The inorganic fraction is mostly sand and grit that settles to form an inorganic sludge layer. Total suspended solids comprise both settleable solids and colloidal solids. Settleable solids will settle in an Imhoff cone within one hour, while colloidal solids (which are not dissolved) will not settle in this period. Suspended solids are easily removed by settling and/or filtration. However, if untreated wastewater with a high suspended solids content is discharged into the environment, turbidity and the organic content of the solids can deplete oxygen from the receiving water body and prevent light from penetrating.

Organic constituents

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources.

Organic compounds usually are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. Organic matter is determined by following characteristics:

- BOD - Biochemical Oxygen Demand
- COD - Chemical Oxygen Demand

Biodegradable organics are composed mainly of proteins, carbohydrates and fats. If discharged untreated into the environment, their biological stabilization can lead to the depletion of natural oxygen and development of septic conditions.

BOD test results can be used to assess the approximate quantity of oxygen required for biological stabilization of the organic matter present, which in turn, can be used to determine the size of wastewater treatment facilities, to measure the efficiency of some treatment processes and to evaluate compliance with wastewater discharge permits.

Nutrients

Wastewater often contains large amounts of the nutrient, mainly nitrogen and phosphorus in the form of nitrate and phosphate. These nutrients are primarily responsible for promoting plant growth. Organisms only require small amounts of nutrients in biological treatment, so there is typically an excess available in treated wastewater. In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow resulting in rapid depletion of oxygen in the receiving water bodies. Deprived of oxygen, fish and other aquatic life die, as well as emitting foul odors in the environment.

Nitrogen and phosphorus, also known as nutrients or bio-stimulants, are essential for the growth of microorganisms, plants and animals. When discharged into the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life, which rob the water of dissolved oxygen. When discharged in excessive amounts on land, they can also lead to groundwater pollution.

Pathogens

Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals who are infected with or are carriers of a disease.

For example, greywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants. The measurement of pathogen content is generally expressed using two parameters.

- TC (MPN) - Total coliforms, Most Probable Number
- FC (MPN) - Fecal coliforms, Most Probable Number

Pathogenic organisms present in wastewater can transmit communicable diseases. The presence of specific monitoring organisms is tested to gauge plant operation and the potential for reuse. Coliform bacteria include types that originate in feces (e.g. Escherichia) as well as the genre not of fecal origin (e.g. Enterobacter, Klebsiella, Citrobacter). The assay is intended to be an indicator of fecal contamination; more specifically of E. coli which is an indicator microorganism for other pathogens that may be present in feces. Presence of fecal coliforms in water may not be directly harmful and does not necessarily indicate the presence of feces.

1.4.6 EcoSan- Ecological Sanitation

The introduction of the EcoSan systems is bound to lower the total costs of urban sanitation. Sewers and treatment plants and sludge disposal arrangements will cost several times as much as an EcoSan system. This is particularly important for developing countries, where public institutions face stringent financial limits. EcoSan systems require much less investment as they need neither water for flushing nor pipelines for the transport of sewage, nor treatment plants and arrangements for the disposal of toxic sludge.

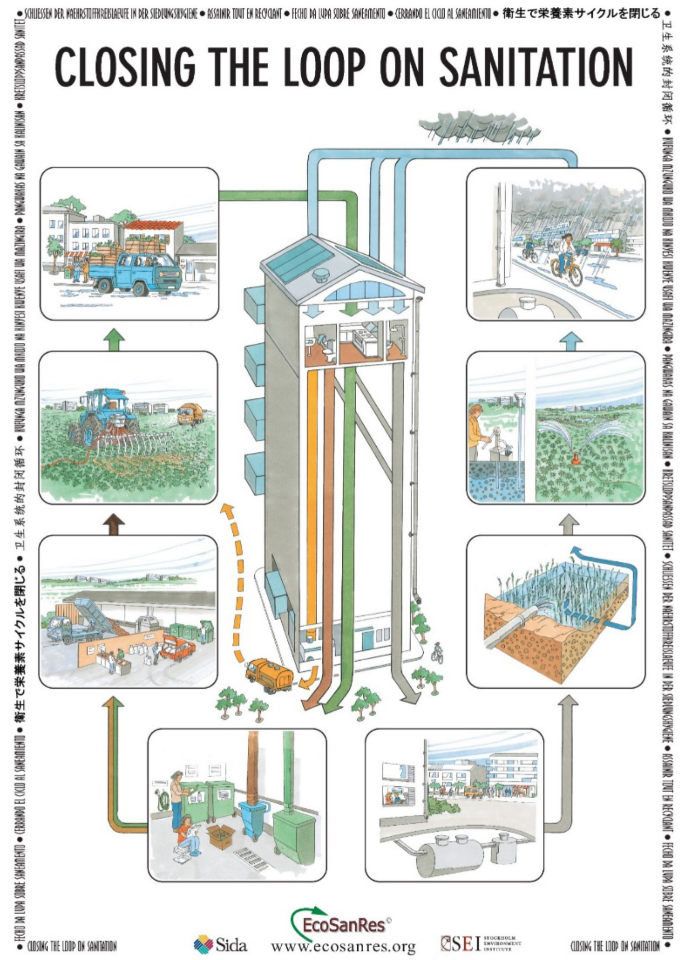

Figure 6: Ecological Sanitation (Source: EcoSanRes)

If this vision of ecological sanitation could be realized, then it would lead to many advantages to the environment, households and families and to municipalities. If ecological sanitation could be adopted on a large scale, it would protect our groundwater, streams, lakes and the sea from faecal contamination. The amount of water consumed would be lower than the usual requirement. Farmers' usage of commercial fertilizers would reduce, much of which today washes out of the soil into water, thereby contributing to environmental degradation.

Characteristics of main waste products

Greywater - The composition of grey wastewater depends on sources and installations from where the water is drawn, e.g. kitchen, bathroom or laundry. The chemical compounds found in greywater originate from household chemicals, cooking, washing, and the piping. In general greywater contains lower levels of organic matter and nutrients compared to conventional wastewater, since urine, feces and toilet paper are not included.

Water consumption in low-income areas with water scarcity and rudimentary forms of water supply can be as low as 20 30 liters per person and day. Greywater volumes are even lower in regions where rivers or lakes are used for personal hygiene and for washing clothes and kitchen utensils.

Households in affluent areas with piped water may, however, generate several hundred liters of greywater per day. In urban and peri-urban areas of low and middle-income countries, greywater is often discharged directly into stormwater drains or sewers – provided they exist –from where it flows typically into aquatic systems. This practice may lead to oxygen depletion, increase in turbidity, eutrophication, as well as microbial and chemical contamination of aquatic systems.

Urine - The concentration of nutrients in the excreted urine depends on the nutrient and liquid intake, the level of personal activity and climatic conditions. Urine, rich in nitrogen and phosphorus, can be used as fertilizer for most non-nitrogen-fixing crops after appropriate treatment to reduce potential microbial contamination.

Since spinach, cauliflower and maize are crops with a high nitrogen content, they respond well to nitrogen fertilization. The nutrients in urine are present in ionic form, and their plant availability and fertilizing effect compare well with those of chemical (ammonium and urea-based) fertilizers (Kirch-mann and Petterson 1995, pp. 149 154; Johansson et al. 2001). Environmental transmission of urine- excreted pathogens is of minor concern in temperate climates. However, fecal cross-contamination may create a health risk. In tropical climates, fecal contamination of collected urine poses the primary health risk.

Feces - From a risk perspective, exposure to untreated feces is always considered unsafe because of the high levels of pathogens whose prevalence is dependent on the given population. Enteric infections can be transmitted by pathogenic species of bacteria, viruses, parasitic protozoa, and helminths. (WHO 2006). Fecal compost can be applied as a complete phosphorus-potassium fertilizer or as a soil improver.

About 40–70% of the organic matter and slightly lower nitrogen content are lost through biological activity and volatilization. Most of the remaining nitrogen will become available to plants during degradation. The organic matter content in feces also increases the water-holding and ion-buffering capacity of soils, an essential aspect to improving soil structure and stimulating microbial activity. (WHO 2006).

Table 3: Characterization of waste products

	Total	Greywater	Urine	Faces
Volume (L/cap.yr)	25,000-100,000	25,000-100,000	500	50
Nitrogen (kg/cap.yr)	2.0-4.0	5%	85%	10%
Phosphorus (kg/cap.yr)	0.3-0.8	10%	60%	30%
Potassium(kg/cap.yr)	1.4-2.0	34%	54%	12%
COD (kg/cap.yr)	30	41%	12%	47%
Faecal coliform (per 100 mL)	-	10^4-10^6	0	10^7-10^9

1.4.7 What is integrated wastewater and septage management (IWSM)?

IWSM can be considered a holistic approach that address the entire sanitation service chain, including both wastewater and faecal sludge/septage. It recognizes the fact that sanitation for all cannot be achieved by managing either wastewater or faecal sludge/septage i.e. the management of all forms of human waste generated from a toilet needs to be done comprehensively.

1.4.8 Citywide Inclusive Sanitation (CWIS) approach

CWIS is an approach developed by the World Bank's Water Global practice, in partnership with sector development partners with a view to address the global sanitation crisis. Provision of conventional sewerage and wastewater treatment is considered to be the only solution in urban sanitation. CWIS aims to shift our mindset by prioritizing everyone's need to access safely managed sanitation. The approach stresses upon sanitation service provision through a broad range of solutions that includes onsite and sewered, centralized or decentralized but they should be based on the ground realities. Therefore, it can be said that the CWIS approach focuses more on enabling environment for service provision, rather than simply building infrastructure.

For changing the mindsets, the CWIS approach calls upon all stakeholders including governments, development agencies, consulting organisations, departments involved in education, etc. It is necessary for governments and development agencies to understand that adopting conventional approaches to urban sanitation may not work going forward and that new approaches are required. Consulting organisations have to adopt new ways of thinking and should be adept in understanding the local requirements before finalising a particular solution; simply adopting solutions from high-income countries will further create troubles for other stakeholders in managing an urban service. Education setup need a revamp to include design and management of innovative systems other than conventional systems and further open the possibilities to develop solutions that answer the growing demands of public health and environmental protection.

CWIS demands raising awareness and build capacities, bring forward best practices, work in coordination with complementary city services, and the development and use of tools that help in building a better sanitation system design. Such a system design should also include aspects such as ease of use to meet every person's aspirations and the sustainability factor both, in terms of environment protection and financial models.

The following are the principles which reflect a successful adoption of the CWIS approach:

1. ***Everybody benefits*** from adequate sanitation service delivery outcomes that meet user aspirations and that protect the health of users.
2. Human waste is ***safely managed along the whole sanitation service*** chain ensuring protection of the environment and of human health.
3. A ***diversity of appropriate technical solutions*** is embraced, combining ***both on-site and sewered solutions***, in either centralized or decentralized systems, with consideration of ***resource recovery and re-use***.
4. Cities demonstrate political will, technical and managerial leadership, and identify new and creative long-term funding options for sanitation.
5. ***Institutional arrangements*** and ***regulations***, with well-aligned incentives, are in place for the operation and maintenance of the full sanitation service chain.
6. Funding is allocated for ***non-infrastructure aspects of service delivery***, such as capacity building, household engagement and outreach, and sanitation marketing.
7. ***Complementary urban services***, including water supply, drainage, greywater management and solid waste management, are incorporated into sanitation planning.
8. Activities are included to ***target specific unserved and underserved groups***, such as women, ethnic minorities, the urban poor and people with disabilities.

1.4.9 Urban challenges

Over the last several decades, effective strategies have been developed to provide affordable sanitation services to the urban populations of developing countries. Rapid implementation of these approaches is, however, urgently needed in developing countries to close the growing gap between those with access to sanitation services and those without. Factors leading to deficiencies in water and sanitation can be found at every level – from local to international. The causes for the inadequacies are thus proximate (household/local), contributory (city & town) or underlying (global/international).

Challenges faced in the household level: 1/4–2/3 of the urban population live in slums (informal or illegal settlements) in India. Many public or private official water and sanitation providers do not operate in illegal settlements. Moving from illegal to legal status is complicated and expensive. House plots don't have formal addresses and clear boundaries. Hence, it is difficult for the ULBs to give individual connections to the households in illegal settlements. The transition of illegal to legal requires the agreement of several different agencies. The ULBs also lack qualified workforce such as lawyers and surveyors for such purpose. Planning, funding, implementing, operating, and maintaining water and sanitation systems require qualified skills and expertise in different disciplinary fields. Since illegal settlements lack regular plot layouts, access roads, substantial waste collection, the tasks are far more complicated than in regulated settlements.

Challenges faced in the city level: The WHO/UNICEF Assessment identified cost recovery and inadequate operation and maintenance as two of the main constraints on the development of water supply and sanitation – both largely a consequence of the weakness or incapacity of water and sanitation agencies. The spatial distribution of the population has always been a key factor on the policy agenda of governments. The governments of developing countries have often expressed concern about their inability to provide basic services for their rapidly growing urban populations, including safe drinking water, sanitation, affordable housing, and public transport.

1.5 Notes for trainer

This session acts as a base for understanding the various issues & challenges faced for sustainable sanitation & water management. Thus, it is encouraged to have discussions with the participants regarding their experience in handling such situations. Alternatively, colour cards can be used to document the problems, challenges and learnings from the participants after the session.

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Session

02

Missions & Programs

2. Missions & Programs

2.1 Learning Objectives

- To understand the history of different policies & programs undertaken by the government related to sanitation
- To understand the SBM 2.0 & Atal Mission for Rejuvenation and Urban Transformation mission 2.0 programs

2.2 Session Plan

Duration- 45 minutes

Topics	Time	Material/Method
Growing Recognition of FSSM	3 min	Power point presentation
Swachh Bharat Mission 2.0	2 min	Power point presentation
Atal Mission for Rejuvenation and Urban Transformation 2.0	2 min	Power point presentation
Policies & Guidelines	3 min	Power point presentation

2.3 Key Facts

- Under the Smart Cities Mission, a total of 2529 projects valued around Rs. 41,960 crores have been completed
- Under the AMRUT Mission, a total of 3512 projects valued around Rs. 18,483 crores have been completed
- SBM – Urban 2.0 will be implemented by the Ministry of Housing and Urban Affairs (MoHUA) for all statutory towns in India

2.4 Learning Notes

2.4.1 Growing Recognition of FSSM

There is a growing recognition in India that connecting all the households in urban India to a sewerage network is not viable. Retrofitting an entire city with a sewerage system is a tedious job as it not only requires digging-up entire roads of the city, but also needs all the households to be connected to the system. The challenge is further exacerbated by the fact that the majority of our cities are unplanned with, a large proportion of population residing in densely populated old settlements with narrow lanes.

Over the last few years, India's tryst with sanitation has reached centre stage, mostly due to the efforts channelled under the government's flagship sanitation scheme, the Swachh Bharat Mission. The program has been extremely successful in accelerating access to safe sanitation by creating household toilets across urban and rural parts of the country and helped India achieve its target of preventing open defecation. The government is determined to further improve the public health outcomes through the next set of targets in the sector; ODF+, ODF++, and Water+ certifications. With many Indian households reliant on on-site sanitation systems for its affordability; disposal and treatment of faecal waste assumes as much importance as its containment. That said, on-site sanitation systems remain viable only as long as the entire service chain can be adequately managed. This is where Faecal Sludge and Septage Management (FSSM) assumes importance.

FSSM represents an innovative, smart, and sustainable system that works across the value chain. Its built-in adaptability allows it to be a solution for both urban and rural areas, thereby allowing it to complement India's efforts to achieve its targets under SDG 6.2 , and accelerate our performance under other SDGs relating to healthy living, inclusive cities, and accruing gender parity. In the past few years, faecal sludge management has received much awaited focus in the country, and we have been able to formalize FSSM services in many Indian cities. Since the National FSSM Policy, 2017, many states have made great strides through the enactment of policies, legislative frameworks, issuance of guidelines, and by leveraging funding from multiple sources like SBM, AMRUT and 14th FC. As a result, about 499 ULBs have already achieved the ODF++ status. The success of FSSM lies in ensuring uniform access to quality service delivery, which is driven by local governance systems like municipalities, municipal corporations, etc. Complementing synergies produced from partnerships with other stakeholders, such as private sectors players, domain experts and development practitioners,; are also key to the success of FSSM. Such partnerships infuse technological innovations and help bridge funding gaps–which remain critical to achieving outcome- driven results. To continue progress in this sector, it is imperative that we develop robust business models, promote private sector participation, leverage the latest technological advancements, and bring extensive mechanization in operations. Lastly and perhaps most importantly, it is also crucial to create a strong repository of FSSM best practices that can be observed, adapted, and replicated appropriately across the country.

2.4.2 Swachh Bharat Mission 2.0

The Swachh Bharat Mission (Urban) was implemented by the Ministry of Housing & Urban Affairs. The SBM (U) had two primary components of implementation: (a) achieving 100% open defecation free (ODF) status (with construction of 66 lakh individual household toilets and 5.08 lakh community/public toilet seats), and (b) ensuring 100% solid waste management — in all ULBs in the country, by 2nd October 2019 (extended to 31st March 2021). This was to be done through large scale citizen engagement to create a 'Jan Andolan'. The Cost of implementation was ₹ 62,009/- Crores, including GoI share of ₹ 14,600/- Crores , and State share of ₹ 4,874/- Crores. Balance funds (₹ 42,535/- Crore) were to be generated through other sources.

The Mission is now being extended by a period of 5 years, from 1st April 2021 – 31st March 2026, as Swachh Bharat Mission (Urban) 2.0 (SBM U 2.0), for sustaining the sanitation and SWM outcomes achieved under SBM (U).

In the Swachh Bharat 2.0, the government is trying to tap other aspects under the Swachh Bharat mission, including safe containment, transportation, disposal of faecal sludge, and septage from toilets. Under this mission, wastewater will be adequately treated before it is discharged into water bodies, and the government is trying to make maximum reuse a priority. It also focuses on source segregation of garbage, reduction in single-use plastic and air pollution, by effectively managing waste from construction and demolition activities and bioremediation of all legacy dump sites.

It will be implemented over five years ,from 2021 to 2026, with an outlay of Rs.1.41 lakh crore.

This will be a continuation of the Swachh Bharat Mission (Urban), with the following components for funding and implementation across all statutory towns, viz.

- Sustainable sanitation (construction of toilets)
- Wastewater treatment, including faecal sludge management in all ULBs with less than 1 lakh population
- Solid Waste Management
- Information, Education and Communication, and
- Capacity building

At the end of the Mission, the following outcomes are expected to be achieved:

- All statutory towns will become ODF+ certified
- All statutory towns with less than 1 lakh population will become ODF++ certified
- 50% of all statutory towns with less than 1 lakh population will become Water+ certified
- All statutory towns will be at least 3-star Garbage Free rated as per MoHUA's Star Rating Protocol for Garbage Free cities
- Bio-remediation of all legacy dumpsites

2.4.3 Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0

Atal Mission For Rejuvenation And Urban Transformation (AMRUT) 2.0 has been designed to provide universal coverage of water supply to all households through functional taps in all 4,378 statutory towns in accordance with SDG Goal- 6.

2.68 crore is the estimated gap in urban household tap connections that is proposed to be covered under AMRUT 2.0. Likewise, an estimated gap in sewer connections/septage in 500 AMRUT cities proposed to be covered in AMRUT 2.0 is 2.64 crore. Rejuvenation of water bodies to augment sustainable fresh water supply and creating green spaces and sponge cities to reduce floods and enhance amenity value through an Urban Aquifer Management plan are other key areas of the Mission. AMRUT 2.0 will promote circular economy of water through development of city water balance plan for each city, focusing on recycle/reuse of treated sewage, rejuvenation of water bodies and water conservation. 20% of water demand to be met by reused water with development of institutional mechanism. A Technology Sub-Mission for water is proposed to leverage latest global technologies in the field of water.

Information, Education and Communication (IEC) campaign is proposed to spread awareness among masses about conservation of water. Pey Jal Survekshan will be conducted in cities to ascertain equitable distribution of water, reuse wastewater and map water bodies with respect to quantity and quality of water through a challenge process. Mission has a reform agenda with focus on strengthening urban local bodies and water security of the cities. Major reforms are reducing non-revenue water to below 20%; recycle of treated used water to meet at least 20% of total city water demand and 40% for industrial water demand at State level; dual piping system; unlocking value and improving land use efficiency through proper master planning; improving credit rating & accessing market finance including issuance of municipal bonds and implementation Online Building Permission System under EoDB.

The Mission also seeks to promote AatmaNirbhar Bharat through encouraging Start-ups and Entrepreneurs with an aim to promote GIG economy and on-boarding of youth & women.

Salient features of the mission:

- The total outlay proposed for AMRUT 2.0 is ₹ 2,77,000 crore.
- In order to promote Public private partnership, it has been mandated for cities having million plus population to take up PPP projects worth a minimum of 10 percent of their total project fund allocation.
- For Union Territories, there will be 100% central funding. For North Eastern and Hill States, central funding for projects will be 90%. Central funding will be 50% for cities will less than 1 lakh population, one third for cities with 1 lakh to 10 lakh population and 25% for cities with a million plus population.

- Mission will be monitored through a technology-based platform on which beneficiary response will be monitored along with progress and output-outcome.
- Funding from Government for projects will be in three tranches of 20:40:40. Third installment onwards will be released based on outcomes achieved, and credible exclusion will be exercised while funding.

2.4.4 Policies & Guidelines

Following are a brief description of guidelines developed by the Government of India:

AMRUT - The components of the AMRUT consist of capacity building, reform implementation, water supply, sewerage and septage management, storm water drainage, urban transport and development of green spaces and parks. During planning, the Urban Local Bodies (ULBs) will strive to include some smart features in the physical infrastructure components. The details of the Mission components are given below.

1. **Water Supply**
   - Water supply systems including augmentation of existing water supply, water treatment plants and universal metering.
   - Rehabilitation of old water supply systems, including treatment plants.
   - Rejuvenation of water bodies specifically for drinking water supply and recharging of ground water.
   - Special water supply arrangement for difficult areas, hill and coastal cities, including those having water quality problems (e.g., arsenic, fluoride).
2. **Sewerage**
   - Decentralised, networked underground sewerage systems, including augmentation of existing sewerage systems and sewage treatment plants.
   - Rehabilitation of old sewerage system and treatment plants.
   - Recycling of water for beneficial purposes and reuse of wastewater.

3. **Storm water drainage**
   - Construction and improvement of drains and storm water drains in order to reduce and eliminate flooding.

4. **Urban Transport**

5. **Green Spaces/Parks**

Smart Cities Mission - It was launched by the Hon' Prime Minister on 25 June, 2015. The main objective of the Mission is to promote cities that provide core infrastructure, clean and sustainable environment and give a decent quality of life to their citizens through the application of 'smart solutions'. The Mission aims to drive economic growth and improve quality of life through comprehensive work on social, economic, physical and institutional pillars of the city. The focus is on sustainable and inclusive development by creation of replicable models which act as lighthouses to other aspiring cities. 100 cities have been selected to be developed as Smart Cities through a two-stage competition.

The Mission is operated as a Centrally Sponsored Scheme. Central Government will give financial support to the extent of Rs. 48,000 crores over 5 years i.e. on an average Rs.100 crore per city per year. An equal amount on a matching basis is to be provided by the State/ULB. Additional resources are to be raised through convergence, from ULBs' own funds, grants under Finance Commission, innovative finance mechanisms such as Municipal Bonds, other government programs and borrowings. Emphasis has been given on the participation of private sector through Public Private Partnerships (PPP). Citizens' aspirations were captured in the Smart City Proposals (SCPs) prepared by the selected cities. Aggregated at the national level, these proposals contained more than 5,000 projects worth over Rs. 2,00,000 crores, of which 45 percent is to be funded through Mission grants, 21 percent through convergence, 21 percent through PPP and rest from other sources.

There is no standard definition or template of a smart city. In the context of our country, the six fundamental principles on which the concept of Smart Cities is based are:

- Communities at the core of planning & implementation
- Ability to generate greater outcomes with the use of lesser resources
- Cities selected through competition
- Innovative, integrated & sustainable solutions
- Careful & relevant selection of technologies as per cities
- Sectoral & Financial Governance

2.5 Notes for Trainer

This session showcases/ divulges details about all the programs, policies & guidelines that have been kick-started by the Government of India in the last few years for sustainable sanitation, wastewater management, faecal sludge management, water supply management etc.

2.6 Bibliography

- Swachh Bharat Mission (Urban) Phase I Guideline (2014) and Swachh Bharat Mission (Urban) 2.0 Guidelines (2021), Ministry of Housing and Urban Affairs (MoHUA)
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- SMART Cities Mission Guidelines, Ministry of Housing and Urban Affairs (MoHUA), 2015

Session

03

Sanitation Systems

3. Sanitation systems

3.1 Learning objectives

- To get in-depth knowledge of sanitation systems and suitability of different types of sanitation systems
- To understand different functional groups in sanitation systems and specific objective of each functional group
- To understand the options for each functional group and their inter-linkages

3.2 Session plan

Duration - 45 minutes

Topics	Time	Material/Method
Sanitation systems	10 min	Power point presentation
Functional groups	15 min	Power point presentation
Case studies	10 min	Power point presentation, videos
Q&A	10 min	Discussion

3.3 Key facts

Sanitation systems can be broadly classified into two types – (1) Dry Sanitation Systems and (2) Wet Sanitation Systems. This classification is based on the use of water to flush the excreta and other waste. While the dry sanitation systems are simple to implement and operate, the wet sanitation systems on the other hand, are relatively complex and difficult to operate.

A functional group is a grouping of technologies that have similar functions. There are five different functional groups from which technologies can be chosen to build a system. The five functional groups are:

- User Interface
- Collection and Storage/Treatment
- Conveyance
- Treatment
- Reuse and/or Disposal

3.4 Learning notes

3.4.1 Role of City Wide Inclusive Sanitation (CWIS) in sanitation systems

City Wide Inclusive Sanitation (CWIS) is characterized as *"Everyone benefits from adequate sanitation service delivery outcomes; human waste is safely managed along the whole sanitation service chain; effective resource recovery and re-use are considered; a diversity of technical solutions is embraced for adaptive, mixed and incremental approaches; and on-site and sewerage solutions are combined, in either centralized or decentralized systems, to better respond to the realities found in developing country cities."*

The four CWIS building blocks are:

1. Prioritization of the right of all to sanitation, with inclusive strategies reaching informal settlements and vulnerable populations, especially women and children,
2. Delivery of "safe management" along the entire sanitation service chain by focusing on service outcomes rather than technologies, and by embracing innovation and incrementalism.
3. Recognition of the role played by sanitation to a thriving urban economy by it's integrating into urban planning, reforming regulatory policies, and embracing resource recovery and reuse.
4. Commitment to work in partnership across sectors and stakeholders to make progress through clear institutions with accountability and embedding sanitation within urban governance systems.

Citywide inclusive sanitation is explicitly agnostic about technology choice. Clear service outcomes – for all residents, in sewered and non-sewered areas – and system feasibility considerations (e.g., financial, environmental, political, organizational capacity, cultural, and other factors) inform system design and technology choice. CWIS is based on the fundamental understanding that urban human waste management is characterized by inherent market failures, and therefore must be organized as a public service – including ensuring safe containment – to achieve public interest components of sanitation (i.e., safety and inclusivity). This requires government engagement in market structuring. At the same time, it does not preclude or diminish the role of the private sector. For service authorities to achieve the outcomes embedded within their legal mandates, they must ensure services are well executed. This expands opportunities for private sector participation by creating market incentives for investment and innovation.

The CWIS service framework identifies core outcomes and functions for public service delivery systems. The specifics of how outcomes are defined and how functions are institutionalized and executed will vary by country and city. Sanitation authorities need to consider an evolving range of diverse technologies and business models to generate service improvements over time, including delegation of service provision to the private sector when appropriate. Likewise, a range of models and tools are needed for meaningful accountability and resource management in different contexts, including but not limited to economic regulators. Irrespective of context, any well-functioning service system relies on robust, institutionalized performance indicators and effective monitoring systems to inform decisions.

In order to be able to implement CWIS, one needs to understand sanitation systems and its components. The following sections elaborate on sanitation systems and its five core components.

3.4.2 Sanitation systems

Sanitation system is a multi-step process in which human excreta and wastewater are managed from the point of generation to the point of use or ultimate disposal with minimal human intervention. It is important to understand that sanitation can act at different levels, protecting the household, the community and society. In the case of twin-pit toilet, it is easy to see that this sanitation system acts at a household level. However, poor design or inappropriate location may lead to migration of waste matter and contamination of local water supplies putting the community at risk. Furthermore, the effects of waterborne sewage contamination could affect the entire society resulting in ill health and environmental damage.

Objectives of the sanitation systems

- Safe sanitation systems should keep disease-carrying waste and insects away from people, both at the site of the toilet, in nearby homes, and in the neighboring environment.
- It should avoid air, soil, water pollution, return nutrients/resources to the soil, and conserve water and energy.
- The system must be operational with locally available resources (human and material). Where technical skills are limited, simple technologies should be favored.
- Total costs (including capital, operational, maintenance costs) must be within the users' ability to pay.

- It should be adapted to local customs, beliefs, and desires.
- It should address the health needs of every human being of the society.

Sanitation systems can be classified mainly as water-based and water-less system.

Table 4: Classification of sanitation systems

Waterborne or Wet – requires water for its functioning	Non-waterborne or dry- No need water for its functioning
• Full flush or cistern flush (water comes from the cistern) • Pour flush (use of bucket to throw water for flushing purpose) • Low flush toilet (flushing mechanism release small quantity of water) • Aqua privy	• Urine diverting dry toilet (UDDT) • Dry toilet (sit or squat pan) • VIP toilet • Vault toilet • Tiger toilet

3.4.3 Dry sanitation

Dry sanitation is defined as the disposal of human waste without the use of water as a carrier and the by-products i.e. decomposed solids and urine are then used as fertilizer. In developed countries, dry sanitation toilets were initially designed for use in remote areas for practical and environmental reasons. However, increasing environmental awareness has led to some people using them as an alternative to conventional systems. In developing countries, they can be a low-cost, environmentally acceptable, and hygienic option.

The main benefits of a dry sanitation systems are:

- Works without the use of water and therefore produces no wastewater; and
- Can be used easily within nutrient-retrieval systems (closing the nutrient loop).

A. Dry toilets

A dry toilet is a toilet that operates without freshwater. The dry toilet may be a raised pedestal on which the user can sit or a squat pan over which the user squats. In both cases, excreta (both urine and faeces) fall through a drop hole. Here, a dry toilet refers specifically to the device over which the user sits or squats. In other literature, a dry toilet may refer to a variety of technologies or different combination of technologies.

The dry toilet is usually placed over a pit. If two holes are used, the pedestal or slab should be designed in such a way that it can be lifted and moved from one pit to another. The slab or pedestal base should be well sized to cover the entire pit so that it is both safe for the user and prevents storm water from infiltrating the pit (which may cause it to overflow). The hole can be closed with a lid to prevent unwanted intrusion from insects or rodents. Pedestals and squatting slabs can be made locally with concrete (if sand and cement are available).

Table 5: Pros & Cons for dry toilets

Pros	Cons
• No need for flushing water • Can be made on site with locally available materials • It is inexpensive	• Since dry toilets do not have a water seal; odour are normally noticeable even if the vault or pit used to collect excreta is equipped with a vent pipe • The excreta pile is visible except where a very deep pit is used • Safety concerns for children, disabled, and elderly

B. Urine-diverting dry toilet (UDDT)

A urine-diverting dry toilet (UDDT) is a toilet that operates without water and has a divider so that the user, with little effort, can divert the urine away from the faeces.

It is important that the two sections of the toilet are well separated to ensure that, a) faeces do not fall into and clog the urine collection area in the front, and that b) urine does not splash down into the dry area of the toilet. There are also 3-hole separating toilets that allow anal cleansing water to go into a third, dedicated basin separate from the urine drain and faeces collection. Both a pedestal and a squat slab can be used to separate urine from faeces depending on user preference.

Urine tends to rust most metals; therefore, metals should be avoided in the construction and piping of the UDDT. To limit scaling, all connections (pipes) to storage tanks should be kept as short as possible; whenever they exist, pipes should be installed with at least a 1% slope, and sharp angles (90°) should be avoided. A pipe diameter of 50 mm is sufficient for steep slopes and where maintenance is easy. Larger diameter pipes (> 75 mm) should be used elsewhere, especially for minimum slopes, and where access is difficult. To prevent odours from coming back up the pipe, an odour seal should be installed at the urine drain.

The UDDT is built such that urine is collected and drained from the front area of the toilet, while faeces fall through a large chute (hole) in the back. Depending on the collection and storage/treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecating. The UDDT is simple to design and build, using materials such as concrete and wire mesh or plastic. The UDDT design can be altered to suit the needs of specific populations (i.e., smaller for children, people who prefer to squat, etc.).

Table 6: Pros & cons for UDDT

Pros	Cons
• No need for water • Since faeces are dry and urine is separated, odour nuisance is minimal, though a lid should be used • Can be built on site with locally available materials • It is inexpensive	• Its use may be difficult for some people (heavy, old and young) • Faeces can be accidentally deposited in the urine section and lead to clogging and cleaning problems • Urine pipes/fittings can become blocked with time

C. Urine diverting flush toilet (UDFT)

The urine-diverting flush toilet (UDFT) is similar in appearance to a cistern flush toilet except for the diversion in the bowl. The toilet bowl has two sections so that the urine can be separated from the feces. Both sitting and squatting models exist. Urine is collected in a drain in the front of the toilet and feces are collected in the back. The urine is collected without water, but a small amount of water is used to rinse the urine- collection bowl when the toilet is flushed. The urine flows into a storage tank for further use (use of urine at small or large-scale) or processing (storage, desiccation, struvite production), while the feces are flushed with water and should be treated (onsite pre- treatment and treatment in septic tanks, biogas settlers, anaerobic baffled reactors; semi-decentralized treatment units, e.g. DEWATS systems; centralized sewage treatment plants).

Table 7: Pros & Cons of UDFT

Pros	Cons
• Requires less water than a traditional flush toilet • No real problems with odours, if used correctly • Looks like, and can be used almost like, a cistern flush toilet	• Limited availability; cannot be built or repaired locally • High capital and low to moderate operating costs (depending on parts and maintenance) • Labour-intensive maintenance • Requires training and acceptance to be used correctly • Is prone to clogging and misuse • Requires a constant source of water • Men usually require a separate urinal for optimum collection of urine

D. Tiger toilet

The tiger toilet is a pour-flush pit latrine toilet that uses vermifiltration to treat waste. The vermifiltration technology uses earthworms or tiger worms to decompose the waste from latrines rapidly into vermi-compost, while liquids drain out of the system. It consists of a strong and durable toilet room and the Tiger biodigester attached to it. The system needs minimal maintenance and offers users a flush-and-forget experience. The Tiger Toilet can be constructed as a complete solution comprising the tiger toilet superstructure and the tiger toilet biodigester which is a single pit with tiger toilet vermifiltration technology.

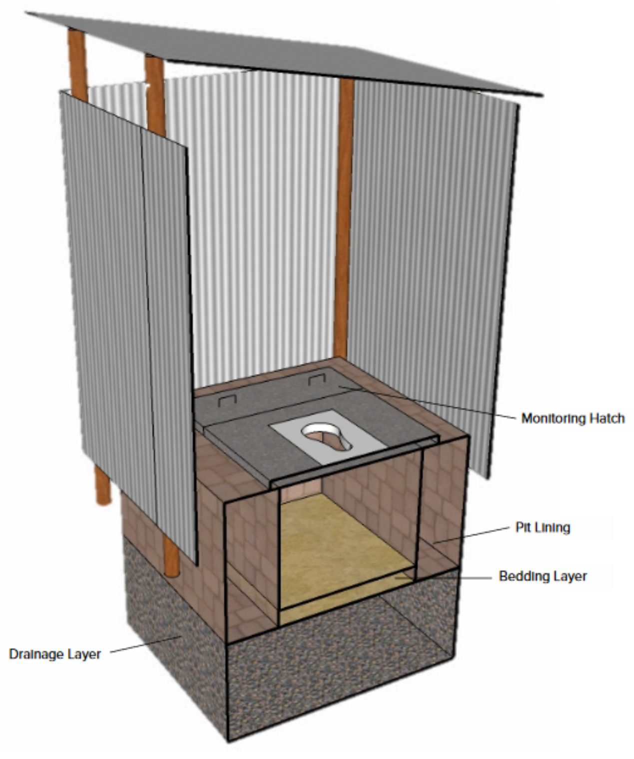

Figure 7: Tiger toilet

Advantages:

- No need of handling sludge as faecal sludge is converted into vermicompost.
- Safer and easier emptying as vermicompost is stable, soil-like material and can be removed.
- No energy requirements as it is a passive process.
- Easy to construct and run.
- Compact with a smaller footprint than a septic tank or a twin pit latrine.
- A self - regulating ecosystem that stabilizes and adapts gradually to effectively handle wide.

3.4.4 Functional groups

A functional group is a grouping of technologies that have similar functions. There are five different functional groups from which technologies can be chosen to build a system.

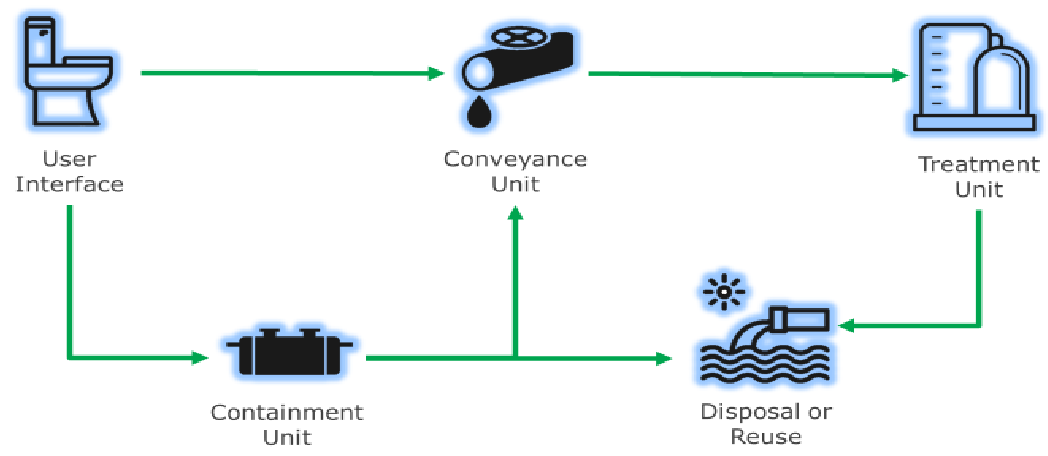

Figure 8: Functional groups of sanitation

User interface - The user interface must guarantee that urine and excreta are hygienically separated to prevent exposure to pathogenic and/or faecal contamination. The user interface is the way in which the sanitation system is accessed. Choice of the user interface has a significant impact on the entire system design, as it defines the products or product mixtures fed into the system. Therefore, the user interface strongly influences the technological choices of subsequent processes. Selection of user interface depends on the following six technical and physical criteria-

- Availability of space
- Ground condition
- Groundwater level and contamination
- Water availability
- Climate

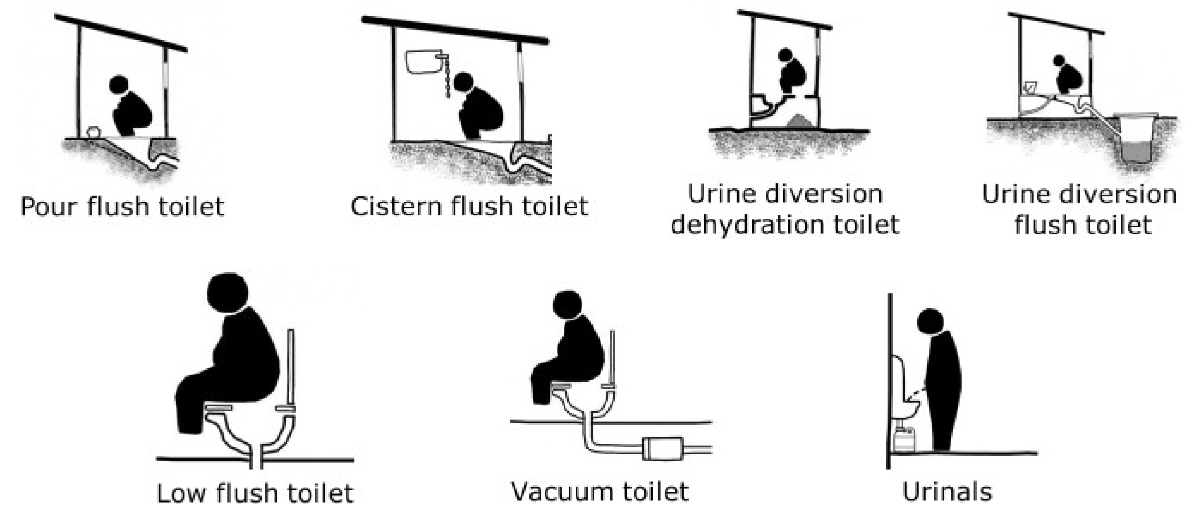

Figure 9: User interface options

Collection & storage/treatment - The functional group Collection and Storage/Treatment describes the ways of receiving, storing, and sometimes treating the products received from the user interface. The treatment provided by these technologies is often the function of storage, and is usually passive, without requiring energy input. Products that emanate from these technologies often require subsequent treatment before use or disposal. There's quite a wide range of technologies which belong to this functional group. The technical and physical criteria for choosing appropriate collection, storage and treatment technology are as follows:

- Ground condition (Soil and strata (percolation and cost of construction))
- Groundwater level and contamination (Cross contamination (pathogens))
- Climate-Temperature (degree of treatment) and rainfall (percolation rate)

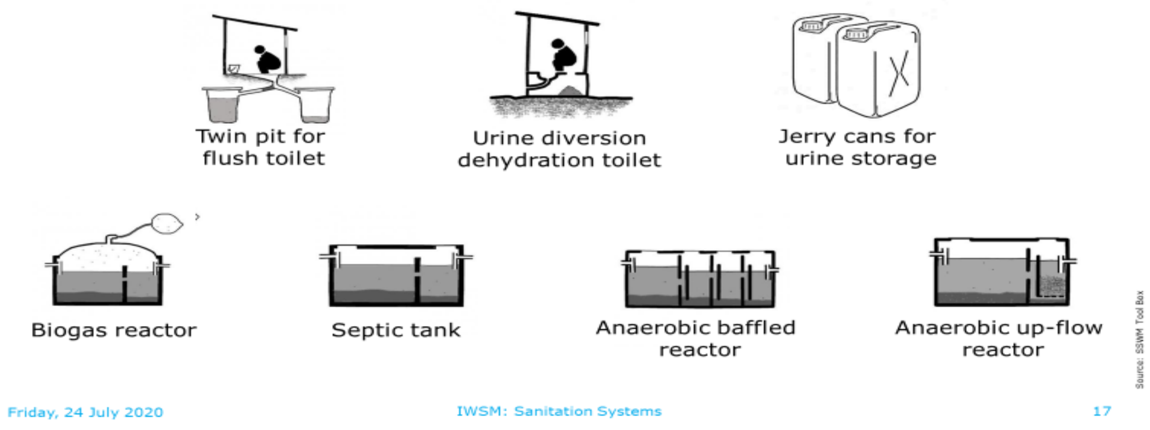

Figure 10: Conveyance Options

Conveyance - If waste products cannot be safely disposed of or even suitably reused on site, they have to be transported elsewhere. Conveyance describes the way in which products are moved from one process to another. Although products may need to be moved in various ways to reach the required destination, the longest and most important gap lies between on-site storage and (semi-) centralised treatment. The technical and physical criteria for choosing appropriate conveyance technology/system are as follows:

- Water availability
- Ground condition
- Ground water level and contamination

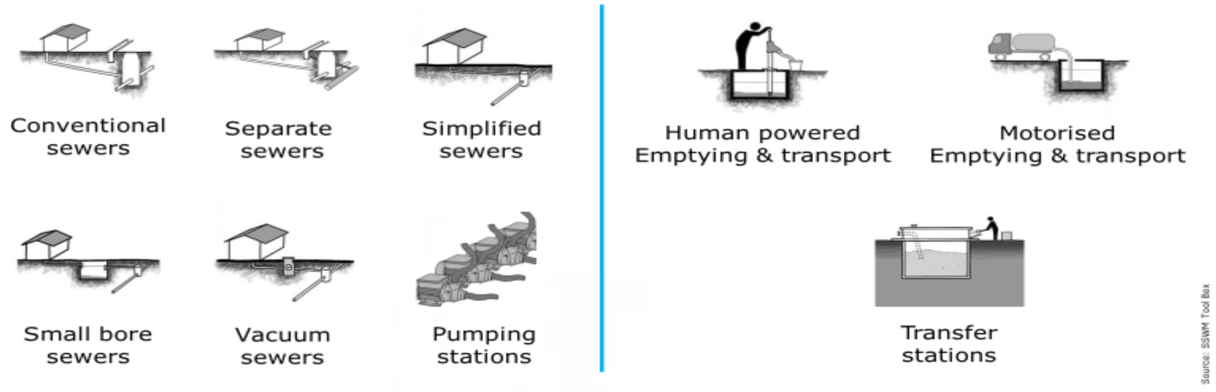

Figure 11: Collection and Storage Options

Semi-centralized treatment - Compared to household-centred storage technologies, these treatment technologies are designed to accommodate increased volumes of flow and provide, in most cases, improved removal of nutrients, organics and pathogens. A semi-centralised treatment refers to the treatment systems which, unlike those used on-site, are larger, require a greater inflow (that can usually not be met by just one family) and often more skilled operation. The technical and physical criteria for choosing appropriate technology for treatment are as follows:

- Availability of space and other resources (Choice of technology)
- Climate (Temperature affects rate of reactions)
- Ground condition (Flood-prone area)
- Groundwater level and contamination (Cross contamination from tanks underground)

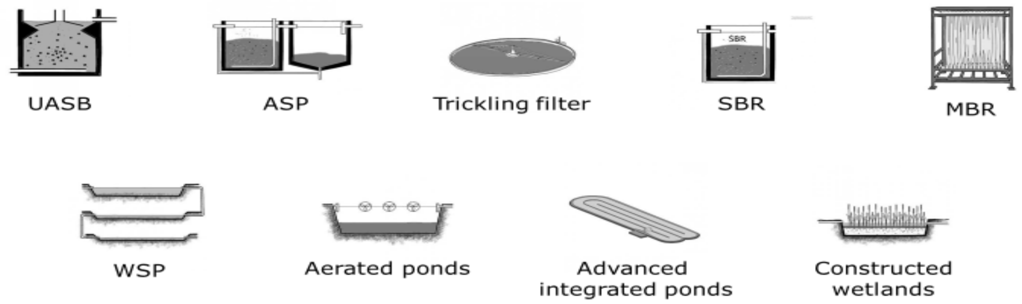

Figure 12: Semi-centralized Treatment Options

Reuse and/or disposal - Reuse and/or disposal refers to the ways in which products are ultimately returned to the soil, either as harmless substances or useful resources. Furthermore, products can also be re-introduced into the system as new products. A typical example is the use of partially treated greywater used for toilet flushing. There are different points of reuse such as:

- **Agriculture:** The dried faecal matter is used as soil conditioner in agriculture. The soil conditioner improves the texture of the soil and helps to increase the moisture retention capacity of the soil. The sterile urine after disinfection is used as fertilizer in the agriculture. Urine as a liquid fertilizer contains high nitrates and phosphates which can reduce the consumption of inorganic fertilizers.
- **Aquaculture:** The term aquaculture refers to the controlled cultivation of aquatic plants and animals by making use of various types of wastewater as a source for nutrients and/or warm temperatures for plants and fish to grow. Fish can be grown in ponds that receive effluent or sludge where they can feed on algae and other organisms that grow in the nutrient-rich water. The fish, thereby, remove the nutrients from the wastewater and are eventually harvested for consumption.
- **Recharge or disposal:** This can be done is several ways. The most common way is to have a leach field of soak pit. However, there are other ways like soil aquifer treatment, short crop rotation which are popular in other countries and utilize the treated wastewater in a more sophisticated way.
- **Energy products from sludge:** The sludge can be processed to make solid or liquid fuel depending on treatment process used. The biogas generated through anaerobic digestion can be directly used as liquid fuel or alternatively converted into electricity. Dried sludge can also be used as solid fuel in furnaces or brick kiln due to its high calorific value.

Wastewater discharge standards

As per Environment Protection Act and Rules, 1986 and Amendments, 2017, the following are the effluent discharge standards which have to be followed for the disposal or reuse of the wastewater after treatment in sewage treatment plants across India.

Table 8: Effluent/Wastewater Discharge Standards

Sr. No.	Parameter	EPA, 1986 Norms	MoEFCC Notification October 2017
1	pH	5.5 – 9.0	6.5 – 9.0
2	BOD (mg/l)	< 30	(Metro Cities) < 20 / (Other Region) < 30
3	COD (mg/l)	< 250	-
4	TSS (mg/l)	< 100	(Metro Cities) < 50 / (Other Region) < 100
5	NH_4-N (mg/l)	< 50	-
6	Total N (mg/l)	< 50	-
7	Faecal coliforms (MPN/100ml)	-	< 1000

(Source: Environmental Protection Rules 1986 and Amendments, 2017)

The 2006, World Health Organisation's (WHO) Guidelines for the safe use of wastewater, biosolids and greywater maximises the public health protection and the beneficial use of important resources. These guidelines provide a comprehensive framework for managing health risks associated with the use of human wastes in agriculture and aquaculture.

Use of wastewater is becoming increasingly attractive to policy makers and water users in the face of increasing water scarcity and competing demands for water. Peri-urban agricultural and aquaculture using wastewater also has many market advantages. In addition to being a reliable year-round water supply, wastewater also contains valuable nutrients that can increase crops yields and save on artificial fertilizers and alternative water sources. However, expanding formal reuse is typically complicated by weak coordination, complexity in the inter-operability of policies and regulations for reuse, and difficulties in identifying and managing the real and perceived health risks associated with reuse.

3.5 Notes for trainer

Case studies on reuse of treated products are quite useful and can convey a lot as compared to the normal technical presentations. Case study presentations stimulate the participants to start thinking about sanitation systems and technologies with the benefit of reuse approach. We end the session with two case studies i) East Kolkata Wetlands, and ii) Sewage Treatment Plant at Bhandewadi, Nagpur.

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Session

04

Sanitation Technologies

4. Sanitation technologies – wet sanitation systems

4.1 Learning objectives

- To know the flow of products in wet sanitation system and its types
- To understand the functional groups involved in a wet sanitation system
- To know the working of each functional group in a wet sanitation system

4.2 Session plan

Duration - 60 minutes

Activity	Time	Material/Method
Wet sanitation systems	10 min	Power point presentation
Functional groups: User interface Containment systems Collection and transport Conveyance	35 min	Power point presentation
Videos and Q&A	15 min	Video presentation and discussion

4.3 Key facts

- In India, hybrid sanitation system is mostly followed, wherein the septic tank effluent along with the grey water is discarded by the household.
- Solid free sewer is appropriate for collection and conveyance system of sullage.
- Regular emptying of septic tank is necessary for proper functioning of solid free sewers.

4.4.1 Learning notes

4.4.1 Wet sanitation systems

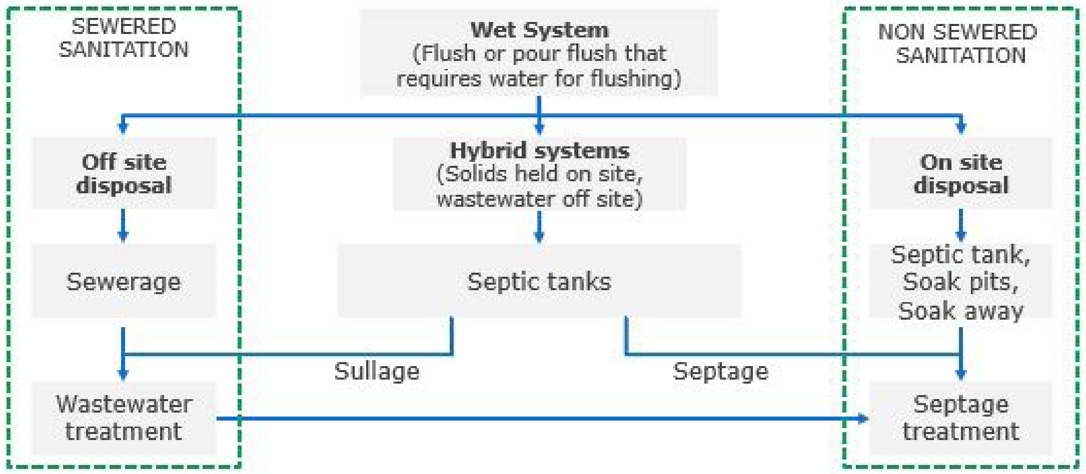

Figure 13: Wet sanitation system

In the urban centres of the developing countries, due to availability of the water, use of flush toilets and water borne systems is a predominant method of sanitation. The type of sanitation systems that use water to transport the waste from one point to another are called wet systems. The wet systems can be classified into two types depending on where the treatment of waste is done. In case of "off-site" disposal, the waste is carried away from the point of generation using water. The sewerage network brings the waste from all the households to a wastewater treatment plant. This type of system is called as sewered sanitation.

In the case of "on-site" disposal, the solids are stored in the containment unit and the liquid effluent is disposed into the ground using soak pits. After every few years, the contents of the containment unit are emptied and transported for further treatment. Since this conveyance of solids is done by mechanised equipment such as vacuum trucks and not by a pipe network, this type of sanitation system is called as non-sewered sanitation.

However, in India, we have developed a hybrid system where in the solids are contained in the septic tank at the household level and the sullage is disposed into the drains outside the houses. The network of drains thus collects the sullage from all the households and by gravity brings it to surface water bodies such as rivers, lakes and ponds. The septage from the septic tank is emptied after few years and transported by vacuum trucks for either treatment or direct disposal. This system cannot be classified as completely sewered or non-sewered sanitation system and thus is referred to as a hybrid sanitation system.

4.4.2 Functional groups

A sanitation system consists of five different components namely, user interface, containment unit, conveyance unit, treatment unit and disposal or reuse.

A. User interface (major technical options)

a. Pour flush toilet

A pour flush toilet is like a regular flush toilet wherein the water is poured in by the user during the usage of the toilet. When the water supply is not continuous, any cistern flush toilet can become a pour flush toilet. Just like a cistern flush toilet, the pour flush toilet has a water seal that prevents odours and flies from coming back up the pipe. Water is poured into the bowl to flush the toilet of excreta. Around 4 to 6 litres is usually sufficient in such a toilet system. The quantity of water and the force of the water (pouring from a height often helps) must be sufficient to move the excreta up and over the curved water seal. Both pedestals and squatting pans can be used in the pour flush mode. Due to rise in demand, local manufacturers have become increasingly efficient at mass-producing affordable pour flush toilets and pans.

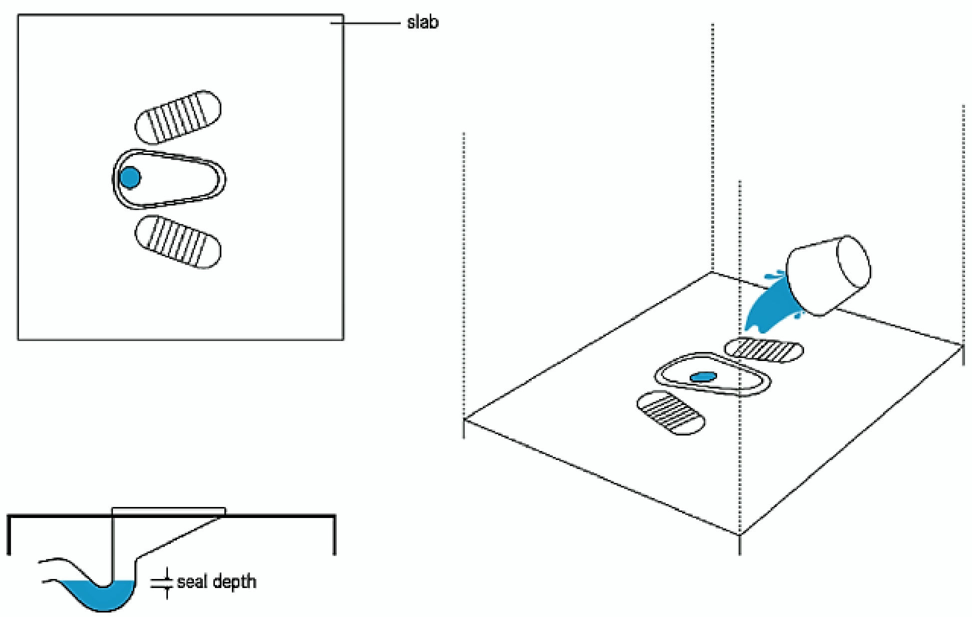

Figure 14: Schematic of pour flush toilet

Table 9: Pros and cons of pour flush toilet

Pros	Cons
• The water seal effectively prevents odour • The excreta of one user are flushed away before the next user arrives • Suitable for all types of users (sitters, squatters, wipers and washers) • Low capital costs; operating costs depend on the price of water	• Requires a constant source of water (can be recycled water and/or collected rain water) • Requires materials and skills for production that are not available everywhere • Coarse dry cleansing materials may clog the water seal

b. Cistern flush toilet

The cistern flush toilet is made of porcelain and can be easily mass-produced. It consists of a cistern which is basically a water tank that supplies water for flushing the excreta and a bowl into which the excreta are deposited. Excreta are flushed away with water stored in the cistern (depending on the type between 6 to 12 litres per flush). Cistern flush toilets provide a high level of convenience for the user but their installation can result in a significantly high fresh water consumption and increase of wastewater to be collected and treated. Dual flush toilets (with a smaller flush-volume for urine), low-flush toilet and urine diverting toilets are available in order to reduce the amount of generated blackwater.

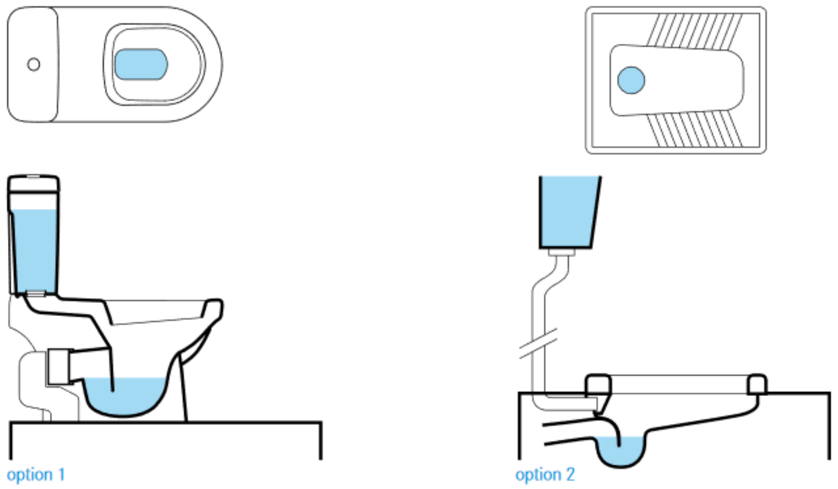

Figure 15: Schematic of cistern flush toilet (Source: Tilley et all, 2014)

Table 10: Pros and Cons of cistern flush toilet

Pros	Cons
The excreta of one user are flushed away before the next user arrives	High capital costs; operating costs depend on the price of water
No real problems with odours if used correctly	Requires a constant source of water
Suitable for all types of users (sitters, squatters, wipers and washers)	Cannot be built and/or repaired locally with available materials

c. Vacuum toilet

The use of vacuum toilets provides a similar level of comfort as traditional flush toilets, but they use much less water due to air sucked into the toilet when flushing, thereby producing a vacuum. This results in a minimal requirement of water (0.5 to 1.5 liters) for the transport of faeces and urine. The system is completely closed. Due to the fact that the effluent has a high organic matter content, vacuum toilets are specifically adapted for the use in combination with separate greywater and blackwater treatment; or anaerobic digestion treatment for biogas production. To further minimize the water consumption of a vacuum toilet, urine diversion bowls can be applied. Vacuum toilet systems are applicable both in large and small buildings, trains, ships and airplanes.

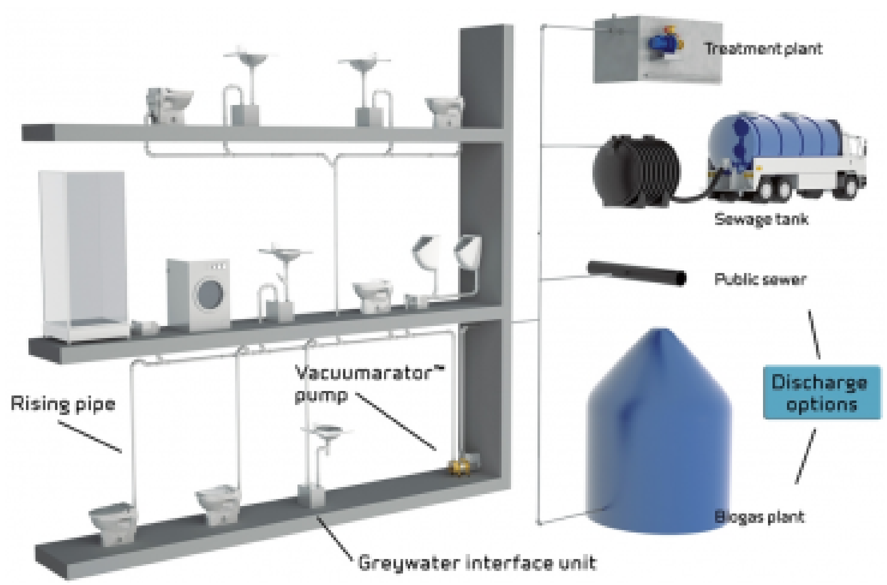

Figure 16: Vacuum system with various discharge options (Source: Jets Group, 2005 & 2009)

Table 11: Pros and cons of vacuum toilet system

Pros	Cons
Saving significant quantities of water (only 0.5 to 1 liter required per flush) and allows a large flexibility for on-site treatment (independent of large sewer collection systems).	High capital and operation costs and design by skilled person/expert

B. Collection & storage/treatment (major technical options)

a. Twin pit for pour flush toilet

This technology consists of two alternating pits connected to a pour flush toilet. The blackwater (and in some cases greywater) is collected in the pits and allowed to slowly infiltrate into the surrounding soil. Over time, the solids are sufficiently dewatered and can be manually removed with a shovel. The twin pits for pour flush technology can be designed in various ways; the toilet can be located directly over the pits or at a distance from them. The superstructure can be permanently constructed over both pits, or it can be moved from side to side depending on which pit is in use. No matter how the system is designed, only one pit is used at a time. While one pit is filling, the other pit is said to be resting.

As liquid leaches from the pit and migrates through the unsaturated soil matrix, pathogenic germs are adsorbed onto the soil surface. In this way, pathogens can be removed prior to contact with groundwater. The degree of removal varies with soil type, distance (depth) travelled, moisture and other environmental factors.

The difference between this technology and the double ventilated improved pit or Fossa Alterna is that it allows for water usage in the toilet and does not require addition of soil or organic material to the pits. As this is a water-based technology, the full pits require a longer retention time to degrade the material before it can be excavated safely. Twin pits for pour flush are a permanent technology appropriate for areas where it is not possible to continuously build new pit latrines. If water is available, this technology is appropriate for almost all types of population density.

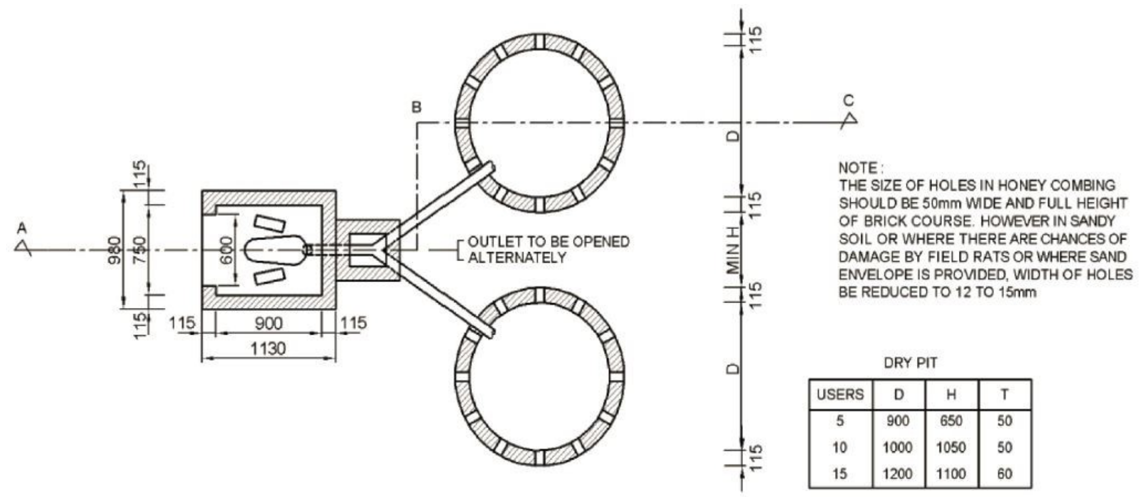

Figure 17: Twin pit pour flush system (Source: CPHEEO Manual: Sewerage and Sewage Treatment Systems)

Table 12: Pros & cons of twin pit pour flush system

Pros	Cons
• Because double pits are used alternately, their life is virtually unlimited • Excavation of humus is easier than faecal sludge • Potential for the use of stored faecal material as soil conditioner • Flies and odours are significantly reduced (compared to pits without a water seal) • Can be built and repaired with locally available materials • Low (but variable) capital costs depending on materials; no or low operating costs if self-emptied • Small land area required	• Manual removal of pit humus is required • Clogging is frequent when bulky cleansing materials are used • Higher risk of groundwater contamination due to more leachate than with waterless system

b. Septic tank

A septic tank is a watertight chamber made of concrete, fibreglass, PVC or plastic, through which blackwater and greywater flow for primary treatment. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

Liquid flows through the tank, and heavy particles sink to the bottom, while scum (mostly oil and grease) floats at the top. Over time, the solids that settle to the bottom are degraded anaerobically. However, the rate of accumulation is faster than the rate of decomposition, and the accumulated sludge and scum must be periodically removed. The effluent from the septic tank must be discharged through a soak pit, leach field or transported to another treatment technology via a solid-free sewer system. The removal of 50% of solids, 30 to 40% of BOD and a 1-log removal of E. coli can be expected in a well-designed and well-maintained septic tank. These treatment efficiencies vary greatly depending on operation and maintenance and climatic conditions.

The design of a septic tank depends on the number of users, the amount of water used per capita, the average annual temperature, the desludging frequency and the characteristics of the wastewater. The retention time should be 48 hours to achieve moderate treatment.

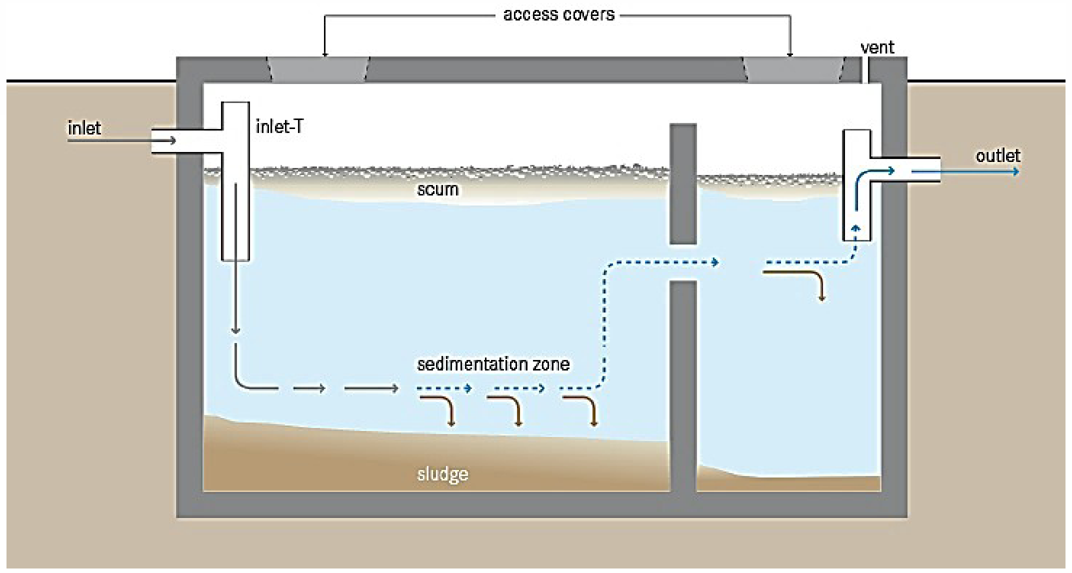

Figure 18: Schematic of septic tank (Source: Tilley et all, 2014)

Table 13: Recommended size of septic tank up to 20 users (Source: CPHEEO, 2013)

No. of Users	Length (m)	Breadth (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Table 14: Recommended size of septic tank for housing colony up to 300 users (Source: CPHEEO Manual, 2013)

No. of Users	Length (m)	Breadth (m)	Liquid depth (cleaning interval of)	
			2 years	3 years
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
150	10.0	3.00	1.0	1.24
200	12.0	3.30	1.0	1.24
300	15.0	4.00	1.0	1.24

This technology is most commonly applied at the household level. Larger, multi-chamber septic tanks can be designed for groups of houses and public buildings (e.g., schools). A septic tank is appropriate where there is a mode for discharging or transporting the effluent. If septic tanks are used in densely populated areas, onsite infiltration should not be used. This will result in the oversaturation of the soil profile,contaminate the groundwater and wastewater may rise up to the surface posing a serious health risk. Instead, the septic tanks should be connected to some conveyance unit, through which the effluent is safely transported to a subsequent treatment or disposal site. Even though septic tanks are watertight, it is not recommended to construct them in areas with high groundwater tables or areas prone to frequent flooding.

Table 15: Pros & cons of septic tank

Pros	Cons
• Simple and robust technology • No electrical energy is required • Low operating costs • Long service life • Small land area needed (can be built underground)	• Low reduction in pathogens, solids and organics • Regular desludging must be ensured • Effluent and sludge require further treatment and appropriate discharge

c. Anaerobic baffled reactor

An anaerobic baffled reactor (ABR) is mainly a small septic tank (settling compartment) followed by a series of anaerobic tanks (at least three). Most of the solids are removed in the first which also has the largest volume. Effluent from the first tank then flows through the baffles and is forced to flow up through layers of anaerobic sludge in the subsequent tanks. Each chamber provides increased removal and digestion of organics leading to an overall BOD removal of 90%. Increasing the number of chambers also improves performance.

The majority of settleable solids are removed in the sedimentation chamber provided before the ABR. Small-scale stand-alone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate settler or another preceding technology (e.g., existing septic tanks). Designs without a settling compartment are of particular interest for (semi-) centralized treatment plants that combine the ABR with other technologies, or where prefabricated, modular units are used.

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 blackwater and greywater is generated. A (semi-) centralised ABR is applicable when there is a pre-existing conveyance system such as a simplified sewer.

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 settling compartment).

ABRs can be installed in every type of climate, although the efficiency is lower in colder climates. They are not efficient at removing nutrients and pathogens and so the effluent usually requires further treatment.

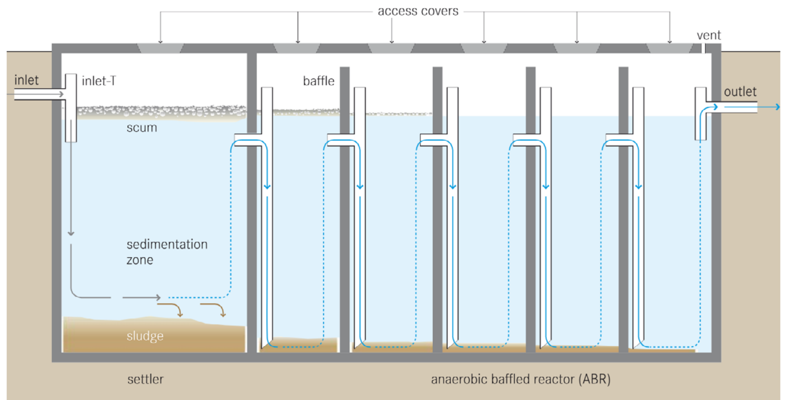

Figure 19: Schematic diagram of anaerobic baffled reactor (ABR)

Table 16: Pros & cons of anaerobic baffled reactor (ABR)

Pros	Cons
• Low cost when divided among members of a housing cluster or small community • Minimum operation and maintenance • Resistant to organic and hydraulic shock loads • Reliable and consistent treatment	• Requires expert design and skilled construction; partial construction work by unskilled labourers • Requires secondary treatment and discharge

d. Anaerobic up-flow filter

An anaerobic up-flow filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, the particles are trapped and the organic matter is degraded by the active biomass layer formed over the filter material. With this technology, suspended solids and BOD removal can be as high as 90% but is typically between 50% and 80%. Nitrogen removal is limited and usually does not exceed 15% regarding total nitrogen (TN).

Pre- and primary treatment is essential to remove solids and garbage that may clog the filter. The functioning of this unit is similar to that of an ABR wherein the first step involves solids removal using either a sedimentation chamber or pre-existing units such as septic tanks.These filters are usually operated in an up-flow mode because there is less risk that the fixed biomass will be washed out. The water level should cover the filter media by at least 0.3 m to guarantee an even flow regime. The hydraulic retention time (HRT) is the most critical design parameter influencing filter performance. An HRT of 12 to 36 hours is recommended.

The microbial growth is retained on the stone media, making containment units receive higher loading rates and provide efficient digestion. The capacity of the unit is 0.04 to 0.05 m3 per capita or 1/3 to 1/2 the liquid capacity of the septic tank it serves. BOD removals of 70% can be expected. The effluent is clear and free from odour. This unit has several advantages: (a) high degree of stabilization; (b) low sludge production; (c) low capital and operating cost; and (d) low containment units of head in the filter (10 to 15 cm) in normal operation.

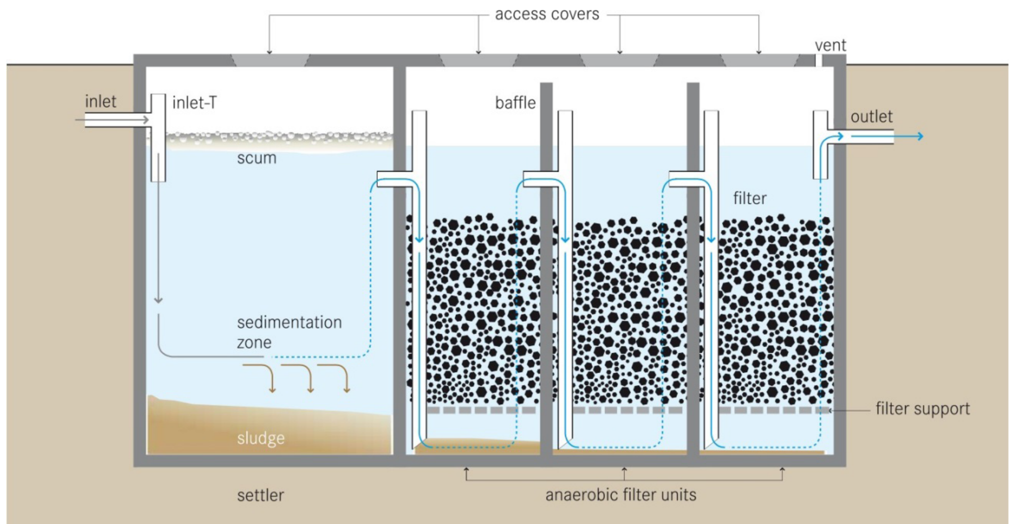

Figure 20: Schematic diagram of anaerobic up-flow filter

The ideal filter should have a large surface area for bacteria to grow, with pores large enough to prevent clogging. The surface area ensures increased contact between the organic matter and the attached biomass that efficiently degrades it. Ideally, the material should provide between 90 to 300 m2 of surface area per m3 of occupied reactor volume. Typical filter material sizes range from 12 to 55 mm in diameter. Materials commonly used include gravel, crushed rocks or bricks, cinder, pumice, or specially formed plastic pieces, depending on local availability.

The connection between the chambers can be designed either with vertical pipes or baffles. Accessibility to all chambers (through access manholes in the top slab of the unit) is necessary for maintenance. The tank should be sufficiently ventilated to allow for controlled release of odorous and potentially harmful gases.

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 blackwater is generated. The anaerobic filter can be used for secondary treatment, to reduce the organic loading rate to a subsequent aerobic treatment step, or for polishing.

This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. Accessibility by vacuum truck is important for desludging.

Table 17: Pros & cons of Anaerobic Up-flow filter

Pros	Cons
• No electrical energy is required • Low operating cost • Long service life • High reduction of BOD and solids • Low sludge production; the sludge is stabilized • Moderate area requirement (can be built underground)	• Requires expert design and construction • Low reduction of pathogens and nutrients • Effluent and sludge require further treatment and appropriate discharge • Risk of clogging, depending on pre- and primary treatment • Removing and cleaning the clogged filter media is cumbersome

C. Collection and transport (major technological options)

a. Vacuum trucks

Motorized emptying and transport refer to a vehicle like vacuum trucks equipped with a motorised pump and a storage tank for emptying and transporting faecal sludge and urine. The tank is connected to a hose, which is lowered down into a septic tank or pit, and the sludge is pumped out of the containment unit into the storage tank.

The people required in the operation of a vacuum truck is only to operate the pump and manoeuvre the hose in the containment unit. This is also one way to overcome the need to manually empty the containment unit and transport the waste produts. A truck is fitted with a pump which is connected to a one end of the storage tank and the hose which is connected to the outlet of the storage tank is lowered down into a containment unit (e.g. septic tank or lined pit as in the case of pit latrines), and the sludge is pumped up into the storage tank located on the vehicle.

The vacuum trucks come in different sizes and types. Trailer mounted tank fitted with vacuum pump is the most basic form of equipment. In this case, the trailer can be tugged with tractor and the vacuum pump is operated using a diesel run motor. An improved version is a truck mounted tank fitted with the vacuum pump. In this case there is possibility that the vacuum pump can be coupled with the drive train of the truck, thus eliminating the need for a separate diesel run motor. Nowadays, vacuum trucks fitted with jetting equipment is also available for cleaning sewerage network and manholes. The trailer mounted vacuum trucks can be found in the range of 3 – 4.5 kilolitres (volume of storage tank) and truck mounted vacuum systems in the range of 3 – 11 kilolitres.

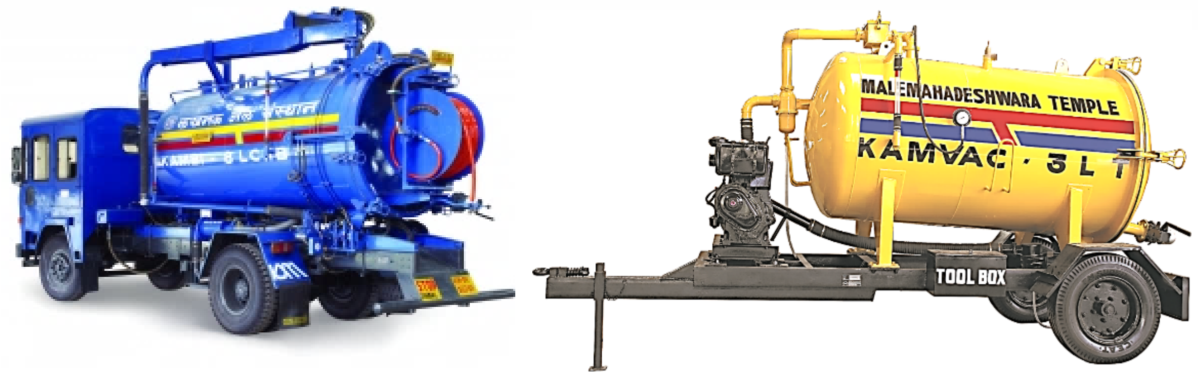

Figure 21: a) Truck mounted and b) Trailer mounted vacuum system

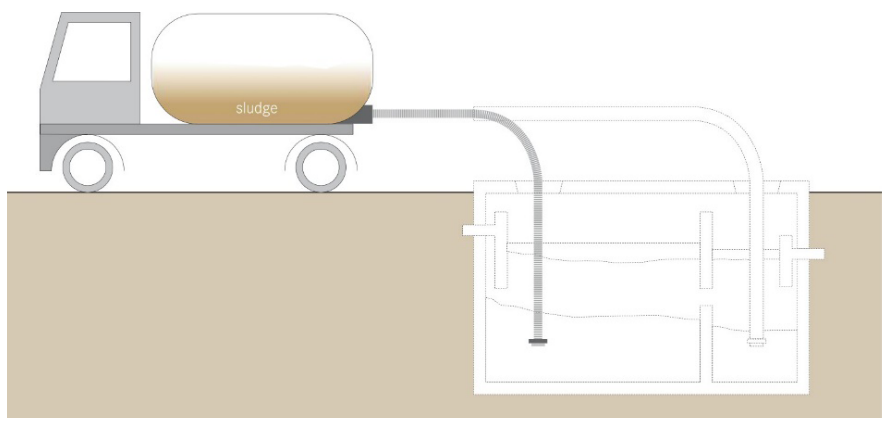

Figure 22: Schematic diagram of motorized emptying and transport

b. Vacutug

Vacutug is a smaller version of the trailer mounted type of vacuum truck which carry a small sludge tank and a vacuum pump. The need for such a smaller size desludging equipment arises from the fact that not all the containment units are easy to access. In the case of unorganized settlements such as urban slums, the access roads are small and a vacuum truck cannot be driven to all the containment units. Hence, a vacutug is used to empty the content of the containment unit in batches and empty it into a larger storage tank or truck with higher storage capacity. The vacutugs can found to have a storage capacity of 300 to 2000 litres. The vacutug should be developed keeping in mind that it should be easy enough to pull it by person/s or a small vehicle. Under favourable circumstances, small vehicles like the vacutug are found to have low operating and maintenance costs. However, the capital costs are high and can be a disadvantage in creating a sustainable business.

The vacutug can be an effective tool in sludge management because:

- Many vacutug models have a small footprint and can access sites that are hard to reach.
- Acts as a support tool for larger vacuum trucks to reduce the number of trips.
- Works efficiently and hygienically.
- Relatively inexpensive to operate.

- Requires minimal maintenance as spare parts are inexpensive and readily available at many local markets.
- Has the potential to create a viable micro-enterprise.

Table 18: Pros & cons of motorized emptying & transport (Vacutug)

Pros	Cons
• Fast, hygienic and effective sludge removal • Efficient transport possible with large vacuum trucks • Potential for local job creation and income generation • Provides an essential service to non-sewered areas	• Cannot pump thick, dried sludge (must be converted into a slurry with water or manually removed) • Garbage in pits may block hose • Cannot empty deep pits due to limited suction lift • Very high capital costs; variable operating costs depending on use and maintenance • Hiring a vacuum truck may be unaffordable for poor households • Not all parts and materials may be locally available • May have difficulties with access

D. Conveyance

a. Gravity sewers

Conventional gravity sewers are large networks of underground pipes that convey blackwater, greywater and, in many cases, stormwater from individual households to a (semi-) centralized treatment facility, using gravity (and pumps when necessary).

Conventional gravity sewers normally do not require onsite pre-treatment, primary treatment or storage of the household wastewater before it is discharged. The sewer must be designed so that it maintains the self-cleansing velocity (i.e., a flow that will not allow particles to accumulate). For typical sewer diameters, a minimum velocity of 0.6 to 0.7 m/s during peak dry weather conditions should be adopted. A constant downhill gradient must be guaranteed along the length of the sewer to maintain self-cleansing flows, which can require deep excavations. When a downhill grade cannot be maintained, a pumping station must be installed. Primary sewers are laid beneath roads at depths of 1.5 to 3 m to avoid damages caused by traffic loads. The depth also depends on the groundwater table, the lowest point to be served (e.g., a basement habitation) and the topography. The selection of the pipe diameter depends on the projected average and peak flows. Commonly used materials are concrete, PVC, and ductile or cast-iron pipes.

Access manholes are placed at defined intervals above the sewer, at pipe intersections and at the point where the direction of pipeline changes (vertically and horizontally). Manholes should be designed such that they do not become a source of stormwater inflow or groundwater infiltration. In the case that connected users discharge highly polluted wastewater (e.g., industry or restaurants), onsite pre- and primary treatment may be required before discharging it into the sewer system. This will allow the reduction in the risk of clogging and the pollution load on the wastewater treatment plant.

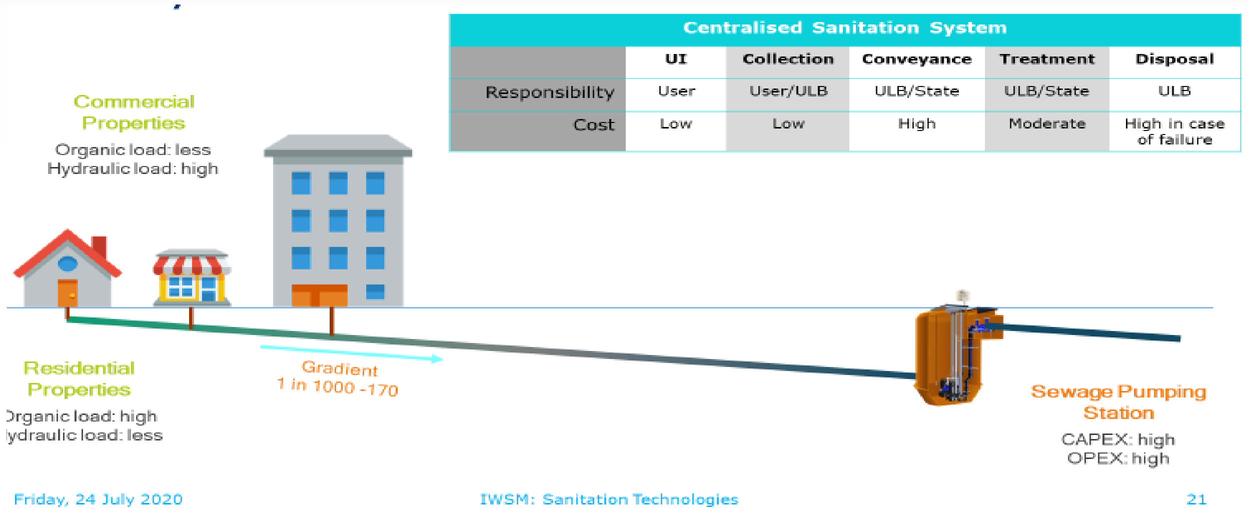

Figure 23: Schematic of conventional gravity sewers

Table 19: Pros and Cons of conventional gravity sewers

Pros	Cons
• Less maintenance compared to simplified and solid-free sewers • Greywater and possibly stormwater can be managed concurrently • Can handle grit and other solids, as well as large volumes of flow	• Very high capital costs and high operation and maintenance costs • A minimum velocity must be maintained to prevent the deposition of solids in the sewer • Requires deep excavations • Difficult and costly to extend as a community expands horizontally • Requires expert design, construction and maintenance • Leakages pose a risk of wastewater exfiltration and groundwater infiltration and are difficult to identify

b. Solid-free sewer

A solids-free sewer is a network of small-diameter pipes that transports pre-treated and solid-free wastewater (such as septic tank effluent). It can be installed at a shallow depth and does not require a minimum wastewater flow or slope to function.

Solid-free sewers are also referred to as settled, small-bore, variable-grade gravity, or septic tank effluent gravity sewers. A precondition for solid-free sewers is efficient primary treatment at the household level. An interceptor, typically a single-chamber septic tank, captures settleable particles that could clog small pipes. These solid interceptor also functions to attenuate peak discharges. Because there is little risk of depositions and clogging, solid-free sewers do not have to be self-cleansing i.e. no minimum flow velocity or tractive tension is needed. A minimum diameter of 75 mm is required to have the desired operation and facilitate maintenace. They require few inspection points, can have inflective gradients (i.e., negative slopes) and follow the topography. When the sewer roughly follows the ground contours, the flow is allowed to vary between open channel and pressure (full-bore) flow.

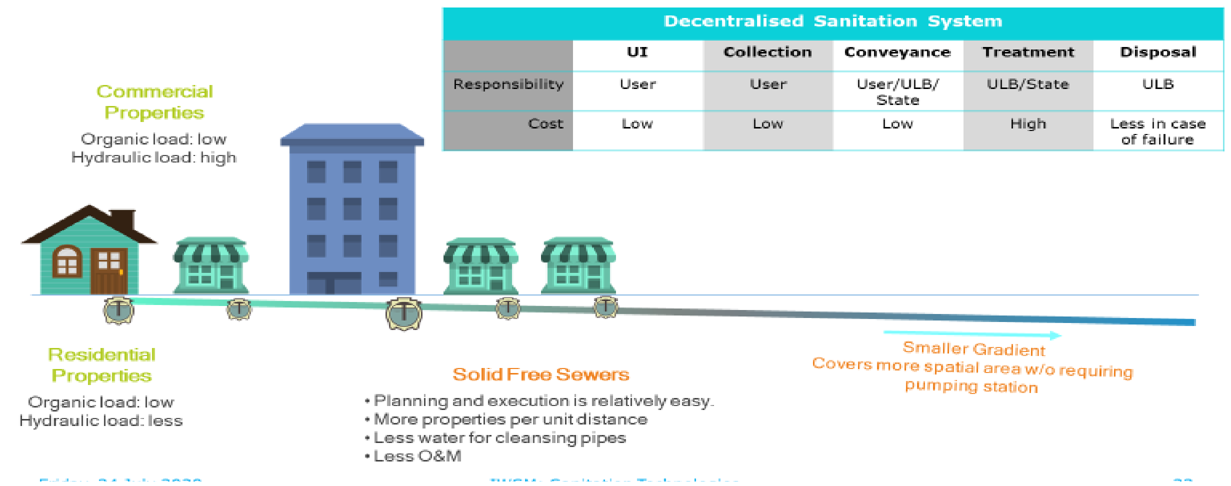

Figure 24: Schematic of solid-free sewer

Table 20: Pros and Cons of solid-free sewer

Pros	Cons
• Does not require a minimum gradient or flow velocity • Can be used where water supply is limited • Lower capital costs than conventional gravity sewers; low operating costs • Can be extended as a community grows • Greywater can be managed concurrently	• Space for interceptors is required • Interceptors require regular desludging to prevent clogging • Requires training and acceptance to be used correctly • Requires repairs and removals of blockages more frequently than a conventional gravity sewer • Requires expert design and construction • Leakages pose a risk of wastewater exfiltration and groundwater infiltration; both situations can be difficult to identify

c. Simplified sewers

A simplified sewer describes a sewerage network that is constructed using pipes of smaller diameters, laid at shallow depths and with flatter gradients in comparison to conventional sewers. The simplified sewer allows for a more flexible design at lower costs.

In contrast to conventional gravity sewers that are designed to ensure a minimum self-cleansing velocity, the design of simplified sewers is based on a minimum tractive tension of 1 N/m2 (1 Pa) at peak flow. The minimum peak flow should be 1.5 L/s and a minimum sewer diameter of 100 mm is required. A gradient of 0.5% is usually sufficient. For example, a 100 mm sewer laid at a gradient of 1 m in 200 m will serve around 2,800 users with a wastewater flow of 60 L/person/day.

It is recommended to use PVC pipes in this type of sewer system. The depth at which they should be laid depends mainly on the amount of traffic load above the surface. On the other hand, these pipes can be laid at a depth of 40 to 65 cm below the sidewalks. The simplified design can also be applied to sewer mains with their location at a shallow depth and placed away from the points of heavy traffic.

Expensive manholes are normally not needed. At each junction or change in direction, simple inspection chambers (or cleanouts) are sufficient. Inspection boxes are also used at each house connection. Where kitchen greywater contains an appreciable amount of oil and grease, the installation of grease traps is recommended to prevent clogging.

Greywater should be discharged into the sewer to ensure adequate hydraulic loading, but stormwater connections should be discouraged. However, in practice it is difficult to exclude all stormwater flows, especially where there is no alternative for storm drainage. The design of the sewers (and treatment plant) should, therefore, take into account the extra flow that may result from stormwater inflow.

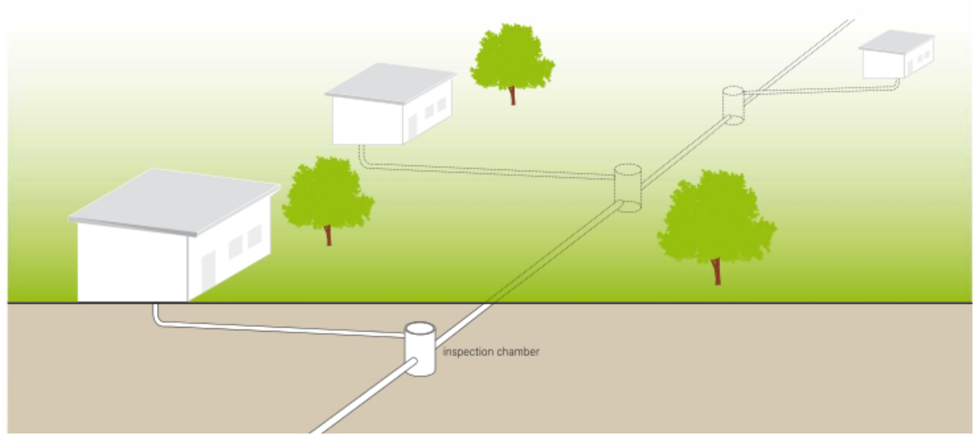

Figure 25: Schematic representation of simplified sewers

Table 21: Pros and Cons of simplified sewers

Pros	Cons
Can be laid at a shallow depth and flat gradient in comparison to conventional sewers Lower capital costs than conventional sewers; low operating costCan be extended as a community expands horizontallyGreywater can be managed concurrently Does not require onsite primary treatment units	Requires repairs and removal of blockages more frequently than a conventional gravity sewer Requires expert design and construction Leakages pose a risk of wastewater exfiltration and groundwater infiltration and are difficult to identify

4.4.3 Adopting CWIS principles for sanitation planning

Figure 26: Drone image of Mumbai city from "Unequal Scenes"

A graphic illustration project by photographer and journalist Mr. Johnny Miller (Source: https://unequalscenes.com/ mumbai)

The provision of conventional sewerage with a wastewater treatment system is considered to be the only solution to urban sanitation. But, as an urban area grows organically, the application of this fixed solution will not be enough to attain safely managed sanitation for the urban population. Organic growth of an urban space means the 'fly-by' approach where planning of infrastructure and services occur along with migration of people into urban areas i.e. urbanisation.

For any urban area, the provision of infrastructure and services includes but is not limited to buildings, mobility, access to drinking water, sanitation facilities, waste management facilities, etc. In the case of a planned urban area, the provision of these infrastructure and services will be planned with an aim to provide a comfortable and good quality of life to its residents. In fact, the provision of sanitation services in a well-planned area often includes sewer connections from households to an underground sewerage system which combines all the domestic wastewater, conveys it to a designated treatment site, provides the necessary treatment before disposing or reusing it as per the desired end goal.

On the other hand, when an urban area grows organically, it is often observed that the rate of migration is higher than the rate at which infrastructure and services are made available to the people residing in it. As a result, the provision of infrastructure and services in such an urban area depends on new and innovative methods for achieving the required living standards of the people. However, it is always difficult to stick to the planned approach of providing services in an organically growing urban area, especially services like water supply and sanitation. While there are several factors that affect urbanisation, the above example is a simple explanation of how we need to rethink our approach to service provision in the coming future.

Hence, the citywide inclusive sanitation (CWIS) approach takes into consideration this particular aspect of urban development. By understanding the needs of the people with regards to sanitation, the CWIS principles prove to be very useful in guiding the decision-makers for implementing appropriate solutions. The principles promote adoption of both conventional and innovative methods for planning of sanitation infrastructure and combining them with other services such as water supply, waste management, etc. and linking it to novel concepts like resource recovery and reuse to improve financial viability.

4.5 Notes for trainer

The aim of the session is to make the participants understand different types of wet sanitation systems and various options for containment, collection and conveyance of liquid waste. Along with the theory, it is recommended to use visual tools such as videos using animations to show the working of various containment units and conveyance systems.

4.6 Bibliography

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Session

05

Building Sanitation System

Activity Session

5. Building sanitation system - Activity session

5.1 Session objectives

The group activity will help the participants visualize a sanitation system with a matrix of functional groups (columns) and products (rows) that are linked together where potential combinations exist.

5.2 Session plan

Duration - 30 minutes

Activity	Time	Material/Method
Offsite sanitation system Onsite sanitation system Hybrid sanitation system	30 min	Exercise - flipcharts & colour cards

5.3 Instructions for activity session

A sanitation system can be visualized as a matrix of functional groups (columns) and products (rows) that are linked together where potential combinations exist. Such a graphical presentation gives an overview of the technology components of a system and of all the products that it manages. Products are successively collected, stored, transported and transformed along different compatible technologies from the five functional groups. The output of a technology in one functional group, thereby, becomes the input for the next. It is not always necessary for a product to pass through a technology from each of the five functional groups; however, the ordering of the functional groups should usually be maintained regardless of how many of them are included within the sanitation system.

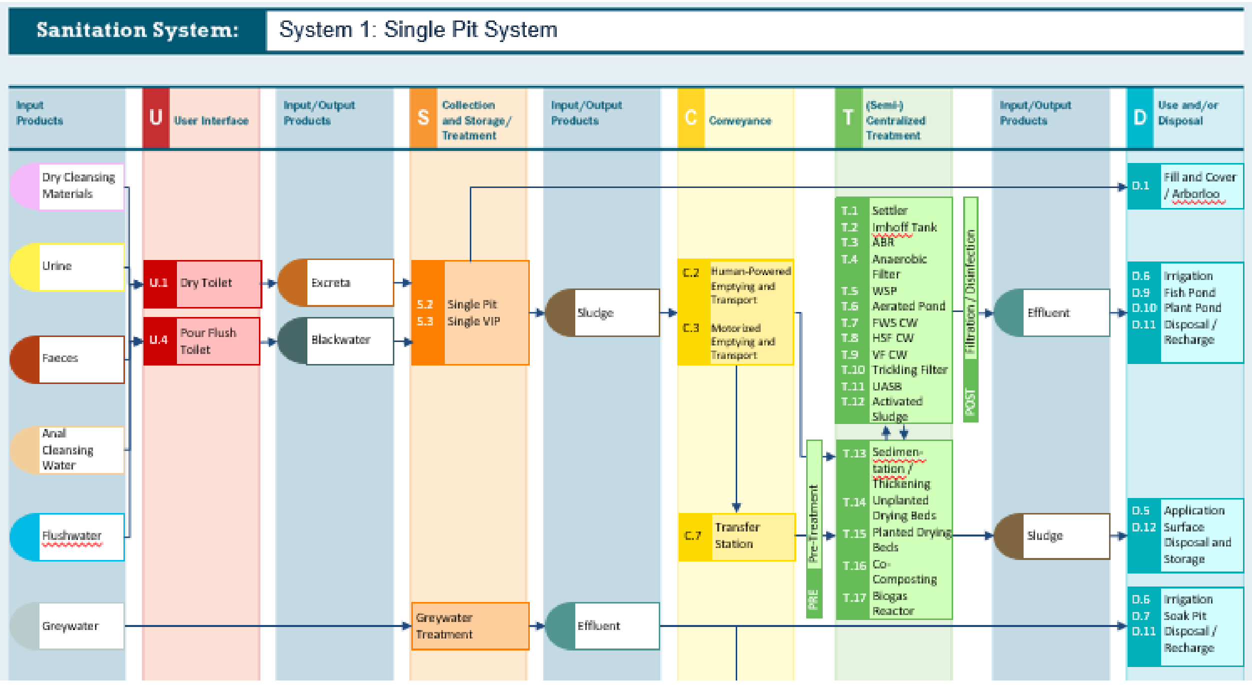
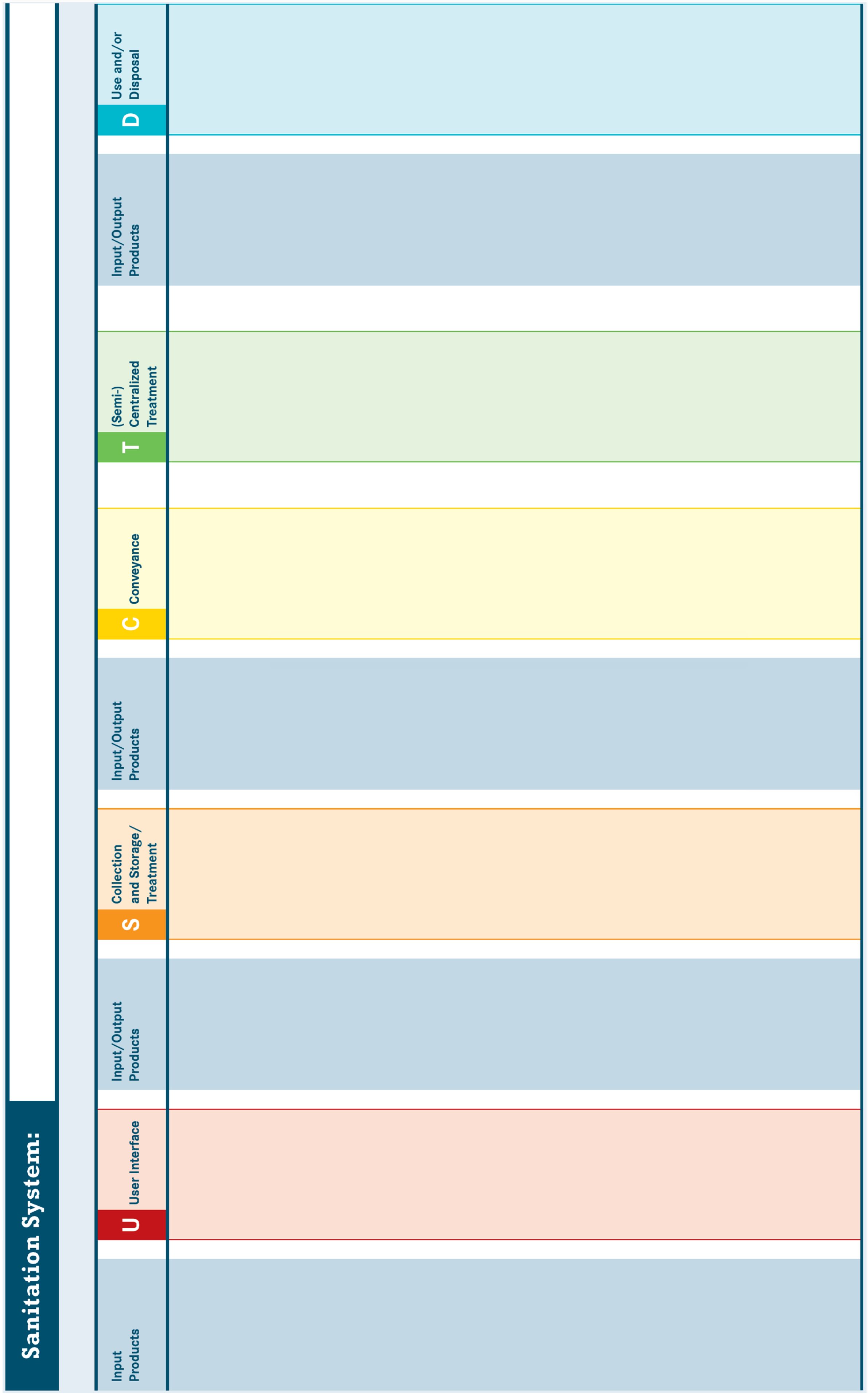


Figure 27: Template for documenting sanitation systems

Each group has to use the template shown above and document the three sanitation systems: (a) offsite sanitation system, (b) onsite sanitation system and (c) hybrid sanitation system. The group have to identify and label each unit in different functional group which are required during the journey of the waste products from point of generation to point of disposal or reuse.



In this group activity, each group will have to be assigned a moderator. The job of the moderator is to conduct discussions with the group and direct them towards understanding and visualizing the systems in totality. Once the documentation is done, the moderator should go ahead and discuss with the group to identify the gaps which are present in the existing sanitation systems deployed in their cities.

5.4 Notes for trainer

This group activity can be conducted using flip charts and markers. Alternatively, to make the activity more interesting, use of colour cards or sticky notes can be done. This helps the group to modify the systems as per the progress of the discussions with the moderator.

5.5 Bibliography

- Tilley, E.; Luthi, C.; Morel, A.; Zurbruegg, C.; Schertenleib, R. (2008): Compendium of Sanitation Systems and Technologies. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (EAWAG) and Water Supply and Sanitation Collaborative Council (WSSCC).
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Session

06

Liquid waste management

6. Liquid waste management

6.1 Lesson objectives

- To understand different levels of liquid waste management with respect to changing urban settings
- To gain a detailed understanding of different aspects of centralized and decentralized liquid waste management
- To understand the different aspects and tools used for planning of liquid waste management

6.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
Levels of wastewater management	5 min	Power point presentation
Centralized wastewater management	10 min	Power point presentation
Decentralized wastewater management	10 min	Power point presentation
Other aspects of liquid waste management	5 min	Power point presentation
Planning of sanitation system	5 min	Power point presentation
Levels of wastewater management	5 min	Power point presentation
Q&A	5 min	Discussion

6.3 Key facts

- Liquid waste management is crucial for maintaining environmental health.
- Different levels of management fit appropriately in different urban and rural scenarios.
- Planning of sanitation systems need to take into consideration affordability and long-term sustainability of infrastructure.
- Centralized and decentralized management compliments and provides maximum sanitation coverage.

6.4 Learning notes

6.4.1 Liquid waste management

In order to decide the level of liquid waste management to be applied in a situation, there are a few important factors to be considered. These are population density, the type of housing, availability of space or land for development of utility infrastructure such as sewerage lines or treatment plants and affordability of the environmental services by the local administration. Liquid waste management has two approaches: centralised systems or decentralised systems.

In the liquid waste management approach, it is very crucial to understand the level or type of habitat. There are different levels or types of habitat like urban, peri-urban, rurban and rural.

A. Urban habitat

In an urban habitat, the most common features are a high population density and areas with high rise buildings. Generally, urban administrations and urban population have high affordability of implementing and maintaining these environmental services. However, a major challenge is the lack of space or land area for development of utility infrastructure. In an urban area, it is suitable to implement a centralised system for sanitation. This would involve household connections to a sewerage system and the wastewater is transferred via this centralised sewer network to a treatment plant before disposing the treated wastewater as desired.

B. Peri-urban habitat

A peri-urban habitat can be associated with a habitat having medium or high population density along with high rise buildings. Generally, the local administration and the people residing in a peri-urban area can afford to develop and maintain their environmental services. In the case of a peri-urban area, the appropriate sanitation system applicable is a decentralised system. This is because a peri-urban area will have residential, institutional and commercial development that have connections to a sewer system or an on-site sanitation system. The households with on-site sanitation system will have a dedicated sewer network and treatment plant while those with off-site sanitation system will have a direct access to a sewer network and convey the wastewater as well to a treatment plant. The sewer system conveying the wastewater from on-site sanitation system will be gravity based and may not require any pumping station. In fact, if the situation permits, the wastewater from both the sewer systems can be connected to a single treatment plant before disposing the treated wastewater as per requirement.

C. Rurban habitat

The habitat having scattered housing or other forms of habitable infrastructure with 2 to 3 storeys and has a low or medium population density can be categorised as a rurban habitat. In this form of habitat, the local administration and population have a lower degree of affordability for developing and maintaining the environmental services. In a rurban type of habitation, the suitable form of sanitation is clustered or regional approach for wastewater management system i.e. household have individual household toilets (IHHT) and septic tanks which can be connected with solid free sewers and wastewater is collected at cluster-level wastewater treatment systems by gravity. Further, it can be disposed into the surface water bodies after treatment or reused for irrigation or other non-potable purposes.

D. Rural habitat

In a rural habitat, it can be observed that the population are served by scattered hamlets having either a single or double storeyed building. This form of habitat can often be seen having a low population density. The people residing in the rural habitat often find it difficult to afford an improved form of environmental services. On-site sanitation systems are the most appropriate in this case. Here, households have individual household toilets and septic tanks / soak pits. It would also involve a segregation of black water and grey water collection. Generally, the disposal happens using leach pits or soak away zones. In this case, the wastewater management occurs at individual household level with primary treatment. In some cases, toilets are connected with biogas systems located within the farmland premises or household premises.

6.4.2 Centralised wastewater management

The conventional, centralized wastewater management concept, consisting of a water-borne wastewater collection system leading to a central treatment plant, has been successfully applied over many decades. In fact, it has been found to be very well adopted in densely populated areas of industrialized countries and has significantly contributed to improving the hygienic conditions in these areas. However, the appropriateness of this model in the context of cities in developing countries must be questioned, given their urgent need for affordable and sustainable infrastructure.

In a centralised wastewater management system, the following requirements have to be considered:

- The individual household toilets have to be connected to a sewerage network.
- The sewerage network should be safely collecting and conveying the wastewater from the

source to the point of treatment including the provision of sewage pumping stations and other required appurtenances.
- The sewage treatment plant (STP) with mechanization and appropriate control system to safely treat the collected wastewater before its disposal or reuse.

A centralized system consists of: i) centralized collection system (sewers) that collects wastewater from many wastewater producers: households, commercial areas, industrial plants and institutions, and conveys to a treatment plant; ii) centralized wastewater treatment plant in an off-site location outside the settlement; and iii) disposal/reuse of the treated effluent, usually far from the point of origin.

Limitations of centralized systems

Aside from its proven benefits, the centralized wastewater management system is nothing more than a transport system for human excreta and industrial waste to a central discharge point or a treatment system. By using valuable drinking water as the transport medium, this system is wasteful of water and nutrients that could otherwise be easily treated and reused. A centralized wastewater management system reduces wastewater reuse opportunities and increases the risk to humans and the environment in the event of system failure.

In the past, conventional thinking favoured centralized systems since they are easier to plan and manage in comparison to decentralized systems. This belief is partly true if municipal administration systems are centralized. However, experience reveals that centralized systems have been particularly poor at reaching peri-urban areas and informal settlements. Centralized systems are usually much more complicated and require professional and skilled operators. Operation and maintenance of centralized systems must be financed by the local government which are often unable or willing to guarantee sustained performance.

Economic aspect

In a centralized approach, the ULB has to bear the capital and operation & maintenance cost of the infrastructure. However, taking into consideration the efficiency of collection of taxes in Indian cities, maintaining the infrastructure and providing services to the masses becomes a cumbersome process.

6.4.3 Decentralised wastewater management

Decentralized wastewater management is defined as the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation. In case of decentralized systems, both solid and liquid fractions of the wastewater are utilized near their point of origin, except in some cases when a portion of liquid and residual solids may be transported to a centralized point for further treatment and reuse.

At the international level, increased emphasis has been placed on a more holistic approach to waste disposal, stressing the benefits of reducing the strength or quantity of waste at source and, whenever possible, treating, recycling or reusing it close to its generation point. It is obvious that a decentralized wastewater management approach is better suited to solve sanitation problems as close to their source as possible. Decentralized systems appear to offer some potential advantages.

Constraints of decentralized systems

Even where policy-makers accept the decentralized approach, they may lack the capacity to plan, design, implement, and operate decentralized systems, thus leading to severe constraints in ensuring its widespread implementation.

Most developing countries have no suitable institutional arrangements for managing decentralized systems and lack an appropriate policy framework to promote a decentralized approach. There is a risk that decentralisation will lead to fragmentation and failure to address overall problems adequately. Without technical assistance and other capacity building measures, problems of institutional capacity existing under a centralised operation are simply passed on to the new structures.

Without a formal institutional framework within which decentralized systems can be located, efforts to introduce decentralized management are likely to remain fragmented and unreliable. Decentralisation therefore requires greater coordination between the government, private sector and civil society. Decentralized systems must be compatible with the knowledge and skills available at local level, as even the simplest technologies often fail in practice for lack of attention to operational and maintenance requirements.

Economic aspect

In decentralized approach, the household (who is the consumer of the services) bears most of the cost of wastewater treatment. Since private service providers in terms of collection – transport and treatment are available, the costs get distributed among different stakeholders.

6.4.4 Other aspects of liquid waste management

There are few other aspects which has to be considered for the financial sustainability of the liquid waste management projects. Firstly, the components of centralised sanitation systems are designed for 30 years of span except the pumping stations which are generally designed for 15 years of period. Secondly, the implementation of a sewerage network is very slow and tedious process that can delay the access to utilities in peri-urban and unorganised settlements. Thirdly, higher water supply to limited people leads to the full hydraulic loading of the treatment systems even though sewerage network is not completed as per the planning. Finally, the financial requirements for the upkeep of the infrastructure should be realised through taxation of water supply (e.g. metered water supply).

Idle volumes and time

Invariably, the sewers as a convention are designed for the projected population for the next 30 years. This leads to low sewage volumes against the design sewer capacities till the estimated sewage generation occurs. The gap in design sewage volume and actual sewage volume gives rise to idle volumes and idle expenditures. The underground sewers laid there merely become defunct with time and eventually go into repair. This is a non-productive expenditure, implying that the investment could have been utilized elsewhere like in decentralised treatment systems.

House service connections

While the investment on provision of sewerage is usually met out of capital grant funding, the cost of house service connections is to be met by the house owners when they occupy the property. Repeated road cuts become a perpetual affair over a long time which increases the cost for a single connection. As and when the houses are built, service connection requests arise. An approach that has been tried out is the provision of house service connection sewers at the time of laying down the sewer network with a termination at the boundary of the property. As and when an occupant desires to tap into the sewer network, the termination can be removed and lead into the property of the owner. An additional challenge is the illegal connections done by house owners. This is difficult to check by the limited staff available at the local body.

Recovery of costs

The capital costs are mostly carried out of grant funding whereas most of the time the O&M expenses are to be generated by the ULB. The revenues generated through service connections and taxes by taxes and water and sewerage charges are too meagre to break even for the local body to manage the infrastructure. In fact, it even affects the efforts of increasing reserve funds to be collected for emergency. When an unwieldy coverage of a conventional sewerage is implemented, the problem gets compounded all the more because the house service connections do not keep pace resulting in low revenue generation. Thus, even the cost spent on the house sewer connections becomes a virtual write-off over a period of time.

The multi-barrier approach

The multi-barrier approach focusses more on integration of natural water treatment technologies in the urban scape. These technologies treat perennial and intermittent water sources with special emphasis on resource recovery and reuse. This holistic approach minimises the urban water footprint and enhance the water security of the area, as the water cycle is closed at a local level. It also minimises the pollution of ecosystems and water sources for downstream users, as minimal quantum of freshwater gets polluted. Wherever there is any source of polluted water, it is treated and reused locally.

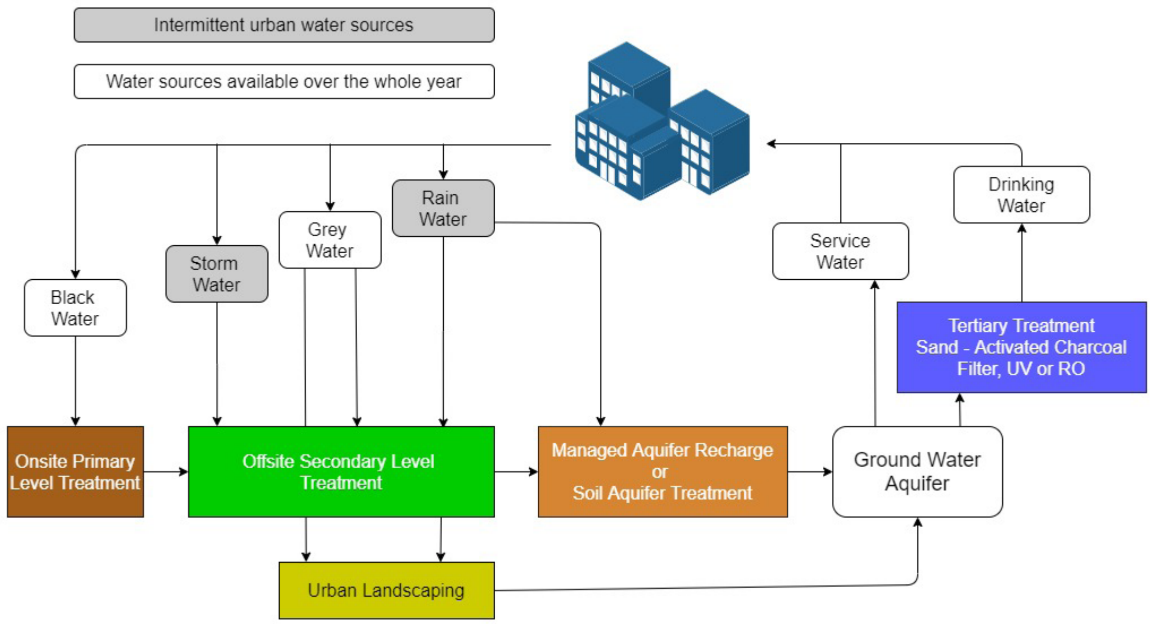

Figure 28: Representation of the multi-barrier approach

6.4.5 Similarity between the multi-barrier and CWIS approaches

It is evident from the underlying ideas of the multi-barrier approach that its main aim is to follow the 3R principle – Reduce, Reuse and Recycle. Similar to these ideas, the principles of CWIS also tries to encompass other complementary urban services into sanitation planning. By creating a paradigm shift in the mindset of governments, organisations and agencies working in the development sector, and educational setup to rethink our understanding of sanitation. The CWIS principles creates space for new approaches in places where historic and traditional knowledge are failing to answer the needs of urban sanitation. They also push the boundaries in terms of implementing solutions suitable to the local needs rather than simply following the approaches found in high-income countries. Finally, it emphasises on designing and management of non-conventional sanitation systems by exploring opportunities to leapfrog them into the mainstream for addressing the public health and environmental challenges of urban sanitation.

6.4.6 Planning of sanitation system

For planning of sanitation systems, a great deal of data collection, analysis of the ground conditions and understanding of the constraints is required. Key determinants of planning are:

- Settlement: population density and population size. Population density plays a very important role in planning of sewered sanitation.
- Physiographical parameters: soil type, topography, altitude, terrain, and ground water table. All these parameters need to be considered in order to select the right option for containment units, conveyance systems and disposal mechanisms. Even the cost of the treatment units is largely dependent on these parameters.
- Land availability and social acceptance: These parameters play an important role in selection of user interface. Land availability in case of an urban landscape becomes a major constraint while deploying user interface linked to a containment unit such as soak pits or septic tank.

Geographic Information System (GIS) tools are mostly used for planning of sanitation systems in large cities. In case of large habitats, the complexity of the systems is high. Thus, a computer-based application such as GIS transforms all the data points into visual data using heat maps etc. This helps in the analysis of large data sets and derive meaningful inferences from it. Visual illustrations also help to see the impact of and correlation between certain parameters. The use of GIS is not only limited to planning but can also be used in operation and monitoring of the system.

For smaller cities, the same type of work can be done developing logic diagrams. Logic diagrams are based on the inferences drawn from the analysis of the data collected. The logic diagrams are simple to understand, acts as a good tool for communication, and helps the decision-maker/s make informed choices based on the effect of parameters.

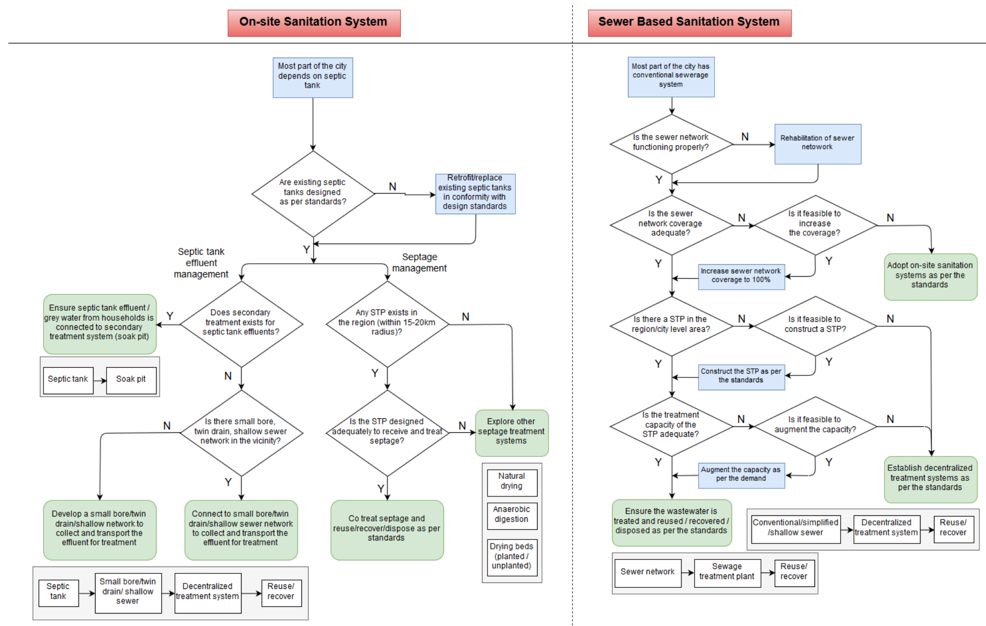

Figure 29: Logic diagrams for onsite sanitation system and sewered sanitation system.

6.5 Notes for trainer

The session is a stepping stone for the participants to understand various terminologies and apply the sanitation system approach to understand the current situation in the city and the identify the gaps. The session is followed by a group exercise which is based on the case methodology.

6.6 Bibliography

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- Wright, A. M. (1997); "Toward a Strategic Sanitation Approach: Improving the Sustainability of Urban Sanitation in Developing Countries", UNDP-World Bank Water and Sanitation Program.
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Session

07

Mapping the city

Activity session

In this session, a board game will be provided to the group of participants. With simple tools of gamification, the participants have to understand the existing sanitation systems, observe the gaps and make inferences pertaining to each functional group of the sanitation systems.

Session

08

Decentralized wastewater management

This is an exercise session – Kindly refer Part C: Workbook

Session

09

Aspects of decentralized wastewater management

9. Aspects of decentralized wastewater management

9.1 Learning objectives

- To understand the importance of enabling environment to scale decentralized wastewater management
- To understand various technical and non-technical aspects of decentralized wastewater management

9.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
Enabling environment	5 min	Power point presentation
Economic aspects	5 min	Power point presentation
Technical aspects	10 min	Power point presentation
Legal aspects	5 min	Power point presentation
Regulatory aspects	5 min	Power point presentation
Social aspects	5 min	Power point presentation
Q&A	10 min	Discussion

9.3 Key facts

- Due to lack of strict law enforcement and meagre financial benefits, wastewater management will be always the last priority for the polluters.
- Black box approach can be followed in thorough understanding about the changing variable and reliable analysis monitoring is available.
- Political backing to the legal framework is needed.
- Regulatory framework to adopt for growing wastewater management assets in India.
- People's participation is key for the success of decentralized wastewater management.

9.4 Learning notes

9.4.1 Enabling environment

An enabling environment is seen as the set of inter-related conditions that impact the potential to bring about sustained and effective change (adapted from World Bank, 2003). This includes political, legal, institutional, financial and economic, educational, technical and social conditions which encourage and support specific activities. An enabling environment is vital to the success of any development investment. Without it, the resources committed to bringing about change will be ineffective. Therefore, an essential part of the decision to undertake the planning process is to review the existing environment and to decide what needs to be addressed to allow the programme to succeed, and to work towards securing these changes.

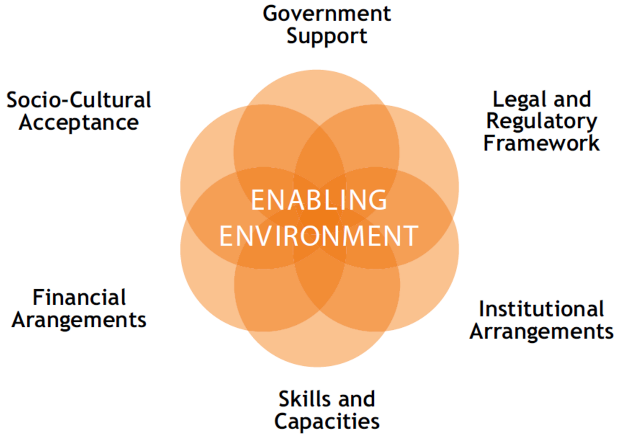

Figure 30: Factors of Enabling Environment

The enabling environment and how it is understood is a key determinant for successful project interventions. The six elements that define an enabling environment need to be nurtured and pro-actively fostered to provide favourable conditions for environmental sanitation planning in challenging urban environments.

- Level of government support in terms of political backing and favorable national policies and strategies.
- Legal and regulatory framework, with appropriate standards and codes at national and municipal levels.
- Institutional arrangements that accept and support the community-centered approach used.
- Effective skills and capacity ensuring that all participants understand and accept the concepts and planning tools.
- Financial arrangements that facilitate the mobilization of funds for implementation.
- Socio-cultural acceptance, i.e. matching service provision to the users' perceptions, preferences, and commitments to both short-term and long-term participation.

These main elements of the enabling environment should be identified during the planning process and the knowledge and understanding of the enabling environment should be continuously improved. Without a thorough understanding of the existing environment, problems and bottlenecks will arise in the planning process. Of course, there never will be 'the perfect enabling environment' – but there are degrees of more or less enabling or disabling factors, which can hinder or facilitate progress.

9.4.2 Economic aspects

Decentralised mode of management allows incremental development and investment in community wastewater systems. Settled sewers can be used to upgrade already existing decentralised systems such as septic tanks, if necessary. New, independent and well-designed sized systems can be added to serve new and well-defined residential, industrial or commercial developments. In contrast, investments in centralised systems have to be made within a short time which mainly burdens the local economy. Centralised systems are usually sized to handle wastewater flows planned to occur in 30 years. Centralised systems are initially often oversized but eventually are found to be undersized in many cases.

Ideally, a cost-benefit analysis should be conducted to compare different sanitation technologies. However, it is virtually impossible to quantify all the benefits (such as improved health or user convenience). Clearly, the costs and all the details of the technology options have to be discussed with the community for it to decide what it wants and is willing to pay.

With sanitation technologies, as with any other public sector investment, whose benefits are not fully quantifiable, a method is required to determine their real costs (economic costs) in relation to the national economy. For example, local engineers may favour conventional sewerage, however, its dependence on large volumes of flushing water could place too great a demand on local water resources and burden the country's budget allotted to exploiting these water resources. So, competing sanitation alternatives should be evaluated with respect to their economic costs (including all costs, regardless of who incurs them or on what level). Thereafter, user costs (financial costs) will have to be determined. Economic costing provides the policy-makers with an appropriate economic basis for their decisions. Financial costs are entirely dependent on policy variables and may vary widely. However, they could prove to be useful for households and sewerage authorities.

Treatment quality and cost

In case of decentralised or centralised wastewater management, there is a requirement of strict discharge standards for protecting the environment. These standards should be based on: i) the location of the discharge, ii) quantum of effluent, and iii) quality of influent.

The location of treated water discharge can be in surface water bodies, land, sewers/drains and marine. It is also dependent on the characteristics of the receiving body i.e. dilution and risk factor. The treated water can be reused for non-potable purposes like irrigation, flushing, gardening etc. For the same quality of effluent, the quantum of effluent is important as the absolute pollution load varies in different levels of wastewater management. (e.g. in the case of urban and rural habitats with different quantum of wastewater).

In comparison with centralised treatment, the decentralised treatment and on-site treatment approaches can reduce around 30%-50% of the organic pollution load by adopting low-cost treatment technologies. Any further treatment requirements would require expensive treatment processes (e.g. the removal of nitrogen and phosphorus through aerobic treatment processes). There are no financial returns and even less genuine interest with the administrations to invest in the wastewater treatment. The 'polluters-pay' principle is found to be useful for attracting investments in wastewater management through hefty fines for polluting the environment. In India, there are many cities who have been found to violate the discharge norms and have received critical remarks along with fines from the National Green Tribunal (NGT).

Technical aspects

Technical aspects such as selection of simplified and appropriate technology play an important role while planning for a decentralised approach. On one hand, it requires gathering information pertaining to social matters by the non-technical staff. On the other hand, it requires the technical/ engineering staff to have a sound knowledge of the implications of several factors including the social matters on technical design. This would result in appropriately designed technology and ultimately, a successful decentralised wastewater management system.

The skills and experience of locally available personnel may either act as an advantage or a disadvantage when selecting appropriate interventions. Complex technical designs may be inappropriate if construction personnel are unable to implement them. However, community participation is not merely the provision of self-help labour. Despite being quite useful to reduce costs, any compromise on the quality of interventions will impact its effectiveness. Hence, the selection of labour as well the implementation work requires skilled supervision. Inputs by a participating community are valuable not only at the planning and implementing stages, but also during monitoring and evaluation.

With regards to the construction aspect, the information about the availability of hardware locally for deployment of technology helps to reduce the implementation cost of the project. The thorough technical knowledge of the design principles and structural details are very crucial for proper implementation of the treatment system.

9.4.3 Institutional and regulatory aspects

Institutional factors are the norms, regulations and informal rules that shape the relationship between the actors/stakeholders in a given context and sector.

Institutional factors outside the WASH sector include:

- Decentralization: transfer of governance to sub-national units of government that may include administrative, fiscal, and political devolution to such units, and which may affect the different aspects including fiscal policy, human resources management and public procurement.
- Public Finance Management: budgeting prioritization of competing needs.
- Anti-Corruption Means and Provisions: measures adopted by governments to prevent fraud, bribery, extortion and use of public resources and power for personal gains.
- Social Norms: power relationships and social decision-making processes.
- Others: context specific factors like quality assurance, equity and sustainability.

Regulation and standards

Laws, regulations, standards and codes defined in greater detail, within the overall policy framework, how the government expects the sector to perform its functions. Regulations specify how services are to be provided and by whom, what delivery standards have to be met, ownership of infrastructure and services, and how tariffs and other cost recovery methods are to be designed and implemented. Standards and codes specify, for example, the level of wastewater treatment needed to protect the quality of receiving waters, the design of sanitation technologies, or the quality of material and equipment to be used in the performance of environmental services.

Many existing regulations and standards are based on those developed in industrialised countries (in the wastewater domain, e.g. range of current technologies, sewer diameters, effluent standards, wastewater reuse regulations, etc.), under conditions entirely different of those in developing countries. Therefore, many of these regulations and standards are found to be inappropriate for direct application in our country.. If there are laws which prevent the installation of a certain technology, or standards which have become the norm over time, it may be very difficult or impossible to introduce a new system.

Organisational setup and responsibilities

The success of any sanitation programme greatly depends on the existence of a functional organisational setup of stakeholders with clearly defined responsibilities with respect to sanitation. In general, three types of organisations manage and organise sanitation systems: private organisations, which run the businesses for profit; public utility companies, financed by public funds (taxes) and operating at a loss or on a cost-recovery basis; and community groups or individuals who operate and maintain a sanitation system without any external funds.

Private companies have recently emerged as an alternative to state-run utilities, which are sometimes inefficient and financially unsustainable. They have, however, been criticised for catering only to customers who can pay. They do not provide equitable services nor invest in infrastructure.On the other hand, public utilities are often overburdened and underfunded. Although, they have a mandate to provide services to all inhabitants of an area, the need for cost recovery and the sheer volume of work make these institutions appear inefficient and obsolete. To fill these service gaps, community groups, NGOs, homeowners, and citizens groups have begun to organise themselves and provide their services, often with little or no input from government institutions.

Political aspects

Political support is often assumed, but rarely explicitly assured before project implementation. Clear commitment within municipal government to improve services for all, especially the poor, is a crucial precondition for the success of sanitation interventions. Lack of explicit political support is often the initial cause of project failure. Unless, there is a political commitment towards increasing community participation and decentralisation of service provision, translated into national sector policies and strategies, projects will be isolated and vulnerable. A proven political commitment to decentralise decision making, service provision and promote community participation, which is supported by the highest levels of government and the top management of the sector agencies, is a crucial precondition for an enabling political environment.

9.3.4 Social aspects

The perspective of the society needs to be changed towards solid and liquid waste management sector. It is usually observed in the citizen and activist driven campaigns, that everybody wishes to have a clean and hygienic place to live. However, nobody is ready to take the responsibility of management of the waste which is created by them. This behaviour is popularly known as NIMBY, which stands for Not in My Back Yard. NIMBY is a characterization of opposition by residents to proposed developments in their local area, as well as support for strict land use regulations. It carries the connotation that such residents are only opposing the development because it is close to them and that they would tolerate or support it if it were built farther away.

Figure 31: Picture illustrating NIMBY!

The foundation of F-diagram was laid by World Health Organization in 1958. It is known that transmission of the diseases happen due to mismanagement of the waste originating from humans or human interventions. However, waste management has still never been the priority when it comes to city planning. Very less research and development has happened in user interface, containment and conveyance systems.

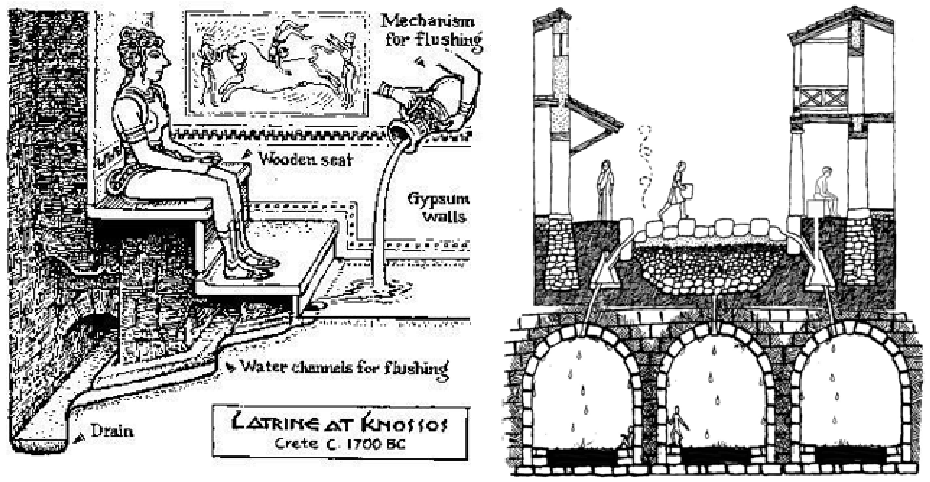

Figure 32: Early designs of pour flush toilets and sewerage systems

In case of decentralized wastewater management, involvement of key stakeholders such as households, government administration and community-based organization or NGOs are important. In the case of households (people), they can play significant role in such projects like:

1. Contribute towards capital investment
2. Contribute land for setting up infrastructure
3. Financing of services for operation
4. Participate in the O&M of the infrastructure
5. Show initiative in reuse of treated end products

9.4.5 Enabling environment through the CWIS approach

In the citywide inclusive sanitation (CWIS) approach, the provision of sanitation is not a responsibility to be borne by a single person, agency, or government body. The CWIS principles clearly outline that all the stakeholders should be brought together through an enabling environment for the provision of the sanitation services, rather than simply focusing on individual responsibilities of building infrastructure. By embedding sanitation into the urban governance framework, the CWIS approach tries to enable the local authorities to demonstrate the required political will and show their techno-managerial leadership skills. This will lead to strengthening the linkages between sanitation with health, education, urban development, and environment protection. As a result, it becomes easier to leverage financial resources to create sustainable sanitation systems for everyone. In fact, it can also create funding that is crucial to build capacity of the stakeholders, conduct household engagement and outreach programs, and market the sanitation systems to increase its acceptability as well as demand.

9.4 Notes for trainer

The main aim of the session is to convey to the participants the non-technical aspects are very important for the success of decentralized waste management systems. The sustainability of the project consisting of decentralized waste management systems is heavily dependent on the enforcement of the laws and policies and the participation of the beneficiaries. Even a technically well-designed system is bound to fail without adequate support from the local beneficiaries.

9.5 Bibliography

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Session

10

Understanding faecal sludge & septage management

10.0 Understanding faecal sludge & septage management (FSSM)

10.1 Learning objectives

- To realise the importance of FSSM as integral part of sanitation system in India
- To understand basics of faecal sludge and septage (FSS) quantification and types of desludging
- To understand the approaches for FSSM

10.2 Session plan

Duration - 60 minutes

Activity	Time	Material/Method
Needs & components of FSSM	15 min	Power point presentation
Planning for FSSM	15 min	Power point presentation
Approaches to FSS treatment	10 min	Power point presentation
Case studies / videos	10 min	Video presentation
Q&A	10 min	Discussion

10.3 Key facts

- FSSM is required to preserve the environmental health as the dependency on onsite containment units is high in India.
- Current challenges involved in operationalizing FSSM.
- Methods and challenges of quantification of faecal sludge and septage.
- Pros and cons of demand and scheduled desludging.
- Primary approaches for faecal sludge and septage management.

10.4 Learning notes

10.4.1 Urbanisation and sanitation

India by 2045 is expected to have more than 50% of its population living in urban area. Although India will have less urban population as compared to the developed countries, it will be host to multiple cities having population more than 10 million persons. The pace at which these urban centers are experiencing population explosion, it is very difficult to develop and deploy infrastructure to provide basic municipal services to the residents of the cities.

Based on the census of 2011, it can be inferred that India has been struggling to improve the sanitation services such as collection and conveyance of the waste along with the treatment and reuse/disposal of the wastewater. Hence, the Government of India in 2014 launched its flagship program Swachh Bharat Mission (SBM).

10.4.2 Introduction to FSSM

Sanitation system are composed of three or more components from the five components listed below:

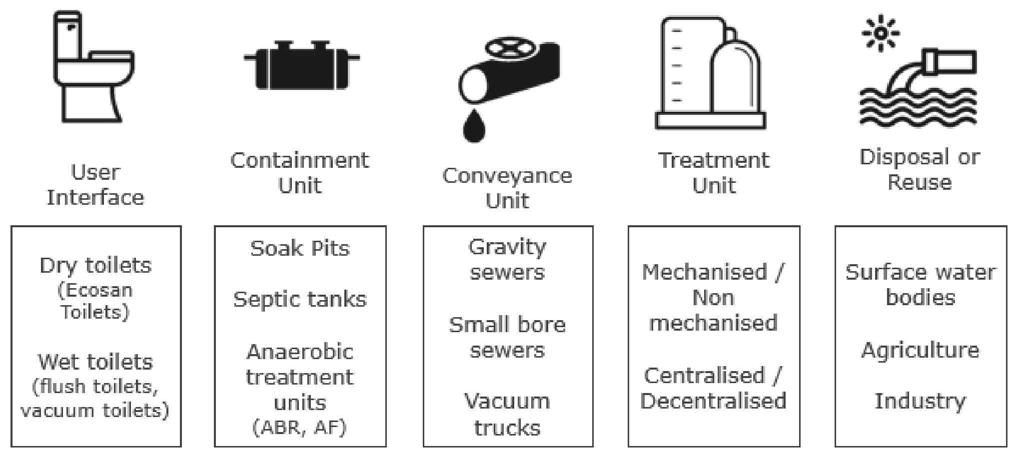

Figure 33: Components of sanitation system

Depending on the use of water for practicing hygiene activities, sanitation systems can be classified as dry and wet sanitation systems. In developing countries such as India, wet sanitation systems are commonly found. These wet sanitation systems can be further classified into sewered and non-sewered sanitation as shown in the figure below. It is interesting to know that India is not practicing a type of sanitation system completely. Across different cities, one can find either completely sewered, non-sewered, or a combination of both i.e. hybrid systems.

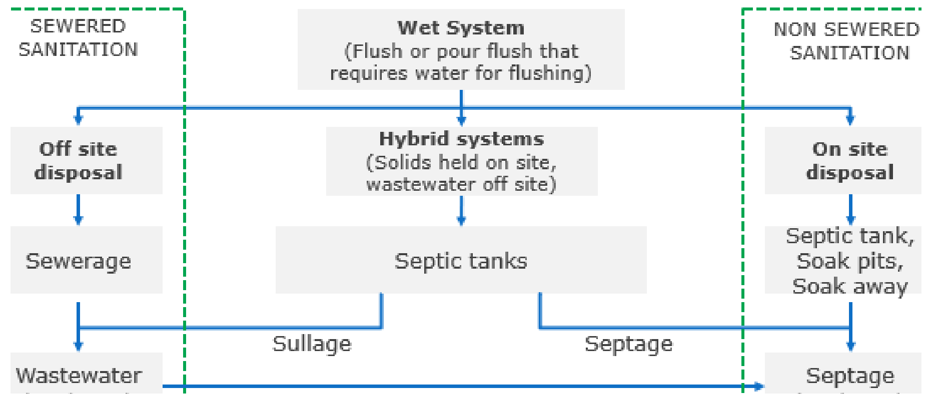

Figure 34: Components of sanitation system

A sanitation service chain is referred to the activities pertaining to managing waste such as FSS. In order to manage FSS from the onsite containment systems, an urbal local body (ULB) requires to have a sanitation service chain as shown in the figure below.

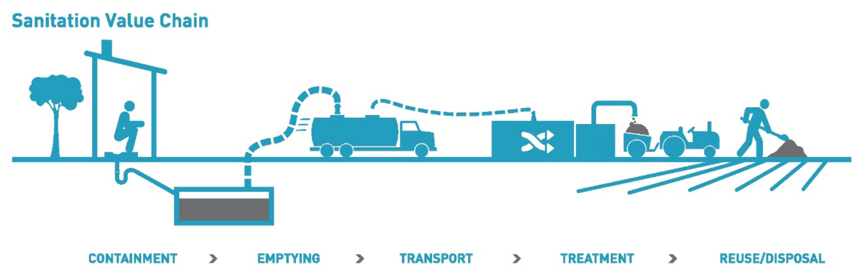

Figure 35: Sanitation service chain for non sewered / hybrid sanitation

In this service chain there are five components namely, containment unit, emptying, transport, treatment and reuse/disposal. In the subsequent session, we will be focussing on each of these components in detail.

10.4.3 Needs and challenges in FSSM

FSSM is needed to manage the liquid waste originating from the human waste in a better and safe way so as to eliminate transmission of diseases from faecal matter. Following are the reasons, why the ULBs need to focus on FSSM.

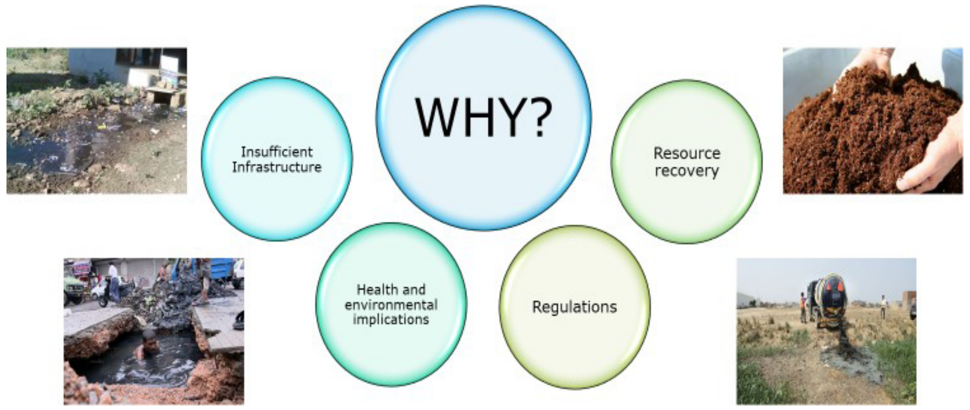

Figure 36: Need of FSSM

Insufficient infrastructure

There is a challenge with respect to sanitation infrastructure in India. Sanitation infrastructure does not pose a challenge only in the form of lack of sewerage network lines, but also in the case of emptying of containment units and treatment of effluent let out by them. For achieving the SBM objectives, there is a need of conveyance facilities for emptying the containment units, which is currently being catered through illegal manual scavenging or through the use of vacuum tankers. There is a need of treatment systems and proposal disposal management.

Regulations

The legislative framework in India has adequate provisions at the national-, state- and city-level to protect water and environment. Public health and sanitation are a part of the 'constitutional responsibility' of the municipalities under the 12th Schedule of the Constitution (74th Amendment, 1992). Some of the key provisions in different laws and regulations that deal with septage management are given in Table 3: Legislative and regulatory provisions for septage management. Municipal acts and regulations normally refer to management of solid and liquid waste, but do not provide detailed rules for septage management. Inadequacy in the implementation and enforcement of regulations worsen the problem. There is a need for better regulatory framework focused on septage management as well as more robust implementation. In February 2017, the Ministry of Urban Development issued the National FSSM Policy. The policy aims to set the context, priorities, and direction for, and to facilitate nationwide implementation of, FSSM services in all ULBs such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town and city in India.

Resource recovery

In India, faecal sludge has still been considered as a social taboo and practices of resource recovery are minimal. Resource recovery is an important aspect in septage management if we can look it as a wealth. It can be seen as a resource containing nutrients such as nitrogen and phosphorus and, in some cases, varying amounts of micro-nutrients such as boron, copper, iron, manganese, molybdenum and zinc. Urine contains 90% nitrogen, 50-60% phosphorus and 50-80% potassium, which are very valuable in agricultural applications. Septage can reduce reliance on chemical fertilizers and their combination can meet the requirements of nutrients for crop production. In some experiments, faecal sludge has also been used to generate energy through biogas systems and bio-methanization process. The methane thus produced can be used as fuel for cooking or for generation of electricity.

Health & environmental implications

Faecal sludge and septage contains elements that may produce bad odour, risk public health and create serious environmental hazards. Since septage is highly concentrated, discharging it into a water body may cause immediate depletion of dissolved oxygen and increase nutrients levels in the water, leading to eutrophication and increase in the number of pathogens, thus creating risk of health hazards. Knowledge of septage characteristics and variability is important in determining acceptable disposal methods. There is a direct discharge of collected septage by the private operators into drains, waterways, open land and agricultural fields, which in turn poses a larger threat to the environment and health.

Table 22: Challenges in FSSM

Components of Services value chain	Challenges
User Interface	• Availability of the space to construct sanitation facilities • Affordability of the construction cost • Non-availability or limited access of water, electricity • Less operation and maintenance of the sanitation facilities • Quality of the material used for the construction ofthe sanitation facilities
Collection	• Access for the on-site systems, Congested locations forthe movement of desludging trucks • No provisions for secondary effluent disposal units in the form of piped sewer network, leach pits or drain fields,thus directly discharging septic effluent into drains. • Most of the septic tanks present are not constructed asper the standard specifications, leading to varying sizes,partial lining, frequent failures, leakages/contamination of water bodies or soil etc.
Conveyance	• Most households only call for septic tank cleaning services when the tank is overflowing or on the verge. The frequency of desludging typically varies from 5 - 10 years due to irregular sizes and usage pattern, which farexceeds the prescribed interval of 2-3 years as recommended by CPHEEO Manual, MoUD advisory on Septage management (2013) • Unsafe handling of faecal sludge by the private operators • Desludging operators and Service providers are not properly trained and do not use safety equipmentduring operations
Treatment	• Requirement of scientific treatment facilities
Disposal	• Private operators practice the direct discharge of desludged faecal sludge/septage in the opendrains, open land, SWM landfill sites etc.

10.4.4 Solving challenges in FSSM through CWIS approach

With respect to a large number of Indian cities, the existing sanitation infrastructure reveals that there is a combination of both on-site and sewered system which is responsible for collecting the waste from our toilets. However, that is just one part of the whole sanitation service chain. The major challenges involved are with regards to dealing with the toilet waste after it is being collected. While there are problems with both sewered and on-site sanitation systems wherever they have been implemented in India, the adoption of on-site sanitation systems has found to be lagging behind in acceptance. There are many reasons behind this that mostly rise from the fact that our understanding of handling an on-site sanitation system is very limited or predominantly affected by the use of sewered systems. In the case of treatment of faecal sludge and septage, the technologies available are similar to those used in a sewage treatment plant. But, it is very important to understand that direct application of these treatment technologies will not be helpful as the characteristics of sewage are very different to those of faecal sludge and septage.

A major challenge that remains unanswered is that of conveyance of toilet waste from on-site sanitation systems in a safe, effective manner to a treatment site. While the use of desludging trucks or tractors mounted with pumps are helpful, we need to realise that they are only a part of the overall solution. There is a need to understand local conditions extremely well to realise whether such desludging trucks/tractors are applicable everywhere. And in case they cannot be applied for some reason, we need to come up with innovative solutions that help in emptying of toilet waste from source and safely transport it as required. It is important to note that such local solution should not involve any manual methods or scavenging of any kind. For example, building a combination of manual and mechanical methods such as sludge gulper have proven to be useful in the African continent. But, such a sludge gulper cannot be directly adopted in an Indian context and hence it needs to be redesigned.

The citywide inclusive sanitation (CWIS) approach is one such way to address these difficult challenges through developing an wide range of applicable and adaptable solutions. These solutions are developed through a combination of on-site and sewered solutions that try to address the sanitation challenges at a centralized or a decentralized level. Furthermore, it also propagates the need for developing appropriate regulatory framework that understand the local conditions and allow setting up of institutions responsible for complete operation of maintenance of the full sanitation service chain.

10.4.5 Planning for FSSM

Why quantification is necessary?

Quantification is necessary for estimating the number of equipment required for providing the service of emptying containment units and transportation of faecal sludge and septage to a treatment facility. It is required to estimate the equipment required to co-treat the septage at STP or to define the capacity of the independent treatment facility. Quantification becomes of utmost importance when financial viability of operationalizing FSSM in a town needs to be understood.

To start with quantification of FSS to be managed, the ULB needs to decide the type of desludging to be practiced. There are two types of desludging practices: i) on-demand desludging, and (2) scheduled desludging.

Deriving accurate estimates for the volume of FSS produced is essential for the proper sizing of infrastructure required for collection and transport networks, discharge sites, treatment plants, and end-use or disposal options. Due to the variability of FSS volumes generated, it is important to make estimates based on the requirements specifically for each location and not to estimate values based on literature. However, no proven methods exist for quantifying the production of FSS in urban areas, and the data collection required in order to accurately quantify FSS volumes would be too labour intensive, especially in areas where there is no existing information. There is therefore a need to develop methodologies for providing reasonable estimates.

Methods of quantification

Two theoretical approaches that have been developed are the sludge production method and the sludge collection method, depending on whether the goal is to determine total sludge production, or the expected sludge loading at a treatment plant.

A. Sludge production method

Sludge production method is useful in case of scheduled desludging. This method is based on the number of people and the standard sludge production rate. This is similar to estimating the wastewater production, where 80% of the water utilized by the person is taken as quantity of wastewater produced. According to the IS 2470 Code of practice for Installation of Septic Tanks (part 1: Design criteria and construction) 1985, volume of digested sludge in the septic tank is given as 0.00021 m3/cap/d. The US EPA handbook on Technology Transfer for Septage Treatment and Disposal mentions the average per capita septage generation as 230 L/cap/annum. It has also been mentioned that his number is highly variable and will change depending on a number of factors discussed in the next session.

B. Sludge collection method

The sludge collection method needs to be adopted for quantification of FSS in case of demand desludging. In most cases of Indian cities, not all of the waste which is generated at the household level is usually collected, be it solid of liquid. Hence, sludge collection method is a much more reliable estimate for quantification of FSS in a city. In this method, structured interviews need to be conducted with important stakeholders such as desludging operators, ULB official such as sanitary inspectors and households. Depending upon the responses and statistical analysis of the data collected, inferences are drawn to arrive at the quantity of FSS to be managed in a city.

Criteria and considerations for quantification

Seasonal and monthly variations need to be taken into account while quantification. Especially in cities which experience inflow of floating population (due to pilgrimage or tourism) on an annual basis, it is important to take into consideration the variation and peaking factor of FSS generation. Peaking factor is necessary to calculate the peak load which the treatment facility might have to handle in a month. The peaking factor in case of FSS can range from 1.5 to 4.

10.4.6 Approaches for FSSM

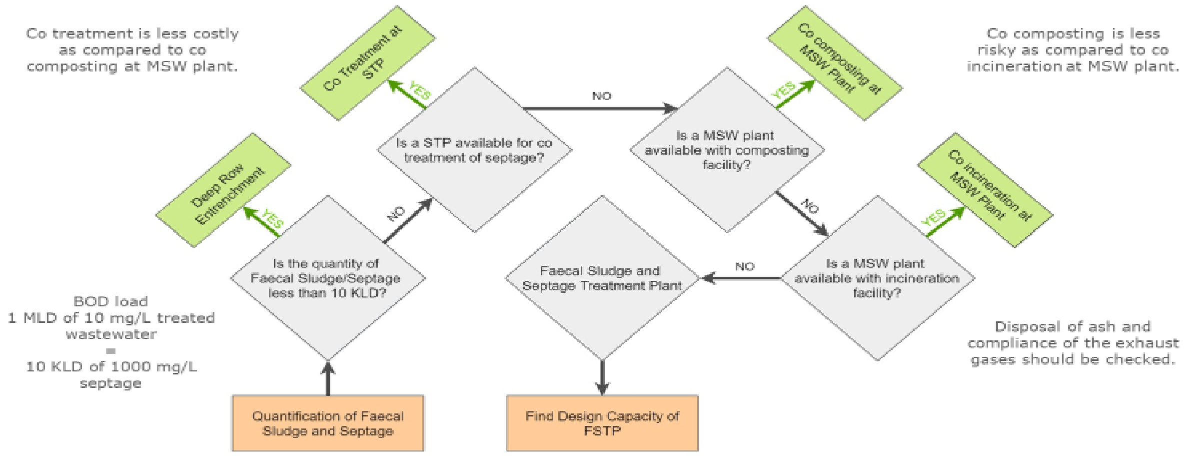

Figure 37: Different approaches for FSSM

The selection of treatment approach is dependent on few specific factors like quantification and characteristics of the FSS, type of sludge, seasonal variations and local conditions. There are different treatment approaches under a given scenario: i) deep row entrenchment, ii) co-treatment at STP, iii) co-treatment in MSW management facility, and iv) faecal sludge and septage treatment plant (FSSTP).

Deep Row Entrenchment (DRE)

It refers to the method where FSS is disposed into an excavated pit. Once the pit is filled with FSS, the liquid seeps into the surrounding soil and the solids are arrested in the pit. Once the pit is full, it is topped off with the excavated earth so that the solids can be stabilized over a period of time. Once stabilized the content of the pit are converted into terra preta, which can be safely used in agriculture to improve the characteristic of the soil. DRE is very simple and low on operational expenditure. It does not create any visible or olfactory nuisance. The ULBs usually have heavy machinery for earth excavation readily available with them and hence, no specialised equipment is required to start practicing DRE. Selection of appropriate site for practicing DRE is the most important stage. DRE should not be practiced in low lying areas and region where ground water table is high.

Co-treatment at STP

Co-treatment of FSS in STP is another treatment approach. It is mainly dependent on the effect of organic and hydraulic loading on various treatment units at STP. In this approach, FSS can be applied at different stages such as, i) at the manhole chamber before the inlet of STP, ii) at the inlet of screens of the STP, and iii) at the sludge management stage of the STP.

Co-treatment at Municipal Solid Waste (MSW) Plant

There are two different approaches in co-treatment at MSW plant.

- Co-composting - In case of co-composting, the dewatered solids with a solid content of up to 40% can be mixed with carbon rich organic waste. The dewatered sludge helps to achieve the C:N ratio which is required for optimum composting of the waste. In ideal conditions, the temperature during composting reaches above 60 OC for a couple of days, which also results into reduction of pathogens, making the compost safe and hygienic for reuse in agriculture.
- Combustion- The dry solids content should be at least 80% and preferably higher. This ensures that there is little energy consumption for evaporation of the moisture from the solids. Thus, it helps to maintain the temperature of the reactor at a constant level. The precise requirements of dry solid content will depend on the process used to burn the sludge.

10.5 Notes for trainer

The aim of the session is to introduce the participants to onsite sanitation systems coupled with FSSM. The session provides insights into FSSM as a subject and further gives background of the first stage of planning i.e. quantification of FSS. The session is followed by an exercise which dives into the planning aspects of FSSM. In order to have a smoother transition, it is recommended that the participants are divided into groups, where they are asked to list down all the necessary data required to start the planning of FSSM in a city.

10.5 Bibliography

- Strande, L.; Ronteltap, M.; Brdjanovic, D. (2014): Systems Approach for Implementation and Operation. London: IWA Publishing
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- Strauss, M., Montangero, A. (2002). Faecal Sludge Management – Review of Practices, Problems and Initiatives. Dubendorf: EAWAG / SANDEC.

Session

11

Faecal sludge & septage management planning

This is an exercise session – Kindly refer Part C: Workbook

Session

12

Stakeholder management

12 Stakeholder management

12.1 Learning objectives

- To understand the process of identification and characterisation of stakeholders
- To learn about stakeholder engagement and different tools involved in it

12.2 Session plan

Duration - 60 minutes

Activity	Time	Material/Method
Stakeholders analysis	7 min	Power point presentation
Exercise – Stakeholders analysis	20 min	Flip charts, markers, colour cards
Stakeholders engagement	12 min	Power point presentation
Exercise – Stakeholders engagement	15 min	Flip charts, markers, colour cards
Q&A	6 min	Discussion

12.3 Key facts

- Stakeholder analysis – a vital tool for understanding social and institutional context of a project.
- Identification and characterization of stakeholders - provide early and essential information about who will influence and be affected by the project.
- Stakeholders' engagement plays a vital role in sustainability of the project. It develops skills, trust, and confidence required amongst the stakeholders to run the system.

12.4 Learning notes

12.4.1 Stakeholder analysis

Integrated wastewater and septage management (IWSM) at city level in an efficient and sustainable way requires the involvement and support of all concerned key stakeholders. Stakeholders mean any group, organization or individual that can influence or be influenced by the project. In order to understand and engage stakeholders, a stakeholder analysis should be performed. Stakeholders analysis is the process of identifying and characterizing the stakeholders, investigating the relationships between them, and planning for their participation. It is a vital tool for understanding the social and institutional context of a project or a policy. Its finding can provide early and essential information about who will be affected by the project and who could influence the project, which individuals, groups or agencies need to be involved in the project and whose capacity needs to be built to enable them to participate.

Stakeholders analysis process is important in order to:

- Identify who to involve and at what level of participation, at different stages of the planning and implementation process.
- Understand who and what kind of interest one has and who is influential in supporting or in blocking/delaying/rejecting the project.
- Identify conflict of interests between stakeholders.
- Identify relations between stakeholders that should be improved and strengthened.
- Structure the knowledge about the project stakeholders and share it with others.
- Understand how to deal with the different people; for example, it should be clear who needs to be empowered, who needs to be informed and who should be dealt with in a particularly careful way (potential threats).
- In partnership with governments and implementing agencies, assess how best to harness the positive aspects of the informal sector, minimize the negative aspects, and look for genuinely effective ways of creating effective links between the formal and the informal.

Identification of stakeholders

Stakeholder identification is one of the first tasks when starting a new project. Collaboration with local facilitators is essential to get the situation under control quickly. Identifying stakeholders is an iterative process, during which additional stakeholders are added as the analysis develops.

Municipal Authorities	• Mayor • Municipal technical services (environment, sanitation, hygiene and public health) • Municipal police
Regional and National Authorities	• Regional director E.g Sanitation, Health, Hydraulics, Water Company, Public works, Statistics, Urbanism and Habitat, Local development, Agriculture
Utilities	• Public, Semi-private (parastatal) or private (commercialised)
Tradistional Authorities and Influential leaders	• Corporators • Ethnic leaders • Religious leaders
Small Business Operators	• Desludging Service Providers, IWSM business owners, IWSM business owners associations or interest groups
Organizations active in Sanitation	• CBOs • Local or international NGOs • Universities, reasearch centres • Donar agencies
Potential endusers	• Farmers, Farmers associations and intitutions helping farmers • Fuel consumers
Household	• Users or Owners

Characterisation of stakeholders

Characterization of stakeholders provides the necessary information on how to best involve each stakeholder and at the end process, how to best attribute roles and responsibilities.

Information to be collected

- Main interest: Consultation with stakeholders should be carried out in order to determine how each interest can be considered in the future FS systems.
- Opportunities/threats: Characterize the potential positive or negative perspective of the project.
- Involvement needs: The action required, results mainly from identified interest, weakness and potential.

Table 23: Example of stakeholder analysis

Stakeholder	Interest	Opportunities /Threats	Involvements Needs
Urban Local Bodies	Public Health Sanitation Work Sanitation fees	Power of Enforcement through regulatory framework Management of treatment units	Sensitization, need for capacity building, collaboration Institutional and regulatory framework, Enforcement Involvement of financing schemes
Stakeholder B			
Stakeholder C			

It is important to differentiate between two different types of the opportunities and threat; the influence over the project and the interest in the project.

Influence: It is the power that stakeholders have on the project i.e. to control which decisions are made, facilitate the implementation or affect the project negatively.

Interest: Characterization of stakeholders whose needs, constraints and problems are a priority in the strategy, e.g. desludging service providers, end users, households and sanitation authorities.

Table 24: Influence and Interest Matrix

	Low influence	High influence
Low interest	Stakeholders are unlikely to be closely involved in the project and require not more than information sharing aimed at general public. **INFORMATION**	Stakeholders may oppose the intervention; therefore, they should be kept informed and their views acknowledged to avoid disruption or conflict. **CONSULTATION - INFORMATION**
High interest	Stakeholders require special efforts to ensure that their needs are met and their participation is meaningful. **CONSULTATION - EMPOWERMENT**	Stakeholders should be closely involved to ensure their support for the project. **CONSULTATION – COLLABORATION – EMPOWERMENT / DELEGATION**

12.4.2 CWIS approach to capture missing stakeholders in sanitation planning

Sanitation planning is generally thought of as an activity wherein the details about the population is captured, translated into sanitation requirements using conventional knowledge, and providing solutions to these requirements through sewer connections, conveyance, and treatment of wastewater before its disposal. Unfortunately, this fixed solution is a 'top-down' approach which covers a certain extent of the population. In order to ensure that everyone has access to the sanitation system, it is necessary to have a 'bottom-up' approach at the time of planning or analysing the sanitation requirements. This is very crucial in India as the sanitation systems have been found to lack the last-mile reach to the communities of different ethnic backgrounds, marginalised population, people with disabilities, and specially women and children.

Including these groups at the first step of sanitation planning will bring out important aspects that should be part of the final sanitation system. It is important for the decision-makers to understand the challenges by such vulnerable population to ensure that everyone has access to safe and affordable sanitation. This is because the health of any city requires every person residing in it to have good quality life and sanitation plays an important role to provide such a lifestyle.

While the conventional approach has shown its shortcomings for addressing the sanitation requirement of an urban area, the citywide inclusive sanitation (CWIS) approach is specifically designed to target these underserved and/or unserved population. Out of the seven principles of CWIS, two of them are vital to capture the needs of the missing key stakeholders.

- Everybody benefits from adequate sanitation service delivery outcomes that meet user aspirations and that protect the health of users.
- Activities are included to target specific unserved and underserved groups, such as women and children, ethnic minorities, urban poor and people with disabilities.

12.4.3 Exercise: Stakeholders analysis

Instructions for participants

- Participants will be divided in 4 or 5 groups.
- Each group will be given a case (A or B) to work on. We can create 4 or 5 cases to distribute in the respective group.
- Each group will be given a flipchart on which they have to work on this exercise.
- The representative exercise tables for stakeholder analysis are given on next page.

Steps for stakeholders analysis are given as follows,

- STEP 1 - In the first stage, each group has to identify stakeholders according to their case;
- STEP 2 – In this step, participants will have to characterize the stakeholders which they have identified;
- STEP 3 – In this step, participants will have to understand the inter-relationships between stakeholders and has to select the key stakeholders from it; andSTEP 4 – In this step, participants will have to complete the influence and interest matrix according to the stakeholder's characterization and selection of key stakeholders.

12.4.4 Stakeholder engagement

Stakeholder engagement or stakeholder involvement is key for the successful implementation of FSSM projects. It includes stakeholders in the planning process in order to take into account their needs, priorities and interests, to achieve consensus and to remove opposition. Stakeholder engagement is largely about defining the participation level of people in the process and how to best answer their needs (e.g. through awareness raising or training and capacity building).

A. Stakeholder participation levels

The level of participation depends on what needs to be achieved with the targeted stakeholders e.g. households may be informed about the process or consulted to understand their collection needs. Collection and transportation operators may be consulted about their routes and to help define optimal disposal sites or collaborate on regulation definition.

- Some of the aspects to be considered when developing the involvement strategy are:
- Perception of involvement - indicates how involved stakeholders feel;
- Willingness to contribute to the project;
- Expected benefit from the project;
- Level of obligation which the stakeholder feels towards their responsibilities in the project; and
- People influencing the willingness of the stakeholder and extent of the peer pressure.

Stakeholder participation matrix

- **Information:** Objective is to enable the stakeholders to understand the situation, the different options and their implications. This is one-way flow of communication.

GROUP EXERCISE: STAKEHOLDERS ANALYSIS

GROUP NO.: ____________

CASE WORK TITLE: ______________________________

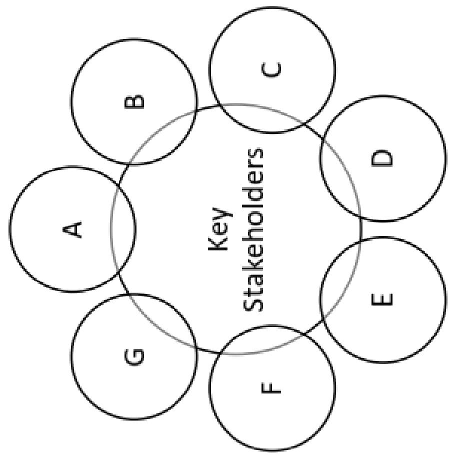
STEP 1: IDENTIFICATION OF STAKEHOLDERS

STAKEHOLDERS	STAKEHOLDERS

STEP 2: CHARACTERIZATION OF STAKEHOLDERS

STAKEHOLDERS	INTEREST	OPPORTUNITIES / THREATS	INVOLVEMENT NEEDS

STEP 3: SELECTION OF KEY STAKEHOLDERS



STEP 4: INTEREST AND INFLUENCE MATRIX

	LOW INFLUENCE	HIGH INFLUENCE
LOW INTEREST	INFORMATION	CONSULTATION – INFORMATION
HIGH INTEREST	CONSULTATION – EMPOWERMENT	CONSULTATION – COLLABORATION – EMPOWERMENT / DELEGATION

- **Consultation:** Objective is to have stakeholders' feedback on the situation, options, scenarios and / or decisions.
- **Collaboration:** Objective is to work as a partner with the stakeholder on various aspects such as creating scenarios and identification of preferred solution.
- **Empowerment / Delegation:** Objective is to build capacities of the stakeholders so that they can make an informed decision, take responsibility in final decision making, and assume their roles and responsibilities in the FSSM system.

B. Involvement tools

Once the participation levels for each stakeholder has been defined, the involvement tools can be selected. There are many ways to involve people in an IWSM process and there is no ready-made recipe for which tool to use and when. Decisions should be context driven. The optimal selection of involvement tool varies from case to case. For example, the involvement needs may differ according to the complexity and boundaries of the project.

There are few following tools which can fit well in an IWSM process, like

- Individual meetings, informal or semi-structured interviews
- Focus groups discussions
- Workshops
- Site visits
- Participatory meetings
- Surveys
- Media campaigns
- Advocacy / lobbying
- Mediation

Selection of appropriate involvement tools

The selection of involvement tools should be done on a case by case basis as it depends on the goals, the personality and capacities of the local stakeholders. The best participatory approach is a combination of several techniques. Before selecting a tool, the process leaders should consider the practical aspects of linked with the socio-economic conditions of the stakeholders and make sure that the tool is adopted to the target group. It is also important to clarify in advance the availability of resources required for conducting an adequate stakeholder's involvement program (time, budget, and know-how). Credibility of the process leaders, official legitimisation and transparency are indispensable for the process success.

Selection of appropriate involvement tool is dependent on the following aspects:

Table 25: Aspects for selection of Involvement Tools

Political framework	Legal framework	Institutional framework	Social framework
• Involvement fit into existing political system • Need of involvement of political leaders	• Involvement conform to the laws	• Involvement match the institutional framework • Right authorities involved	• Involvement conform to social customs

C. Milestones and cross-cutting tasks

The way in which participation level evolves is context specific and the process is marked out by the milestones corresponding to the end of phases, where the participation levels are formally re-thought and important changes can be decided for the next step.

In parallel, the planning process is marked by two participatory cross-cutting tasks, i) awareness raising to a wide audience, and ii) capacity building.

Main milestones in the participatory process

There are three milestones identified for the involvement strategy, namely:

- **Initial launching workshop:** This includes a field visit with all the stakeholders. It mainly consists of an information workshop, aiming to communicate the plans, activities and the current stage of the process. Afterwards, all the stakeholders are expected to have the common understanding of the project.
- **Validation workshop of selected options by all the stakeholders:** This event brings all the key stakeholders together publicly and officially seal the decisions taken up to this point. The technical options and management options are presented, discussed and validated.
- **Validation workshop of the action plan:** This workshop seals the agreements reached on the validation options and how to proceed further. The roles and responsibilities of the different stakeholders in the project are defined in a common understanding, which will facilitate the coordination of the various tasks.

Cross-cutting tasks

- Raising Awareness: Enabling people to make informed choices and adopt good practices. It is critical to reach a common understanding of existing problems and to ensure that the stakeholders agree on the goals.
- Training and capacity building: Skills and capacities are important components of the enabling environment. When it comes to implementation, the capacities at the technical, managerial, financial, commercial and social levels are crucial. Several tools and activities such as workshops, practical exercises, participative document elaboration and field visits can be used for training.

D. Roles and responsibilities

Once the technical options and organizational modes have been chosen, the roles and responsibilities need to be distributed and formalised. According to the particular situation and the stakeholders who are involved formalisation documents can take different forms such as licenses, contracts, partnership agreements, standards and laws. These different types of documents are described below,

- **Licenses:** Issued by authorities for services throughout the whole supply chain. License document should contain list of requirements, activities allowed and validity of the license.
- **Contracts:** Contracts can be signed between the stakeholders involved in the FSSM supply chain for specific activities or services: (1) contracts linking a service provider to its customers, (2) contracts linking two operators undertaking different activities in the supply chain, and (3) contracts between one operator and the authorities.
- **Partnership agreements:** Agreements can be signed between two stakeholders to provide a collaborative framework for the institutional or technical management of any component of sanitation service chain. Public private partnership where stakeholders from the public and the private sector collaborate to provide services to the population.

12.4.5 Exercise: Stakeholders engagement

Instructions for participants:

- Participants will be divided in 4 or 5 groups.Each group will be given a case (A or B) to work on. We can create 4 or 5 cases to distribute in the respective group.
- Each group will be given a flipchart on which they have to work on. The representative exercise tables for stakeholder engagement are given on next page.
- Each group will continue with the next stakeholder's engagement practice after stakeholder's analysis.

Steps for stakeholder's engagement are given as follows,

- **STEP 1 -** In this stage, participants will distribute the stakeholders in participation levels and inter-relationships according to categories i.e. information, consultation, collaboration and empowerment/delegation.
- **STEP 2** – Complete the table given in exercise sheet.

12.5 Notes for trainer

The main aim of the session is to highlight the importance of stakeholder management in FSSM to optimize the sanitation service chain and contribute to sustainability of the project. The exercise plays a key role in putting across this point. Maximum time needs to be spent on the exercise and examples or anecdotes from the case studies should be provided to improve the learning experience of the participants.

12.6 Bibliography

- Strande, L.; Ronteltap, M.; Brdjanovic, D. (2014): Systems Approach for Implementation and Operation. London: IWA Publishing
- EAWAG/SANDEC (2008): (Sandec Training Tool 1.0, Module 5). Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC)

GROUP EXERCISE: STAKEHOLDERS ENGAGEMENT

GROUP NO.: ____________

CASE WORK TITLE: ____

STEP 1: PARTICIPATION LEVELS

Project Management Stages	Sub-Activities	Participation levels			
		Information	Consultation	Collaboration	Empowerment / delegation

Session

13

Faecal sludge & septage treatment

13 Faecal sludge & septage treatment

13.1 Learning objectives

- To understand the difference between faecal sludge and septage and its characteristics
- To learn the objectives and stages of treating faecal sludge and septage
- To understand non-mechanized and mechanized treatment units for handling faecal sludge and septage

13.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
What is faecal sludge & septage?	5 min	Power point presentation
Treatment objectives	15 min	Power point presentation
Treatment stages	5 min	Power point presentation
Treatment units	5 min	Power point presentation
FSTPs in India	10 min	Power point presentation, videos, case studies
Q&A	5 min	Discussion

13.3 Key facts

- Characterization of faecal sludge and septage plays an important role in selection of treatment objective.
- FSS treatment facility consists of up to four stages, each having specific treatment objective.
- Defining the right treatment aim is the key to selection of appropriate treatment components for FSS treatment facility.

13.4 Learning notes

13.4.1 Faecal sludge & septage (FSS)

Assessment of faecal sludge and septage treatment requirements must start from an understanding of the main sanitation options and the ways in which they influence subsequent links in the sanitation chain. Compared to sludges from wastewater treatment plants or to municipal wastewater, FSS characteristics differ widely according to location (from household to household, from city district to city district, from city to city). A basic distinction can usually be made between sludges, which are upon collection still relatively fresh or contain a fair amount of recently deposited excreta (e. g. sludges from frequently emptied, unsewered public toilets) and sludges, which have been retained in on-plot pits or vaults for months or years and which have undergone biochemical degradation to a variable degree (e.g. sludge from septic tanks – septage). Moreover, varying amounts of water or wastewater, which have accumulated in vaults or pits, are collected alongside with the solids.Faecal sludge is referred to the sludge obtained from the containment unit such as a lined pit or pit latrine. It is generally fresh and yellowish in colour. This is due to the fact that the contents of the pits do not undergo digestion and the pits need to be frequently emptied. The water content of faecal sludge is relatively low as compared to other forms of sludge. As a result, it has higher a solid content and corresponding BOD concentration. It requires a higher degree of treatment.

Septage is referred to the sludge obtained from the on-site containment units such as septic tanks or holding tanks. It is well digested and blackish in colour as it has undergone digestion over a period of time before being emptied. The water content of septage is higher than that of faecal sludge (sometimes as high as above 95%). As a result of this, it has lower solid content and corresponding BOD concentration. The treatment required is less extensive.

Figure 38: Faecal sludge being emptied at a FSTP

Figure 39: Septage being emptied at a FSTP

Characteristics of FSS

The characteristics of the sludge is influenced by many things. However, it primarily depends on the origin of the sludge, type of containment unit and the duration for which it was stored in the containment unit. Sewage which is usually collected and conveyed using sewerage system reaches the treatment facility in few hours from the point of generation. The quantum of water used for flushing the waste and the turbulent flow in the pipes and pumping stations, make sewage a homogenous mixture by the time it reaches the treatment facility. Hence, the characteristics of faecal sludge and septage varies significantly from sewage and requires a higher degree of treatment. The following table gives an overview of the characteristics of faecal sludge, septage and sewage.

Table 26: Characteristics of faecal sludge, septage and sewage

Parameters	Faecal Sludge	Septage	Sewage
Characteristic	Highly concentrated, Fresh excreta, Stored for weeks or months	Low concentration, more stabilized, Stored for several years	Tropical sewage
COD [mg/L]	20 - 50,000	< 10,000	500 - 2,500
COD:BOD Ratio	2 – 5	5 – 10	2
NH_4 – N [mg/L]	2 - 5,000	< 1,000	30 – 70
Total Solids [%]	≥ 3.5%	< 3.0%	< 1.0%
Suspended Solids [mg/L]	≥ 30,000	≈ 7,000	200 – 700
Helminth Eggs (no./L)	20 – 60,000	≈ 4,000	300 – 2,000

13.4.2 Treatment objectives

Dewatering or thickening of FSS is an important treatment objective, as FSS contains a high proportion of liquid, and the reduction in this volume will greatly reduce the cost of transporting water weight and simplify subsequent treatment steps. Environmental and public health treatment objectives are achieved through pathogen reduction, stabilisation of organic matter and nutrients, and the safe end-use or disposal of treatment end-products.

Dewatering

One of the important treatment objectives of the FSS is dewatering. Dewatering helps to reduce the volume of sludge to be handled and treated using other treatment mechanisms, thereby reducing the capital expenditure significantly. Separating the solid and liquid stream simplifies the treatment of the faecal sludge and septage and helps to optimise the process. For example, in case of heat drying, dewatering will save significant amount of energy.

FS has different dewatering characteristics compared to septage and wastewater sludge, in that it tends to foam upon agitation, and resist settling and dewatering. The duration of onsite storage, and the age of sludge also affects the ability to dewater the sludge. Empirical evidence shows that ‘fresh’ or ‘raw’ sludge is more difficult to dewater than older, more stabilised sludge. The dewatering, or thickening process can also include adding dry materials such as sawdust to increase the solids content, This is a common practice in processes such as composting where the sawdust also increases the carbon to nitrogen (C:N) ratio. The liquid stream that is produced during dewatering also requires further treatment, as it can be high in ammonia, salts, and pathogen.

Pathogen removal

The second most important objective is pathogen removal. Pathogen removal is important from the discharge and reuse point of view of the end products. FSS is known to contain high number of pathogens and hence, indiscriminate disposal of it may result into cross-contamination of the water resources. Reduction of pathogen is achieved by various ways such as – starvation, predation, exclusions, desiccation, and altering temperature conditions.

FSS contains large amounts of microorganisms, mainly originating from the faeces. These microorganisms can be pathogenic, and exposure to untreated FSS constitutes a significant health risk to humans, either through direct contact, or through indirect exposure. Starvation refers to starving the pathogen to death. Predation refers to introducing or allowing specific types of bacteria to eat (predate) the pathogens. Exclusion refers to physical exclusion of pathogens depending on their size using filters. Desiccation refers to reducing the moisture content to the level where the cell walls ruptures due to dryness. Pathogens are believed to reduced significantly at temperature above 600C.

Nutrient recovery

FSS contains significant concentrations of nutrients, which can be harnessed for beneficial resource recovery. If not managed properly, it can result in environmental contamination. Environmental impacts from nutrients include eutrophication and algal blooms in surface waters and contamination of drinking water (e.g. nitrates leading to methemoglobinemia).

Nutrient recovery is a specific treatment objective which is very important when the end products is to be used as soil supplements for improving its characteristic. FSS contain good amount of nutrients. If managed properly, these nutrients can be used as supplement to synthetic fertilisers in agriculture. However, if not managed properly, it leads to eutrophication of water bodies and further it may lead to contamination of drinking water resources.

Stabilization

Untreated FSS has a high oxygen demand due to the presence of readily degradable organic matter that consumes significant amounts of oxygen during aerobic respiration. If FSS is discharged to the environment, it can result in depletion of oxygen in surface waters. The process of stabilisation results in FSS containing organic, carbon-based molecules that are not readily degradable, and which consists of more stable, complex molecules (e.g. cellulose and lignin). Stabilisation is achieved through the biodegradation of the more readily degradable molecules, resulting in FSS with a lower oxygen demand. Common indicators of stabilisation include measurement of volatile suspended solids (VSS) and organic matter (BOD and COD). In addition, stabilisation ensures that organic forms of nutrients present in treatment end-products are stable, and can be more predictably and reliably used. Stabilisation also reduces foaming of FSS, leading to better dewatering.

13.4.3 Treatment stages

There are multiple stages of FSS treatment and each stage has a specific treatment objective. The figure below shows all the stages and treatment mechanisms under each stage and examples of treatment units for that stage.

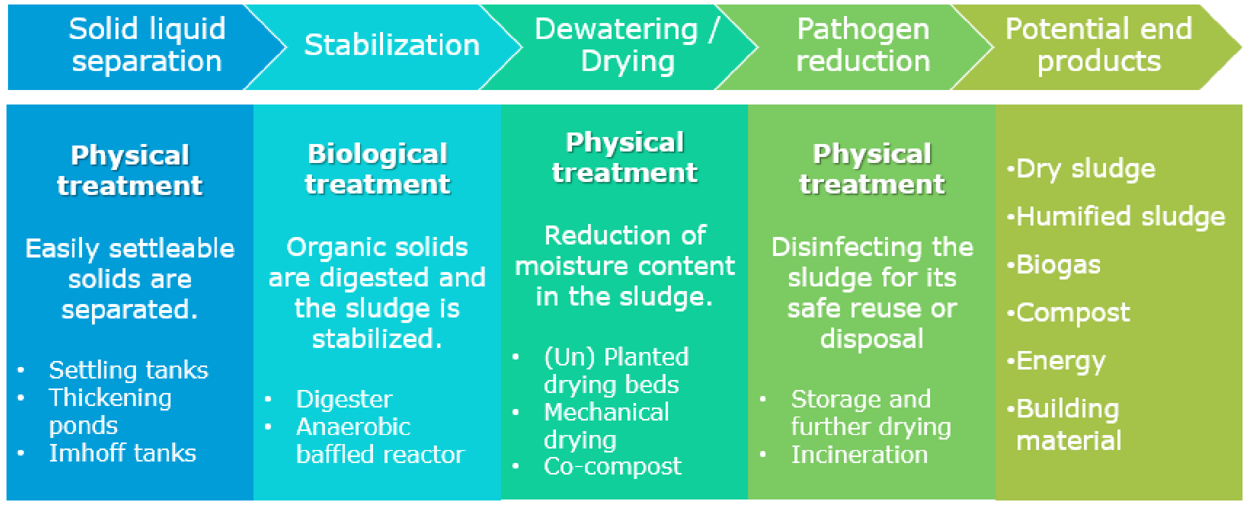


Figure 40: Treatment stages of FSS

13.4.4 Treatment units – non-mechanized

Settling thickening tanks

Settling thickening tanks are sedimentation tanks which are designed based on the settling velocities of the suspended particles in the FSS. The difference in the specific gravity aids the settling process. The FOG has lower specific gravity as compared to the water and hence, float at the top surface of the tank. The solids which settle down in the tank, are further compressed and thickened by the hydrostatic pressure from the water above. The HRT of the settling thickening tank is in hours, however, sludge retention time (SRT) can vary from 10-30 days. The properly designed and well operated settling thickening tank thicken the FSS of solid content as low as 0.5% to up to 12%.

In settling thickening tanks, the suspended solid (SS) particles that are heavier than water settle out in the bottom of the tank through gravitational sedimentation. The types of settling that occur are:

- discrete, where particles settle independently of each other;
- flocculant, where accelerated settling due to aggregation occurs; and
- hindered, where settling is reduced due to the high concentration of particles.

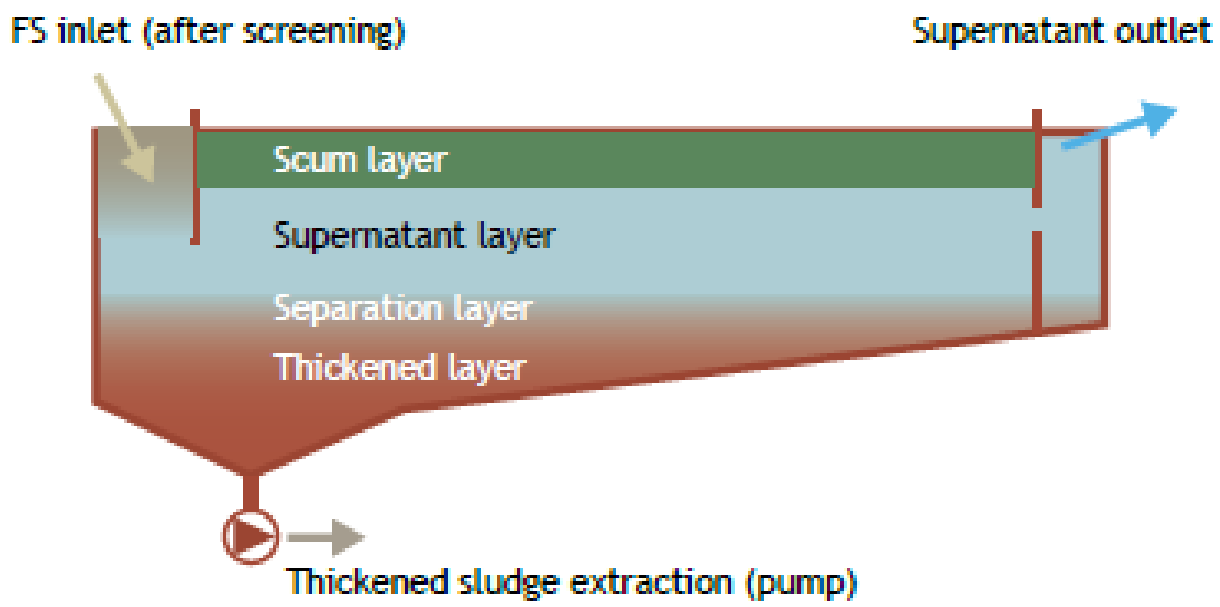


Figure 41: Schematic diagram of a settling thickening tank

Discrete and flocculant settling happen rapidly in the tank. Hindered settling occurs above the layer of sludge that accumulates at the bottom of the tank, where the suspended solids concentration is higher. These combined processes result in a reduction of the solids concentration in the supernatant, and an accumulation of solids at the bottom of the tank. Particles with a greater density settle faster than particles with lower densities. Based on the fundamentals of settling the distribution of types and shapes of particles in FS (and their respective settling velocities) could theoretically be used to design a settling thickening tank. Although this theory is important in understanding the design of settling thickening tanks, the reality is that when designing a settling tank, empirical values are determined and used for the design based on the characteristics of the FSS in specific conditions.

Geotubes

Geotubes are long, relatively narrow, flexible bags fabricated from high-strength permeable textiles. The only opening in a bag is a connection to allow sludge to be discharged into it. Once sludge has been pumped into a Geotube, solids are retained in the bag while free water drains out through the permeable walls of the bag. Geotube is available in a variety of sizes. Geotube must be removed and replaced when they are full. This suggests that the permeable Geotube option has an operational cost, which reduces its little viability as a dewatering option.

Figure 42: Use of Geotubes for solid liquid separation.

Anaerobic digestion

Anaerobic digestion are of different types such as – (a) Psychrophilic, (b) Mesophilic and (c) Thermophilic. Mesophilic anaerobic digestion is appropriate for Indian context as it demands an operating temperature of 200C – 400C with a SRT of 20-30 days.Anaerobic digestion takes place in four stages and a state of balance needs to be maintained in this process. The four stages of anaerobic digestion are – (1) hydrolysis of slowly biodegradable contents such has fats, cellulose and proteins, (2) acidogensis, (3) acetogenesis, and (4) methanogensis. The second and third stage results into organic acids which lowers the pH of the reactor, however the fourth stage is sensitive to pH and slow. Hence, if there is increase in production of acids, the pH lowers below the favorable limit and souring of digester takes place.On the other hand, if organic loading is not maintained properly, then the microorganisms scavenge each other killing the activity rate of digester. In both cases, recommissioning of anaerobic digester may be needed.

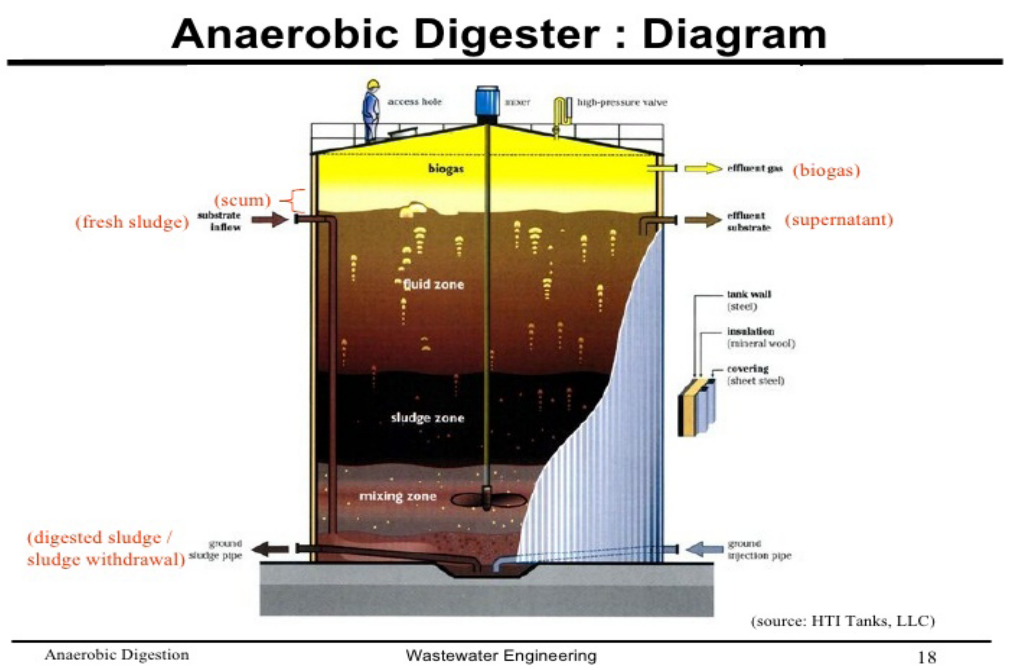


Figure 43: Schematic diagram of a high rate anaerobic digester

Unplanted drying beds

Unplanted sludge drying beds are constructed in multiple number (usually between 8-12 beds) and are operated over a period of weeks before the dried solids are taken out from the bed. The sludge loading and drying cycle depends on the TSS content of the sludge and local climatic conditions such as temperature, humidity and air flow.

Most design guidelines for sludge drying beds specify the allowable solids loading on the bed in kilograms of total solids per square metre per year (kg TS/m^2 year). A solid loading rate of 120–150 kg dry solids/m^2 year for primary sewage-works sludge and 90–120 kg dry solids/m^2 year for sludge from humus tanks is recommended. These figures are intended for use in temperate climates. Referring to conditions in tropical countries, solid loading rates typically vary between 100 and 200 kg TS/m^2 year. In practice, various researchers have reported loading rates higher than 200 kg TS/m^2 year.

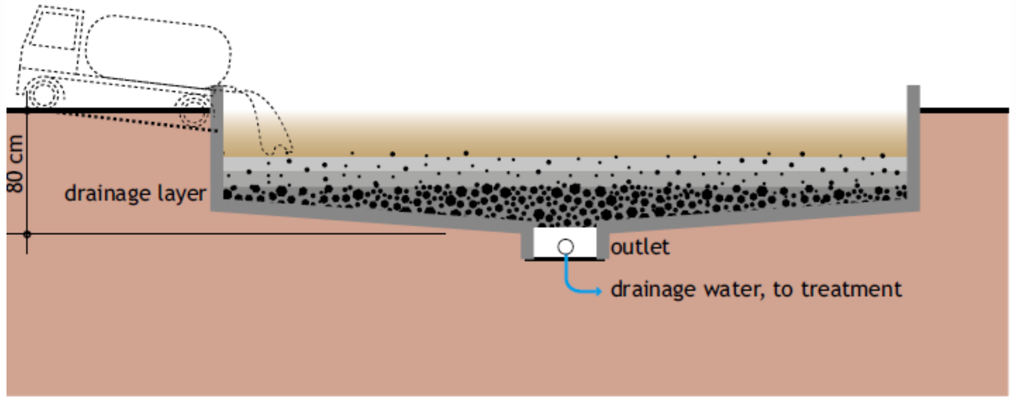


Figure 44: Schematic diagram of unplanted drying bed

The height of solids on the surface of the beds should not be greater than 300 mm. As this slows the drying process significantly and inadequately, it does not ensure removal of pathogens by desiccation process.

Planted drying beds

The treatment of sludge in PDBs is achieved through a combination of physical and biochemical processes. In wet, rainy climates, macrophytes play an essential role in almost all processes, and are responsible for the higher levels of treatment in terms of stabilization and pathogen removal in comparison to unplanted drying beds. Macrophytes therefore play an essential role in the following:

- Stabilizing the beds to prevent media erosion and clogging, and improving the drainage;
- Increasing moisture removal rate (through evapotranspiration, in contrast to only evaporation in unplanted drying beds);
- Providing a surface area for microbial growth within the sludge layer;
- Transferring oxygen to the sludge layer (i.e. within the rhizosphere); and
- Absorbing heavy metals and nutrients.

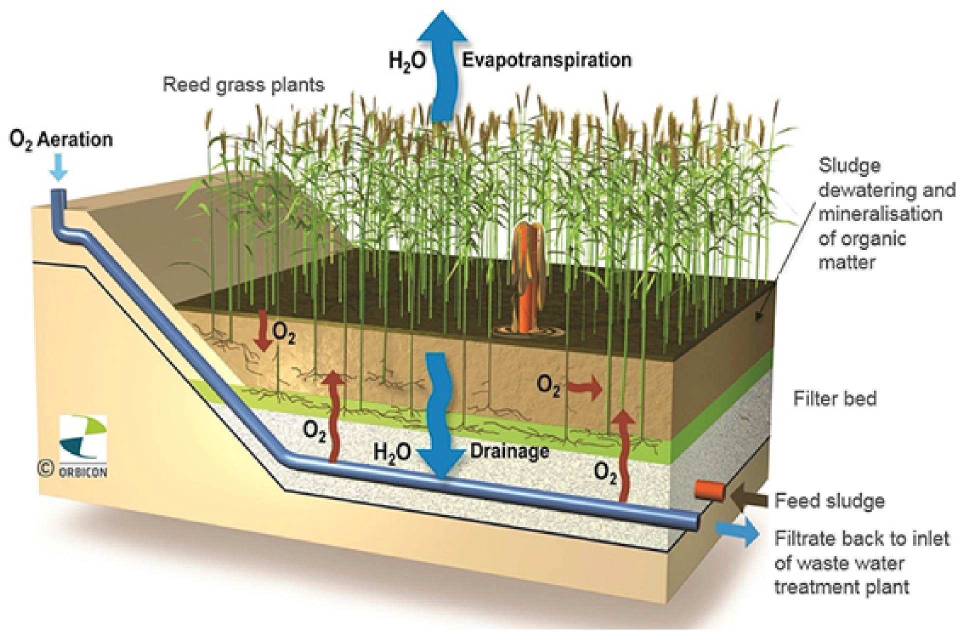


Figure 45: Schematic diagram of planted drying bed

However, while PDBs, and their ability to wick away moisture via transpiration, make them an applicable technology in humid or rainy climates, the macrophytes of a PDB could wilt and die off in a climate that is too hot and dry, especially if the sludge does not provide sufficient moisture. As a solution, the PDB can be operated to induce 'ponding', i.e. keeping a certain amount of water in the beds by turning off the drainage outlet valve of the ponds or by adjusting the level of the outlet valve, then PDBs can be operated efficiently, even in a very dry climate.

Co-composting

Co-composting is a biological process that involves microorganisms that decompose organic matter under controlled predominantly aerobic conditions. The resulting end product is stabilised organic matter that can be used as a soil conditioner. It also contains nutrients which can have a benefit as a long-term organic fertiliser. There are two types of composting systems, open and closed, of which open systems are lower in capital and operating costs but typically require more space. In an open composting system, raw organic matter is piled up into heaps (called windrows) and left for aerobic decomposition. To increase space efficiency, the heaps of waste can also put into walled enclosures which is called box composting. If untreated waste feedstock is placed in a closed container this is called in-vessel or closed drum composting and is considered in the category of closed systems.

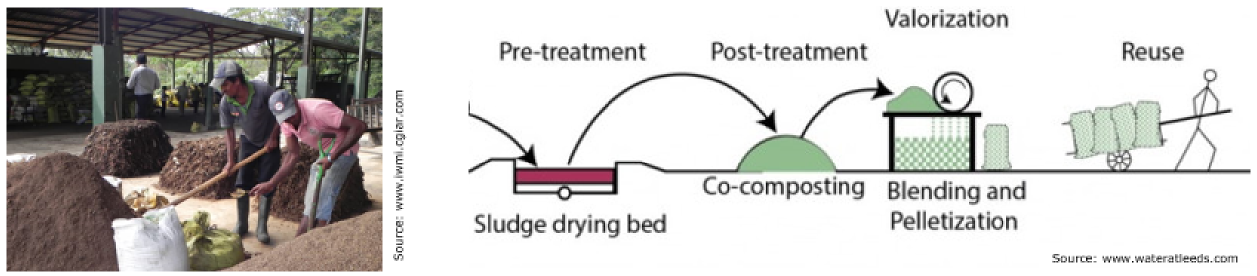


Figure 46: Co-composting of dewatered faecal sludge and septage with organic waste

In a properly operated composting heap, the temperature rises rapidly to 60°C -70°C as heat is released when carbon bonds are broken down in an exothermic process. Pathogen die-off is highest during this time of high temperature. After approximately 30 days, the temperature drops down to 50°C. During the maturation phase the temperature is around 40°C, and the process ends once ambient temperature is reached. The whole composting process (including maturation) takes a minimum of six to eight weeks.

13.4.5 Treatment units - mechanised

A. Mechanized dewatering units

Mechanized dewatering units have been used for dewatering of sewage sludge in the STPs. The mechanical dewatering units are mainly of two types: centrifuge & press. Mechanical centrifuge is quite efficient & mostly appropriate for STP whereas the mechanical press is more suitable for faecal sludge & septage. The mechanical presses are of 2 types: screw press and belt press filter.

a. Screw press

A screw press the liquid from solids by forcing sludge through a screw or auger contained within a perforated screen basket. The screw diameter increases with distance along the shaft while the gap between its blades decreases so that the gap between basket, shaft, and flights continuously decreases and sludge is squeezed into a progressively smaller pace. The dewatered cake drops out at the end of the press for storage, disposal, or further drying on a drying bed or in a thermal dryer.

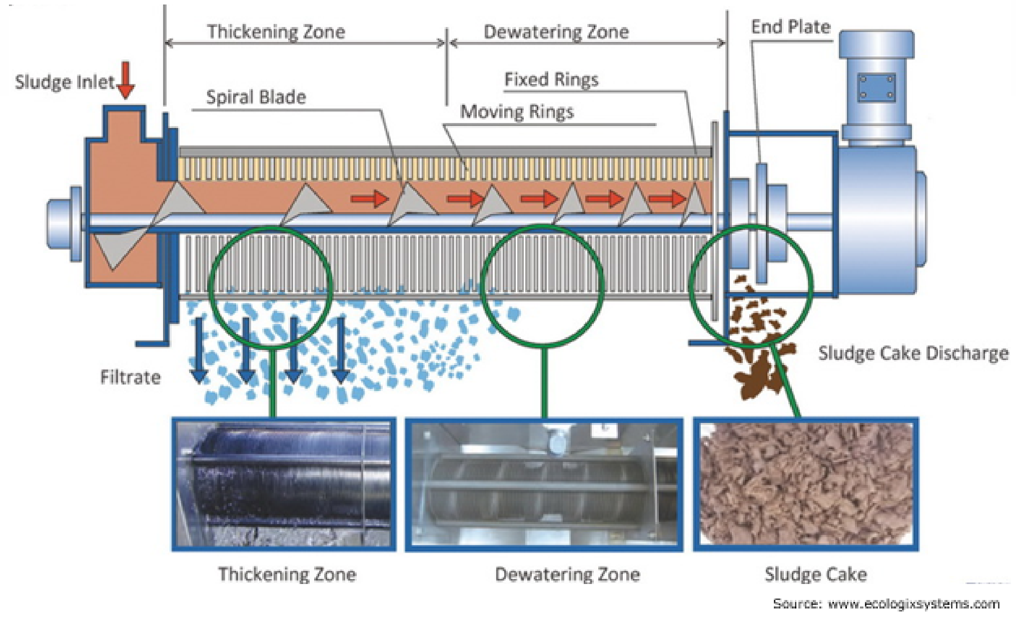


Figure 47: Schematic diagram of a screw press

b. Belt press

Belt filter presses separate liquid from solids, using gravity and applied pressure between fabric belts. The process typically involves four steps: preconditioning, gravity drainage, low-pressure linear compression, and high-pressure roller compression (and shear). After preconditioning, sludge passes through a gravity drainage zone where liquid drains by gravity from the sludge. It is then moved on to a low-pressure zone where two belts come together to squeeze out liquid from the solids, forcing liquid through the fabric belts. The dewatered sludge cake is then scraped off the belts for conveyance to the next stage of treatment or disposal. The belts are cleaned with high-pressure wash water after each pass.

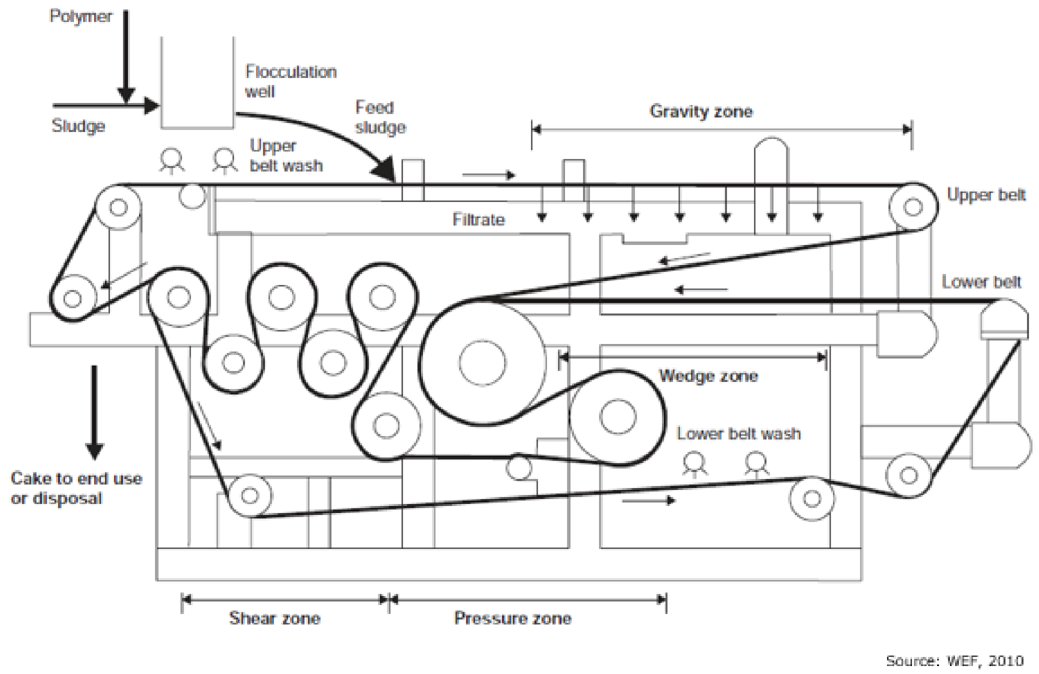


Figure 48: Schematic diagram of a belt press

Following table describes the brief difference between a screw press & a belt filter press:

Table 27: Mechanized dewatering: Screw Press vs Belt Filter Press based on operation

Technology	Operation	Maintenance
Screw press	• Intermittent medium pressure wash water (<10% sludge flow rate at 4 bar pressure) • Simpler operation • Enclosure keeps surrounding environment clean and safe • Low Energy consumption	• Fewer parts to monitor and maintain • Less inventory to maintain
Belt filter press	• Continuous wash water (50-100% sludge flow rate at 8 bar pressure) • Unenclosed units are messy to operate and present health hazard; however, allow visibility of process performance.	• Simple equipment to maintain (rollers, bearing, belt) • More parts to monitor- inspect and maintain

Table 28: Mechanized dewatering: Screw Press Vs Belt Filter Press based on performance

Technology	Dewatering Performance	Cost
Screw press	• Can receive sludge with low solid content (<1%) • 15-25% final dry solids • Less sensitive to non-homogenous sludge characteristics	• Higher capital costs • Slightly lower operation cost
Belt filter press	• Can receive sludge with solid content < 0.5% • 15-25% final dry solids • Can be provided with greater capacity for single unit	• Lower capital cost • Slightly higher operating cost

B. Mechanized drying units

Thermal dryers have high energy requirement, since tremendous amount of energy is required to heat the water and there by vaporise it. However, thermal dryer requires significantly less area for processing the sludge. In an optimised operation, efficiency of the dryer is more than 80%. Health and safety consideration such as production of dust should be taken into account. Operators need to be trained properly and persons with skills and expertise are required for operating such equipment.

a. Rotary dryer

The simplest form of dryer is the direct rotary dryer. This consists of a cylindrical steel shell that rotates on bearings and which is mounted horizontally, with a slight slope down from the feed end to the discharge end. The feed sludge is mixed with hot gases produced in a furnace and is fed through the dryer.

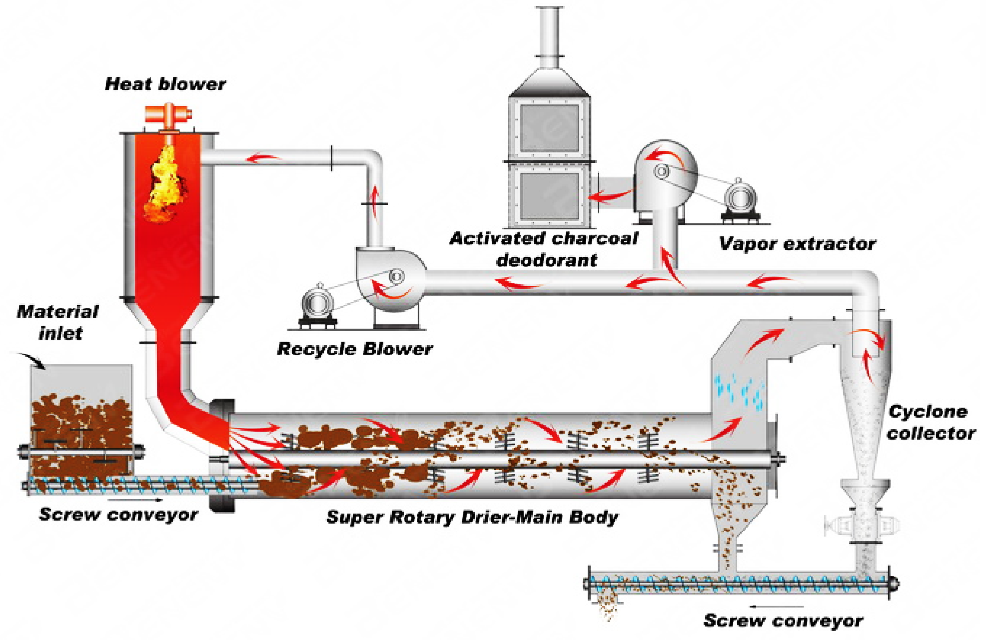


Figure 49: Schematic diagram of a rotary drum dryer

As it passes through the dryer, flights (fin-like attachments to the wall of the cylinder) pick up and drop the sludge, causing it to cascade through the gas stream. Moisture in the sludge evaporates, leaving a much dryer material at the discharge end of the dryer. The dried sludge is separated from the warm exhaust gas, part of which is recycled to the dryer while the remainder is treated to remove pollutants and is then vented to the atmosphere.

b. Belt dryers

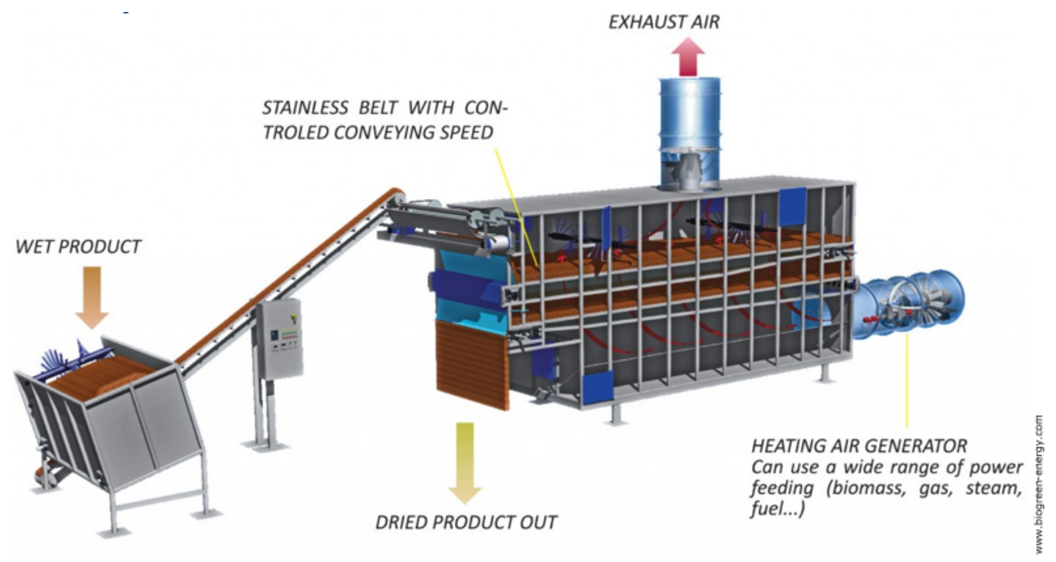


Figure 50: Schematic diagram of a belt dryer

Belt dryers operate at lower temperatures than rotary drum dryers. The heat from the furnace is transferred to a thermal fluid, which heats the air in the dryer. Alternatively, electrical heating coils are also used to heat the air in the dryer. The dewatered cake that is to be dried is distributed onto a slow-moving belt, which exposes a high surface area to the hot air.

c. Paddle dryers

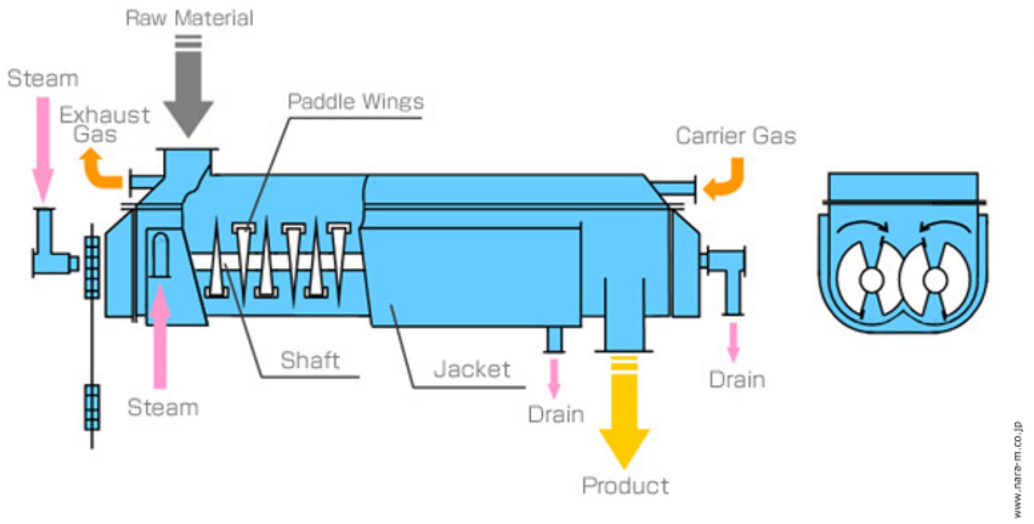


Figure 51: Schematic diagram of a paddle dryer

Paddle dryer has paddle wings which are hollow from inside so that steam can be circulated from it. The paddle system is also encompassed into a jacket which is fed by steam. When raw material is introduced into the paddle dryer, the heat is transferred from the paddles to the sludge. The sludge moves in the forward direction and get churned as it moves ahead. From the other end, the dried solids come out of the dryer. Dry air is introduced in the jacket to drive away the moisture laden air out of the dryer.

d. Pyrolysis

Pyrolysis is the thermal decomposition of material at high temperatures in the absence of oxygen. It may be classified as fast, intermediate, or slow. Fast and intermediate pyrolysis require that the material undergoing decomposition remains in the reactor for seconds or minutes with temperature in between 7000C – 9000C. The slow pyrolysis, the main focus here, requires a retention time measured in hours and a temperature more, up to around 700°C. Pyrolysis differs from combustion in that little or no carbon dioxide is released during the process. Organic material instead undergoes carbonization, or conversion into carbon in the form of hard porous charcoal. This material, which is called biochar, can be used as a soil amendment or as a fuel source.

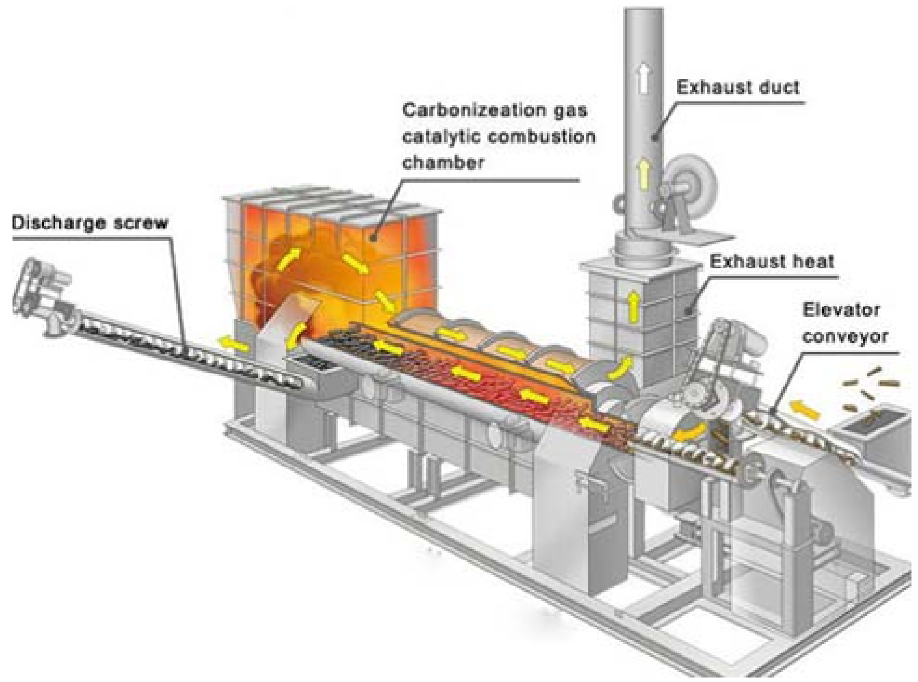


Figure 52: Schematic diagram of a pyrolizer

13.4.6 Selection of treatment mechanism

The selection of the treatment mechanisms is governed by certain criteria which are listed in the figure below. However, it needs to be understood that these criteria are not inclusive and there can be other criteria as well.

Table 29: Selection criteria for treatment mechanisms

Treatment performance	Local context	O&M requirements	Costs
• Effluent and solids quality according to the discharge / reuse standards	• Characteristics of sludge (dewaterability, solids concentration, stabilisation, spread ability) • Quality of the frequency of the sludge to be received at treatment facility • Climate • Land availability and its cost • Interest in the end use	• Availability of skilled persons for operation-maintenance and monitoring • Availability of spares locally in case of mechanical equipment.	• Investment costs covered (land acquisition, infrastructure, human resources, capacity building and training) • O&M costs • Affordability for households and ULB

a. Treatment performance

The default criteria is that the treatment facility should be able to produce end products meeting the standards of discharge/ end use.

b. Local context

Most important criteria are the local context. The characteristic of the sludge and its characterisation ratios determine the degree of stabilisation and dewaterability etc. The frequency of desludging affects the quality of the sludge. Hence, if the frequency of the desludging is high, there is possibility of having faecal sludge. In that case, stabilisation of sludge becomes important. Climate plays important role in case of all-natural treatment mechanisms such as evaporation, evapotranspiration and stabilisation.Land availability and its cost of acquisition must also be considered before finalising the treatment mechanisms. In cases where the land is not available and acquisition of it is costly or time consuming, it is advisable to go for treatment mechanisms demanding less area. If there is interest in the use of end products of treatment, then treatment mechanisms suitable to produce those end products in demand should be chosen. For example, in cases where there is demand for biochar, pyrolysis will be suitable treatment mechanisms for pathogen reduction

c.O&M requirement

Availability of the resources such as skilled persons, spares etc. at local level is very important. In absence of local availability of the resources, no treatment technology is going to economically viable in spite of it producing very high-quality end product.

d. Costs

The capital and operational expenditure (CAPEX and OPEX) of the technology are also one of the criteria and which is often thought to be the only criteria. Affordability of the complete project to the ULB or the end beneficiaries such as households should also be checked.

13.5 Notes for trainer

This session does not have a group activity. However, this session becomes a base for understanding the non-mechanized or mechanized units in faecal sludge and septage treatment system. If time permits and depending upon the type of participants, trainers may choose to show video on Case Studies of FSTPs in India.

Weblinks:

- Faecal Sludge Treatment Plant - Bhubaneshwar
- Faecal Sludge Management – Devanhalli
- Faecal Sludge Management – Wai
- Faecal Sludge Management – Jhansi

13.6 Bibliography

- Kevin Tayler (2018); Faecal sludge & septage treatment- A guide for low income countries
- Technical Note on Shallow and Deep Trenches for Faecal Sludge or Septage by Water, Sanitation and Hygiene Institute, 2019
- EAWAG/SANDEC (2008): (Sandec Training Tool 1.0, Module 5). Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Faecal Sludge Management (SANDEC)
- Strande, L.; Ronteltap, M.; Brdjanovic, D. (2014): Faecal Sludge Management (FSM): Systems Approach for Implementation and Operation. London: IWA Publishing
- Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph. and Zurbrügg, C., 2014. Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.

Session

14

Financial aspects of FSSM

14 Financial aspects of FSSM

14.1 Learning objectives

- To look at different financial aspects related to infrastructure projects such as setting up a FSTP
- To understand different financial models for operating FSSM citywide

14.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
Financial aspects in FSSM	10 min	Power point presentation
Financial transfers in FSSM	10 min	Power point presentation
Financial flow models	15 min	Power point presentation
Q&A	10 min	Discussion

14.3 Key facts

- There are multiple types of cost which need to be considered by setting up a FSTP.
- Selection of the technologies should be done after looking at life-cycle cost of the project.
- There are multiple transfers which happen when FSSM is operationalized.Selecting appropriate contracting and financial transfer model is key to sustainability of the FSSM.

14.4 Learning notes

14.4.1 Financial aspects

Capital expenditure (CAPEX)

CAPEX of the project refers to all the expenditures which will happen only once for setting up or implementation of the project. Following are few examples of capital expenditures:

- Cost of land and site preparation.
- Civil structures, electrical and plumbing components, electromechanical components.
- Establishment cost.
- Site investigation.
- Transport and overhead.

Operational expenditure (OPEX)

OPEX can be classified into: (1) direct costs and (2) indirect costs.

Direct costs refer to the expenditure which may vary and depend on the degree or hours of operations. For example, cost of electrical energy, cost of polymers (coagulants).

Indirect cost refers to the expenditure which is fixed and does not depend on other factors such as load of FSS received etc. For example, lease of the land, human resource cost.

Income and revenue

Income and revenue refer to the incoming monetary streams. In case of FSTP, revenue can be generated through: (a) discharge fees, (b) purchase fees and (c) budget support.

Life cycle cost (LCC) analysis

The LCC Analysis refers to the process which account for the CAPEX, OPEX and revenues over the life period of the project and gives a single cost. Depending upon the type of analysis used, the ultimate derived cost is known as annualized cost or net present value.It is recommended to compare the LCC of project to choose suitable technologies for treatment of FSS. The non-mechanized (natural treatment) components for treatment of FSS require larger area and typically have more CAPEX as compared to mechanized components. However, the OPEX of the non-mechanized component might be lesser as compared to mechanized component. Hence, the LCC gives a much more holistic picture of the cost of treatment.

LCC analysis also gives an opportunity to check the financial viability of the treatment of FSS, as the cost of treatment needs to be covered by the end beneficiaries i.e. the households and/or ULB.

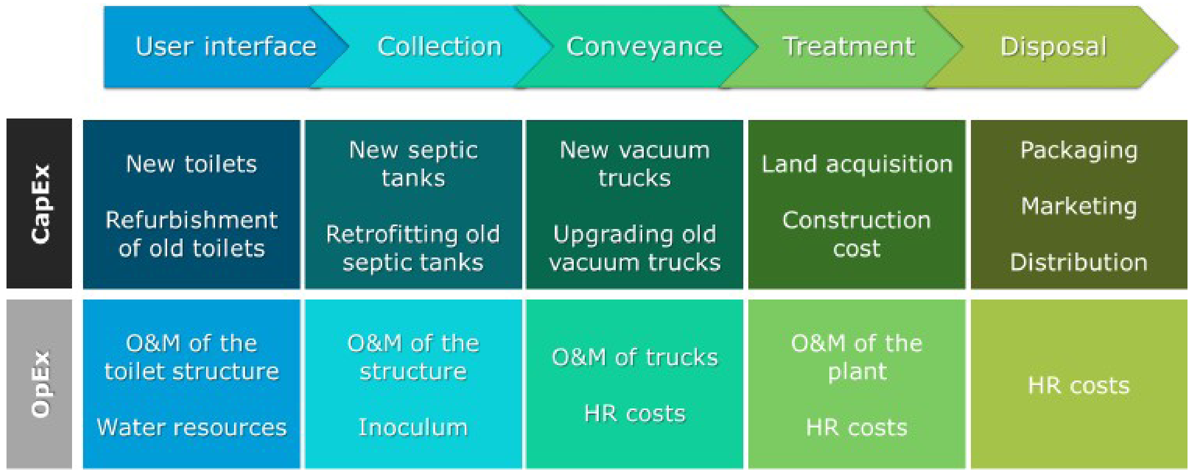


Figure 53: FSSM component-wise financial requirements

14.4.2 Financial transfers

There are various financial transfers which might happen when FSSM is operationalized in the ULB. Understanding of all such types of financial transfers is needed in order to choose an appropriate financial transfer model.

Following are the types of financial transfers which might happen:Budget support

- Capital investment
- Discharge fee
- Discharge incentive
- Discharge license fee
- Emptying fees
- Fines
- Operation and maintenance cost
- Purchase price
- Sanitation tax

14.4.3 Financial flow models

Financial flow model helps to identify the contracting model and inclusion of private companies in operations of FSSM. Following are the type of financial transfer models:

Common public FSSM model - A commonly occurring scenario observed is the ownership and management of FSSM by the public sector for collection, transportation and treatment. Users of containment unit approach local authorities, which are usually the municipality or the state-run water and sewerage companies, to provide emptying services. The service is provided for a prefixed price. The sludge collected is transported to a treatment plant or landfill site, which is also owned and operated by a public utility or the local municipality.

Common private emptying and transportation model – In a commonly occurring scenario, when an emptying activity is initiated by a private enterprise (mechanical or manual emptying), the households or customers with an on-site sanitation systems can contact the private operator to provide emptying services on a fixed agreed tariff. Ideally, the private operator is required to transport and safely dispose the FSS either to a treatment plant or to a designated disposal site, typically a landfill. In the first case, there is a faecal sludge and septage treatment plnat (FSSTP) which is constructed and managed by municipal authority or its on PPP model and private operator is transporting the FSS to the FSSTP. In the second scenario, as there is no binding to private operator with municipal authority, they can opt to perform indiscriminate disposal of FSS on landfill site or water bodies or in open drains.

Licensing model – This model is similar to the commonly occurring private emptying and transportation model. The key difference lies in the issuing of license/permits to the private truck operators by relevant municipal authorities to operate emptying activity. Licensing helps in accounting for all emptying activity in the city, and can potentially track these operations to prevent illegal disposal of FSS. The license/permit could be either a one-time fee or fees paid annually by the truck operators. The municipal authority issuing the license provides basic "do's and don'ts" to the truck operators, and they need to monitor for regulatory compliance by tracking the operations of private truck operators. The license is revoked, if the truck operator is found to be violating any regulations, especially engaging in the illegal disposal of FSS in non-designated sites.

Scheduled desludging sanitation tax model – This model has two key aspects: a) sanitation tax collected from owners of containment unit, and b) mandatory scheduled desludging of tanks/pits. Sanitation tax is collected by the local municipal authority either as a percentage of property tax or by the public utilities as a surcharge on water bills. Local authorities in discussion with the households using containment unit set up a mandatory scheduled desludging plan. The user of the containment unit does not pay for the desludging services unless they require an unscheduled service. The revenue generated from the sanitation tax is designed to cover the O&M cost of collection, transportation and treatment of FSS. Local authorities can contract scheduled desludging to private truck operators to collect and transport sludge to designated disposal or treatment sites. The private entity receives payment based on the quantity of sludge delivered to the treatment plant (preventing illegal dumping) and the number of households that used the desludging service.

Incentivized disposal incorporating licensing and sanitation tax model – This model provides financial incentives to truck operators to encourage disposal of sludge at designated treatment sites. The objective of the model is to eliminate indiscriminate disposal of FSS. The model does not charge disposal fees to truck operators to discharge FSS at treatment sites, and instead the truck operators are paid a fixed price by the treatment plant for delivering FSS.

Table 30: Pros & cons of financial flow models

Financial flow models	Pros	Cons
Common public FSSM model	• Households are free to choose the most competitive price on offer for emptying; • Timing of emptying is flexible and can be done when financially feasible • The household is not committed to a fixed sanitation tax	• The utility's operating expenses must be covered by the discharge fee
Common private emptying & transportation model	• A single operator is able to optimize the business model and improve efficiency; • Less potential for illegal discharge as the single entity will discharge at the self-run treatment works	• High fees may be passed onto the household
Licensing model	• Low-income households' that are not connected to the sewer may have lower C&T costs from cross-subsidies; • C&T operators may benefit from lower discharge fees • Collection and coverage increase	• C&T businesses may avoid • discharge fees by discharge • illegally
Scheduled desludging sanitation tax model	• Industry regulation and legitimization through licensing • Improvement in health and safety conditions; • Minimizes risk of illegal dumping	• The management of too many aspects of the service chain by one entity could prove difficult for a new business or NGO
Incentivized Disposal Incorporating Licensing and Sanitation Tax Model	• Emptying fees for household may be reduced; • Households that are difficult to access, or located far from the treatment plant, may become attractive to C&T operators because of incentives	• Incentives must be corruption proof (e.g. not given for diluted sludge, seawater, etc.) • FSTP operator requires significant budget support to function budget support to function

14.5 Notes for trainer

The aim of this session is to introduce to the participants to financial aspects of FSSM. Since, FSSM is dependent on a service chain, there are multiple financial transaction which might take place and need to be monitored in order to make the services affordable. For further understanding of the participants, examples of case studies such as scheduled desludging in Wai and Sinnar, Maharashtra can be highlighted. The session is followed by an exercise which helps the participants to calculate the cost of operating and maintaining FSSM in a city. To help the transition of the participants, the trainer can initiate the discussion and ask the groups to list down data which might be needed for calculating the cost.

14.6 Bibliography

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Session

15

Operation & Maintenance cost of faecal sludge and septage management

Operation & Maintenance cost of FSSM - Exercise
This is an exercise session – Kindly refer Part C: Workbook

Session

16

Conceptualizing sewage treatment plant (STP)

16 Conceptualizing sewage treatment plant- Activity Session

16.1 Session objectives

The group activity will help the participants to design a wastewater treatment system with different treatment units. This also helps the trainer to understand what the participants already know regarding wastewater treatment mechanisms and treatment units.

16.2 Session plan

Duration - 30 minutes

Activity	Time	Material/Method
Conceptualising of sewage treatment plant	30 min	Flip charts and colour cards

16.3 Instructions for activity session

The activity is to be done in groups. Each group is provided with colour cards or cut-outs of the treatment units which are employed in a sewage treatment plant. The task is to arrange the treatment units and link them together in order to complete the treatment process. After placing the cards, the group also have to draw arrows linking the units together and show the flow of different products from one unit to another. Each group will work on two treatment plants.

Components

Treatment Plant I		Treatment Plant II	
Mechanized screens	Digester	Anaerobic settler	Polishing Pond
Primary Clarifier	Secondary Clarifier	Planted Gravel Filter	Anaerobic Filter
Polymer dosing	Aeration Reactor	Anaerobic Baffled Reactor	Bar screen
Chlorination	Screw Press		
Sludge Thickener	Grease & Grit Removal		
Sand and Charcoal Filter	Inlet Sump		
Discharge Outlet	Dewatered Sludge		
Blowers	Sludge pumps		

Treatment Plant 1: Centralized STP

The first treatment plant is a centralized STP based on an activated sludge process. The STP consists of following stages of treatment preliminary treatment (also known as headworks), primary treatment, secondary treatment and tertiary treatment (consisting of disinfection of the secondary treated water). Different kinds of sludge are produced at different stages of the sewage treatment and it needs to be handled at the treatment plant. The sludge treatment facility consists of gravity thickener, digester and dewatering stage. The diagram below explains the placement of each treatment unit in a centralized wastewater treatment plant and the links between them.

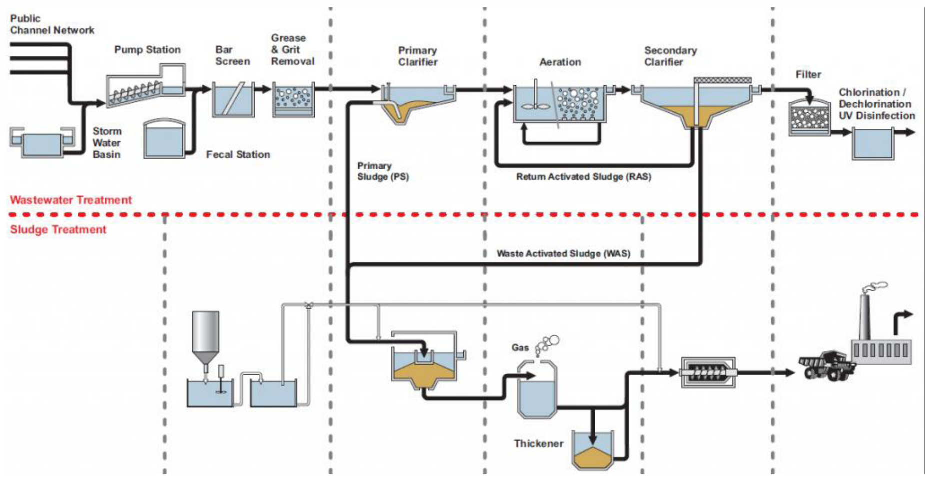

Figure 54: Flow diagram for a centralized sewage treatment plant

Treatment Plant 2: Decentralised STP

The second treatment plant is a decentralized STP considering the low operation and maintenance of treatment units. It also consists of three stages of treatment – preliminary treatment (usually consisting of manually raked bar screens), primary treatment, secondary treatment (anaerobic as well as anaerobic treatment units) and tertiary treatment which consists of disinfection stage.

The sludge produced is stored in the treatment units as it assists in improving the treatment efficiency of the units. The anaerobic treatment units need to be desludged depending on the frequency it is designed for. The diagram below indicate the various stages of the treatment system.

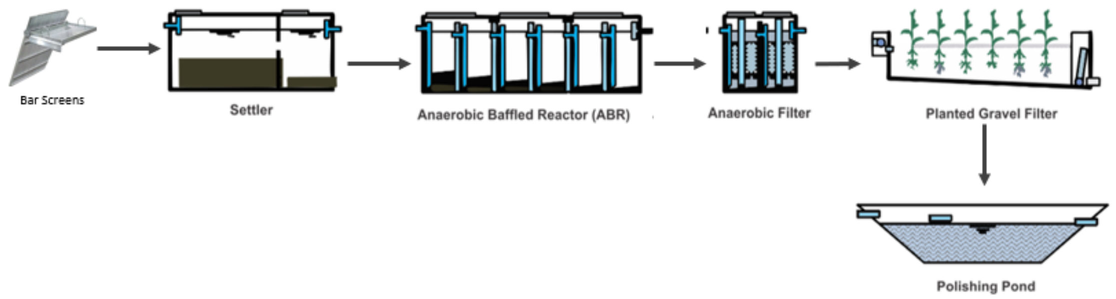

Figure 55: Flow diagram for a decentralized sewage treatment plant

16.4 Notes for trainer

This is an interesting exercise for the participants who have little knowledge about the sewage treatment plants (STPs). The exercise helps the participants to demystify and simply the black box called STP. The aim of the exercise is to make the participants realize that sewage treatment is an amalgamation of different treatment units. The technologies which are usually talked about are only one part of the large STP.

The exercise also helps the trainer to make the participants realize the complexity of the centralized sewage treatment plants as compared to decentralised sewage treatment plants.

16.5 Bibliography

- CPHEEO, GoI (2013): Manual on Sewerage and Sewage Treatment Systems, Part A: Engineering, 3rd Edition, Ministry of urban Development, Government of India.

Session

17

Wastewater treatment principles

17 Wastewater treatment principles

17.1 Learning objectives

- To define and understand the objectives of wastewater treatment
- To learn the underlying processes and their design parameters
- To understand the different stages of treatment with focus on preliminary, primary, and tertiary treatment

17.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
Objectives of wastewater treatment	5 min	Power point presentation
Treatment processes & stages	10 min	Power point presentation
Components of sewage treatment plants	10 min	Power point presentation
Layout of a sewage treatment plant	10 min	Power point presentation
Q&A	10 min	Discussion

17.3 Key facts

- The objectives of wastewater treatment should be clear before considering different options for treatment.
- Wastewater treatment technologies consist of different components.In case of FSTP, design of secondary treatment units needs to be individually tweaked for liquid effluent treatment.
- Nitrification, denitrification and aerobic treatment is needed in order to achieve high standards of treatment.

17.4 Learning notes

17.4.1 Objectives of wastewater treatment

- The ultimate aim of wastewater treatment is to reduce the quantity of pollutants entering the natural environment. In some cases, the specific goals can change from case to case. Specific goals of wastewater treatment can be as follows:
- To supply water to the industry such as cement, pipe manufacturing, stone cutting or thermal power plant as process water.
- To reduce the eutrophication of the surface water bodies such as lakes.To reduce the dependency on the rain and irrigation canal water by reuse in agriculture in drought prone areas.
- To improve the ground water table through indirect aquifer recharge techniques.

17.4.2 Treatment processes

Wastewater treatment processes are of different types- physical, biological, chemical, and photolytic.

- **Physical processes** are based on the physical characteristic of the wastewater constituents. Mainly, it's the specific gravity or the size of the constituent which assists the separation from the water. Most of these methods are based on physical forces, such as screening, mixing, flocculation, sedimentation, flotation, and filtration.
- **Biological processes** rely on the microorganisms to carry out digestion of the organic matter in anaerobic or aerobic conditions. Biological processes are the main heart and soul of any wastewater treatment plant.

Chemical processes rely on the use of chemicals either to treat the water (e.g. ozonation to kill pathogens) or to assist the physical or biological processes (e.g. alum or ferric chloride to coagulate the sludge).

Photolytic processes rely on the photon in the light rays to treat the wastewater directly (e.g. ultraviolet radiation to kill pathogens) or indirectly (e.g. with the help of photosynthesis to uptake the nutrients from the wastewater in case of constructed wetlands).

Design parameters

The different type of design parameters used to design wastewater treatment units. The importance of few design parameter/s may increase or decrease on a case to case basis.

- Organic loading (kg BOD/d, kg COD/d),
- Volumetric loading rate (m3/d)
- Temperature (oC)
- Hydraulic retention time (HRT) (hours or days)
- Sludge age (d)
- Biomass yield (kg VSS/ kg COD)
- Up flow velocity (m/s)
- Specific surface area (m2/m3)

B. Components of sewage treatment plants (STPs)

Screens

Screening is essential for removal of floating materials which are mainly sachets, plastic sheet bits, leaves, fibres, rags, etc. If these are not removed, they will get into the pumps and entangle with the impellers. Screens are used ahead of pumping stations and meters, as a first step in all STPs. A screen is a device with openings generally of uniform size. The screening element may consist of parallel bars, rods, gratings or wire mesh or perforated plates and the openings may be of any shape, although generally they are contrived from circular or rectangular bars.

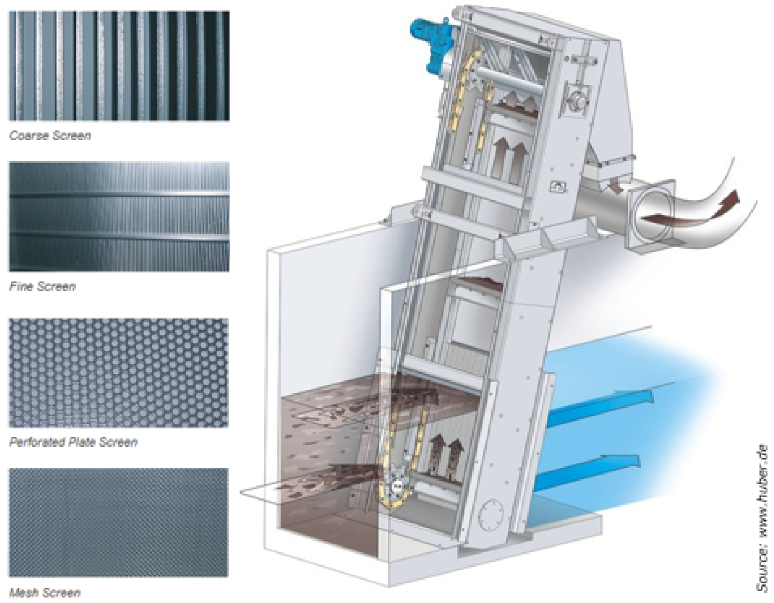

Figure 56: Schematic diagram of a mechanised bar screen

Rotary drum screens- Where the incoming sewage to the STP is at a higher elevation than ground level, the use of horizontal rotary screen is advantageous in that it avoids the need for manual scraping and the complicated forward and backward mechanical rakes. The inlet sewage skims over the rotating screen, the screenings are intercepted and are rotated forward to be are scraped onto the conveyor belting. The screened sewage will go through the slots and fall downwards to be collected in a bottom trough. This way it releases any sticking screenings to the circular screen in its downward rotation and the screenings float up for the screening on the upward movement. The screened sewage at the bottom can be collected in a channel and taken out in any suitable direction for downstream units. Their design criteria are generally as per the chosen manufacturer's design standards.

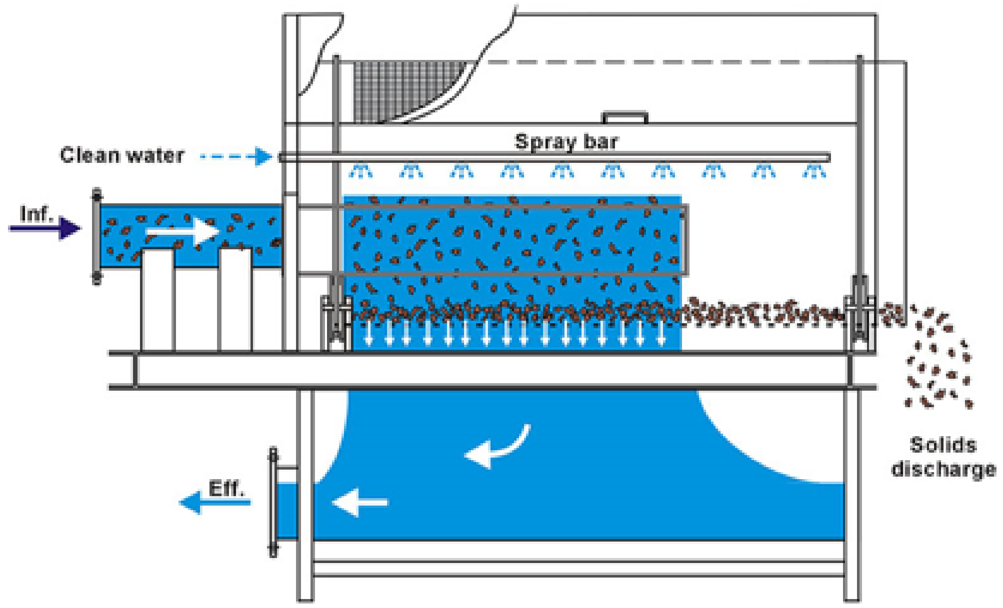

Figure 57: Schematic diagram of rotary drum screens

Grit removal

Grit removal is necessary to protect the moving mechanical equipment and pump elements from abrasion and accompanying abnormal wear and tear. Removal of grit also reduces the frequency of cleaning of digesters and settling tanks. It is desirable to provide screens or commuting device ahead of grit chambers to reduce the effect of rags and other large floating materials on the mechanical equipment, in case of mechanized grit chamber.

Aerated grit chamber- An aerated grit chamber is a special form of grit chamber consisting of a standard spiral-flow aeration tank provided with air-diffusion tubes placed on one side of the tank, 0.6 to 1 m from the bottom. The grit particles tend to settle down at the bottom of the tank at rates dependent upon the particle size and the bottom velocity for roll of the spiral flow. This is in turn controlled by the rate of air diffusion through the diffuser tubes and the shape of the tank. The heavier grit particles with their higher settling velocities drop down to the floor whereas the lighter organic particles are carried with roll of the spiral motion and eventually out of the tank.

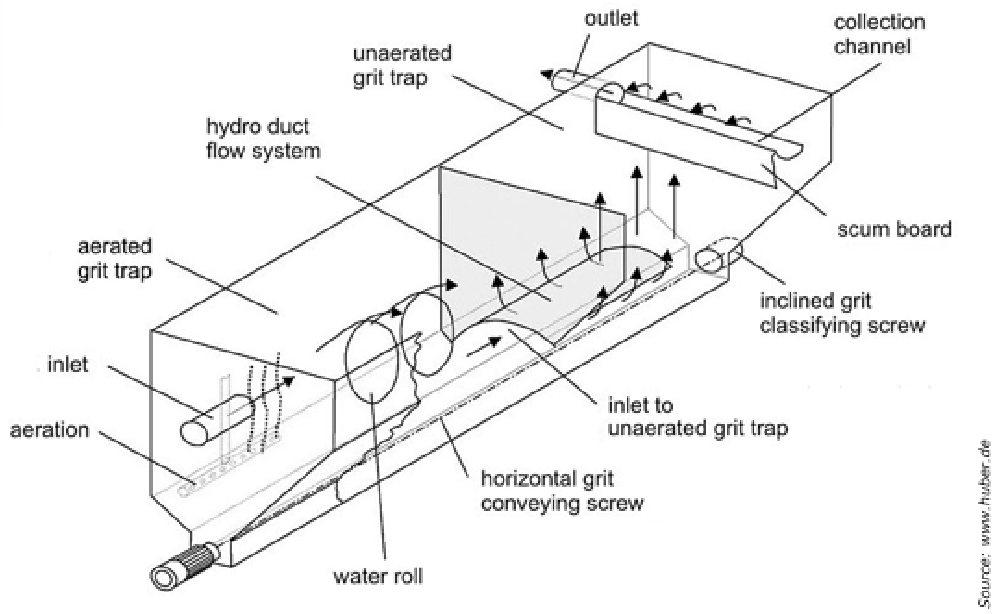

Figure 58: Aerated grit chamber

Vortex grit chamber- The sewage is fed tangentially to induce a vortex type of flow, which will funnel the grit towards the centre, and hence be drawn down at the bottom chamber. An auxiliary agitator at this location keeps the grit in suspension and hence it is washed free of organics. The rim flow of the vortex is the degritted sewage that flows to downstream units. The grit at the bottom can be either drained onto a grit filter bed by gravity or pumped to the beds depending on the levels. The filtrate is returned to the raw sewage.

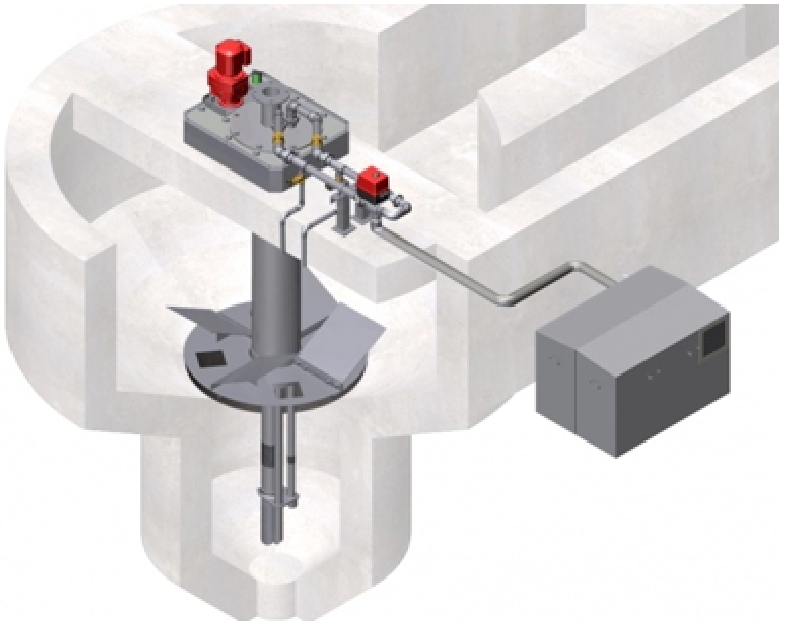

Figure 59: Vortex grit chamber

Primary treatment

Primary clarifier- The primary clarifier generally removes 30 to 40% of the total BOD and 50 to 70% of suspended solids from the raw sewage. The flow through velocity of 1 cm/sec at average flow is used for design with detention period in the range of 90 to 150 minutes. This horizontal velocity will be generally effective for removal of organic suspended solids of size above 0.1 mm. Primary sedimentation tanks can be circular or rectangular tanks designed using average dry weather flow and checked for peak flow condition. The number of tanks are determined by limitation of tank size. The diameter of circular tank may range from 3 to 60 m (up to 45 m typical) and it is governed by structural requirements of the trusses which supports scrapper in case of mechanically cleaned tank. Rectangular tank with length 90 m is in use, but usually tank length more than 40 m is not preferred. The depth of mechanically cleaned tank should be as shallow as possible, with minimum 2.15 m. The average depth of the tank used in practice is about 3.5 m. The floor of the tank is provided with slope 6 to 16 % (8 to 12 % typical) for circular tank and 2 to 8% for rectangular tanks.

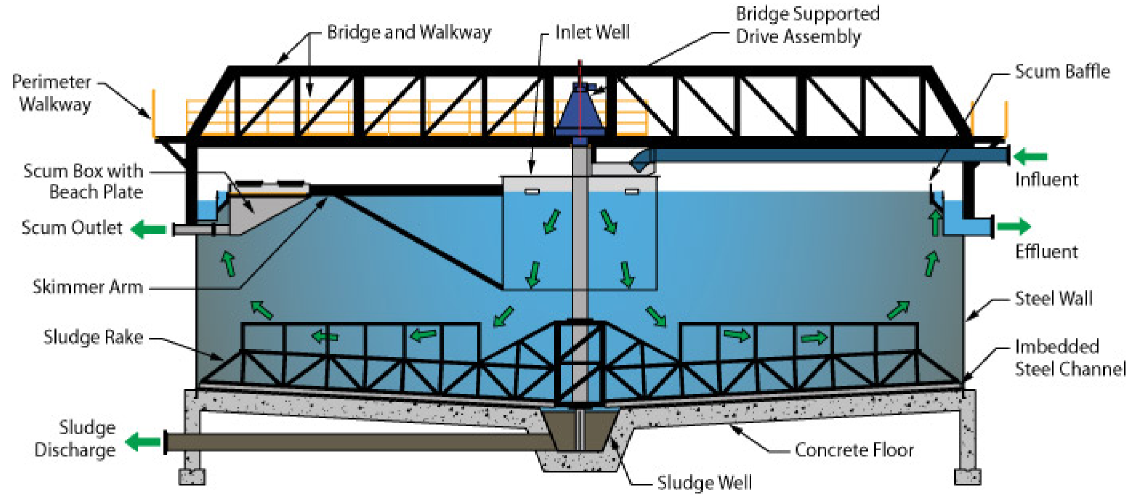

Figure 60: Schematic diagram of a primary clarifier

Secondary treatment

The main objective of secondary treatment is removal of organic matter. Organic matter can be found as:

- Dissolved organic matter (soluble or filtered BOD) that is not removed merely by physical operations such as sedimentation that occurs in primary treatment.
- Organic matter in suspension (suspended or particulate BOD) which is largely removed in the occasionally existing primary treatment, but whose solids with slower settleability (finer solids) remain in the liquid mass.

The essence of secondary treatment of sewage is the inclusion of a biological stage. While preliminary & primary treatments have predominantly physical mechanisms, the removal of the organic matter in the secondary stage is carried out through biochemical reactions, undertaken by micro-organisms.

Tertiary treatment

Chlorination- The destruction, inactivation, or removal of pathogenic microorganisms can be achieved by chemical, physical, or biological means. Due to its low cost, high availability and easy operation, chlorine has historically been the disinfectant of choice for treating wastewater.

Chlorine oxidizes organic matter, including microorganisms and pathogens. Concerns about harmful disinfection by-products (DBP) and chemical safety, however, have increasingly led to chlorination being replaced by alternative disinfection systems, such as (UV) radiation and ozonation (O3).

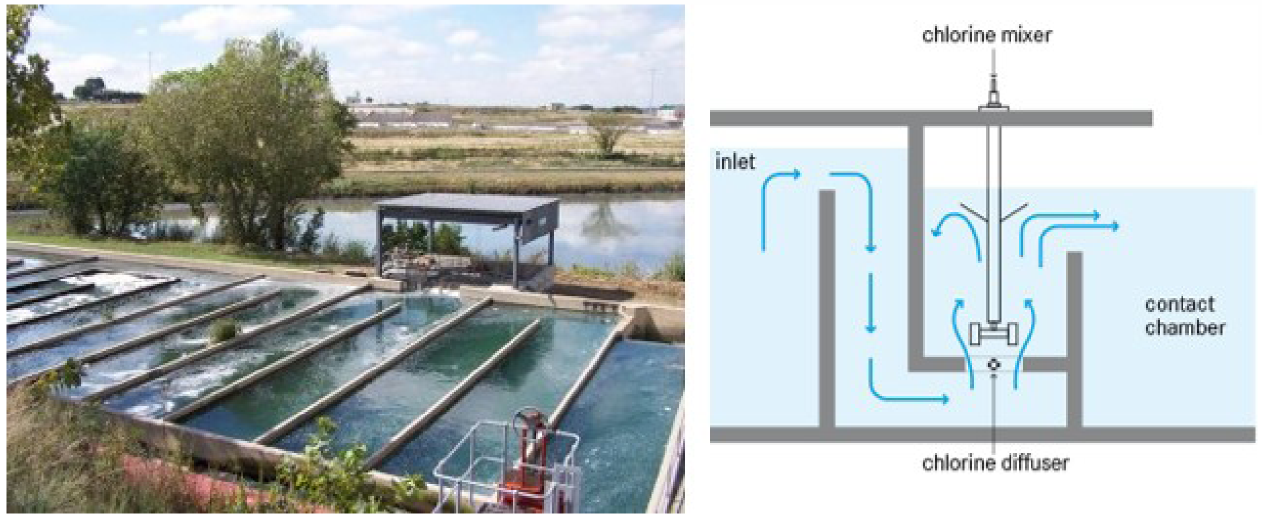

Figure 61: Chlorination basin & schematic diagram of chlorine dosing and mixer

Ozonation- Ozonation is an efficient treatment to reduce the amounts of micropollutants released in the aquatic systems by wastewater treatment plants. Although no residual by-products are generated by ozone itself, some concerns are raised regarding oxidation by-products when water containing both organics and ions, such as bromide, iodide and chlorine ions, are treated with ozonation. A typical ozonation system consists of an ozone generator and a reactor where ozone is bubbled into the water to be treated.

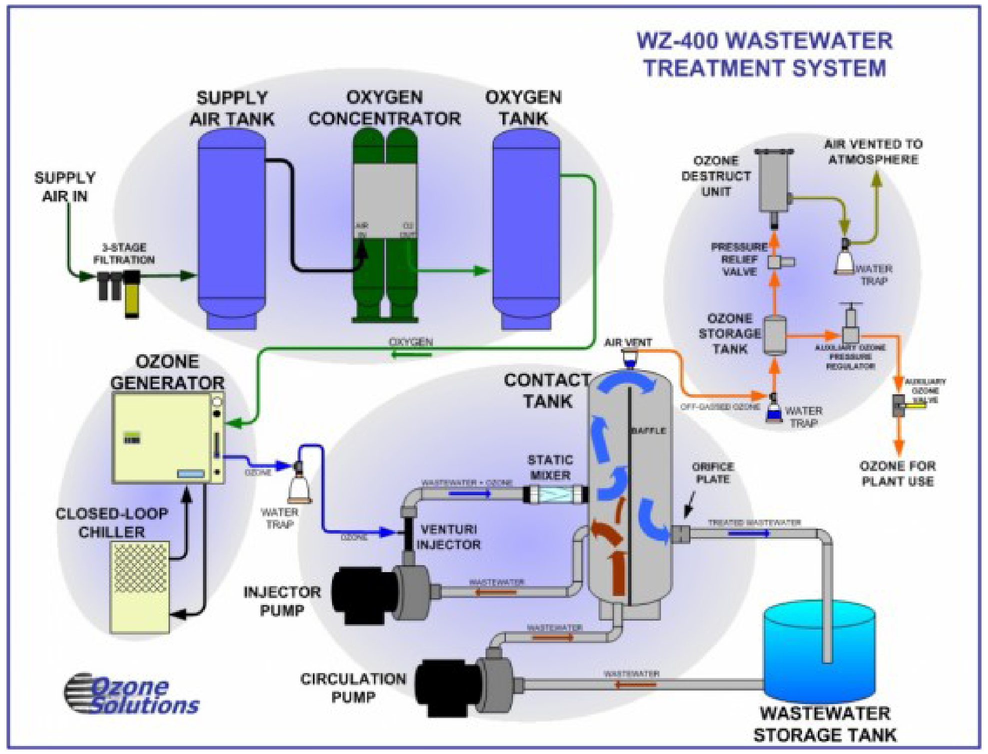

Figure 62: Schematic diagram of ozonation

17.5 Notes for trainer

The aim of the session is to introduce to the participants different treatment principles and the preliminary and primary treatment units involved in wastewater treatment. While delivering the session, use of diagram and videos is recommended to show the working of these treatment units.

The key message is that the treatment technologies such as ASP, SBR, MBBR etc. are used in the secondary stage of treatment (covered in the next session). However, the primary and tertiary treatment more or less remains the same in the centralized STPs.

17.6 Bibliography

- CPHEEO, GoI (2013): Manual on Sewerage and Sewage Treatment Systems, Part A: Engineering, 3rd Edition, Ministry of urban Development, Government of India.
- IWA, (2007): Marcus Von Sperling, Wastewater Characteristics, Treatment & Disposal- volume 1

Session

18

Wastewater treatment technologies

18 Wastewater treatment technologies

18.1 Learning objectives

- To have a detailed understanding of the secondary treatment stage in a wastewater treatment system, its types, and working of each type
- To understand the selection criteria for wastewater treatment technologies

18.2 Session plan

Duration - 45 minutes

Activity	Time	Material/Method
Secondary treatment	5 min	Power point presentation
Non-mechanized treatment system	15 min	Power point presentation
Mechanized treatment system	15 min	Power point presentation
Selection criteria	10 min	Power point presentation

18.3 Key facts

- The secondary treatment stage in a wastewater treatment plant is the heart of the plant. It is the stage which removes most of the pollution load from the wastewater.
- The terminologies pertaining to treatment technologies that are used most commonly in the second stage of the treatment.
- The treatment units can be broadly classified based on degree of mechanization required to treat the wastewater into two categories, (a) non-mechanized treatment systems and (b) mechanized treatment systems.
- The selection of the treatment technologies is based on different criteria; however, the default criteria is that the said technology should be able to meet the discharge standards.

18.4 Learning notes

18.4.1 Non-mechanized treatment system

Anaerobic baffled reactor

Table 31: Anaerobic baffled reactor

Working Principle	Vertical baffles in the tank force the pre-settled wastewater to flow under and over the baffles guaranteeing contact between wastewater and resident sludge and allowing an enhanced anaerobic digestion of suspended and dissolved solids; at least 1 sedimentation chamber and 2–5 up-flow chambers
Capacity/Adequacy	Community (and household) level; For pre-settled domestic or (high-strength) industrial wastewater of narrow COD/BOD ration. Typically integrated in DEWATS systems; Not adapted for areas with high ground-water table or prone to flooding
Performance	70- 95% BOD; 80% - 90% TSS; Low pathogen reduction. HRT: 1 to 3 days
Costs	Generally low-cost; depending on availability of materials and economy of scale
Self-help Compatibility	Requires expert design but can be constructed with locally available material
O&M	Should be checked for water tightness, scum and sludge levels regularly; Sludge needs to be dug out and discharged properly (e.g. in composting or drying bed); needs to be vented
Reliability	High resistance to shock loading and changing temperature, pH or chemical composition of the influent; requires no energy
Main strength	Strong resistance; built from local material; biogas can be recovered
Main weakness	Long start-up phase

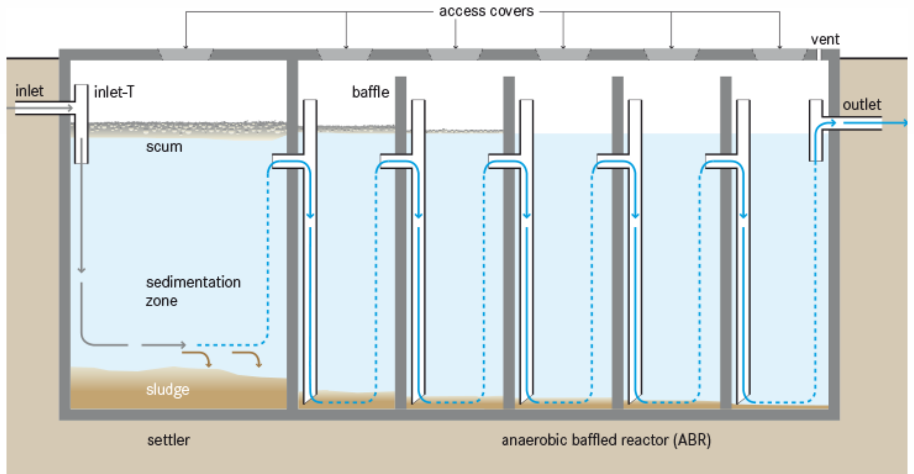

Figure 63: Schematic diagram of anaerobic baffled reactor

Anaerobic filter

Table 32: Anaerobic filter

Working Principle	Dissolved and non-settleable solids are removed by anaerobic digestion through close contact with bacteria attached to the filter media
Capacity/Adequacy	Household and community level; as secondary treatment step after primary treatment in a septic tank or an anaerobic baffled reactor; effluents can be infiltrated into soil or reused for irrigation; not adapted if high ground- water table or in areas prone to flooding.
Performance	BOD: 50 to 90%; TSS: 50 to 80 %; Total Coliforms: 1 to 2 log units. HRT: about 1 day
Costs	Generally low-cost; depending on availability of materials and frequency of back flushing and desludging.
Self-help Compatibility	Requires expert design but can be constructed with locally available material.
O&M	Regularly backflush to prevent clogging (without washing out the biofilm); desludging of the primary settling chambers; needs to be vented if biogas not recovered.
Reliability	Reliable if construction is watertight and influent is primary settled; Generally good resistance to shock loading.
Main strength	Resistant to shock loading; High reduction of BOD and TSS.
Main weakness	Long start-up phase.

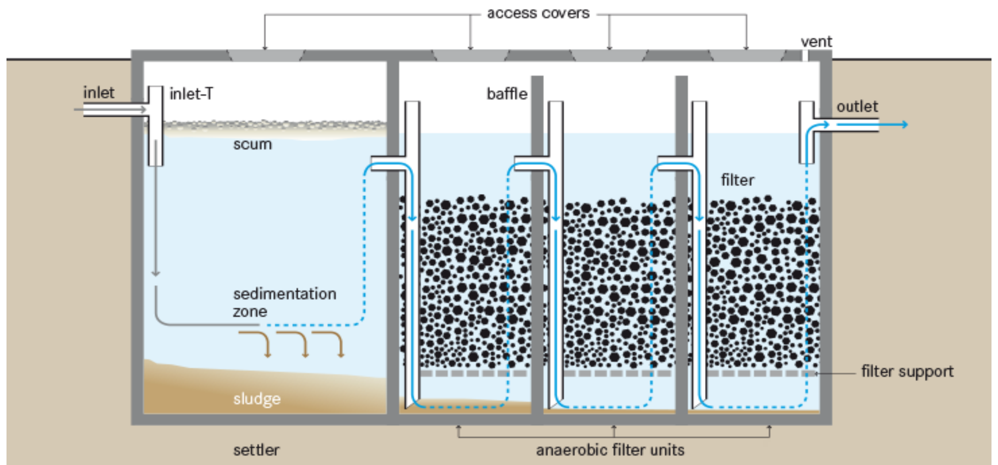

Figure 64: Anaerobic filter

Horizontal-flow constructed wetlands

Table 33: Constructed wetlands- Horizontal flow

Working Principle	Pre-treated grey or blackwater flows continuously and horizontally through a planted filter bed. Plants provide appropriate environments for microbiological attachment, growths and transfer of oxygen to the root zone. Organic matter and suspended solids are removed by filtration and microbiological degradation in aerobic anoxic and anaerobic conditions
Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water
Performance	BOD = 80 to 90 %; TSS = 80 to 95 %; TN = 15 to 40 %; TP = 30 to 45 %; FC ≤ 2 to 3 Log; LAS > 90 %
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/ outlet systems
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose
Main weakness	Permanent space required; risk of clogging if wastewater is not well pre-treated, high quality filter material is not always available and expensive; expertise required for design, construction and monitoring

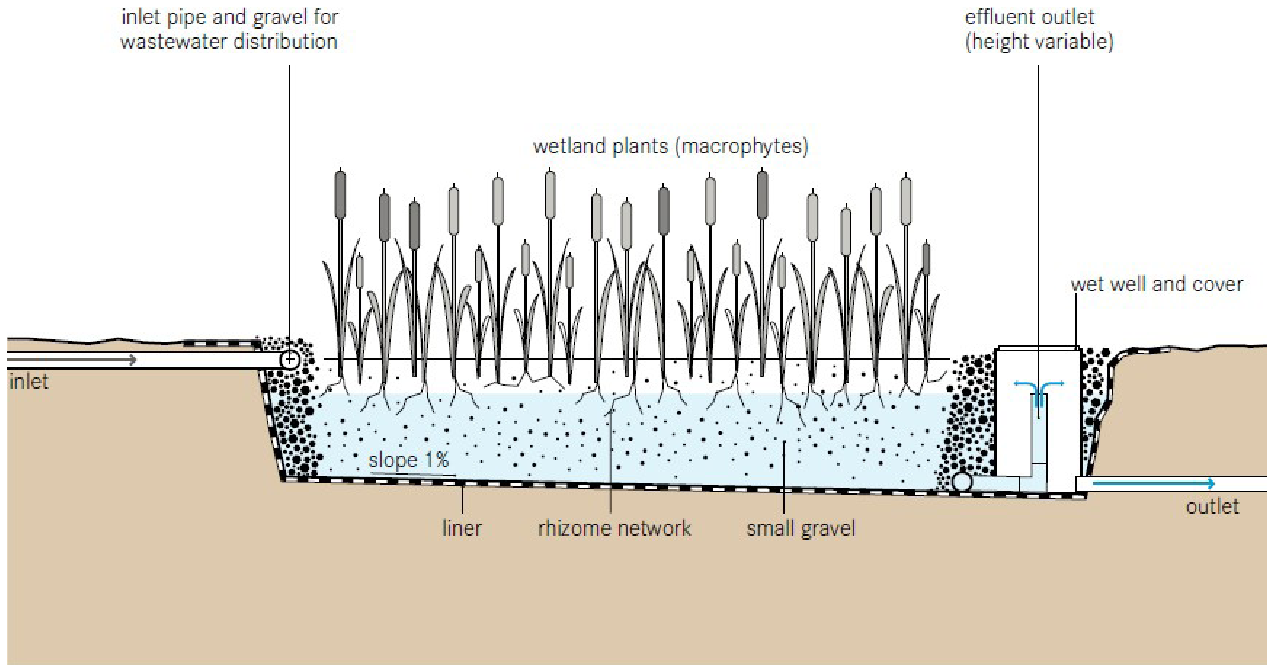

Figure 65: Schematic diagram of horizontal flow constructed wetland

Vertical-flow constructed wetlands

Table 34: Constructed wetlands- Vertical flow

Working Principle	**Pre-treated grey- or blackwater is applied intermittently to a planted filter surface, percolates through the unsaturated filter substrate where physical, biological and chemical processes purify the water. The treated wastewater is collected in a drainage network**
Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water
Performance	BOD = 75 to 90%; TSS = 65 to 85%; TN < 60%; TP < 35%; FC ≤ 2 to 3 log; MBAS ~ 90%
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design. Electricity pumps may be necessary
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose
Main weakness	Even distribution on a filter bed requires a well-functioning pressure distribution with pump or siphon. Uneven distribution causes clogging zones and plug flows with reduced treatment performance; high quality filter material is not always available and expensive; expertise required for design, construction and monitoring

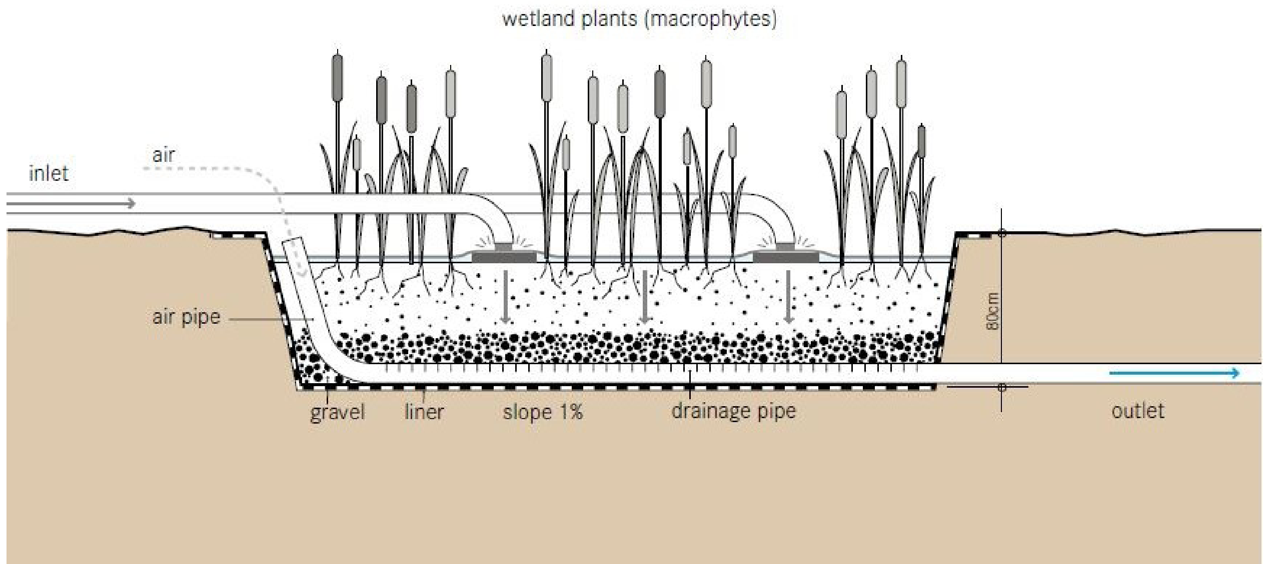

Figure 66: Schematic diagram of vertical flow constructed wetland

Waste stabilization pond

Table 35: Waste stabilization pond

Working Principle	**In a first pond (anaerobic pond), solids and settleable organics settles to the bottom forming a sludge, which is, digested anaerobic by microorganism. In a second pond (facultative pond), algae growing on the surface provide the water with oxygen leading to both anaerobic digestion and aerobic oxidation of the organic pollutants. Due to the algal activity, pH rises leading to inactivation of some pathogens and volatilization of ammonia. The last ponds serve for the retention of stabilized solids and the inactivation of pathogenic microorganisms via heating rise of pH and solar disinfection.**
Capacity/Adequacy	Almost all wastewaters (including heavily loaded industrial wastewater) can be treated, but as higher the organic load, as higher the required surface. In the case of high salt content, the use of the water for irrigation is not recommended
Performance	90% BOD and TSS; high pathogen reduction and relatively high removal of ammonia and phosphorus; Total HRT: 20 to 60 days
Costs	Low capital costs where land prices are low; very low operation costs
Self-help Compatibility	Design must be carried out by expert. Construction can take place by semi- or unskilled labourers. High self-help compatibility concerning maintenance.
O&M	Very simple. Removing vegetation (to prevent BOD increase and mosquito breath) scum and floating vegetation from pond surfaces, keeping inlets and outlets clear, and repairing any embankment damage
Reliability	Reliable if ponds are maintained well, and if temperatures are not too low
Main strength	High efficiency while very simple operation and maintenance
Main weakness	Large surface areas required and needs to be protected to prevent contact with human or animals

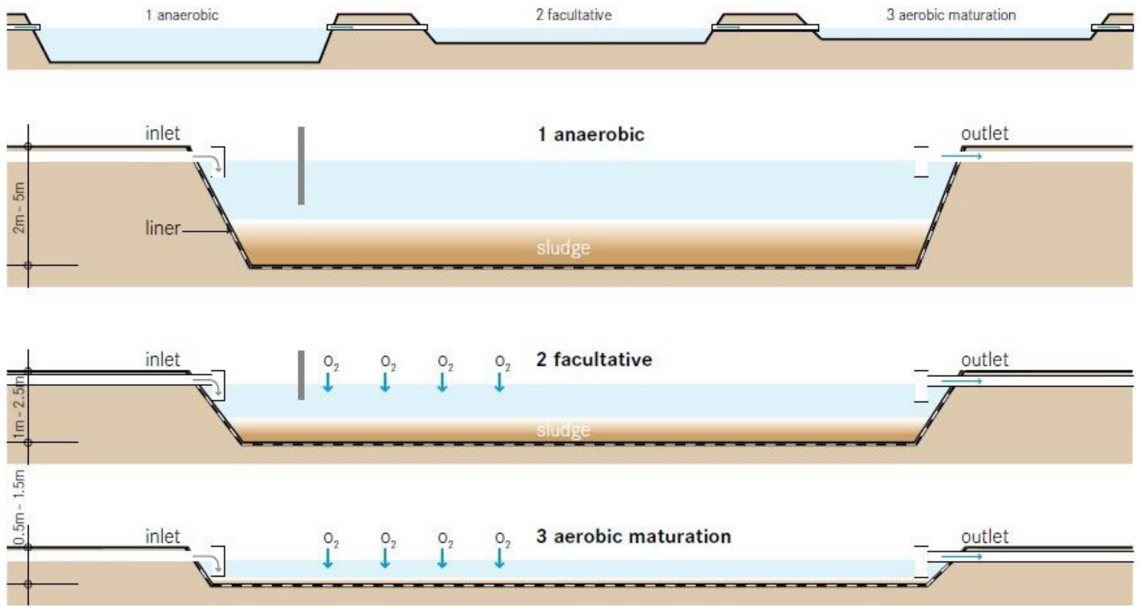

Figure 67: Schematic diagram of waste stabilization pond

Advanced integrated ponds

Table 36: Advanced integrated pond

Working Principle	**In a primary advanced facultative pond (AFP) containing a digester pit on its bottom, solids and organic are trapped and degraded via anaerobic digestion and aerobic degradation. In a high rate alga pond (HRP) BOD is further aerobically degraded and taken up by growing microalgae. In the next step, algae are settled in the algal settling pond (ASP) and can be harvested (and used as fish fodder or fertilizer). A final maturation pond (MP) enhances pathogen abatement**
Capacity/Adequacy	Due to the complexity of the system it is adapted for community or large-scale application, but almost every wastewater can be treated
Performance	90 to 100 % BOD; 90 to 100 % TSS; 60 to 90 % nitrogen; 90 to 100 % ammonia; 60to 100 Phosphorus; 6 log units E. coli
Costs	Compared to the high BOD, TSS and pathogen removal, AIWPS are cost-effective. However, investment costs are high and expert skills for design and construction are required
Self-help Compatibility	Presently, no clear guidelines for the design are available and planning and construction supervision. Operation and maintenance need to be carried out by technical experts; the community may contribute during construction
O&M	Large objects and coarse particles need to be screened; The algal settling pond needs to be desludged once to twice a year. HRPs are sensitive and require skilled maintenance
Reliability	High reliability and good resistance to shock loading
Main strength	High removal efficiency and almost no sludge produced
Main weakness	Not well experienced yet and expert skills required since the system is somehow complicated

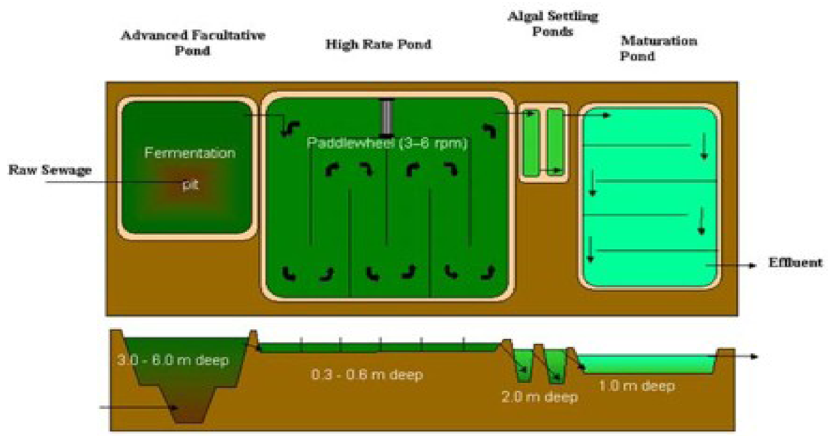

Figure 68: Schematic diagram of advanced integrated pond

18.4.2 Mechanized treatment system

Activated sludge process (ASP)

Aerobic suspended growth systems are of two basic types, those which employ sludge recirculation, viz., conventional activated sludge process and its modifications and those which do not have sludge recycle, viz., aerated lagoons. In both cases, sewage containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the soluble and suspended organic matter. Part of the organic matter is synthesized into new cells and part is oxidized to carbon dioxide and water to derive energy. In activated sludge systems, the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in clarifiers. A part of this activated sludge is recycled to the aeration basin and the remaining form waste or excess sludge. In aerated lagoons, the microbial mass leaves with the effluent stream or may settle down in areas of the aeration basin where mixing is not sufficient.

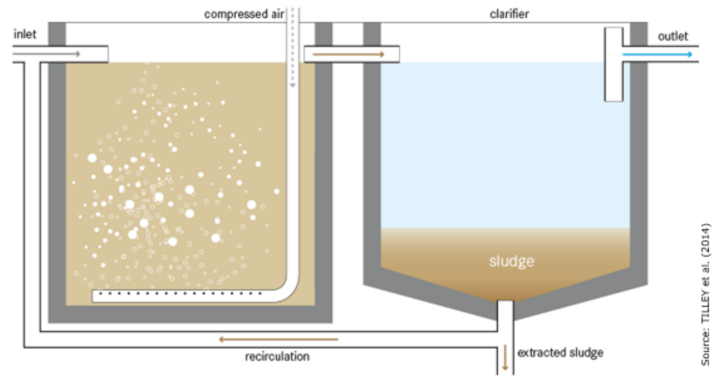

Figure 69: Schematic diagram of activated sludge process

The suspended solids concentration in the aeration tank liquor, also called mixed liquor suspended solids (MLSS), is generally taken as an index of the mass of active micro-organisms in the aeration tank. However, the MLSS will contain not only active micro-organisms but also dead cells along with inert organic matter derived from the raw sewage. The mixed liquor volatile suspended solids (MLVSS) value is also used and is preferable to MLSS as it eliminates the effect of inorganic matter. The conventional system is always preceded by primary settling. The plant itself consists of a primary clarifier, an aeration tank, a secondary clarifier, a sludge return line and an excess sludge waste line leading to a digester. The BOD removal in the process is about 85% to 92%.

UASB Reactor

The Upflow Anaerobic Sludge Blanket Reactor (UASB), maintains a high concentration of biomass through formation of highly settleable microbial aggregates. The sewage flows upwards through a layer of sludge. At the top of the reactor phase, separation between gas-solid-liquid takes place. Any biomass leaving the reaction zone is directly recirculated from the settling zone. The process is suitable for both soluble wastes and those containing particulate matter. The process has been used for treatment of municipal sewage at few locations and hence, limited performance data and experience is available presently.

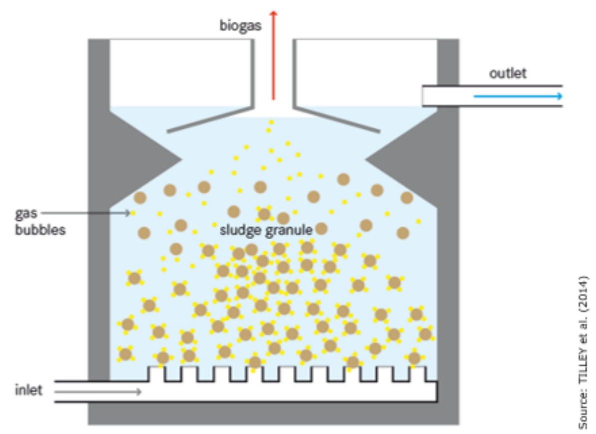

Figure 70: Schematic diagram of upflow anaerobic sludge blanket reactor

Sequencing batch reactor

In its functional process scheme, a Sequencing Batch Reactor (SBR) is the same as the activated sludge process. The only difference is in the activated sludge process, the sewage flows through a primary clarifier, an aeration tank and then through a secondary clarifier continuously. Whereas in the SBR, the aeration and settling are carried out in batch mode one after the other in the same tank. Primary clarifiers do not seem to be provided in a treatment plant based on SBR. Consequently, at least two SBR basins are needed in parallel so that when one is in aeration, the other can be in settling and decanting of the supernatant. In fact, the activated process can be referred to as continuous flow reactor. For this reason, the footprint on like-to-like basis of this type of SBR will be higher.

SBRs are typically configured and operated as multiple parallel basins. It aims to provide process and equipment performance. It can include an instrumental control system that regulates timed sequences for filling, reaction, settling and effluent decanting. All these are referred to as one cycle of process control operation. It is the time duration between successive decanting sequences during which the liquid level moves from a lower water depth (bottom water level) to its fill depth (top water level) and back to its lower water depth (bottom water level). This volume progression takes place in repetitive sequences that permit reactive filling to be followed by solid-liquid separation.

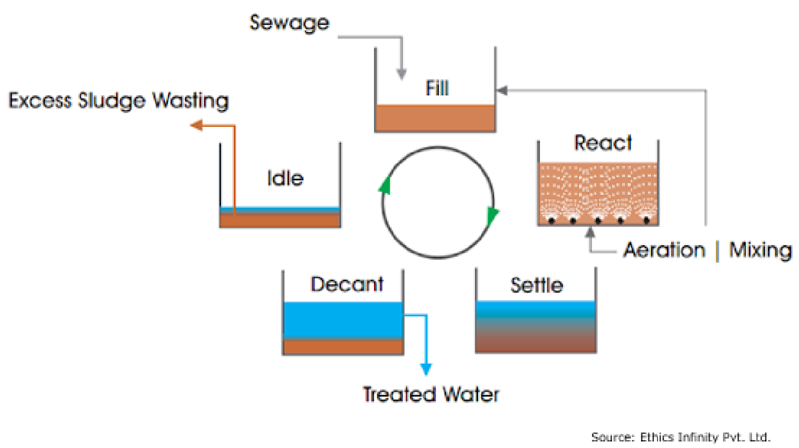

Figure 71: Schematic diagram of sequential batch reactor

Moving bed biofilm reactor

The moving bed biofilm reactor (MBBR) is based on the biofilm carrier elements. Several types of synthetic biofilm carrier elements have been developed. These biofilm carrier elements are floated in the mixed liquor of the aeration tank and are kept floating by the air sparged from the diffusers. The biofilm carriers have a tendency to accumulate at the top zones. Hence, wall mounted mixers propel the media downwards so that they again float and are in circulation throughout the depth of the aeration tank. They are retained by suitably sized sieves at the outlet.

This process is intended to enhance the activated sludge process by providing a greater biomass concentration in the aeration tank. Thus, they also offer the potential to reduce the basin volume requirements. The MBBR system has also been used to improve the volumetric nitrification rates and to accomplish the denitrification in aeration tanks by having anoxic zones within the biofilm depth. Because of the complexity of the process and issues related to understanding the biofilm area and activity, the processes design is empirical. There are now more than 10 different variations of the processes in which

a biofilm carrier material of various types, is suspended in the aeration tank of the activated sludge process. There are many examples of such activated sludge treatment process with suspended biofilm carrier in the world.

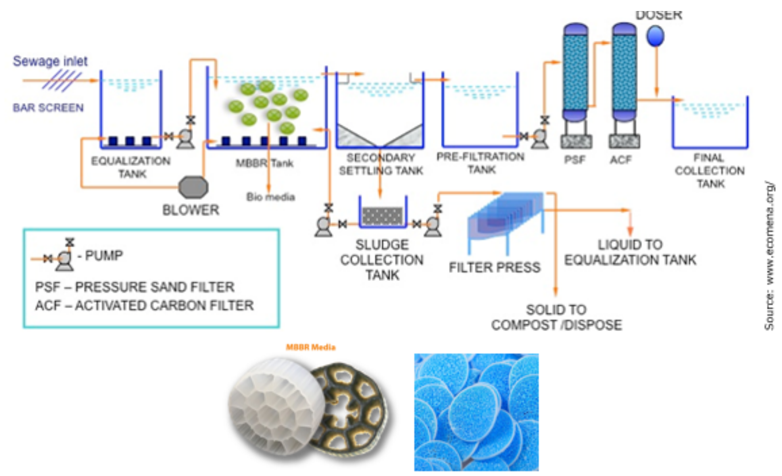

Figure 72: Schematic diagram of moving bed biofilm reactor (MBBR)

Membrane bio-reactor

The membrane bioreactor (MBR) process is a combination of activated sludge process and membrane separation process. Low pressure membranes (ultrafiltration or microfiltration) are commonly used. Membranes can be submerged in the biological reactor or located in a separate stage or compartment and are used for solid-liquid separation instead of the usual settling process. Primary sedimentation tank, final sedimentation tank and disinfection facilities are not installed in this process. The reaction tanks comprises of an anoxic tank and an aerobic tank, and the membrane modules are immersed in the aerobic tank. Pre-treated, screened influent enters the membrane bioreactor, where biodegradation takes place. The mixed liquor is withdrawn by water head difference or suction pump through membrane modules in a reaction tank, being filtered and separated into biosolids and liquid. Surfaces of the membrane are continuously washed down during operation by the mixed flow of air and liquid generated by air diffusers installed at the bottom of the reaction tank. The permeate from the membranes is the treated effluent.

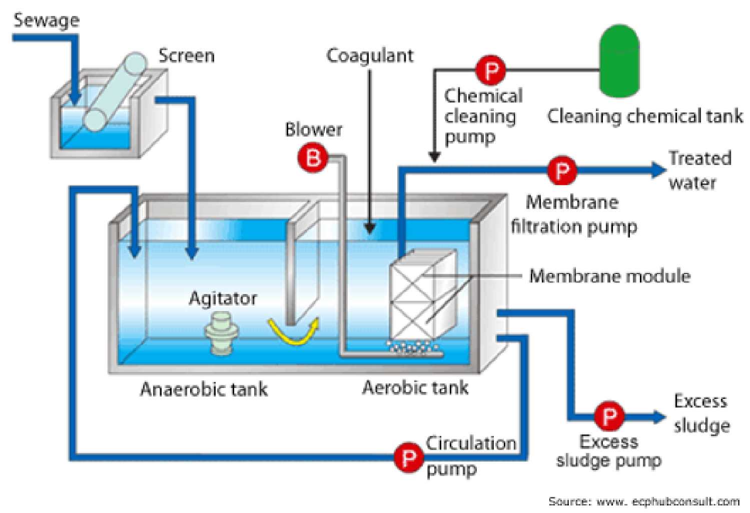

Figure 73: Schematic diagram of membrane bioreactor (MBR)

18.5 Notes for trainer

The aim of the session is to introduce the participants to various secondary treatment technologies available in the market. Use of audio-visual aids is recommended while explaining the functioning of the technologies. Applicability of the technologies depending on the different scenarios should be explained. Emphasis should be given on the illustrating the choice of technology through suitable examples.

18.6 Bibliography

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Session

19

Case studies

Case studies

19.1 Learning objectives

- In this session, participants will be introduced to different case studies of STPs and FSTPs of India and gather key takeaway messages
- Gather information regarding the components and treatment units adopted in STPs and FSTPs in India

19.2 Session plan

Duration - 30 minutes

Activity	Time	Material/Method
Sewage treatment plants	15 min	Power point presentation
Faecal sludge treatment plants	15 min	Power point presentation

19.3 Sewage treatment plants

19.3.1 East Kolkata Wetlands

The wetland is largely man-made, comprising inter-tidal marshes, with significant wastewater treatment areas like sewage farms, settling ponds, oxidation basins. These wetlands have been successfully managed by the local fishermen and fisherwomen for the past 100 years. East Calcutta Wetlands has been designated as a Ramsar Site in November 2002. Wetlands in West Bengal constitute about 31% of the total freshwater resources. Back in the day when the city began to grow faster, the British authorities started to engineer an advance drainage system. In 1860, a health officer of the Calcutta corporation started sewage farm & in 1930, regulated proportions of sewage water began to be used for fisheries. The nutrients present in the wastewater is used for aquaculture. The wastewater is also used for plantation & livestock farming.

These wetlands spread over 125 square kilometers are the shock absorbers for all life activities of the Kolkata city. It is a unique example of a man-made and man-managed wetland that includes salt marshes, salt meadows, sewage farms and settling ponds and wherein untreated sewage of the city is utilized extensively for fish culture.Wastewater passes through a water hyacinth tank where some amount of heavy metals and suspended solids may be absorbed from the wastewater before this water is allowed to enter the fish ponds. This process is called rhizofiltration. Here, the plant roots act as bio-curtains or bio-filters for the passive remediation of wastewater.

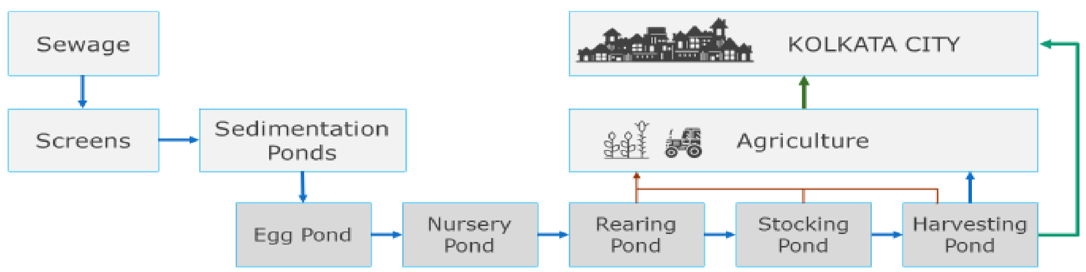

Figure 74: Illustrative diagram of the East Kolkata wetlands

The wetlands are managed by the community of local fisherman who also earn their living through this ecosystem. East Kolkata wetlands is a perfect example of ecological sanitation wherein the water loop as well as the nutrient loop is closed by integrating a high value product such as fishes.

19.3.2 Sewage treatment plant - Bhandewadi, Nagpur

This STP is designed & commissioned by SMS Ltd. This unique, state-of-the-art, fully automated & one of the largest sewage reuse plants in India is spread over 12.5 acres which takes in 130 MLD of sewage water from Nag river in Nagpur. The entire process is automated and monitored through the operating team located in the administrative building of the plant premises. It is the nerve centre of the project & houses state-of-the-art equipment and control panels. An electrical 33 KV indoor sub-station houses the control mechanisms. The entire facility is powered by 5000 kilowatts of energy as regulated by a powerhouse in the premises.

Water from the Nag river is brought to the facility through pipeline into the intake structure where floating material up to sizes of 6 mm is removed by fine screens. The water then passes through the mechanical detritus tank which removes the sand & grit from sewage water. After preliminary cleaning, the water is sent to primary clarifiers for partial removal of BOD & TSS. This is done by adding alum as a coagulant at the Parshall flume. HRT of 30 min. is considered at the primary clarifiers for settling purpose. After passing through the primary clarifier, the sewage overflows through the launder and through. An underground duct passes to the sea-tech basin for secondary treatment. The water flows to 8 sea-tech basins for aerobic digestion of biological impurities in presence of oxygen supplied through air blowers operated round-the-clock.

The water is now subjected to sequential filling & aeration, sedimentation & decanting mode for secondary cleaning. The decanted water now passes through the chlorine contact tank for addition of chlorine to treated water for treatment of balanced bacteria. The water after processing with chlorine is passed to a sump before reaching the tertiary treatment plant. Using 8 vertical turbine pumps in tertiary treatment, water is passed through a multi-bed media filter comprising of anthracite sand & pebbles for final cleaning to achieve the desired parameters. The treated water is then transferred to the thermal power station.

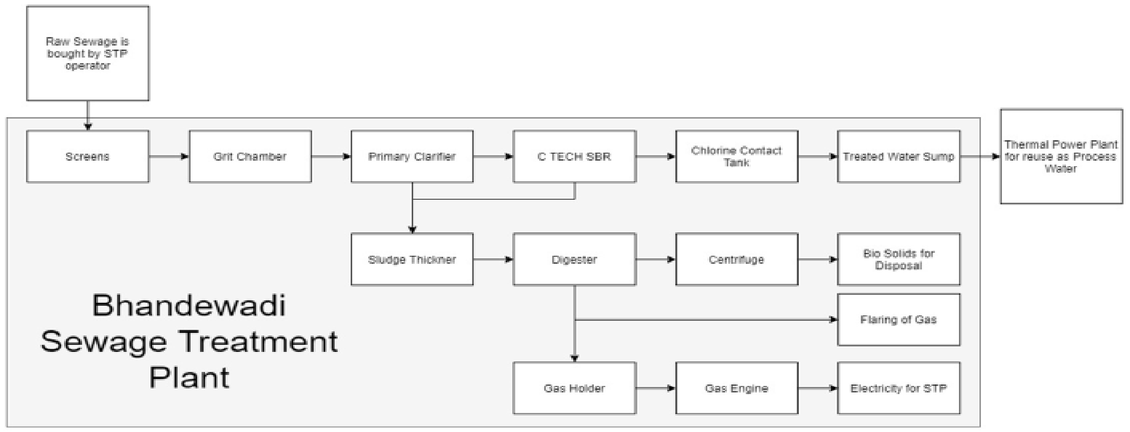

Figure 75: Sewage Treatment Plant at Bhandewadi, Nagpur

This case study shows that the planning process needs to be started from the last point i.e. reuse of the treated wastewater. In this case, the choice of technology and the integration of various treatment units was done in order to meet the standards of water to be used at the thermal power plant. Also, the integration of anaerobic digester which generates methane gas plays a crucial role in lowering the operation costs of the plant. The system seems to be complex, but with right aim and objectives, integration of the units becomes easy. If the whole system is designed well, the operation and maintenance can also be simplified.

19.3.3 Decentralized wastewater treatment system - CoEP, Pune

The College of Engineering, Pune is one of the most popular education institute in Maharashtra. It has a large campus that is divided into four parts, two of which belong to the academic section, one is the hostel campus, and the last is the sports campus. The following picture shows the layout of the college.

Figure 76: Layout of College of Engineering, Pune

The hostel campus caters to 2000 persons consisting of students and staff who reside there during the academic year. There are ten students block out of which 7 are reserved for males and 3 are for females.

The details of the water and wastewater at the hostel campus are given in the picture below:

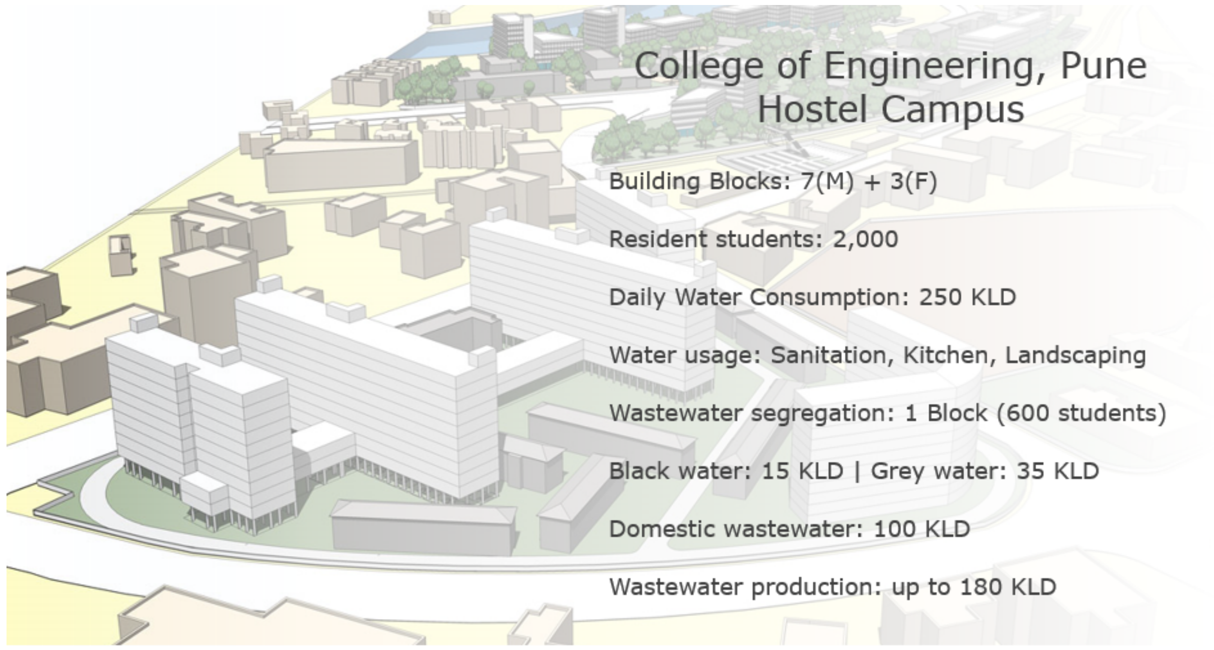

Figure 77: Details of the water consumption and wastewater generation at the CoEP hostel campus, Pune

There are three system installed to manage the different kinds of wastewater generated at the campus.

System A caters to the blackwater generated from the 3 hostel blocks of girls where black and grey water segregation has been done. System consists of anaerobic treatment system consisting of anaerobic settler, anaerobic baffled reactor and anaerobic up flow filter. The secondary treated water is discharged into the sewer.

System B caters to the grey water produced in these blocks. This system consists of grease trap followed by vertical flow constructed wetland. The secondary treated water is further treated using sand filter and UV. The reclaimed water is then used for landscaping and toilet flushing in one of the hostel blocks.

System C caters to the rest of the seven blocks where segregation is not possible and hence wastewater is generated. The wastewater is first treated in an anaerobic treatment system consisting of settler, baffled reactor and upflow filter. The anaerobically treated water is further treated aerobically in vertical flow wetlands. The secondary treated water is further clarified using charcoal and sand filter. Final disinfection is provided using UV lamp. The treated water is mostly used for toilet flushing and landscaping purpose all around the campus.

The details of the three systems are given in the picture below. The key take-away message from this case study is that integrating the natural wastewater treatment systems in the urban landscape is key to reducing the water footprint of the residential apartments. It can also prove to be an important way in providing treated water right at the point of generation and at a cheaper cost.

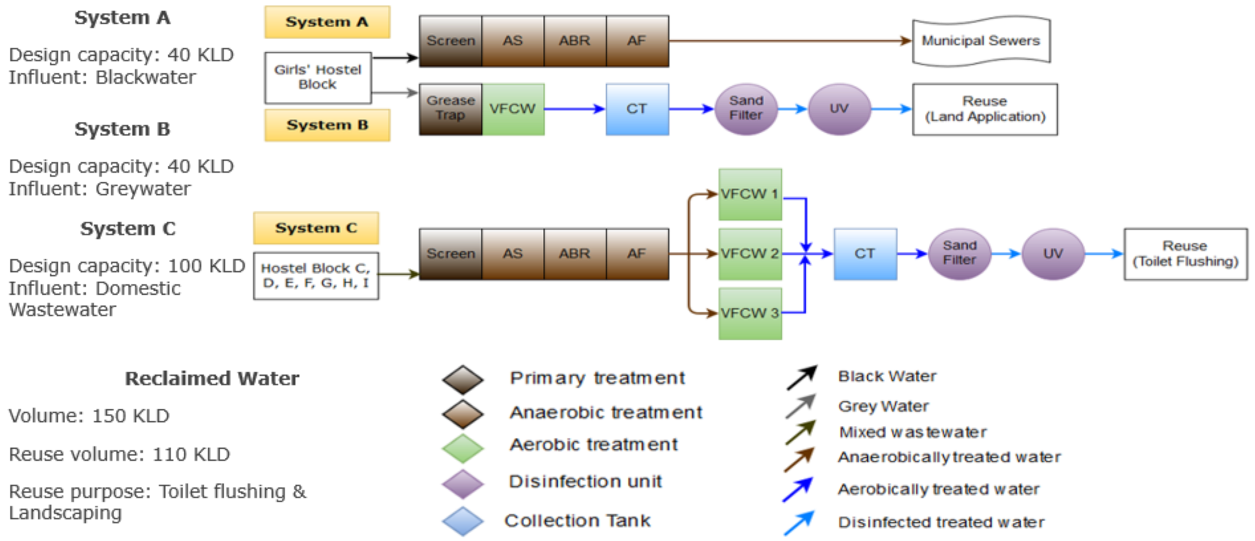

Figure 78: Decentralized wastewater treatment system, CoEP Hostel Campus

19.4 Faecal sludge and septage treatment plants

19.4.1 Co-treatment facility, Puri

A Septage Treatment Plant (SeTP) having the capacity of 50 KLD (Kilo Litre per Day) was constructed by OWSSB (Odisha Water Supply and Sewerage Board) in 2017. The plant was constructed under the AMRUT (Atal Mission for Rejuvenation and Urban Transformation) scheme and is one of its kind in the nation as it uses the co-treatment technology for the treatment of septage. The settling-cum-thickener tank of SeTP allows heavier particles of the unloaded septage to settle down at the bottom of tank while the lighter part of septage (i.e. water & oil) floats at the top surface. The settled solids (sludge) get thickened in the settling-cum-thickener tank and are removed by pumping at regular intervals. By pumping the settled solids to the sludge drying bed, the removal of moisture content from biosolids is achieved. The leachate from sludge drying bed is collected in a leachate sump which is pumped to the pre-treatment unit of Sewage Treatment Plant (STP) which is located near to the SeTP, for further treatment and disposal.

The municipality have 6 number of cesspool vehicles out of which 4 were procured by the OWSSB and handed over to ULB while the other 2 were procured by the ULB. The 4 newly procured vehicle are of 3000 L capacity and have been handed over to the professional agency under the contract.

Details of FSTP: 50 KLD Capacity
Details of STP: 15 MLD, Present flow: 12 MLD, Technology: Aerated Lagoon

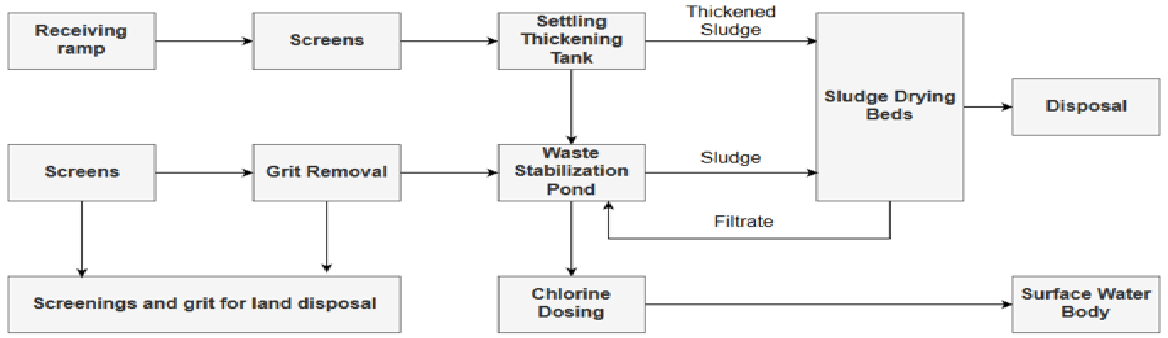

Figure 79: Treatment Flow chart - Co-treatment facility, Puri

19.4.2 Septage treatment plant - Bhubaneshwar

The city of Bhubaneshwar is planning for sewered sanitation system. However, until the sewerage network and STP is developed, the Odisha Water Supply and Sewerage Board (OWSSB) installed a SeTP with the design capacity of 75 KLD. The treatment chain is elaborated in figure given below. The plant treats the solids and liquid completely and has been designed as a zero liquid discharge plant. The bio-solids are reused for plantation within the premises and the liquid is also completely utilised in and around the plant to maintain the green spaces.

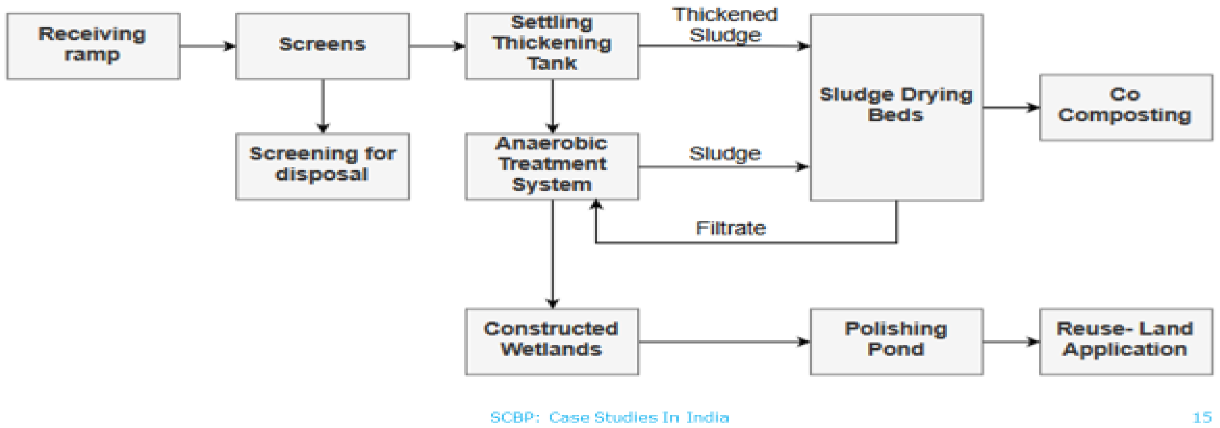

Figure 80: SeTP Treatment Flowchart, Bhubaneshwar

At the receiving ramp, the septage is emptied into the screen chamber, which segregates the solid waste from the septage. The septage then flows into the settling thickening tank (STT), where the solid-liquid separation occurs and the sludge undergoes thickening process. The thickened sludge is then pumped to the sludge drying beds for further dewatering and drying. The dried solids are further co-composted with the organic waste (dry waste from the lawn and plants in the SeTP premise). The liquid from the STT flows under gravity to the anaerobic treatment (anaerobic settler, anaerobic baffled reactor and anaerobic up flow filter) followed by aerobic treatment through the constructed wetlands. Finally, the clarified water comes to the polishing pond where it is disinfected and kept aerated using cascade aeration setup.

19.4.3 Faecal sludge and septage treatment plant - Wai

Wai Municipal Council (WMC) has setup a pyrolysis technology based faecal sludge treatment facility. It has a capacity of 70 KLD spread over 19,602 sq.ft. area. The system comprises of grit removal, pasteurization, solid-liquid separation, dryer, pyrolizer, heat exchanger and dewatered effluent treatment system. These different subsystems integrated together form a complete plant that can process faecal sludge into biochar. The counter flow heat exchanger recuperates the heat generated from pyrolysis and is reused back within the system. No external heat source is required thus enabling sustained operations. The system is equipped with online temperature monitoring systems optimizing the energy consumption and ensuring the required conditions pasteurization to occur. The biochar and pasteurized liquid are the by-products from the process.

In Wai, septic tanks at the household-level are emptied by a private contractor (Sumeet Facilities Pvt. Ltd.), and septic tanks of community and public toilets are emptied by WMC's vacuum tankers. The collected faecal sludge and septage is then taken to the treatment facility.

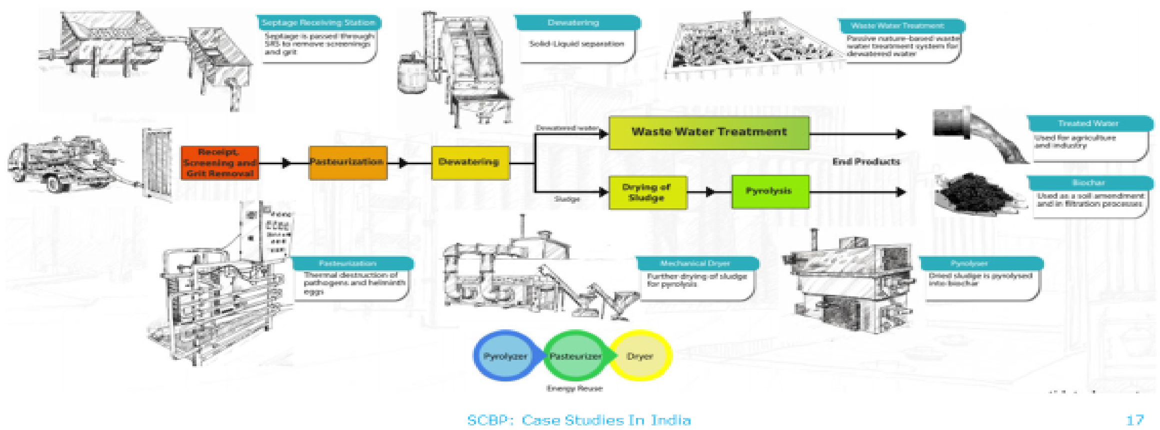

Figure 81: Faecal Sludge and Septage Treatment Facility Flow Chart, Wai

Pyrolyzation of septage with a limited oxygen supply destroys all pathogens present in excreta, and provides fast volume and mass reduction, a net energy output (heat and electricity) and a usable end product in the form of biochar. Biochar provides excellent soil enrichment when used with compost. The treated liquid from the treatment plant is used for landscaping within the premise and for washing vacuum tankers and solid waste collection vehicles.

19.5 Notes for trainer

The aim of the session is to introduce the participants to various case studies of sewage treatment systems and FSS treatment systems in India. Use of audio-visual aids is recommended while explaining the cases in India and its treatment approach.

19.6 Bibliography

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- NaWaTech - Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India. https://sswm.info/perspective/nawatech

Notes:

Notes:

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About SCBP

The Sanitation Capacity Building Platform (SCBP) is an initiative of the National Institute of Urban Affairs (NIUA) to address urban sanitation challenges in India. SCBP, supported by Bill & Melinda Gates Foundation (BMGF) is an organic and growing collaboration of credible national and international organisations, universities, training centres, resource centres, non-governmental organisations, academia, consultants and experts. SCBP supports national urban sanitation missions, states and ULBs, by developing and sourcing the best capacity building, policy guidance, technological, institutional, financial and behaviour change advise for FSSM. SCBP provides a unique opportunity for:

- Sharing and cross learning among the partner organisations, to pool in their knowledge resources on all aspects of urban sanitation capacity building;
- Developing training modules, learning and advocacy material including key messages and content, assessment reports and collating knowledge products on FSSM. Through its website (scbp.niua.org), SCBP is striving to create a resource centre on learning and advocacy materials, relevant government reports, policy documents and case studies;
- Dissemination of FSSM research, advocacy and outreach to State governments and ULBs.

Its strength is its ability to bring together partners to contribute towards developing state sanitation policy, training of trainers and training content development, technical and social assessments, training programme delivery, research and documentation.

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Integrated Wastewater and Septage Management- Planning Module

Part B: Learning Notes