# INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT DESIGN MODULE

## PART B: LEARNING NOTES

National Institute of Urban Affairs

ECOSAN SERVICES FOUNDATION

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## 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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## DISCLAIMER



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# INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT DESIGN MODULE

## PART B: LEARNING NOTES

**Collaborative Effort Under Training Module Review Committee (TMRC)**

National Institute of Urban Affairs

NFSSM Alliance

ecosan SERVICES FOUNDATION

# 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 28 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 to regulatory and institutional frameworks across the sanitation value chain. The NFSSM Alliance working in collaboration with the Ministry of Housing and Urban Affairs has been instrumental in the passage of India's First Policy on FSSM launched in 2017. This resulted in 19 out of 36 states adopting guidelines and policies for FSSM 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 pilots
3. Building Capacities of key stakeholders across the value chain

The collaborative effort 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 Alliance partners. TMRC which is a**nchored by National Institute of Urban Affairs (NIUA)**, has the following broad objectives:

- Identification of priority stakeholders and accordingly training modules for Capacity Building
- Development of a Normative Framework – For Capacity Building at State Level
- Standardization of priority training modules – appropriate standardization of content with flexibility for customization based on State context
- Quality Control of Trainings – 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 - Design Module |
| Purpose | The Government of India has made sanitation its priority through the launch of Swachh Bharat Mission. SBM-U 2.0 goes beyond eliminating open defecation in cities, to focus on planning sanitation systems at city-level, through integrated wastewater and septage management targeted at recycle and reuse.<br><br>Further, the recently announced Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) lays emphasis on creating a circular economy of water by ensuring treatment and reuse of wastewater and faecal sludge. This Module provides participants a holistic understanding of designing of wastewater and septage management solutions, to address the above mentioned priorities under these national missions. |
| Target Audience | Officials with engineering background and professional experience in wastewater and septage management such as technical faculties from nodal training institutes, technical officials/ engineers from state govt, parastatal bodies and ULBs; consultants from TSU/ PMUs and sector partners. |
| Learning Objective | 1. Understand priorities under various national urban missions for wastewater and septage management to address aspects of circular economy.<br>2. Gain in-depth knowledge about sanitation systems and to understand the concept and principles of citywide inclusive sanitation.<br>3. Get hands-on experience in designing wastewater and septage treatment solutions.<br>4. To leverage various funding avenues and understand contracting mechanisms at city level.<br>5. Comprehend the aspects of IWSM, such as O&M and sustainability, occupational safety, public awareness and participation. |
| Structure of the Module | The training is based on Case Method and includes an exercise which will enable the participants to improve analytical skills required to develop wastewater and septage management plans. It also includes a financial modelling tool which helps to calculate Life Cycle Cost of the project using different approaches of waste management.<br><br>Case studies to demonstrate the learning from the module will be showcased through expert's lecture and handouts. This helps to trainee to apply the knowledge grasped during the session and reinforce it further. |
| Duration | In a face-to-face training format, this training is conceptualized for two days without site visits and can be adopted for including the site visits depending upon the city where it is being conducted. |

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## ABBREVIATIONS

| | |
|---|---|
| ABR | Anaerobic Baffled Reactor |
| AMRUT | Atal Mission for Rejuvenation and Urban Transformation |
| CAPEX | Capital Expenditure |
| CPHEEO | Central Public Health and Environmental Engineering Organisation |
| CSO | Combined Sewer Overflows |
| CSP | City Sanitation Plan |
| CSZ | Core Sanitation Zone |
| CW | Constructed Wetlands |
| CWIS | City Wide Inclusive Sanitation |
| CWWIS | City Waste-Water Infrastructure Status |
| DPR | Detailed Project Report |
| DTS | Decentralised Treatment System |
| DWF | Dry Weather Flow |
| DWATS | Decentralised Wastewater Treatment System |
| ESF | Ecosan Services Foundation |
| FSS | Faecal Sludge and Septage |
| FSSM | Faecal Sludge and Septage Management |
| FSTP | Faecal sludge and Septage Treatment Plant |
| RS/GIS | Remote Sensing/Geographic Information System |

| | |
|---|---|
| IHHT | Individual Household Toilet |
| I&D | Interception and Diversion |
| IWSM | Integrated Wastewater and Septage Management |
| LCCA | Life-Cycle Cost Analysis |
| MBBR | Moving Bed Bio Reactor |
| MoHUA | Ministry of Housing and Urban Affairs |
| NIUA | National Institute of Urban Affairs |
| NMCG | National Mission for Clean Ganga |
| O&M | Operation & Maintenance |
| OPEX | Operational Expenditure |
| SBM (U) | Swachh Bharat Mission (Urban) |
| SRT | Solid Retention Time |
| STP | Sewage Treatment Plant |
| SCBP | Sanitation Capacity Building Program |
| UASB | Up-flow Anaerobic Sludge Blanket Reactor |
| ULB | Urban Local Body |
| VCW | Vertical Constructed Wetlands |
| WWM | Wastewater Management |
| WHO | World Health Organisation |
| WSP | Waste Stabilization ponds |

## 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 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 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. |



| | |
|---|---|
| Flush water | The water is 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 flush water 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). |

## INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT (IWSM)

## Advanced Training Module

## AGENDA

| Time Duration (Hours) | Session Title |
|---|---|
| **Day 1** | |
| 9.30 - 10.00 | Registration |
| 10.00 - 10.30 | Introduction, Setting ground rules, Understanding Expectation, Aims and Objectives of the training |
| 10.30 - 11.15 | Introduction to Integrated Wastewater and Septage Management |
| 11.15 - 11.30 | **Tea & Coffee Break** |
| 11.30 - 12.15 | Missions and Programs - Journey of Urban Sanitation in India |
| 12.15 - 12.30 | Swachh Bharat Mission 2.0 |
| 12.30 - 13.15 | Planning Approaches for IWSM |
| 13.15 - 14.00 | **Lunch Break** |
| 14.00 - 14.45 | Baseline Surveys and Assessment |
| 14.45 - 15.15 | Exercise: Data Collection |
| 15.15 - 16.00 | Design Aspects |
| 16.00 - 16.15 | **Tea & Coffee Break** |
| 16.15 - 16.45 | Exercise: Population Projection |
| 16.45 - 17.00 | Wrap up |

| Time Duration (Hours) | Session Title |
|---|---|
| **Day 2** | |
| 9.30 - 10. 15 | Recap, Feedback & Quiz |
| 10.15 - 11.00 | Collection & Conveyance System |
| 11.00 - 11.30 | Exercise: CapEx and OpEx of collection and conveyance system |
| 11.30 - 11.45 | **Tea & Coffee Break** |
| 11.45 - 12.30 | Wastewater Treatment |
| 12.30 - 13.00 | Exercise: CapEx and OpEx of wastewater treatment |
| 13.00 - 14.00 | **Lunch Break** |
| 14.00 - 15.00 | Project Management |
| 15.00 - 15.45 | Exercise: Financial Modelling |
| 15.45 - 16.00 | **Tea & Coffee Break** |
| 16.00 - 16.45 | O&M & Sustainability |
| 16.45 - 17.30 | Feedback and Wrap-up |

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Session

01

# Introduction to Integrated Wastewater & Septage Management

# 1. Introduction to Integrated Wastewater & Septage Management

## 1.1 Learning objectives

- To understand the basics of environmental sanitation and the concept of natural and built environment
- To understand the sources of water pollution: point & non-point pollution source
- To understand the waste products and their characteristics

## 1.2 Session plan

Duration - 45 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Environmental Sanitation | 10 min | Powerpoint presentation |
| Natural & Built Environment | 5 min | Powerpoint presentation |
| Sources of Water Pollution | 5 min | Powerpoint presentation |
| Waste product & its characteristics | 15 min | Powerpoint presentation |
| Q&A | 10 min | Discussion |

## 1.3 Key facts

- Many people worldwide still lack access to adequate & hygienic water, sanitation, drainage, and solid waste management due to inadequate environmental sanitation.
- Cities with good planning and trained officials will be able to handle the challenge of changing demographic and rapid urbanization taking place in the cities.

## 1.4 Learning notes

### 1.4.1 Environmental Sanitation

Sanitation means the safe management of human excreta through a toilet that confines faeces until they are digested or flushed away into a sewer for offsite treatment. In its fullest sense, sanitation also includes environmental and personal cleanliness, solid waste, and wastewater management. It therefore includes both the hardware (e.g., latrines and sewers) and the software (regulation, hygiene promotion) needed to reduce faecal-oral disease transmission. It encompasses the potential reuse or safe disposal of waste products generated. Interventions to reduce public exposure to disease by providing a clean environment to live in, with measures to break the cycle of disease is known as environmental sanitation.

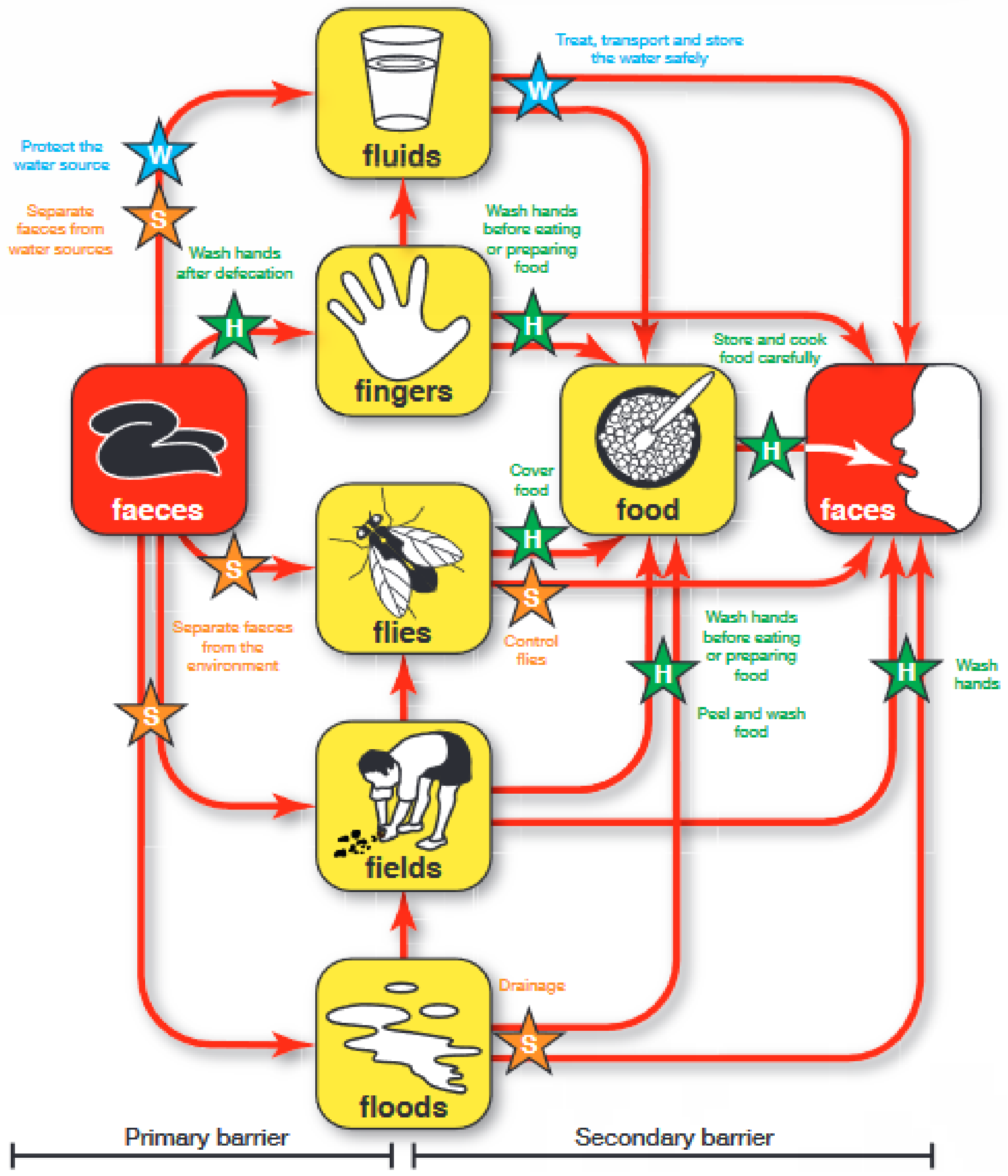


Figure 1: F-diagram

*Source: WEDC,2020*

The movement of pathogens from the faeces of a sick person to where they are ingested by somebody else can take many pathways, some direct and some indirect. The F Diagram illustrates the main pathways. They are easily memorized as they all begin with the letter 'f': fluids (drinking water), flies, fields (crops and soil), floors, fingers and floods (and surface water generally). Barriers can stop disease transmission; these can be primary (preventing the initial contact with the faeces) or secondary (preventing it from being ingested by a new person). They can be controlled by water, sanitation and hygiene interventions.

**Components of Environmental Sanitation-**

**Wastewater/Faecal Sludge & Septage Management:** In developing countries, large amounts of excreta and faecal sludge is managed by on-site sanitation facilities where private or public flush toilets are connected to septic tanks. As opposed to developed countries, where excreta is managed via cistern-water flush toilets, city-wide sewerage systems and central wastewater treatment plants, are widespread technologies in industrialised countries but unaffordable or inappropriate in developing countries.

The faecal sludge and septage collected from on-site containment units are often disposed of in an uncontrolled manner without prior treatment, thus posing severe health risks and polluting the environment. If treatment facilities are available in larger cities, haulage distances or the time required for transport due to traffic congestion may be prohibitive for efficient sludge emptying services.

**Solid Waste Management:** Collection, transport, recycling, treatment, and safe disposal are crucial elements in solid waste management. Decentralised approaches, such as solving problems as close to the source of waste generation as possible, are considered promising approaches to reduce the waste stream. Enabling a wide variety of enterprises (small local enterprises, informal sector), neighbourhood or community-based organisations and NGOs to engage in waste management as well as involving all stakeholders in planning and decision-making are considered key issues contributing to improvements.

**Disease Vector Control:** Environmental management seeks to change the environment in order to prevent or minimize vector propagation and human contact with the vector-pathogen by destroying, altering, removing or recycling non-essential containers that provide larval habitats.

**Infrastructure for Hygiene Practices:** To provide quality care, hygiene facilities need to have a safe and accessible water supply; clean and safe sanitation facilities; hand hygiene facilities at points of care and at toilets; and appropriate waste disposal systems. Infrastructure that supports water, sanitation, hygiene (WASH) helps prevent the spread of diseases within the healthcare facility and to the surrounding community. Without appropriate WASH infrastructure and services, communities are at increased risk of diseases.

**Behaviour & Habit:** Specifically, regarding WASH, there are still many developing nations in the world that don't exercise positive behaviours & habits towards safe hygiene and sanitation practices. For awareness regarding positive approaches, every citizen has to inculcate such habits & behavioural practices in themselves for protecting environmental health and sanitation.

### 1.4.3 Natural & Built Environment

The natural environment encompasses all living and non-living things occurring naturally. This environment encompasses the interaction of all living species, climate, weather and natural resources that affect human survival and economic activity. The concept of the natural environment can be distinguished as components:

- Complete ecological units that function as natural systems without massive civilized human intervention, including all vegetation, microorganisms, soil, rocks, atmosphere, and natural phenomena within their boundaries and nature.
- Universal natural resources and physical phenomena lack clear-cut boundaries, such as air, water, climate, energy, radiation, electric charge, and magnetism, not originating from civilized human actions.

The term-built environment refers to the human-made environment that provides the setting for human activity, including homes, buildings, zoning, streets, sidewalks, open spaces, transportation options, and more. It is defined as "the human-made space in which people live, work and recreate on a day-to-day basis".

The built environment also includes how communities have approached environmental issues that have arisen as a result of such altering of the environment for human activities amongst those of plants and animals. The built environment is made up of physical features.

### 1.4.3 Sources of Water Pollution

In point-source pollution, the pollutants reach the water body in points concentrated in space. Usually, the discharge of domestic and industrial wastewater generates point-source pollution since the discharges are through outfalls. In diffuse pollution, the pollutants enter the water body distributed at various locations along its length. This is the typical case of storm water drainage, either in rural areas (no pipelines) or in urban areas (storm water collection system, with multiple discharges into the water body).

**Table 1: Pollutants, their source & their effects**

| Sr No. | Pollutant | Parameters | Effects of pollutant |
|---|---|---|---|
| 1 | Suspended solids | Total suspended solids | • Aesthetic problems<br>• Sludge deposits<br>• Pollutant's adsorption<br>• Protection of pathogen |
| 2 | Biodegradable organic matter | Biological oxygen demand | • Oxygen consumption<br>• Death of fish<br>• Septic conditions |
| 3 | Nutrients | Nitrogen, Phosphorous | • Excessive algae growth<br>• Toxicity to fish (ammonia)<br>• Illnesses in new-born infants (nitrate)<br>• Pollution of groundwater |
| 4 | Pathogens | Coliforms | • Water-borne diseases |
| 5 | Non-biodegradable organic matter | Pesticides, Detergents | • Toxicity (various)<br>• Foam (detergents)<br>• Reduction of oxygen transfer (detergents)<br>• Non-biodegradability<br>• Bad odours (e.g., phenols) |
| 6 | Metals | Specific elements (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) | • Toxicity<br>• Inhibition of biological sewage treatment<br>• Problems in agriculture use of sludge<br>• Contamination of groundwater |
| 7 | Inorganic dissolved solids | Total dissolved solids, Conductivity | • Excessive salinity – harm to plantations (irrigation)<br>• Toxicity to plants (some ions)<br>• Problems with soil permeability (sodium) |

### 1.4.4 Waste Products & Characteristics

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 are 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.



The different sanitation systems generate the following products:

- Blackwater is the mixture of urine, faeces 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 faeces or water
- Brown water is blackwater without urine
- Excreta is the mixture of urine and faeces 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 systems such as septic tanks 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 aerobic treatment of domestic wastewater at the sewage treatment plant.
- Storm water 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.

**Characteristics of the waste are determined using following parameters:**

**Solids:** All the contaminants of water, with the exception of dissolved gases, contribute to the solids load. In wastewater treatment, the solids can be classified according to: (a) their size and state, (b) their chemical characteristics and (c) their settleability.

The division of solids by size is above all a practical division. For convention it can be said that particles of smaller dimensions capable of passing through a filter paper of a specific size correspond to the dissolved solids, while those with larger dimensions and retained by the filter are considered suspended solids.

If the solids are submitted to a high temperature (550  C), the organic fraction is oxidised (volatilised), leaving after combustion only the inert fraction (unoxidized). The volatile solids represent an estimate of the organic matter in the solids, while the non-volatile solids (fixed) represent the inorganic or mineral matter.

Settleable solids are considered those that are able to settle in a period of 1 hour. The volume of solids accumulated in the bottom of a recipient called an Imhoff Cone is measured and expressed as mL/L. The fraction that does not settle represents the non-settleable solids.

**Organic Constituents:** The organic matter present in sewage is a characteristic of substantial importance, being the cause of one of the main water pollution problems: consumption of dissolved oxygen by the microorganisms in their metabolic processes of using and stabilising the organic matter. The organic substances present in sewage consist mainly of protein compounds, carbohydrates, oils and grease and urea, surfactants, phenols, pesticides and others.

*BOD*- The main ecological effect of organic pollution in a water body is the decrease in the level of dissolved oxygen. Similarly, in sewage treatment using aerobic processes, the adequate supply of oxygen is essential, so that the metabolic processes of the microorganisms can lead to the stabilisation of the organic matter. The BOD represents the quantity of oxygen required to stabilise, through biochemical processes, the carbonaceous organic matter.

*COD*- The COD measures the consumption of oxygen occurring as a result of the chemical oxidation of the organic matter. The COD/BOD5 ratio also varies as the wastewater passes along the various units of the treatment works.

#### Nutrients

Nitrogen- Nitrogen is an essential nutrient for algae leading, under certain conditions, to the phenomenon of eutrophication of lakes and reservoirs. It is an essential nutrient for the microorganisms responsible for sewage treatment. The determination of the prevailing form of nitrogen in a water body can indicate the stage of pollution caused by an upstream sewage discharge. If the pollution is recent, nitrogen is basically in the form of organic nitrogen or ammonia and, if not recent, in the form of nitrate (nitrite concentrations are normally low).

- Total Kjeldahl Nitrogen = Ammonia + organic nitrogen (prevailing form in domestic sewage)
- TN = TKN + NO2 + NO3 (total nitrogen)

Phosphorus- Total phosphorus in domestic sewage is present in the form of phosphates. Phosphorus is an essential nutrient for the growth of the microorganisms responsible for the stabilisation of organic matter. Usually, domestic sewage has sufficient levels of phosphorus, but a lack may occur in some industrial wastewaters. It is an essential nutrient for the growth of algae, eventually leading, under certain conditions, to the eutrophication of lakes and reservoirs.

#### Pathogens

The biological quality of water or wastewater is related to disease transmission by pathogenic organisms. The major groups of pathogenic organisms are bacteria, viruses, protozoans and helminths. The indicators of faecal contamination are total coliforms & faecal coliforms.

The group of total coliforms (TC) constitutes a large group of bacteria that have been isolated in water samples and in polluted and non-polluted soils and plants, as well as from faeces from humans and other warm-blooded animals. The total coliforms could be understood in a simplified way as “environmental” coliforms, given their possible occurrence in non-contaminated water and soils, thus representing other free-living organisms, not only the intestinal ones. For this reason, total coliforms should not be used as indicators of faecal contamination in surface waters. However, in the specific case of potable water supply, it is expected that treated water should not contain total coliforms. These, if found, could suggest inadequate treatment, post contamination or excess of nutrients in the treated water.

Faecal coliforms are a group of bacteria predominantly originated from the intestinal tract of humans and other animals. Escherichia coli is the main bacterium of the faecal coliform group, being present in large numbers in the faeces from humans and animals. It is found in wastewater, treated effluents and natural waters and soils.



## 1.5 Notes for trainer

This session acts as an introduction for understanding the overall environmental sanitation and various wastewater and septage characteristics. This session will make participants understand the concept of natural & built environment, point source & non-point source.

## 1.6 Bibliography


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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 of India related to sanitation
- To understand the SBM 2.0 & Atal Mission for Rejuvenation and Urban Transformation 2.0 programs

### 2.2 Session Plan

Duration- 45 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Growing Recognition of FSSM | 10 min | Powerpoint presentation |
| Swachh Bharat Mission 2.0 | 5 min | Powerpoint presentation |
| Atal Mission for Rejuvenation and Urban Transformation 2.0 | 10 min | Powerpoint presentation |
| Policies & Guidelines | 10 min | Powerpoint presentation |
| Q&A | 10 min | Discussion |

### 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 (SBM). 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 sector 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 robust 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
- Bioremediation of all legacy dumpsites

### 2.4.3 AMRUT 2.0

AMRUT 2.0 has been designed to provide universal coverage of water supply to all households through functional taps in all 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 a circular economy of water through development of a 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 mechanisms. 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 a 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, electric vehicle charging points; Wi-fi infrastructure in new buildings; unlocking value and improving land use efficiency through adequate urban planning; GIS based master plans of the cities; raising funds through the issuance of municipal bonds and rejuvenation of water bodies.

Salient features of the mission:

- The total outlay proposed for AMRUT 2.0 is ₹2,77,000 crore which includes ₹10,000 crores for continuing financial support to AMRUT Mission.
- In order to promote Public Private Partnership (PPP), 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 with 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 the Government for projects will be in three tranches of 20:40:40. Third instalment 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, stormwater 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 groundwater.
- 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 systems 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. The Central Government will give financial support to the extent of ₹48,000 crores over 5 years i.e. on an average ₹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 the 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 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 and septage 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)
- AMRUT 2.0 - Operational Guidelines (2021), Ministry of Housing and Urban Affairs (MoHUA)
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT) (2015), Ministry of Housing and Urban Affairs (MoHUA), 2021
- SMART Cities Mission Guidelines, Ministry of Housing and Urban Affairs (MoHUA), 2015

Session

# 03

# Swachh Bharat Mission 2.0

# 3. Swachh Bharat Mission 2.0

## 3.1 Learning Objectives

- To understand the guidelines of Swachh Bharat Mission 2.0
- To understand the checklist for the preparation of City Wastewater Infrastructure Status (CWWIS)

## 3.2 Session Plan

Duration - 30 minutes

| Topics | Time | Material/Method |
|---|---|---|
| SBM 2.0: Objectives for WWM | 5 min | Powerpoint presentation |
| Proposed strategy | 5 min | Powerpoint presentation |
| Components | 5 min | Powerpoint presentation |
| Proposed Approach | 5 min | Powerpoint presentation |
| City Wastewater Infrastructure Status | 5 min | Powerpoint presentation |
| Q&A | 5 min | Discussion |

## 3.3 Key facts

- Swachh Bharat Mission Urban 2.0 mainly focuses on wastewater and faecal sludge management
- SBM-U 2.0 is the crucial program which covers ODF++ and Water+ status of the ULBs
- SBM-U 2.0 has the initial step of City Wastewater Infrastructure Status followed by the detailed project reports at the city level.

## 3.4 Learning notes

### 3.4.1 Swachh Bharat Mission 2.0

Swachh Bharat Mission (SBM) was launched in 2014 to eliminate open defecation and improve solid waste management. The first phase aimed to achieve 100% ODF status for Urban and Rural areas by 2nd Oct 2019. The objectives of the first phase of the mission also included eradication of manual scavenging, generating awareness and bringing about a behaviour change regarding sanitation practices, and augmentation of capacity at the local level. The second phase of the mission (SBM 2.0) aims to sustain the open defecation free status and improve the management of solid and liquid waste. The mission aims to progress towards target 6.2 of the Sustainable Development Goals (SDGs) established by the United Nations in 2015.

In continuation to SBM (U), the Ministry of Housing and Urban Affairs launched SBM (U) 2.0 in 2021 with a focus on complete faecal sludge management, wastewater treatment, source segregation of garbage, reduction in single use plastic, reduction in air pollution by effectively managing waste from construction and demolition activities, and bioremediation of all legacy dumpsites.

Under the Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0), the following objectives are targeted to be achieved:

a) Sustainable Sanitation and treatment of Wastewater
- Holistic Sanitation
- Eradication of hazardous entry into sewers and septic tanks and sustaining elimination of manual scavenging
- Treatment of wastewater before discharge into water bodies and maximum reuse of wastewater

b) Sustainable Solid Waste Management
- Ensuring cleanliness and hygiene in public places
- Air pollution arising out of SWM activities brought under notified norms of CPCB
- Phased reduction in use of single-use plastic

c) Awareness creation along with large scale citizen outreach to create 'Jan Andolan'
d) Creating Institutional capacity

Under SBM 2.0 envisioned the following outcomes 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
- Bioremediation of all legacy dumpsites.

### 3.4.2 Proposed Strategy for Wastewater Management

ULBs are encouraged to identify its "Core Sanitation Zone (CSZ)" for providing sewer network, which should have at least 50% of the town's current population settled over an area comprising about 20-30% of the town's spread. In the next step, suitable sites for sewage treatment plants (STP) will be identified in the vicinity of the CSZ. The STPs need to cater for 50% of the design population (Design year-2052) or 70% of the current population.

For inhabitants residing outside the CSZ (in fringe areas), the town authorities must work out economically judicious solutions, opting between continuing with onsite disposal systems (septic tanks followed by soak pits) or providing localized community level sewage treatment plants. The septage from these households should continue to be safely hauled to a designated STP under professional arrangements. It is advised that the fringe areas may try to strengthen their onsite disposal arrangements by making soak fields or drain fields were missing and forcing the septic tank effluent into the ground adhering to design norms. Only some concentrated fringe pockets with a population of more than 10000 should opt for STP (Roughly 1 MLD caters for 10000 users). For smaller quantity flow (< 1 MLD), it is usually better to collect the sewage and pump it down to the larger plant catering to the CSZ.

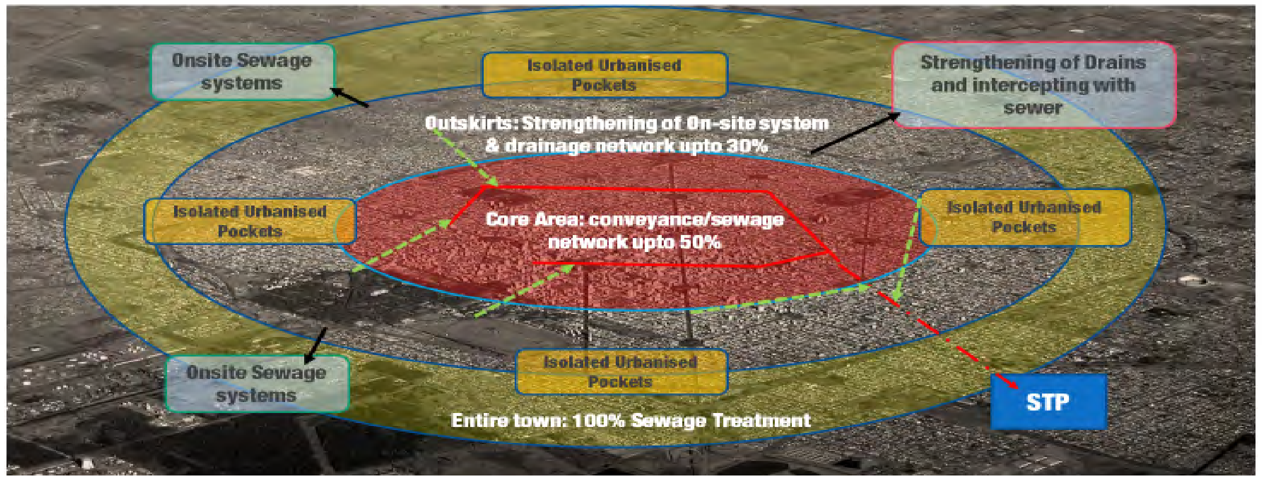



**Figure 2: Representation of liquid waste management strategy under SBM-U 2.0**
*(Source: SBM 2.0 Guidelines, 2021)*

**Management of Flow of Sewage in Urban Drains:** Urban drains of various sizes, dimensions and construction material form the tertiary, secondary and primary tributaries discharging into the natural water bodies. During dry weather (when it is not raining), almost the entire flow in urban drains consists of raw sewage from toilets not connected to a sanitary disposal system, partially treated effluent from existing septic tanks and other onsite management systems where soak pits are not provided or are blocked. The discharge finds its way into surface drains ,or in many cases across India, the sullage (all wastewater except the latrine discharge) is illegally allowed to be discharged into the drains. As an interim arrangement, till sewers are laid or in periphery of core area of town (about 30% area in periphery of core area) where providing sewerage system is uneconomical, strengthening of drainage networks to be taken up simultaneously by ULBs and intercepted in core area sewer network wherever feasible, to efficiently convey sewage/ sullage to STP in the town.

In outer fringe areas (approx. 20%), on-site systems like septic tanks and soak pits are provided by individual households. if the sewage discharging households are unable to provide space to construct soak pits or the ground condition does not permit such a structure, the municipal authorities may collect the discharge of up to 50-60 HHs (300 persons or so) and may provide a community level soak pit on suitable municipal owned open space in vicinity of such an area.

If no such suitable municipal owned space is available in vicinity of the discharging households and the untreated/ partially treated wastewater continues to be discharged in surface drains, ULBs need to develop a suitable **Interception and Diversion (I&D) Plan leading to STP.**

All tertiary and secondary drains will be provided with bar screens to trap floating debris, as per the following norm:
- Drain up to 6 Sqft cross-section – at every 500 metres
- Drain above 6 Sqft cross-section- as per the local engineer's assessment

ULBs will also need to repair all surface drains to maintain continuity so that the discharge is not dissipated through a breach or overflow. As far as is economical, the pucca drains of up to 3ft width must be covered with RCC slabs to provide covered conveyance and check entering of solid waste into such drains.

As per the analysis of the dry weather discharge flowing in the drains, the ULB will intercept the drains at suitable locations so that at least 50% of the current sewage pollutant load in the drains of the town is suitably tapped into I&D Sewers to divert the captured flow into the STP. Pumping arrangements are permitted if necessary; however, gravity sewers are preferred.

### 3.4.3 Components Covered for Funding

Under SBM (U) 2.0, the following wastewater management components are covered for funding:

- Setting up of Sewage Treatment Plants (STPs/ WWTPs)
- Laying the Interceptor and Diversion (I&D) structures including provision of pumping stations and pumping main/gravity main up to STP.
- Procuring septic tank desludging and onsite dewatering equipment.
- Deploying Digital (IT enabled) tools for online systems monitoring.

### 3.4.4 Proposed Approach for Wastewater Management

Under SBM-U 2.0, ULBs have to follow the wastewater management approach as shown in the following representation at the city level. As a first step, ULB will be required to update the City Sanitation Plan (CSP) for the town; if already available and if not available, the same needs to be immediately prepared. CSP must contain a gap analysis in sewage management and prospective projects to be taken up under SBM 2.0 along with its prioritization. The tentative block cost estimate (adopting thumb rule) for components like STP, sewer networks, pumping stations and I&D etc. to be prepared with suitable zoning.

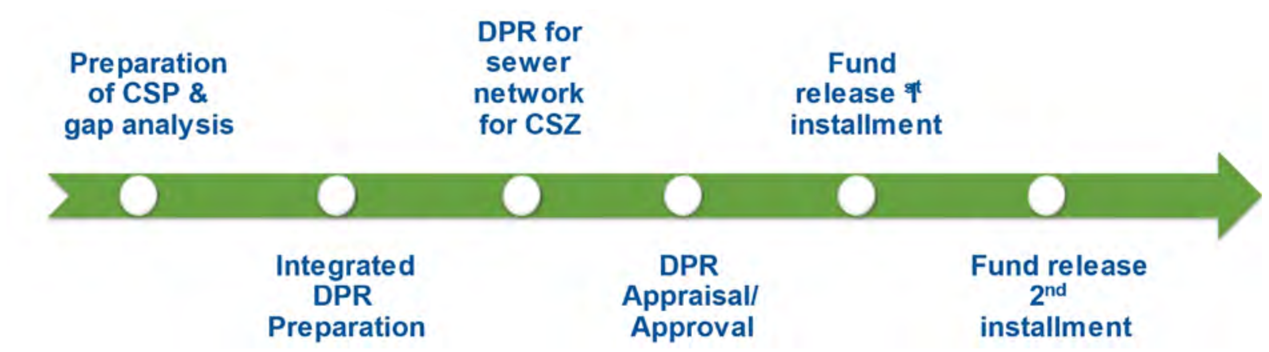



Figure 3: Proposed Approach for the Wastewater Management under SBM-U 2.0

In the next step, State/ULB will be required to prepare a Detailed Project Report (DPR), as per those identified in CSP, following the CPHEEO Manual on Sewerage & Sewage Treatment. ULBs also need to prepare a detailed project report for the sewer network for CSZ, and they have to take approval of both DPRs for fund sanctioning.

### 3.4.5 City Wastewater Infrastructure Status (CWWIS)

ULBs need to understand the current wastewater infrastructure situation and assess the gaps in it. ULBs also need to assess the existing policy on sewage treatment and conveyance networks such as sewer network and existing STP cum FSTP planning and implementation scenario at city level.



As per the SBM 2.0 guidelines, ULBs have to check the city wastewater infrastructure status and upload the details on the SBM Urban website integrated MIS through official login. ULBs have to collect and upload data such as city profile, off-site sanitation infrastructure, on-site sanitation infrastructure and existing interception and diversion infrastructure. There is a section wise checklist given on the MIS platform which ULBs have to upload in a certain deadline given by the central government.

## 3.5 Notes for Trainer

This session showcases details about the SBM-U 2.0 program and its guidelines. The guidelines mainly focus on the aspects covered under the program, i.e. sanitation and wastewater management at city level. Trainer needs to understand the recent amendments about the program and need to share with the participants.

## 3.6 Bibliography


- Swachh Bharat Mission (Urban) 2.0 Guidelines (2021), Ministry of Housing and Urban Affairs (MoHUA)

Session

# 04

# Planning Approach

# 4 Planning Approach

## 4.1 Learning Objectives

- To understand concept of Citywide Inclusive Sanitation (CWIS), role of CWIS in sanitation systems and planning principles of CWIS
- To understand revised City Sanitation Plan (CSP) as per new SBM 2.0 guidelines and data required to make city sanitation plan.
- To understand the centralized and decentralized approach of a city to manage wastewater.
- To get in-depth knowledge about the Sanitation System and its approach in the city for safe collection and disposal of wastewater generated.
- To get idea about various stages in preparation of Detailed Project Report of a city under SBM 2.0

## 4.2 Session Plan

Duration - 45 minutes

| Topics | Time | Material/Method |
|---|---|---|
| City Wide Inclusive Sanitation | 5 min | Powerpoint presentation |
| City Sanitation Plan | 5 min | Powerpoint presentation |
| Wastewater Management Approaches | 5 min | Powerpoint presentation |
| Sanitation Systems Approach | 5 min | Powerpoint presentation |
| Sewered Sanitation | 10 min | Powerpoint presentation |
| Stages in DPR preparation | 5 min | Powerpoint presentation |
| Q&A | 10 min | Discussion |

## 4.3 Key facts

- CWIS approach emphasizes on the whole sanitation service chain for a 'safe management' of human waste.
- Centralized and decentralized approach for the city sanitation zone depends on the local condition and viability of the same shall be carried out in CSP and/or DPR.
- Conveyance infrastructure is complex and CapEx and OpEx intensive. Hence, its viability shall be checked in detail.
- Detailed Project Report of a city under SBM 2.0 includes data collection, surveys, treatment options, designs and financial aspects.

## 4.4 Learning notes

### 4.4.1 City Wide Inclusive Sanitation

Citywide inclusive sanitation (CWIS) emphasis that everybody 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 onsite and sewerage solutions are combined, in either centralized or decentralized systems, to better respond to the realities found in developing country cities. Cities need to develop comprehensive approaches to sanitation improvement that encompass long-term planning, technical innovation, institutional reforms and financial mobilization.

Citywide inclusive sanitation requires collaboration between many actors, including: national, sub-national and city/municipal governments; utilities and municipal service providers; business and the private sector; civil society, local and international NGOs; donors, bilateral and multilateral agencies and private foundations; as well as academia and, importantly, households themselves. Each city is organized in uniquely. Local actors need to acknowledge shared responsibilities and work collaboratively to chart their path to providing urban sanitation to all.

***Poor Sanitation leads to stunted economic growth***

There are seven principles of CWIS that help in achieving objectives of safe and proper sanitation systems in the city.

- Everyone in an urban area, including the urban poor, benefits from equitable, safe sanitation services
- Gender and social equity are designed into planning, management, monitoring
- Human waste is safely managed along the sanitation services chain, starting with containment
- Authorities operate with a clear, inclusive mandate, performance targets, resources and accountability
- Authorities deploy a range of funding, business and hardware approaches – sewered/non-sewered to meet goals
- Long term planning demand for innovation and is informed by analysis of needs/resources
- Political will and accountability systems incentivize service improvements in planning, capacity and leadership

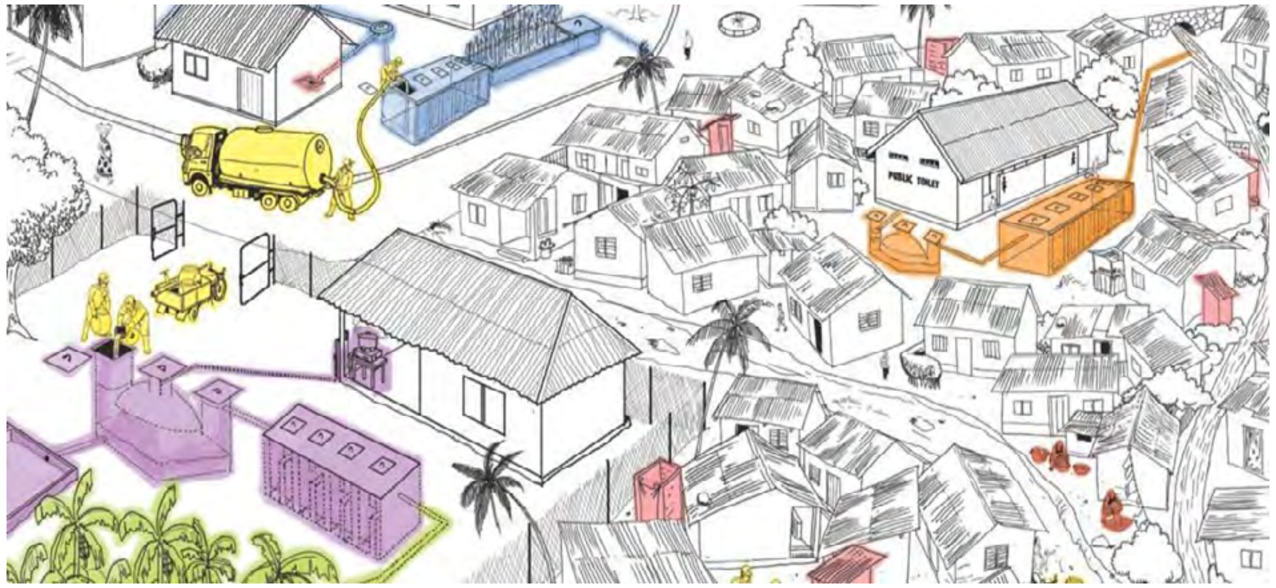


**Figure 4: Citywide Inclusive Sanitation (CWIS)**

*Source: Sanitation Action Plan, BORDA South Asia, 2020*

The four CWIS building blocks are:

- Prioritization of the right of all to sanitation, with inclusive strategies reaching informal settlements and vulnerable populations, especially women and children.
- Delivery of "safe management" along the entire sanitation service chain by focusing on service outcomes rather than technologies and embracing innovation and incrementalism.



- Recognition of the role played by sanitation to a thriving urban economy by integrating into urban planning, reforming regulatory policies, and embracing resource recovery and reuse.
- Commitment to working in partnership across sectors and stakeholders to make progress through transparent 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 evolving 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. To be able to implement CWIS, one needs to understand sanitation systems and its components.

### 4.4.2 City Sanitation Plan

The City Sanitation Plan is a comprehensive document which describes the short, medium and long term measures for the issues related to governance, technical, financial, capacity enhancement, awareness raising and pro-poor interventions to achieve the goal of NUSP to create community driven, totally sanitised, healthy and liveable cities and towns.

The City Sanitation Plan's purpose is to support Urban Local Bodies (ULB) and NGOs, CBOs, citizens and private sector agencies to take concrete steps to achieve 100% sanitation in their respective cities. Although each city should prepare a framework adapted to its needs and local situation, the following figure depicts the process that should be followed when planning, implementing and evaluating a City Sanitation Plan.

As indicated in the previous chapter, ULB will be required to update the City- Sanitation Plan (CSP) for the town; if already available and if not available, the same needs to be immediately prepared. The CSP is expected to contain the information on Sewage Management. CSP must contain a gap analysis in sewage management and prospective projects to be taken up under SBM 2.0. The below data needs to be collected to make CSP for city.

**Table 2: City Level Data Collection**

| Description | Activities |
|---|---|
| Baseline Information | • Details of the city – Maps, locations etc.<br>• Demography – Census data & growth<br>• Land use pattern – Population settings |
| Technical Information – Sanitation Facilities | • Access to toilets – IHHT, CT, PT<br>• Existing Sewage Infrastructure – STPs, Drains, sewers etc.<br>• Sewage Management |
| Institutional & Governance | • Regulatory Framework<br>• Institutional Arrangement<br>• Governance & Reforms |
| Capacity Enhancement | • Human Resource Development |
| Gap Analysis & Conclusion | • I&D & STP cum FSTP<br>• Sewer network<br>• Storm water drainage system<br>• Recycle & reuse projects |

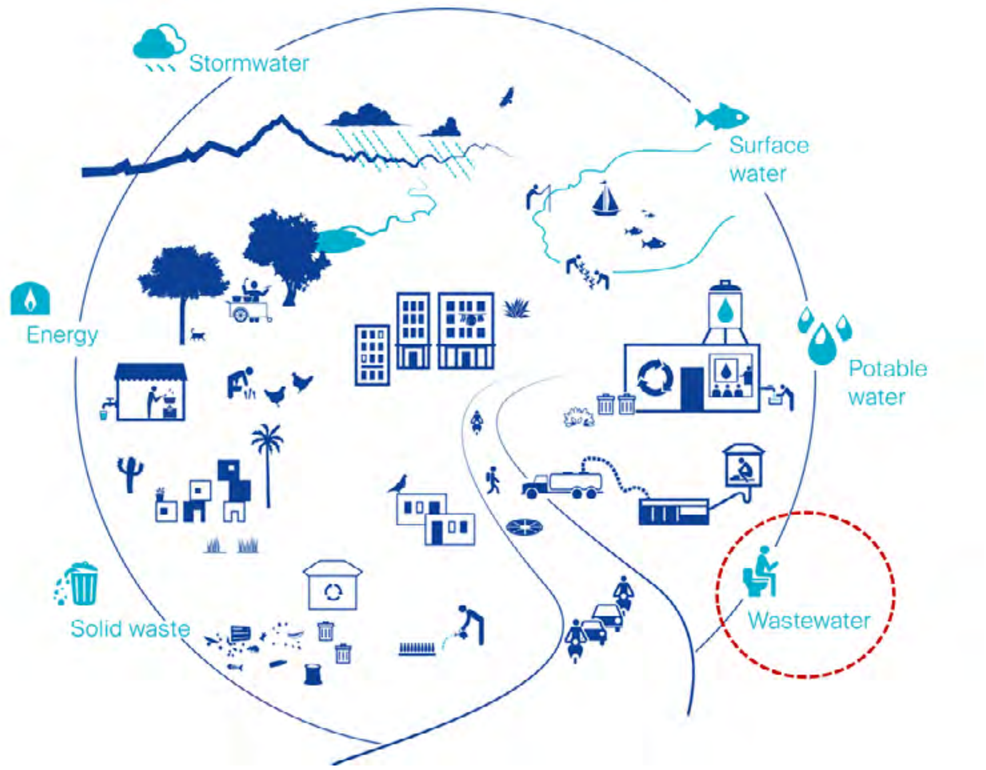



**Figure 5: City Sanitation Plan (CSP)**

*Source: Integrated Sanitation Approach, BORDA, 2020*

### 4.4.3 Wastewater Management Approaches

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 habitats 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 a high affordability of implementing and maintaining these environmental services. However, a major challenge is the lack of space or land area for the 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 of 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 systems will have a dedicated sewer network and treatment plant, while those with off-site sanitation systems will have 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 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 is 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.

### 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 systems safely treats the collected wastewater before its disposal or reuse.

A centralized system consists of: i) Sewerage system that collects wastewater from different wastewater producers: households, commercial areas, industrial plants and institutions, and conveys to a treatment plant; ii) Centralized STP 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

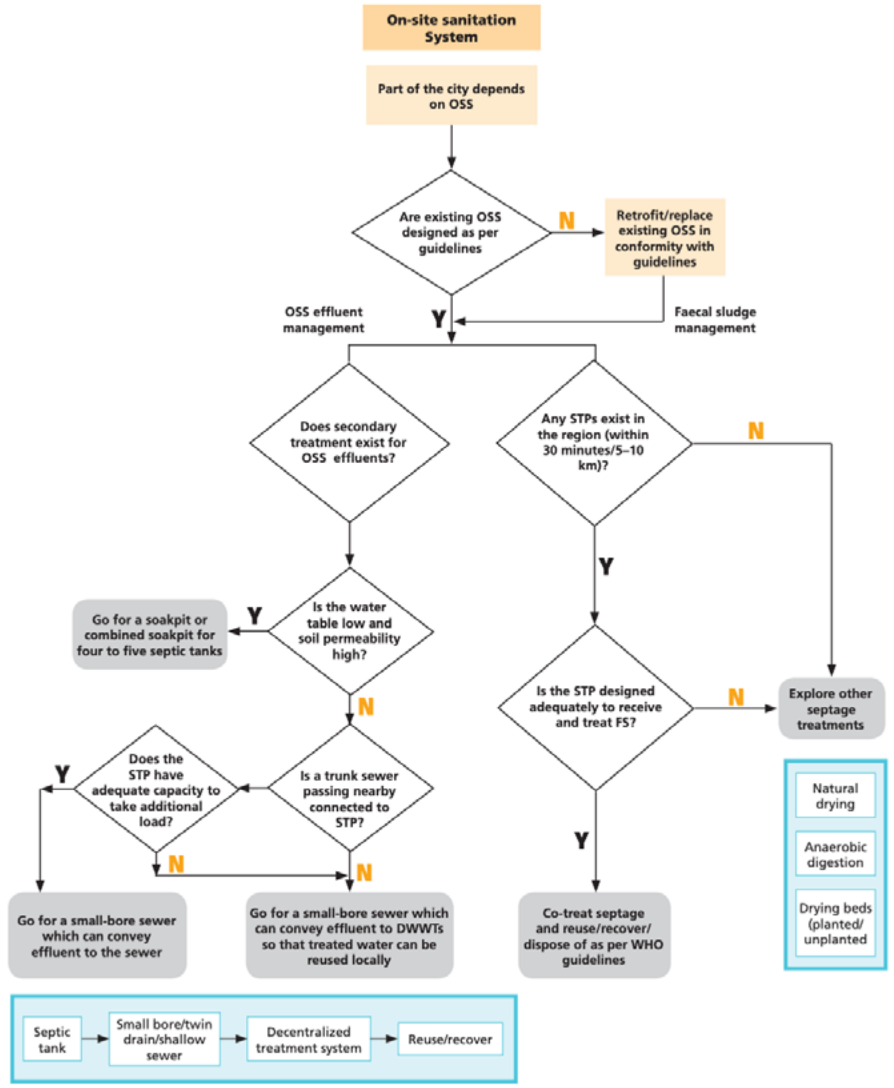
In a centralized approach, the ULB has to bear the capital and operation & maintenance cost of the infrastructure. However, considering the efficiency of collecting taxes in Indian cities, maintaining the infrastructure and providing services to the masses becomes a cumbersome process.



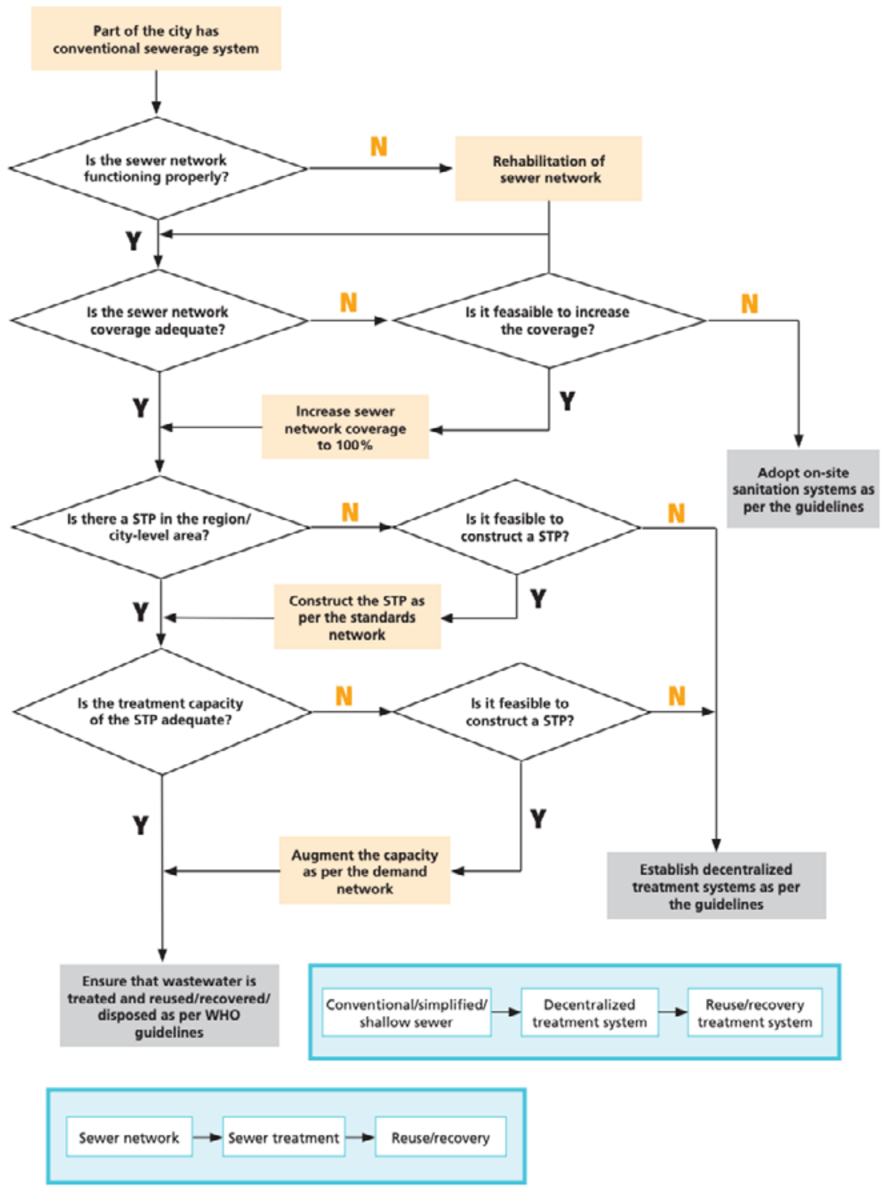
### Decentralised wastewater management

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.




Source: Adapted from IWFM, 2018.




Source: Adapted from IWFM, 2018

**Figure 6: Logic diagrams for onsite sanitation system and sewered sanitation system**

### 4.4.4 Sanitation Systems Approach

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 the 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 neighbouring 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 in the society.

**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.

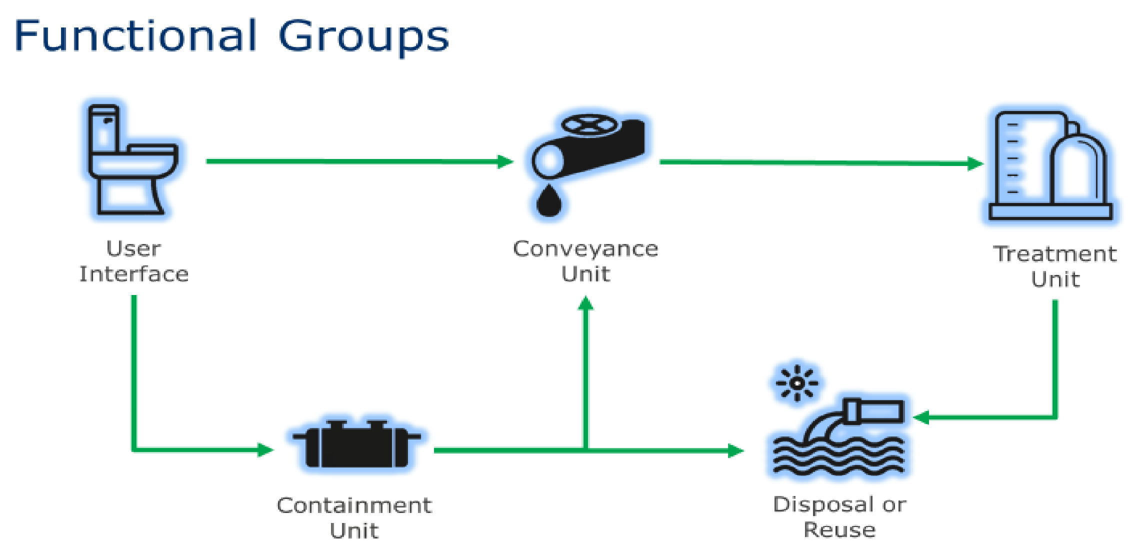



**Figure 7: Functional groups in Sanitation**

**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 how 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

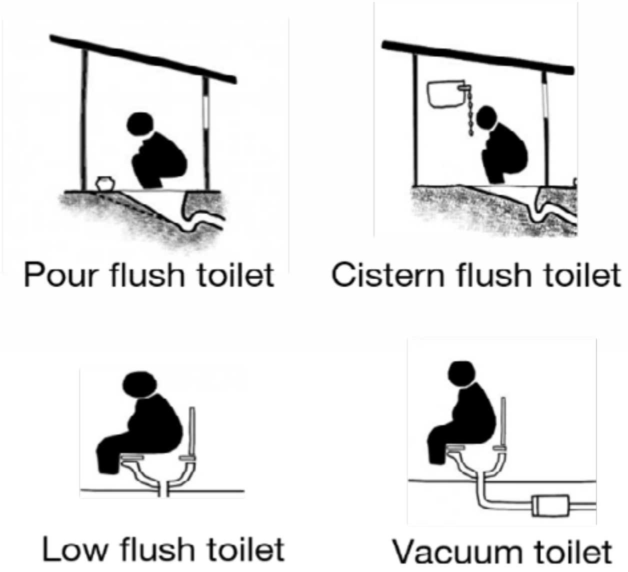



**Figure 8: User interface Options**

**Collection and storage-** 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)

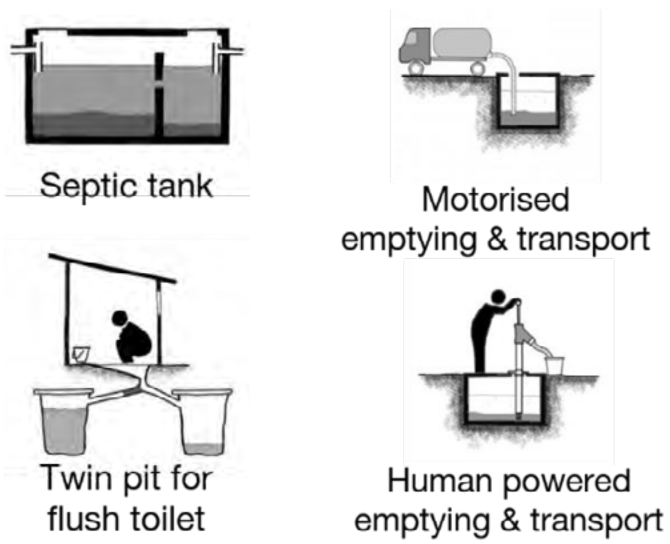



**Figure 9: Collection & storage options**

**Conveyance -** If waste products cannot be safely disposed of or even suitably reused on site, they have to be transported elsewhere. Conveyance describes how 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 10: Conveyance options**

**Reuse and/or disposal -** Reuse and/or disposal refers to how 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 a soil conditioner in agriculture. The soil conditioner improves the soil texture and helps to increase the moisture retention capacity of the soil. The sterile urine after disinfection is used as fertilizer in agriculture. Urine as a liquid fertilizer contains high nitrates and phosphates, reducing the consumption of inorganic fertilizers.
- Aquaculture: The term aquaculture refers to the controlled cultivation of aquatic plants and animals by using various types of wastewaters 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 to 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 in 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 that are popular in other countries, and utilising 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 the treatment process used. The biogas generated through anaerobic digestion can be directly used as liquid fuel or converted into electricity. Dried sludge can also be used as solid fuel in furnaces or brick kilns due to its high calorific value.

Figure 11: Reuse options

### 4.4.5 Sewered Sanitation

The products generated at the User Interface or onsite Collection and Storage/Treatment technology by removing and/or transporting them to a subsequent offsite (Semi-) Centralized Treatment, Use and/or Disposal technology. They are sewer-based technologies.

- Combined sewer is a sewage collection system of pipes, tunnels, and bodies of water designed to simultaneously collect surface runoff and sewage water in a shared system.
- Separate sewer consists of a separate collection of municipal wastewaters (blackwater from toilets, greywater and industrial wastewater) and surface run-off (rainwater and stormwater).
- Solids-free sewer is a network of small-diameter pipes that transports pretreated and solids-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.
- Simplified sewer describes a sewerage network that is constructed using smaller diameter pipes laid at a shallower depth and a flatter gradient than Conventional Sewers. The simplified sewer allows for a more flexible design at lower costs.
- Vacuum sewerage systems consist of a vacuum station, where the vacuum is generated, the vacuum pipeline system, collection chambers with collection tanks and interface valve units.

Table 3: Comparison of Sewerage option

| Criteria | Combined sewers | Separate sewers | Solid Free sewers | Simplified sewers | Pressurized sewers |
|---|---|---|---|---|---|
| Water Consumption | 💧 💧 💧 | 💧 💧 | 💧 | 💧 💧 💧 | ½ 💧 |
| CapEx | ₹ ₹ ₹ | ₹ ₹ ₹ | ₹ | ₹ ₹ | ₹ ₹ |
| STP Operation | 🔧 🔧 🔧 | 🔧 | 🔧 | 🔧 | 🔧 |
| OpEx | ₹ ₹ | ₹ ₹ | ₹ | ₹ ₹ | ₹ ₹ ₹ |
| Management | 👷 | 👷 | 👷 👷 👷 | 👷 👷 | ½ 👷 |

**a. Conventional 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.

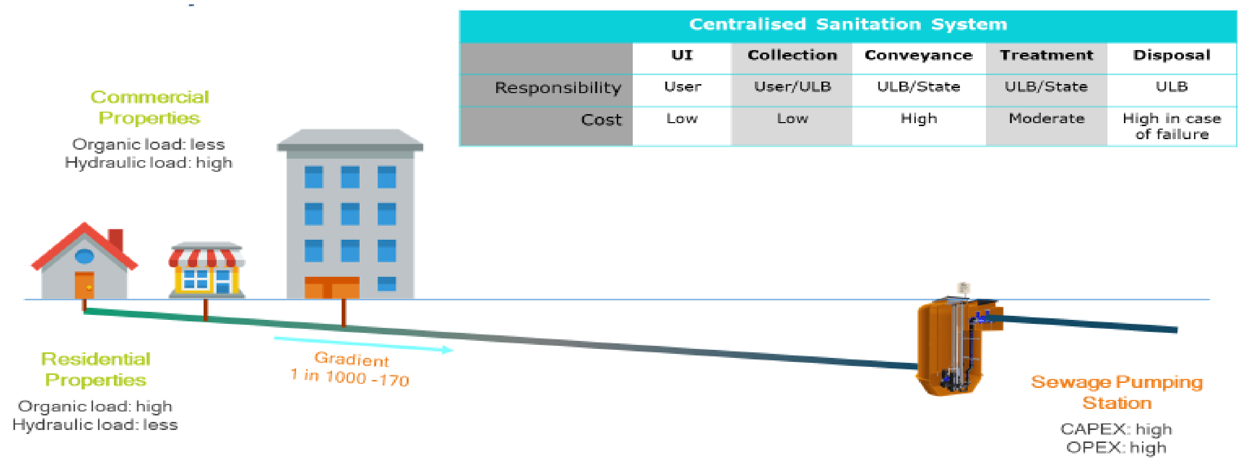



Figure 12: Schematic of conventional gravity sewers

Table 4: Pros and Cons of conventional gravity sewers

| Pros | Cons |
|---|---|
| • Less maintenance compared to simplified and solid-free sewers<br>• Greywater and possibly stormwater can be managed concurrently<br>• Can handle grit and other solids, as well as large volumes of flow | • Very high capital costs and high operation and maintenance costs<br>• A minimum velocity must be maintained to prevent the deposition of solids in the sewer<br>• Requires deep excavations<br>• Difficult and costly to extend as a community expands horizontally<br>• Requires expert design, construction and maintenance<br>• Leakages pose a risk of wastewater ex filtration 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. This 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 maintenance. They require few inspection points, have inflective gradients (i.e., negative slopes) and follow the topography. When the sewer roughly follows the ground contours, the flow varies between open channel and pressure (full-bore) flow.

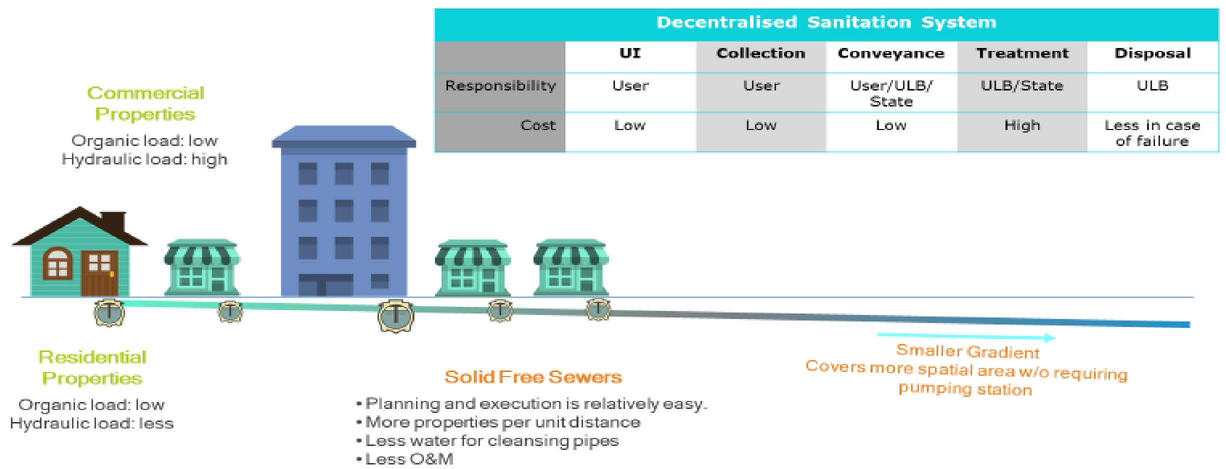



Figure 13: Schematic of solid-free sewer



Table 5: Pros and Cons of solid-free sewer

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

Sewerage is the infrastructure that conveys sewage or surface runoff (stormwater, meltwater, rainwater) using sewers. It encompasses components such as receiving drains, manholes, pumping stations, storm overflows, and screening chambers of the combined sewer or sanitary sewer. Sewerage ends at the entry to a sewage treatment plant at the point of discharge into the environment. It is the system of pipes, chambers, manholes, etc. that conveys the sewage or storm water.

**Lateral & Branch sewers** are the upper ends of the municipal sewer system. Laterals dead-end at their upstream end with branch sewers collecting the wastewater from several lateral sewer lines.

**Main sewers** are collectors for numerous lateral and branch sewers from an area of several hundred acres or a specific neighbourhood or housing development. They convey the wastewater to larger trunk sewer lines, to lift stations or to a neighbourhood package water quality treatment centre.

**Trunk sewers** serve as the main arteries of the wastewater collection system. They collect and convey the wastewater from numerous main sewer lines either to a water quality treatment centre or to an interceptor sewer.

**Interceptor sewers** receive the wastewater from trunk sewers and convey it to a water quality treatment centre. These are the largest diameter lines in the sewer system and the furthest downstream in the system.

**Lift or pump stations** are utilized in gravity sewer systems to lift (pump) wastewater to a higher elevation when the route followed by a gravity sewer would require the sewer to be laid at an insufficient slope or at an impractical depth. Lift stations vary in size and type depending upon the quantity of wastewater to be handled and the height it must be lifted.

**Machine holes** are the commonly used maintenance utility underground structures to provide access to installed pipelines for inspection and cleanout. It is a vital component of the water supply and sanitary system, the basic underground utilities.

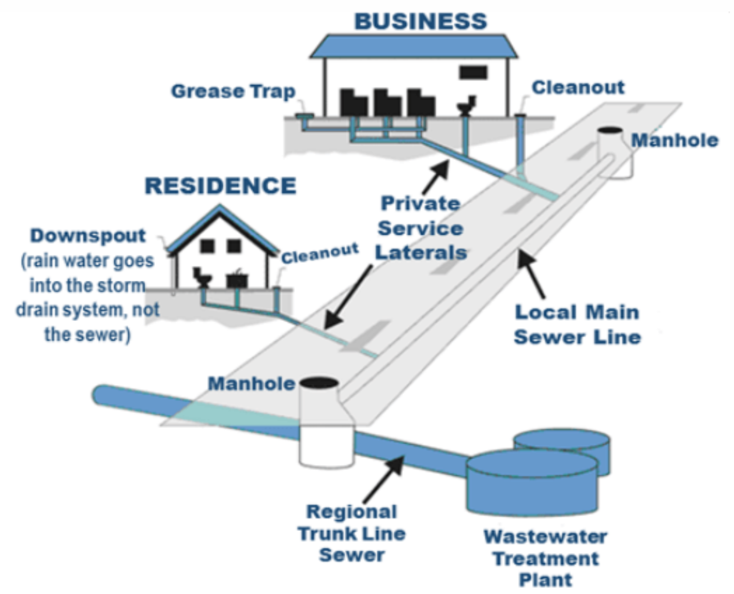



**Figure 14: Components of sewer**

*Source: Reliable Basement & Drain, Ohio*

Ministry of Housing and Urban Affairs launched Safaimitra Suraksha Challenge across 243 cities in November 2020. Manhole to Machine-hole: A Step That Practically Strives to End Manual Scavenging mechanization mandatory in sewer cleaning to avoid deaths due to manual scavenging

"The Challenge focuses extensively on creating citizen awareness on this critical issue along with infrastructure creation for mechanized cleaning and capacity building of the workforce. Cities will be awarded in three sub-categories – with a population of more than 10 lakhs, 3-10 lakhs and up to 3 lakhs, with total prize money of INR 52 crore to be given to winning cities across all categories."

### Features of Machine Hole

The main parts of a manhole are the chamber or ring and the Vertical Circular Pipe. The vertical circular pipe is available in varying depth and sizes. These pipes are used to access the inspection joints in the system. Manholes are mainly positioned 0.5m away from the curb lines of the road. Mostly it is constructed such that it is away from the wheel line of the traffic. The cover of a manhole is a plug that protects the manhole from any unauthorized access. The covers used for manholes can be either rectangular, square or circular in shape. The material of cover can be precast concrete, composite material or any glass-reinforced plastic material. The provision for access through the manhole is performed through steps. If the depth of the manhole is less than 1 m, a step ladder is constructed. If the depth of the manhole is greater than 2.5m, a regular ladder is fitted. Now modern manholes do not demand physical entry.

### Types of Machine holes

**Shallow Machine holes**

A shallow manhole has a depth ranging between 75 to 90cm. These are constructed at the start of a branch sewer or in an area with no traffic. The shallow manhole is provided with a light cover called the inspection chamber.

**Normal Machine holes**

These are provided at the sewer line with a heavy cover on its top. It has a depth of 150cm. Normal manhole takes a square shape.

**Deep Machine holes**

Deep manhole is provided at a depth greater than 150cm with a very heavy cover at its top. The size can be increased and the facility for going down is also increased.

**Drop Machine holes**

A drop manhole is a manhole in which a vertical pipe is provided to allow for flow between the branch sewer and the main sewer. It is utilized in areas where the slope is steep or when an inlet pipe's invert elevation is much higher than the outlet pipe's invert level. In a typical manhole arrangement, the invert elevation at the stop end of the inlet pipe is the same as the manhole invert. In a drop manhole, the invert at the stop end is at a significantly higher level than that of the manhole invert level.

Gradient differences between two sewer pipes can sometimes be more than 0.5m, which is too big of an elevation difference for unimpeded sewage flow between the branch sewer and main sewer. Drop manholes are used in this scenario as well as when larger sloping gradients are impractical or uneconomical. Flow to the main sewer can either be routed outside of the manhole known or through the manhole channel's interior. The pipe that passes through the manhole barrel is called the inside drop. The one that is on the exterior is the outside drop. Outside drops lack accessibility making routine inspections, maintenance, and cleaning difficult. Drop manholes form a part of steep, sloped, urban sewer systems as they can reduce flow velocities by lessening the slopes in the network's pipes and dissipating energy. High speeds can result in damage to lines and overall poor hydraulic performance. To avoid damage to the manhole in continuous flow situations, drop manholes are sometimes constructed with protective lining and corrosion proofing. The design of drop manholes ensures that there is no back up of flow in the collection system. During maintenance of the drop manhole, provisions may be implemented to store or divert flow in the upstream collection network so that there is no interruption of flow. It is essential that drop manholes also be designed to lessen the amount of entrained air from the flow transported to the main sewer.

The drop manhole is the interface between the branch sewers at the surface and the tunnel system. Therefore, it serves as a preferred location to analyse the efficiency of the collection system. Odour control systems, flow monitoring, and flow control apparatus are installed at the drop manhole location for monitoring purposes. The most common types of drop structures fall under vortex type and plunge type for wastewater sewer networks.

**Side Entry Machine hole**

Side entry manholes are normally used to gain mid run access entry into an in-line or off-line tank and consists of a standard concrete pipe complete with access shaft. Depending upon the overall depth, a sealed manhole cover slab or reducing slab with a 1200mm sealed manhole complete with a load bearing seal can be supplied. 1200mm rings are used to make up the desired shaft height and double steps or ladders can be fitted into the unit.  Side entry manholes can be supplied with a separated bend to provide a change of direction and access can be either side of the pipe.

Instead of installing a traditional large diameter manhole to provide man entry, side entry manholes can be installed directly into the pipeline which offers the following key benefits: safer, faster, cost effective. The floor of the side-entrance passage, which should fall at about 1 in 30 towards the sewer, should enter the chamber not lower than the soffit level of the sewer. In large sewers where the floor of the side entrance passage is above the soffit, either steps or a ladder (which should be protected either by a removable handrail or by safety chains) should be provided to reach the benching.

**Pumping Station**

Pumping stations are either as in-line for lifting the sewage from a deeper sewer to a shallow sewer or for pumping to the STP or the out fall. They are required where low lying development areas cannot be drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity. The type of pumping stations can be:

- Horizontal pumps in dry pit
- Vertical pumps in dry pit
- Vertical pumps in suction well
- Submersible pumps in suction sump

The proper location of the pumping station requires a comprehensive study of the area to be served, to ensure that the entire area can be adequately drained. Special consideration has to be given to undeveloped or developing areas and to probable future growth. The location of the pumping station will often be determined by the trend of future overall development of the area. The site should be aesthetically satisfactory. The pumping station has to be so located and constructed such that it will not get flooded at any time. The storm-water pumping stations have to be so located that water may be impounded without creating an undue amount of flood-damage, if the flow exceeds the pumping station capacity. The station should be easily accessible under all weather conditions. Pumping stations are typically located near the lowest point in a development. The O&M of pumping systems presented here applies to all such types of pumping stations.

**Lift stations**

In highwater table and rocky terrain locations, a typical conventional sewer design and its construction pose a series of challenges when excavation depths exceed about 3 m. Eventually, the depth of wet-well is also negatively influenced by this issue. In such situations, it is advantageous to opt for intermediate lift stations, which are like "on line". In general, these are submersible pump stations, which are interposed in the gravity sewer network. The procedure is to sink a wet-well on the road shoulder or an acquired plot beyond the shoulder and divert the incoming deeper sewer to it and the submersible pump set therein will lift the sewage and discharge it to the next on-line shallow sewer. As the sewer progresses, any number of such lifts can be inserted based on the location. These shall be connected to dedicated electricity feeders as installation and O&M of standby diesel pump sets etc., are not feasible in such locations. It is invariably used in gravity sewer network where depth of cut of sewers poses a problem in high water prone areas. The procedure is to sink a wet well on the road shoulder or an acquired plot after the shoulder and divert the deeper sewer there. The submersible pump will lift the sewage and discharge it to the next on-line shallow sewer.

**Pumping/Lift stations become necessary as soon as sewage has to be lifted from a lower part to a higher part.**

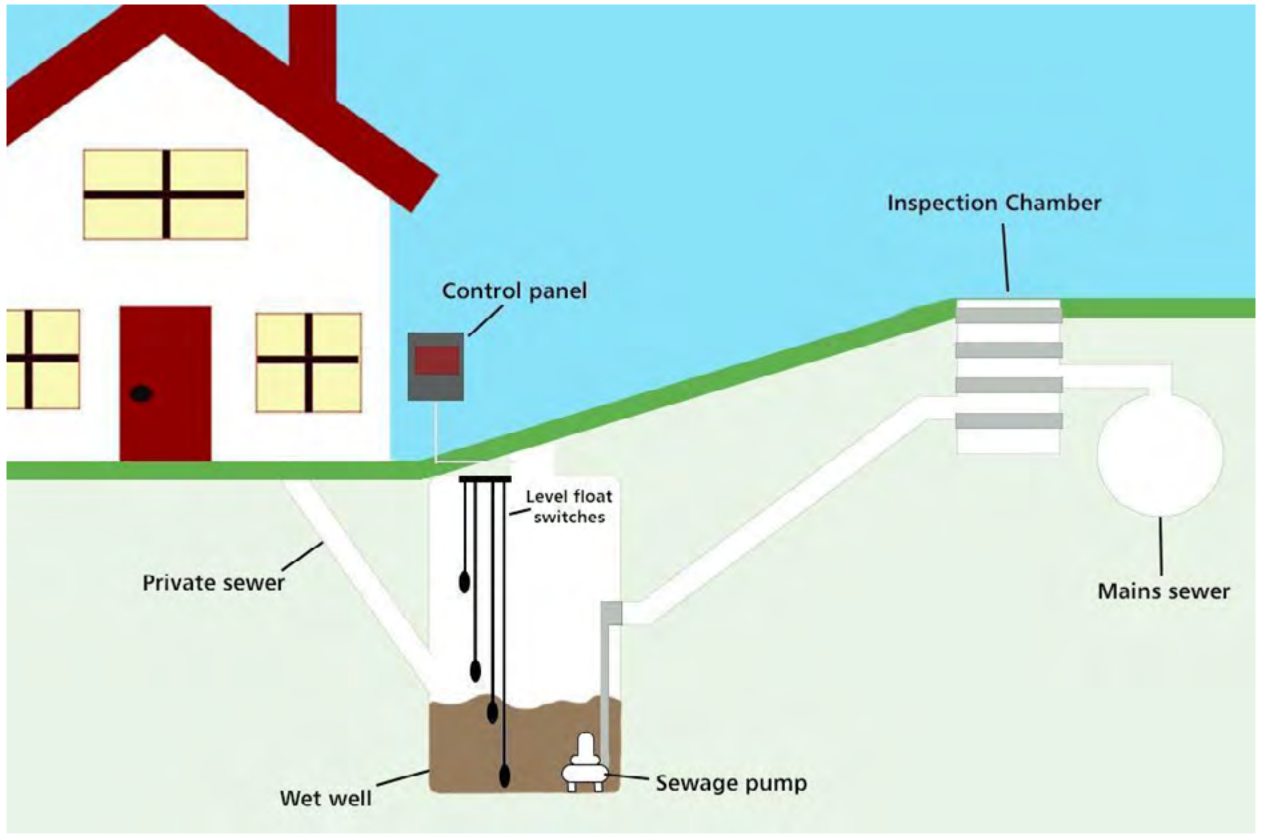



**Figure 15: Schematic diagram of lift station (Source: Country Clean Group, UK)**

### 4.4.6 Stages in DPR Preparation

Collection of data required for preparing DPRs for works of interception and diversion of drains and sewage treatment plants of the project area. The DPR should be prepared on the basis of available data that has been generated by the concerned agencies. Additional data will have to be generated by undertaking suitable survey and investigation. However, DPR should integrate all the data provided by agencies concerned for pollution abatement.

The DPR shall be prepared to achieve a clearly spelt objective and outcome in terms of abatement of pollution from the drains carrying wastewater of the town and improving water quality of the river to make it suitable for bathing. The objective and outcome of the DPR should be clear before the beginning of the process of data collection. Detailed designs and engineering of the works shall be based on extensive survey and investigation and collection of the required data. An integrated and comprehensive scheme of management of wastewater in the town will include other aspects such as covering all the localities with sewers and connecting every household to it, dealing with non-point sources of pollution, solid waste management etc. The interception and diversion sewers, sewage pumping stations and sewage treatment plants proposed under this DPR would ultimately become a part of the town's integrated and comprehensive system of dealing with wastewater. This aspect should be kept in mind while designing the infrastructure works.

The stages of preparation of DPR are as below:

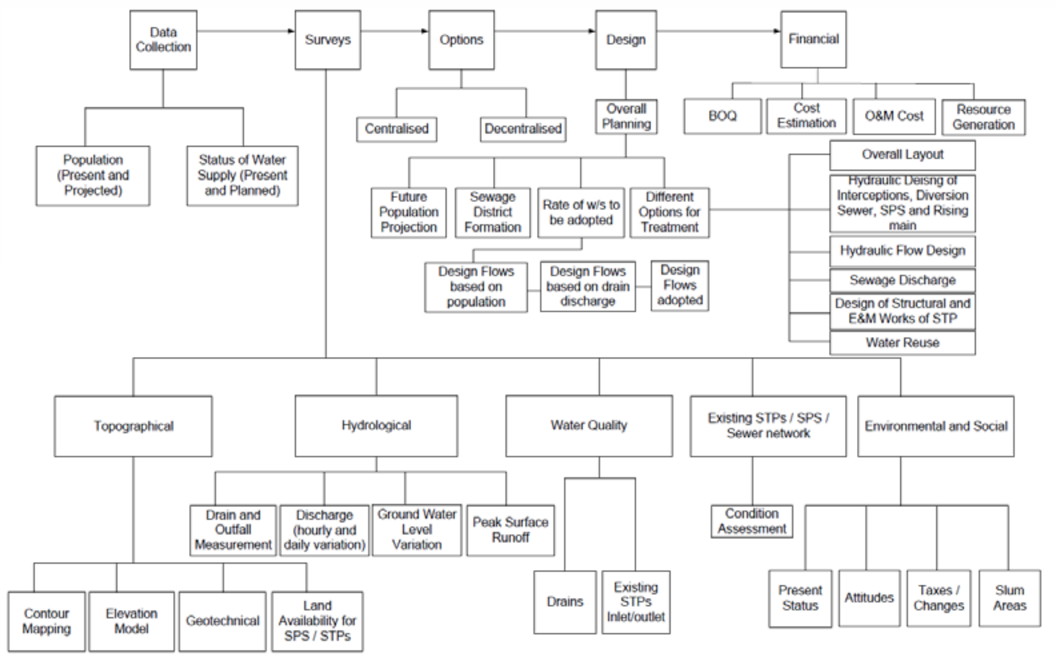



**Figure 16: Stages of DPR Preparation**

*Source: NMCG Guidelines, 2018*

## 4.5 Notes for trainer

This session acts as a base for developing CSPs & DPR as per SBM 2.0 guidelines, to make participants understand the citywide sanitation approach and its planning for the city. This session will also give clarity to participants about the sanitation system and its components required to make their city a safe and sustainable sanitation managed city.

## 4.6 Bibliography


- NMCG Guidelines (2018): Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants
- CPHEEO (2013): Manual on Sewerage and Sewage Treatment Systems
- Swachh Bharat Mission (Urban) 2.0 Guidelines (2021), Ministry of Housing and Urban Affairs (MoHUA)
- Eawag & IWA (2nd Edition): Compendium of Sanitation Systems and Technologies




Session

# 05

# Baseline Survey and Assessment

## 5. Baseline Survey and Assessment

### 5.1 Learning Objectives

- To understand the approach for identification of project area and collection of baseline information
- To know data assessment for the gap identification and selection of technological solutions

### 5.2 Session Plan

Duration - 30 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Identification of project area | 5 min | Powerpoint presentation |
| Application of remote sensing and geographic information system (GIS) | 5 min | Powerpoint presentation |
| Access to water and sanitation | 5 min | Powerpoint presentation |
| Investigation and pollution monitoring | 5 min | Powerpoint presentation |
| Q&A | 5 min | Discussion |

### 5.3 Key facts

- Appropriate baseline data collection and assessment is important for identification of project area and selection of technical solutions.
- Application of GIS for sanitation and water management projects can play a crucial role in rapid decision making.
- GIS mapping simplifies the process of visualizing and understating the project area.
- Baseline data of existing infrastructures, gaps identification and site investigation are the necessary aspects for the preparation of a detailed project report on wastewater management systems.

### 5.4 Learning notes

#### 5.4.1 Identification of project area

The identification of the project area after studying the available data and priority needs is the important step in planning wastewater management systems. The factors that influence the determination of project area include natural topography, layout of buildings, administrative boundaries, economic factors, city master plan or city development plan etc. Considering the wastewater management approach, i.e., sewer network system with STPs or intercepting the urban drains and treating the diverted sewage into STPs, the concerned administrative agencies need to demarcate the project area and the respective data collection has to be initiated.

For larger drainage areas, though it is desirable that the sewer capacities are designed for the total project area, sometimes the administrative boundaries and legal restrictions prevent construction of sewers beyond the limits of the local authority. However, when designing sewers for larger areas, there is usually an economic advantage in providing adequate capacity initially for a certain period of time and constructing additional sewers, when the pattern of growth becomes established. The need to finance projects within the available resources necessitates the design to be restricted to administrative boundaries.

In case of Interception and Diversion based projects, there are possibilities that the identified project area might be within the administrative boundaries or outside the boundaries as there is difficulty to limit the contributing pollution sources of the drains which subsequently pollutes the river. It is utmost important to precisely demarcate the project area so as to correctly project design population, sewage flows and design proposed works. The project area under consideration should be clearly mapped on a key plan of the city to be measured and considered in the project planning.

### 5.4.2 Baseline Data Collection

The purpose of the baseline data collection within the planning procedure is to collect background information that is essential to determine the requirements for adequate sanitation and wastewater management projects from a technical perspective. The gathered information will provide the details necessary for the design of the project. The baseline information can be collected from the different sources e.g., planning documents i.e., city master plan, City Development Plan (CDP), City Sanitation Plan (CSP), DPRs etc. The respective documents can be collected from different concerned administrative agencies i.e., Urban Local Body (ULB), Urban Development Department (UDD), Town Planning Department (TPD), Pollution Control Board (PCB), Survey of India, Meteorological Department, Water Resources Department, Agricultural Department etc. The following data sets need to be collected:

- General baseline information i.e., location and physical aspects, demographics etc.
- Statistical information i.e., access to water, toilet and other infrastructure in place to manage wastewater
- Institutional and governance information i.e., the roles and responsibilities of various agencies involved in the project
- Capacity enhancement and management i.e., building capacity of those involved to implement and sustain the project

**Table 6: General baseline information required of the project area or city**

| Aspects | Details |
|---|---|
| • General city profile / project area profile | • Locations i.e., Latitude and Longitude<br>• Total area of the city (sq.km)<br>• Landuse and landcover<br>• Historic information<br>• Commercial, Industrial, Educational activities<br>• Cultural and religious activities |
| • Demographic Information | • Population data<br>• Households<br>• Decadal population growth<br>• Population density<br>• Ward wise information |
| • Hydrology and geographical features | • Topography<br>• Plain, Terrain, Hilly region<br>• Elevation<br>• Landuse / Landcover<br>• Hydrological features<br>• Rivers, Lakes, Drainage area<br>• Watershed area |

### 5.4.3 Application of Remote Sensing (RS) and Geographic Information System (GIS)

Remote Sensing Technology coupled with geographic information system (GIS) has opened up new vistas of adopting geo-spatial databases to effectively plan and execute various projects. These tools can effectively support the urban planners, technical engineers, decision/policymakers in the development of sanitation infrastructure and water management systems.

Remote sensing is acquiring information about an object or phenomenon without making physical contact with it. Geographic information system (GIS) is the conceptualized framework that cancapture, manage, and analyze spatial and geographic data. GIS applications are computer-based tools that allow the user to store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as thematic maps. The data is stored in the form of layers which can be overlapped on a base map. Examples of such layers is landuse, demographics, surface water bodies, groundwater table etc. These layers can also be embedded with data in the form of attributes. For example; landuse layer can have population density as an attribute, groundwater table can have depth, salinity, TDS etc as attributes.

GIS is a tool which can ease out the process of planning sanitation and water management services. We can create and use different data sets for the planning of on ground environmental services. The different applications of GIS are listed below:

A. **City Mapping:** GIS tools can extract varied information through high resolution satellite imagery or drone imagery and can represent the city level data set like land use or landcover, build-up areas or other urban infrastructure, hydrological and geographical features, etc. The GIS tool can also integrate the specific city level information pertaining to natural and built environment with spatial information and it can be represented inform of thematic maps and tables. Road network, number of building structures and similarly, water bodies such as lakes and drains etc. can be extracted. These layers can be attributed with statistical data procured from different organizations to visualize a large amount of data in an image format.

B. **Mapping of Water Supply Systems:** GIS can be used to integrate the water supply system dataset at city or project area level i.e., water supply pipelines, junctions, water meters, water treatment plants etc. GIS tools can be further used for real time monitoring of operation and maintenance activities of the systems.

C. **Mapping of Sanitation Infrastructure:** GIS can be used to integrate the sanitation infrastructure dataset at city or project area level i.e., type of toilets (IHHT, CT, PT, etc.), the onsite containment system (i.e. septic tanks, soak pits, anaerobic baffled reactors, etc.), road mapping for proper access of onsite sanitation facilities to services providers, effective desludging services with route optimization, mapping of clustering or regionalization approaches, etc. with the georeferenced spatial data inform of the thematic map. This tool can be further used for real time monitoring of operation and maintenance activities of the systems.

D. **Mapping of Wastewater Management:** GIS tool can be used to integrate the sewerage management dataset i.e., collection and transportation systems like existing sewer network, manholes, sewage pumping stations, rising mains, sewage treatment plants (STPs) etc. with the georeferenced spatial data inform of thematic maps. GIS tool is also useful for the modelling of sewer networks and other infrastructure.

Under SBM 2.0 guidelines, ULBs or parastatal bodies have to utilize the GIS application and prepare thematic maps while preparing Detailed Project Report (DPR) of wastewater management systems. It would help in visualizing the project area with proposed solutions, fast-moving decision-making process and finalizing appropriate sewer network systems without disturbing other infrastructure. GIS can also be further used during O&M phase of the projects for real time monitoring of the system.

### 5.4.4 Access to Water and Sanitation

**Status of Water Resources and Water Supply System**

ULBs have to collect information on the existing water resources available in the project area or city from where the water is pumped off, treated and distributed for different purposes. It is necessary to monitor and assess the water quality of the water resources before planning for water management infrastructure at the project area or city. The water quality reports should be studied and represented as a part of planning documents. The parameters such as pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Faecal Coliforms, Total Coliforms, Colour, Odour, Temperature, Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Ammoniacal Nitrogen (NH4-N), Nitrite & Nitrate Nitrogen (NO2 + NO3), Total Phosphate (Total P), Chemical Oxygen Demand (COD) need to be analysed to understand the quality of water resources.

It is crucial to understand the existing water supply management at the project area or city while planning the wastewater management infrastructure. ULBs need to collect the following information:

- Existing sources of water i.e., rivers, lakes, etc.
- Existing water supply systems
  - Water treatment plant capacity (MLD)
  - Water supply network (kms)
  - Water connections (No.)
- Water consumption (LPCD)
- Augmentation plan of water supply system

**Access to Sanitation**

The details of existing sanitation infrastructure at city or project area are the necessary dataset while planning for wastewater management systems. The sanitation infrastructure includes access to toilets (i.e., Individual Household Toilets, Community Toilets and Public Toilets), onsite containment system (i.e., septic tanks, soak pits). The project area or city level sanitation infrastructure details need to be collected from the data sources like city master plan, city development plan, city sanitation plan or detailed project report of existing sewerage system projects etc.

Sewage Generation – The quantity and quality of sewage generated in a city or project area carried by the drains into the river and by sewers to existing sewage treatment plant(s) for treatment need to be measured and analysed.

**Existing Wastewater Management Systems**

The following information of the existing sewerage management systems need to be collected:

- Details of sewer system introduced in the city, works carried out / under progress in different programs, sanctioned cost, year of sanction, year of commissioning, details of sewerage system components such as sewage pumping stations (with detailed specifications i.e., diameters, installed capacity of pumps, rising mains, year of commissioning etc.), sewage treatment plants (with treatment capacity, treatment technology, year of commissioning etc.), sewer network details, technical studies / condition assessment reports conducted in the past for assessing the condition of existing structures.
- Number of drains falling out into the river(s), nos. of drains intercepted and diverted to STPs, reports on discharge measurement and sewage quality of drains carried out in the recent period.
- Designed capacity / performance, present performance and O&M details.
- Plan of existing sewers showing diameters, lengths and RLs etc.
- Information relating to existing sewage disposal works, septic tanks, existing STPs and drains intercepted.
- Condition assessment of existing works: Condition assessment should invariably be carried out for all existing works. Normally this is carried out by destructive and or non-destructive tests on structures and other works by qualified and experienced test houses and experts. If required,this draining out of the tanks may also be done so that the true assessment of life of works can be made. Suppose the performance of the works is less than the designed one or that required at the end of the design period. In that case,the causes and remedial measures may be identified component wise i.e., interception works, sewers, SPS, STPs.

### 5.4.5 Investigation and Pollution Monitoring

**Soil and Groundwater Investigation**

Soil and groundwater investigation shall be carried out at all the identified sites for deep Sewers, Sewage Pumping Stations (SPSs), STPs and locations having dispersive soil characteristics. For laying deep sewers, soil and groundwater investigation and test bores need to be carried out at suitable intervals along the alignment of sewers to ascertain the type of soil at different depths, behavior of groundwater table and Soil Bearing Capacity (SBC). The information about groundwater levels and their fluctuation should be obtained along the river bank where the interception sewer needs to be laid. The levels should be recorded pre monsoon and just after the monsoon when the levels are the highest. Soil and groundwater investigation report should include soil description i.e., type, classification and characteristics, SBC, pre and post monsoon groundwater levels etc. These investigation reports are important for structural design of the components and thereby its cost.

**Bulk Generators and Consumers**

Apart from domestic pollution sources, it is important to identify and monitor the commercial and industrial sources of pollution. Depending on the nature of the activity that is undertaken in the city or project area, appropriate parameters need to be monitored in the water samples drawn from the drain or the river.

The mixing of industrial effluents with domestic sewage adversely affects the sewage treatment process. In such cases, necessary corrective / enabling actions need to be adopted and the flow parameters should be measured accordingly before finalizing the treatment technology for the sewage treatment plant (STP). The data related to industrial wastewater, points of discharge into the sewer network/drains etc., can be provided by the state or regional pollution control boards or concerned government bodies.

### 5.4.6 Sources of Data

The secondary data required for the planning of wastewater management infrastructure at the project area or city need to be collected from the following sources:

- Central and State Pollution Control Boards.
- Water Resources department for drainage basins and rivers.
- District planning office
- District officers of agriculture, forests etc.
- Survey of India topographical sheets
- India Meteorological Department
- State Remote Sensing Agency
- Census Office / Library
- Urban Local Body
- Parastatal bodies i.e., Jal Sansthan, Pey Jal Nigam, MJP, PHED etc.
- Central and State Ground Water Board
- Urban Development Departments
- Water & Sewerage Board / Authority
- Technical Institutions and Universities
- Households / Bulk Generators
- Desludging Service Providers

## 5.5 Notes for trainer

This session represents the baseline information required for the planning of wastewater management systems at city or project area level. ULBs need to understand their requirements and collect information from different sources at the local level.

## 5.6 Bibliography


- NMCG Guidelines (2018): Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants
- CPHEEO (2013): Manual on Sewerage and Sewage Treatment Systems




Session

# 06

# Design Aspects

# 6. Design Aspects

## 6.1 Learning objectives

- To understand the basic principles of developing wastewater management options using sanitation systems approach.
- To introduce in situ treatment technologies as incremental solutions for wastewater treatment.
- To understand various population projections techniques and their application.

## 6.2 Session plan

Duration - 60 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Developing Options | 10 min | Powerpoint presentation |
| Water Consumption vs Water Supply | 10 min | Powerpoint presentation |
| Reuse Options- Circular Economy | 10 min | Powerpoint presentation |
| Incremental Solutions | 10 min | Powerpoint presentation |
| Population Projection | 10 min | Powerpoint presentation |
| Q&A | 10 min | Discussion |

## 6.3 Key facts

- For the country facing the most serious water scarcity, polluted rivers as well as contaminated groundwater, the treatment and reuse of wastewater seems the only solution.
- The most significant environmental problem and threat to public health in both rural and urban India is inadequate access to clean drinking water and sanitation facilities.
- As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets converted into wastewater.

## 6.4 Learning notes

### 6.4.1 Developing Options

Urban environmental management is one of the most pressing issues as the urbanization trend continues globally. Among the challenges faced by urban planners is the need to ensure ongoing basic human services such as the provision of water and sanitation. The under-management of domestic wastewater in many southern urban areas presents a major challenge. The accumulation of human waste is constant and unmanaged wastewater directly contributes to the contamination of locally available freshwater supplies. Additionally, the cumulative results of unmanaged wastewater can have broad degenerative effects on both public and ecosystem health.

Urban India has become a massive and perhaps frightening reality as far as waste management is concerned. This country can no longer afford to allow urban areas constituting cities and towns of varying magnitude to take care of them; they need the full and undivided attention of our planners and decision makers for the protection of environment, aquatic resources and ultimately for better management of health aspects.

**Sewered Sanitation System-** This system is especially appropriate for dense, urban and peri-urban settlements with little or no space for onsite storage technologies or emptying. The system is not well-suited to rural areas with low housing densities. Since the sewer network is (ideally) watertight, it is also applicable for areas with high groundwater tables. There must be a constant supply of water to ensure that the sewers do not become blocked. The capital investment for this system can be very high.

Conventional Gravity Sewers require extensive excavation and installation that is expensive, whereas Simplified Sewers are generally less expensive if the site conditions permit a condominium design. Users may be required to pay user fees for the system and its maintenance. This system is most appropriate when there is a high willingness and ability to pay for the capital investment and maintenance costs and where there is a pre-existing treatment facility that has the capacity to accept additional flow.

**Hybrid Sanitation System-** This system is especially appropriate for urban settlements where the soil is not suitable for the infiltration of effluent. Since the sewer network is shallow and (ideally) watertight, it is also applicable for areas with high groundwater tables. This system can be used to upgrade existing, under-performing Collection and Storage/Treatment technologies (e.g., Septic Tanks) by providing improved treatment.

The success of this system depends on high user commitment concerning the operation and maintenance of the sewer network. A person or organization can be made responsible on behalf of the users. There must be an affordable and systematic method for desludging the interceptors since one user's improperly maintained tank could adversely impact the entire sewer network. Also important is a well-functioning and properly maintained treatment facility. In some cases, this will be managed at the municipal or regional level. In the case of a more local, small-scale solution (e.g., constructed wetlands), operation and maintenance responsibilities could also be organized on the community level.

With the offsite transport of the effluent to a (Semi-) Centralized Treatment facility, the capital investment for this system is considerable. Installation of an onsite Collection and Storage/ Treatment technology may be costly, but the design and installation of a Simplified or Solids-Free Sewer will be considerably less expensive than a Conventional Gravity Sewer network. The offsite treatment plant itself is also an important cost factor, particularly if there is no pre-existing facility to which the sewer can be connected.

**Non Sewered Sanitation-** This system is only appropriate in areas where desludging services are available and affordable and where there is an appropriate way to dispose of the Sludge. For the infiltration technologies to work there must be sufficient available space and the soil must have a suitable capacity to absorb the effluent. This system can be adapted for use in colder climates, even where there is ground frost. The system requires a constant source of water. This water-based system is suitable for Anal Cleansing Water inputs, and, since the solids are settled and digested onsite, easily degradable Dry Cleansing Materials can also be used. However, rigid or non-degradable materials (e.g., leaves, rags) could clog the system and cause problems with emptying and, therefore, should not be used. In cases when Dry Cleansing Materials are collected separately from the flush toilets, they should be disposed of in an appropriate way.



The capital investment for this system is considerable (excavation and installation of an onsite storage and infiltration technology), but several households can share the costs, if the system is designed for a larger number of users.

**Sewered Sanitation Criteria**

**Conventional 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). As pumps may be necessary if the landscape is very flat, or in hilly regions, they are mostly found in urban areas. The conventional gravity sewer system is designed with many branches. Typically, the network is subdivided into primary (main sewer lines along main roads), secondary and tertiary networks (networks at the neighbourhood and household level). This system is mostly found in urban areas.

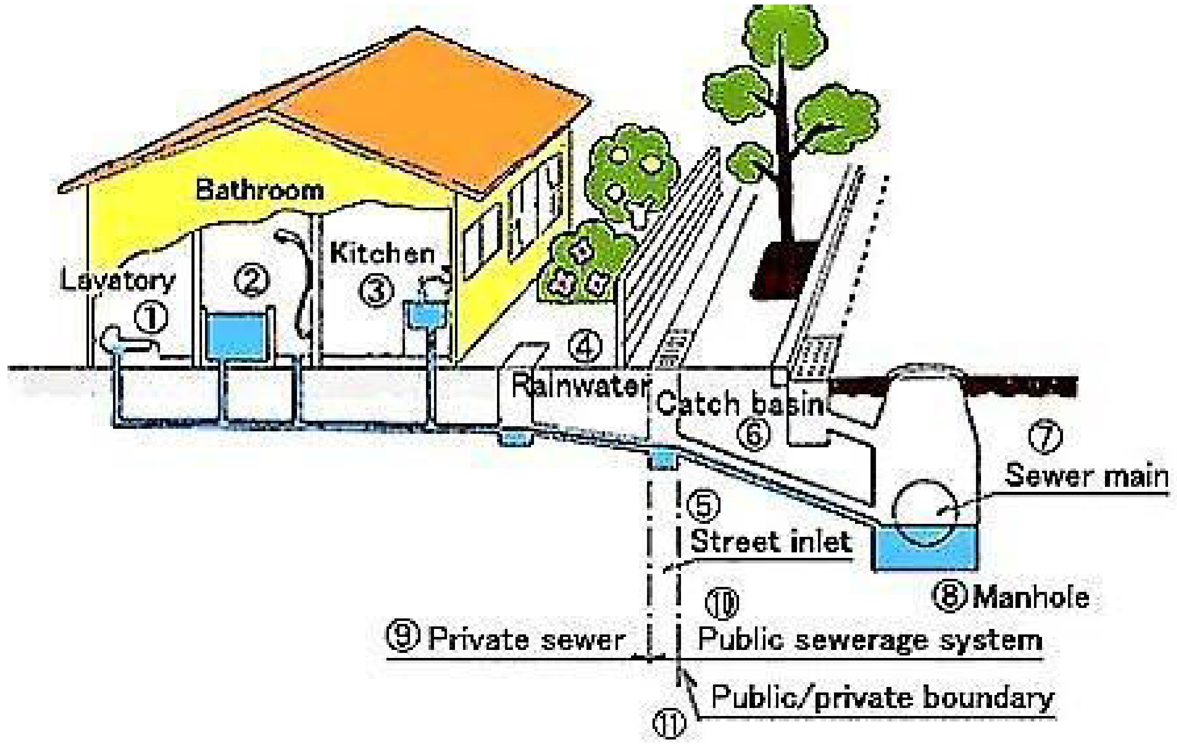



**Figure 17: Cross-section of a conventional sewer in a common urban set-up.**

*Source: EAWAG/SANDEC*

**Design Considerations-** 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, however, so that it maintains 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) 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.

**Health Aspects-** If well-constructed and maintained, sewers are a safe and hygienic means of transporting wastewater. This technology provides a high level of hygiene and comfort for the user. However, because the waste is conveyed to an offsite location for treatment, the ultimate health and environmental impacts are determined by the treatment provided by the downstream facility.

**Cost Considerations-** The initial cost of such systems is high (50 to 80% more than simplified sewer systems according to TILLEY et al. 2008) because they need excavation and refilling of trenches to lay the pipes, especially below roads that have to be rebuilt afterwards. The system design is also costly, as it requires specialised engineers. The maintenance costs are high compared to decentralised systems and comprise mainly inspection from time to time and eventual unblocking and repair. These can be kept rather low with a careful building design, but they still require specialised operators. The extension of the system can be difficult and costly because entire parts of the system may have to be redesigned due to the flow requirements and dimensioning.

**Operation & Maintenance-** Manholes are used for routine inspection and sewer cleaning. Debris (e.g., grit, sticks or rags) may accumulate in the manholes and block the lines. To avoid clogging caused by grease, it is important to inform the users about proper oil and grease disposal. Common cleaning methods for conventional gravity sewers include rodding, flushing, jetting and bailing. Sewers can be dangerous because of toxic gases and should be maintained only by professionals, although, in well-organised communities, the maintenance of tertiary networks might be handed over to a well-trained group of community members. Proper protection should always be used when entering a sewer. The maintenance is to be systematically planned and carefully implemented. When stormwater is also carried by the sewer (which is then called a combined sewer, as opposed to a separate sewer), sewer overflows are required to avoid hydraulic surcharge of treatment plants during heavy rain events. Local and temporary pollution may occur due to the untreated excess water.

**Applicability-** Because they can be designed to carry large volumes, conventional gravity sewers are very appropriate to transport wastewater to a (Semi-) Centralized Treatment facility. However, this system is suitable for urban areas that have the resources to implement, operate and maintain such systems plus provide adequate treatment to avoid pollution at the discharge end (UNEP 2002). Planning, construction, operation and maintenance require expert knowledge.

Construction of conventional sewer systems in dense, urban areas is complicated because it disrupts urban activities and traffic. Conventional gravity sewers are expensive to build and, because the installation of a sewer line is disruptive and requires extensive coordination between authorities, construction companies and property owners, a professional management system must be in place.

Ground shifting may cause cracks in manhole walls or pipe joints, which may become a source of groundwater infiltration or wastewater exfiltration, and compromise the performance of the sewer.

Conventional gravity sewers can be constructed in cold climates as they are dug deep into the ground and the large and constant water flow resists freezing.

### Simplified Sewers

A simplified sewer describes a sewerage network that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers. The simplified sewer allows for a more flexible design at lower costs. Conceptually, simplified sewerage is the same as conventional gravity sewerage, but without unnecessarily conservative design standards and with design features that are better adapted to the local situation. The pipes are usually laid within the property boundaries, through either the back or front yards, rather than beneath the central road, allowing for fewer and shorter pipes. Because simplified sewers are typically installed within the condominium, they are often referred to as condominium sewers. The pipes can also be routed in access ways, which are too narrow for heavy traffic, or underneath pavements (sidewalks). Since simplified sewers are installed where they are not subjected to heavy traffic loads, they can be laid at a shallow depth and little excavation is required.

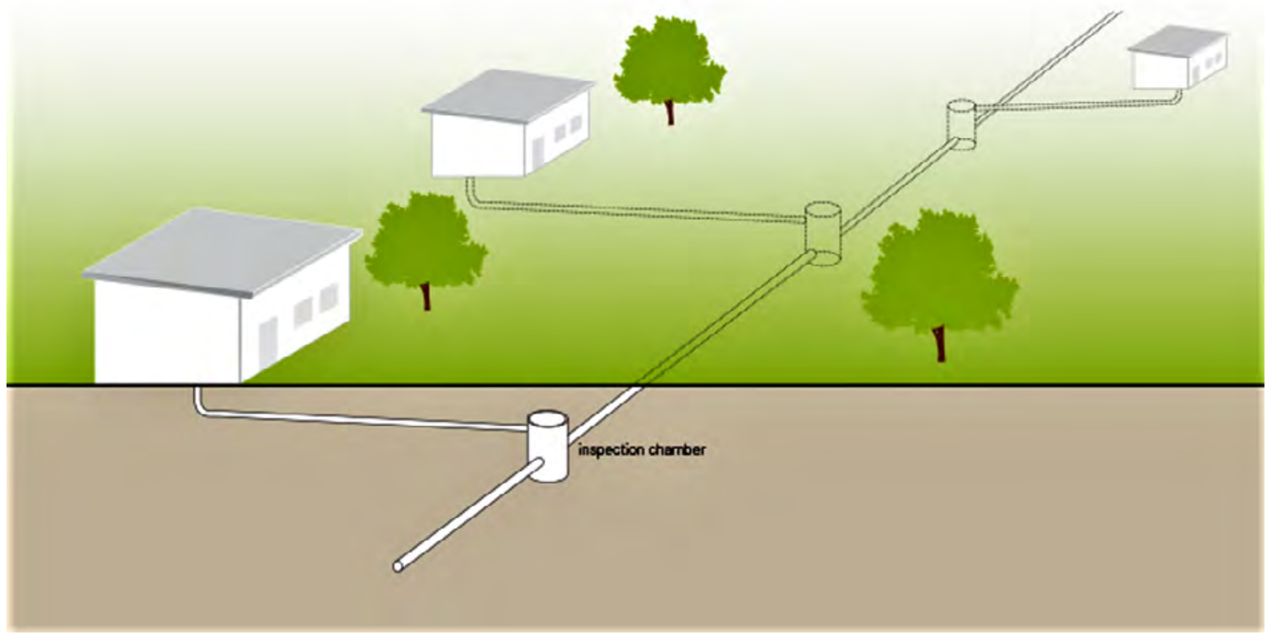



**Figure 18: Schematic of a simplified sewer system.**

*Source: TILLEY et al., 2014*

**Design Considerations-** In contrast to conventional 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. PVC pipes are recommended to use. The depth at which they should be laid depends mainly on the amount of traffic. Below sidewalks, covers of 40 to 65 cm are typical. The simplified design can also be applied to sewer mains; they can also be laid at a shallow depth, provided that they are placed away from traffic.

**Health Aspects-** If well-constructed and maintained, sewers are a safe and hygienic means of transporting wastewater. Users must be well trained regarding the health risks associated with removing blockages and maintaining inspection chambers.

**Operation & Maintenance-** Trained and responsible users are essential to ensure that the flow is undisturbed and to avoid clogging by trash and other solids. Occasional flushing of the pipes is recommended to insure against blockages. Blockages can usually be removed by opening the cleanouts and forcing a rigid wire through the pipe. Inspection chambers must be periodically emptied to prevent grit overflowing into the system. The operation of the system depends on clearly defined responsibilities between the sewerage authority and the community. Ideally, households will be responsible for the maintenance of pre-treatment units and the condominial part of the sewer. However, this may not be feasible in practice because users may not detect problems before they become severe and costly to repair. Alternatively, a private contractor or user's committee can be hired to do the maintenance.

Applicability- Simplified sewers can be installed in almost all types of settlements and are especially appropriate for dense urban areas where space for onsite technologies is limited. They should be considered an option with a sufficient population density (about 150 people per hectare) and a reliable water supply (at least 60 L/person/day).

Where the ground is rocky or the groundwater table high, excavation may be difficult. Under these circumstances, the cost of installing sewers is significantly higher than in favourable conditions. Regardless, simplified sewerage is between 20 and 50% less expensive than conventional sewerage.

### Solid-free Sewers

A solids-free sewer is a network of small-diameter pipes that transports pre-treated and solids-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. Solids-free sewers are also referred to as settled, small-bore, variable-grade gravity, or septic tank effluent gravity sewers. A precondition for solids-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. The solids interceptor also functions to attenuate peak discharges. Because there is little risk of depositions and clogging, solids-free sewers do not have to be self-cleansing, i.e., no minimum flow velocity or tractive tension is needed. 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.



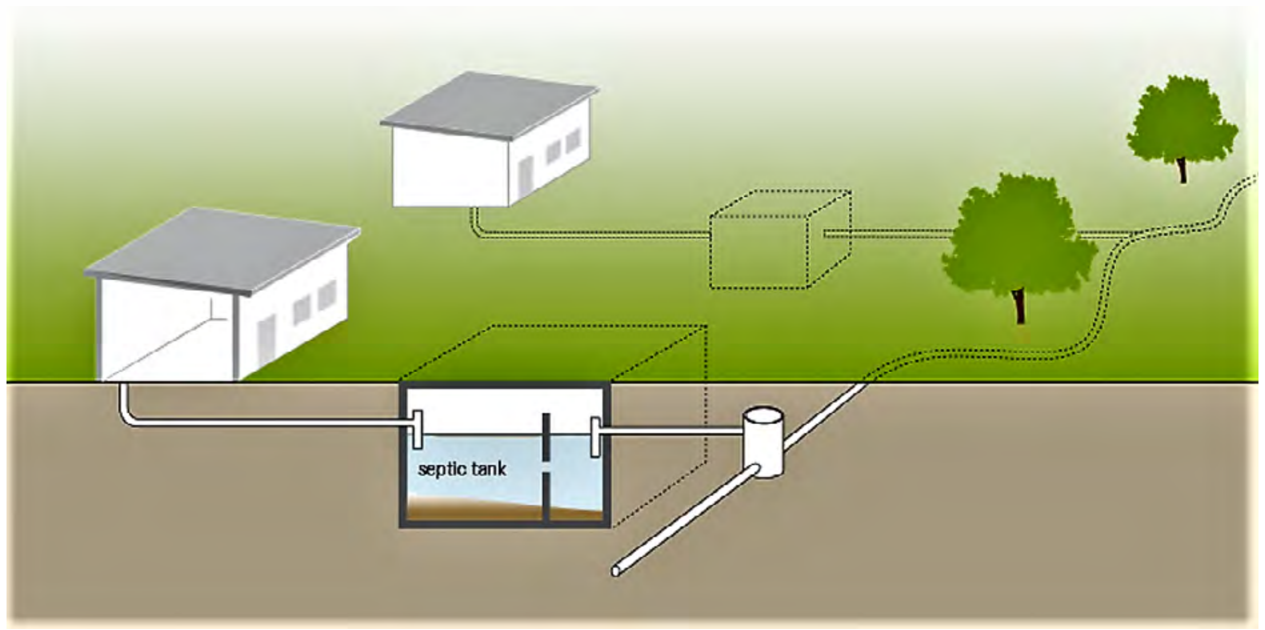



**Figure 19: Schematic of the solids-free sewer system.**

*Source: TILLEY et al., 2014)*

**Design Considerations-** If the interceptors are correctly designed and operated, this type of sewer does not require self-cleansing velocities or minimum slopes. Even inflective gradients are possible, as long as the downstream end of the sewer is lower than the upstream end. Solids-free sewers do not have to be installed on a uniform gradient with a straight alignment between inspection points. The alignment may curve to avoid obstacles, allowing for greater construction tolerance. At high points in sections with pressure flow, the pipes must be ventilated. A minimum diameter of 75 mm is required to facilitate cleaning.

**Health Aspects-** If well-constructed and maintained, sewers are a safe and hygienic means of transporting wastewater. Users must be well trained regarding the health risks associated with removing blockages and maintaining interceptor tanks.

**Operation & Maintenance-** Trained and responsible users are essential to avoid clogging by trash and other solids. Regular desludging of the septic tanks is critical to ensure optimal performance of the sewer. Periodic flushing of the pipes is recommended to insure against blockages. Special precautions should be taken to prevent illegal connections, since it is likely that interceptors would not be installed and solids would enter the system. The sewerage authority, a private contractor or user's committee should be responsible for the management of the system, particularly, to ensure that the interceptors are regularly desludged and to prevent illegal connections.

**Applicability-** This type of sewer is best suited to medium-density (peri-) urban areas and less appropriate in low-density or rural settings. It is most appropriate where there is no space for a leach field, or where effluents cannot otherwise be disposed of onsite (e.g., due to low infiltration capacity or high groundwater). It is also suitable where there is undulating terrain or rocky soil. A solids-free sewer can be connected to existing septic tanks where infiltration is no longer appropriate (e.g., due to increased housing density and/or water use).

As opposed to a simplified sewer a solids-free sewer can also be used where domestic water consumption is limited. This technology is a flexible option that can be easily extended as the population grows. Because of shallow excavations and the use of fewer materials, it can be built at considerably lower cost than a conventional gravity sewer.

**Site Selection-** Feasibility of utilising an existing interception & diversion system with necessary repairs, renovation, upgradation and modernisation.

Where new systems are to be established, availability of land is a critical factor. In a district if suitable land of the required size is not available for installing STP, waste water must be carried to a place where land for the STP is available.

Availability of electricity is crucial as a centralised system usually involves a long interception sewer necessitating laying of sewers at considerable depth and installation of intermediate pumping stations. These require power and since in most states there is shortage of power, standby arrangements in the form of DG sets have to be provided for. Thus, centralised system involves high capital cost and high O&M cost.

There are pros and cons of centralised and decentralised systems. They should be carefully analysed and compared. Life cycle costs of different systems should be compared.

The ability and willingness of the people to meet their obligations to sustain the system etc.

Over the life cycle of the system, the net present value of annual costs and revenues should be worked out of systems that are considered feasible and on that basis the system found to cost the least should be selected. Based on the above factors the most suitable system may be selected.

### 6.4.2 Water Consumption Vs Supply

#### Access to water

The statistics show that the access to water has increased. The number of households with tap connections has increased. However, with the decreasing source of raw water and increasing cost of water purification, the water supply is not as per design supply rate in most of the cities.

The residential units do have their bore wells which supplement the piped water supply. However, with increasing impervious surfaces and reduction in groundwater recharge, the groundwater aquifers are drying. Thus, the households that normally should access 135 LPCD water for its consumption, use far less water.

Hence, even with piped water supply for design supply rate of 135 LPCD, the water consumption is still at the lower end. Hence, the wastewater generation is below 100 LPCD which is the minimum requirement for attaining cleansing velocities in the sewered sanitation system.

#### Water Supply

The wastewater management plan should take into consideration the incremental increases in the water supply. The source of raw water plays an important role in the design of the water supply scheme. The city is able to sustain a higher supply rate only when a perennial water source is available. Many cities are currently facing issues with having such sources and hence are pumping water from more than 100 km. Making wrongful assumptions for planning wastewater management can lead to choosing wrong technological options which will fail eventually.

### 6.4.3 Reuse options- Circular economy

The ability to reuse water, regardless of whether the intent is to augment water supply or manage nutrients in treated effluent, has positive benefits that are also the key motivators for implementing reuse programs. These benefits include improved agricultural production; reduced energy consumption associated with production, treatment, and distribution of water; and significant environmental benefits, such as reduced nutrient loads to receiving waters due to reuse of the treated wastewater. Water reuse is integral to sustainable water management because it allows water to remain in the environment and be preserved for future uses while meeting the water requirements of the present.

Uses for Recycled Water:

- Irrigation for agriculture
- Irrigation for landscaping such as parks, rights-of-ways, and golf courses
- Municipal water supply
- Process water for power plants, refineries, mills, and factories
- Indoor uses such as toilet flushing
- Dust control or surface cleaning of roads, construction sites, and other trafficked areas
- Concrete mixing and other construction processes
- Supplying artificial lakes and inland or coastal aquifers
- Environmental restoration

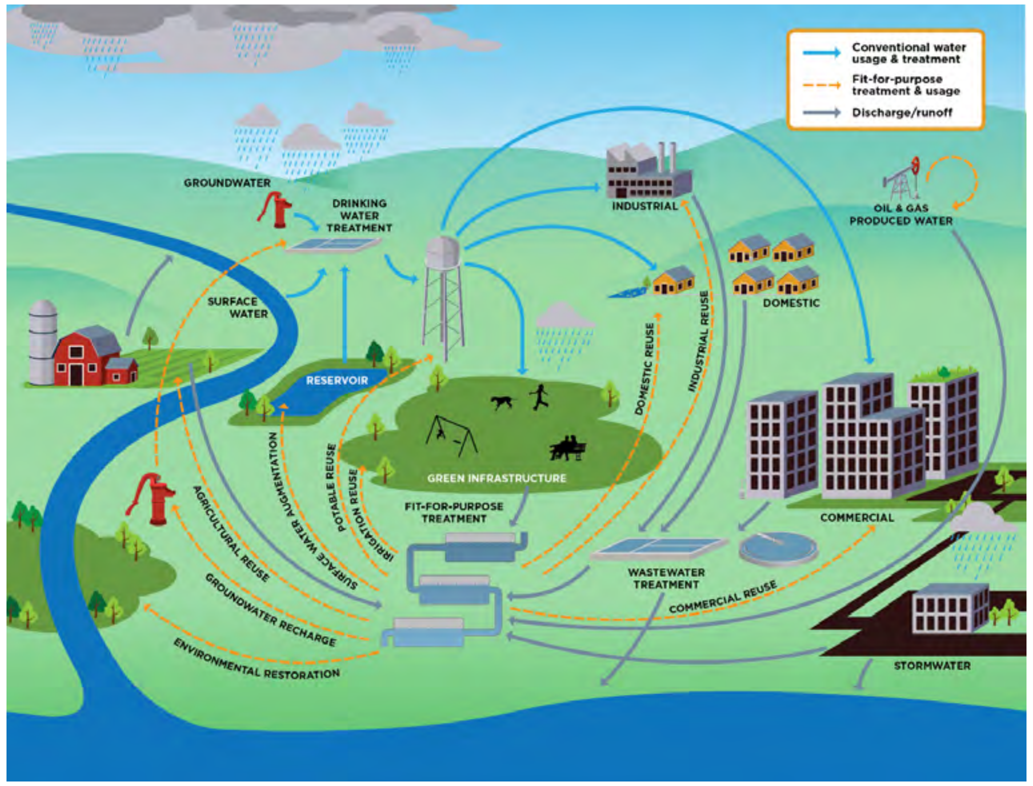



**Figure 20: Examples of water sources and use applications**

*Source: USEPA Water Reuse Guidelines, 2012*

The biosolids can be used for:

- Agriculture- Biosolids can be applied to land at the appropriate agronomic rate which is the sludge application rate designed to provide the amount of nitrogen needed by the crop or vegetation grown on the land. Agronomic rate is dependent on crop type, geographic location, and soil characteristics.
- Reclamation Sites- Biosolids can be used successfully to establish sustainable vegetation, reduce the bioavailability of toxic substances often found in soils, control soil erosion, and regenerate soil layers at sites that have damaged soils. Soil regeneration is very important for reclaiming sites with little or no topsoil.
- Forestry- Biosolids have been found to promote rapid timber growth, allowing quicker and more efficient harvest of an important natural resource.

Lawns and Home Gardens- Biosolids that meet the most stringent pollutant, pathogen and vector attraction reduction requirements may be purchased by the public from hardware stores, home and garden centres or their local wastewater treatment plant.

### 6.4.4 Incremental Solutions

**In-situ bioremediation-** These techniques involve treating polluted substances at the site of pollution. It does not require any excavation; therefore, it is accompanied by little or no disturbance to soil structure. Ideally, these techniques ought to be less expensive compared to ex situ bioremediation techniques, due to no extra cost required for excavation processes; nonetheless, cost of design and on-site installation of some sophisticated equipment to improve microbial activities during bioremediation is of major concern. Some in situ bioremediation techniques might be enhanced (bioventing, biosparging and phytoremediation), while others might proceed without any form of enhancement (intrinsic bioremediation or natural attenuation). In situ bioremediation techniques have been successfully used to treat chlorinated solvents, dyes, heavy metals, and hydrocarbons polluted sites. Notably, the status of electron acceptor, moisture content, nutrient availability, pH and temperature are amongst the important environmental conditions that need to be suitable for a successful in situ bioremediation to be achieved. Unlike ex situ bioremediation techniques, soil porosity strongly influences the application of in situ bioremediation to any polluted site.

**In-situ phytoremediation-** This technique relies on the use of plant interactions (physical, biochemical, biological, chemical and microbiological) in polluted sites to mitigate the toxic effects of pollutants. Depending on the pollutant type (elemental or organic), several mechanisms (accumulation or extraction, degradation, filtration, stabilization and volatilization) are involved in phytoremediation. Elemental pollutants (toxic heavy metals and radionuclides) are mostly removed by extraction, transformation and sequestration. On the other hand, organic pollutants (hydrocarbons and chlorinated compounds) are predominantly removed by degradation, rhizoremediation, stabilization and volatilization, with mineralization being possible when some plants such as willow and alfalfa are used. Some important factors to consider when choosing a plant as a phytoremediator include: root system, which may be fibrous or tap depending on the depth of pollutant, above ground biomass, which should not be available for animal consumption, toxicity of pollutant to plant, plant survival and its adaptability to prevailing environmental conditions, plant growth rate, site monitoring and above all, time required to achieve the desired level of cleanliness. In addition, the plant should be resistant to diseases and pests.

Nonetheless, the process is likely to differ, depending on other factors such as the nature of contaminants and plant type. It is plausible that most plants growing in any polluted site are good phytoremediators. Therefore, the success of any phytoremediation approach primarily depends on optimizing the remediation potentials of native plants growing in polluted sites either by bioaugmentation with endogenous or exogenous plant rhizobacteria, or by bio stimulation.

### 6.4.5 Population Projections

The design population should be estimated by paying attention to all the factors governing the future growth and development of the project area in the industrial, commercial, educational, social, and administration spheres. Special factors causing sudden immigration or influx of population should also be predicted as far as possible. A judgement based on these factors would help in selecting the most suitable method of deriving the probable trend of the population growth in the area or areas of the project from the following mathematical methods, graphically interpreted where necessary-

a) Demographic method of population projection- The population change can occur in three ways: by birth (population gain), by death (population loss), or by migration (population loss or gain depending on whether movement-out or movement -in occurs in excess). Annexation of the area may be considered a special form of migration. Population forecasts are frequently made by preparing and summing up separate but related projections of natural increases and of net migration, and are expressed below. The net effect of births and deaths on population is called natural increase (natural decrease, if deaths exceed births). The migration also affects the number of births and deaths in an area, and hence, projections of net migration are prepared before projections for natural increase. This method thus takes into account the prevailing and anticipated birth rates and death rates of the region or city for the period under consideration. An estimate is also made of the emigration from and immigration to the community. Its area-wise growth and the net increase of population are calculated accordingly considering all these factors by arithmetical balancing.
b) Arithmetic increase method- This method is generally applicable to large and old cities. In this method, the average increase of population per decade is calculated from the past records and added to the present population to estimate population in the next decade. This method gives a low value and is suitable for well-settled and established communities.
c) Incremental increase method- In this method, the increment in arithmetical increase is determined from the past decades and the average of that increment is added to the average increase. This method gives increased values compared to the figures obtained by the arithmetical increase method.
d) Geometrical increase method- In this method, the percentage increase is assumed as the rate of growth and the average of the percentage increase is used to determine the increment in future population. This method gives a much higher value and is applicable to growing towns and cities having a vast scope of expansion.
e) Method of density- In this approach, the trend in rate of increase in population density for each sector of a city is determined and population is forecast for each sector based on the above approach. Addition of population sector-wise, gives the population of the city.

Final Forecast- While the forecast of the population of a project area at any given time during the design period can be derived by any one of the foregoing methods appropriate to each case, the density and distribution of such population in several areas, zones or districts will again have to be estimated based on the relative probabilities of expansion in each zone or district, according to the nature of development and based on existing and contemplated town planning regulations. Wherever population growth forecasts or master plans prepared by town planning authorities or other appropriate authorities are available, the design population should take these figures into account. Floating population should also be considered which includes the number of persons visiting the project area for tourism, pilgrimage or for working. The numbers should be decided in consultation with the tourism departments and specified for water supply and sewerage.

### 6.5 Notes for Trainer

This session defines the basic design aspects of wastewater management & water supply. The session will provide an insight into population projection methods, different water reuse options available & in situ treatment.

### 6.6 Bibliography


- TILLEY et al. (2014): Compendium of Sanitation Systems and Technologies, IWA Publication and Eawag
- Sustainable Sanitation & Water Management Toolbox
- NMCG Guidelines (2018): Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants
- AMRUT 2.0 (2021): Operational guidelines
- CPHEEO (1999): Manual on Water supply & treatment
- CPHEEO (2013): Manual on Sewerage & Sewage Treatment Systems
- USEPA Guidelines for Water Reuse, 2012
- Bioremediation techniques–classification based on site of application: principles, advantages, limitations and prospect, Christopher Chibueze Azubuike et al.




Session

# 07

# Collection and Conveyance System

# 7. Collection and Conveyance System

## 7.1 Learning objectives

- To understand how design flows are computed using data available and to confirm the same using actual measurements at the drain.
- To understand the interception and diversion for surface drain and sewer.
- To understand the components of interception and diversion components and their design criteria.

## 7.2 Session plan

Duration - 60 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Design Flows | 25 min | Powerpoint presentation |
| Interception and Diversion Method | 25 min | Powerpoint presentation |
| Q&A | 10 min | Discussion |

## 7.3 Key facts

- Computational method for design flow estimation is based on statistical data and assumption, hence can lead to inaccurate estimates.
- Actual measurement on surface drains and sewers help to confirm the estimate through a computation method.
- Data collection throughout the year is key to avoid risk of failure.
- The I & D approach might possess operational challenges to STP that lead to urban flooding.
- Infrastructural projects might be required to manage the wet weather overflow to avoid urban flooding in future.

## 7.4 Learning notes

### 7.4.1 Design Flow

Design sewage flow is the expected maximum discharge in the sewer during the life of the system. This is arrived at by multiplying the population expected at the end of the design period with the per capita sewage flow and a peak factor.

Design flow can be calculated using two methods:

- Computational method
- Actual measurement

The computational method is based on the statistical information and assumptions which are rate of water supply and projected population (including floating) of the catchment, in design years whereas the actual measurements indicate the actual flow in the drain/pipe at the specific time of the day. Higher values (peak) from both the above methods should be adopted as a design flow unless justified for the specific city having specific reasons and climatic condition.

In some towns, the flow in the drains is many times higher than the computed flow based on the water supply indicating the contribution of groundwater (secondary sources), canal or springs or some other sources like back and grey water mixing with storm water. In such a situation, a judicious and well considered value should be taken for designing the interception/diversion works, SPS and STPs.

The below tables mentioned about the various sub methods to calculate design flow:

**Table 7: Design flow calculation methodologies**

| Computational Method | Actual Measurement |
|---|---|
| Statistical Method | Float Methods |
| Peak Flow | Measuring devices |
| Groundwater Infiltration | Daily variations |
| Interception | Seasonal Variations |

Higher values, worked out using the above methodologies, may be adopted as design flow unless justified for the specific city having specific reasons and climatic conditions. Design flows shall also include the flow reaching STPs from drains flowing into the city from areas outside city boundary limits.

**A. Computational Methods**

Computational method is based on the rate of water supply and projected population of the catchment in design years, that means it is based on the statistical information and assumptions for future population.

**Sewage Generation**

Quantity and quality of sewage generated in a town carried by the drains untreated into the river and by sewers to STPs for treatment need to be measured and tested. Supply and use of water increase continuously, hence the amount of domestic sewage generation also increases, which means sewage generation depends upon the daily water supply and consumption of users. The sewage generation and consumption also depend upon the socio-economic factor of individual households of the city. The water supply varies from city to city and as per institutional requirements standards mentioned in CPHEEO manual.

**Table 8: Recommended Per Capita Water Supply Levels for Designing Schemes**

| Sr. No. | Classification of towns / cities | Recommended Maximum Water Supply Levels (lpcd) |
|---|---|---|
| 1. | Towns provided with piped water supply but without sewerage system | 70 |
| 2. | Cities provided with piped water supply where sewerage system is existing/ contemplated | 135 |
| 3. | Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/ contemplated | 051 |

The water requirements for institutional needs should be provided in addition to the provisions while calculating design flow.

**Table 9: Water Supply Requirements for Institutional Needs**

| Sr. No. | Institutions | Litres/capita/day |
|---|---|---|
| 1 | Hospital (including laundry) | |
| | No. of beds exceeding 100 | (deb rep) 054 |
| | No. of beds not exceeding 100 | 340 (per bed) |
| 2 | Lodging houses / Hotels | 180 (per bed) |
| 3 | Lodging houses /Hostels | 135 |
| 4 | Nurses' homes and medical quarters | 135 |
| 5 | Boarding schools / colleges | 135 |
| 6 | Restaurants | 70 (per seat) |
| 7 | Airports and sea ports, duty staff | 70 |
| 8 | Airports and sea ports, alighting and boarding persons | 15 |
| 9 | Junction stations and intermediate stations where mail or express stoppage (both railways and bus stations) is provided, duty staff | 70 |
| 10 | Terminal stations | 45 |
| 11 | (spots sserpxe dna liam gnidulcxe) snoitats etaidemretnI | 45 (Could be reduced to 25 where bathing facilities are not provided) |
| 12 | Train and Bus stations, alighting and boarding persons | 15 |
| 13 | Day schools / colleges | 45 |
| 14 | Offices | 45 |
| 15 | ffats ytud ,seirotcaF | 45 (could be reduced to 30 where no bathrooms are provided) |
| 16 | Cinema, concert halls and theatre | 15 |

Design flow to be adopted for different components based on sewage generation which will depend on size of town

**Table 10: Design Flows to be adopted for different components**

| Sr. No. | Component | Design capacity based on |
|---|---|---|
| 1 | Interceptions | Projected peak drain flow in 30 years |
| 2 | Sewers | Computed sewage generation in 30 years @ 135/150 lpcd* |
| 3 | Sewage pumping stations CW | Computed sewage generationin 30 years @ 135/150 lpcd* |
| 4 | Sewage pumping stations EM works | Computed sewage generation in 15 years @ 135/150 lpcd* |
| 5 | STPs | Computed sewage generation in 15 years @ 135/150 lpcd* |
| 6 | Effluent sewers | Computed sewage generation in 30 years @ 135/150* lpcd* |
| 7 | Land | For STPs / SPS on computed sewage generation in 30 years @ 135/150* lpcd* |

**Depending upon size of town*

### Peak Factor

Peak flow is the flow where wastewater generation is maximum during certain hours of the day. Flow in drains and sewers varies hourly and seasonally. However, for design purposes, peak factors may be adopted as per below table. Minimum flow may vary from 1/3 to ½ of average flow.

**Table 11: Peak factors for contributory population**

| Sr. No. | Contributory Population | Peak Factor |
|---|---|---|
| 1 | Up to 20,000 | 3 |
| 2 | Above 20,001 to 50,000 | 2.5 |
| 3 | Above 50,001 to 7,50,000 | 2.25 |
| 4 | Above 7,50,001 | 2 |

*Source: CPHEEO (2013): Manual on Sewerage & Sewage Treatment Systems*

As the population range is very wide in the above table, hence it is recommended to use the empirical formula from table 10 which provides specific peak factors as per the population of the city.

**Table 12: Peak factors for actual population**

| Sr. No. | Formula Name | Peaking Factor | Conditions of Application |
|---|---|---|---|
| 1 | Harmon (Harmon 1918), (Alberta Environment 2006), (Fair, 1954), (City of Toronto 2009), (Ontario 2008), (State of Washington 2003) | | P in thousands |
| 2 | Babbitt (Babbitt et al., 1958), (Ontario, 2008) | | |
| 3 | Gifft (Gifft 1945) (Davis et al., 1969) | | Maximum PF. = 3<br>Minimum PF. = 1.6 |
| 4 | Tchobanoglous (Metcalf et al. 2003) | 4 for P < 5000<br>7.7 – log P for 5000 < P < 5000 | |

### Groundwater Infiltration

The inflow to sanitary sewers may also include flows due to infiltration of groundwater through joints. As per CPHEEO manual, since sewers are designed for peak discharges, allowances for groundwater infiltration for the worst condition shall be made as per Table 11 and that design infiltration value shall be limited to a maximum of 10% of the design value of sewage flow.

**Table 13: Groundwater Infiltration**

| Sr. No. | Item | Unit | Minimum | Maximum |
|---|---|---|---|---|
| 1 | Area | Litres/ha/day | 5000 | 50,000 |
| 2 | Length | Litres/km/day | 500 | 5,000 |
| 3 | Manhole | Litres/day/manhole | 250 | 500 |

For design purposes, ground water infiltration through sewers may be adopted depending on depth of sewers to be laid and depth of sub soil water.



### Interception Factor

The dry weather flow reaching the sewer system is less than that of the per capita water supply due to loss of some water in leakage and evaporation. It varies from 40% of water supplied in arid regions to 90% in well developed areas. For design purposes, the interception factor can be adopted as 0.80 in developed areas. However, conventional sewers shall be designed for a minimum sewage flow of 100 LPCD or higher as the case may be. The suggested interception factors for the different drains are as per below Table 12.

**Table 14: Interception Factor for drains**

| Sr. No. | Type of Drains | Interceptor Factor |
|---|---|---|
| 1 | Covered Lined Drains | 90% |
| 2 | Lined Drains | 75% |
| 3 | Unlined Drains | 60% |
| 4 | Unlined Drains with Vegetation | 40% |

### B. Actual Measurement

The measurement of flows in existing drains or sewers will provide valuable data for a more realistic assessment of the design flows. In general, unsewered areas will most certainly be having a set of drains where the already generated sewages will be flowing out. The assessment of the flows in drains can be done by a variety of methods. Actual measurement methods give more accurate value of sewage flow in drains.

### Float Method

The float measurement is normally not recommended for discharge measurement due to its large uncertainty. In this method, surface velocity of flow of the drain is worked out by the time taken by a float like an empty match-box or a plastic box to travel for about 3 m in a straight reach and flow is calculated by measuring the depth and flow in the drain.

If we assume the respective values as 20 seconds, the width as 0.9 m and depth of flow as 0.6 m, the flow can be assessed as 0.8 × 0.9 × 0.6 × (3/20) × 1000 = 65 lps. The factor of 0.8 is the average velocity in such drains for the depth of flow. Float Method consists of two stages:

- Measuring the cross section of the drains and
- Measuring the time taken by a float to cover a predetermined distance in the drain.

Stage 1: Cross section of a lined and well-shaped drain is relatively easy. Usually, these drains are either rectangular or trapezoidal in cross section and a simple mathematical formula can be used to determine the cross-sectional area. For measuring the cross section of an irregular shaped drain, the width of the channel is divided into a number of multiple sections as shown in the figure (top right). Depth is measured for each section and area is calculated by the formula given on the slide.

Stage 2: A distance of 3 m or approximately 10 feet is marked in a straight line as shown in the picture on the slide. A float (plastic ball, paper, match box etc.) is used. The float is released upstream of the start point and allowed to float till the end point. Time is measured for the float to cover the distance and velocity is determined.

Flow in the drain is equal to the product of velocity of the flow and the cross-sectional area of the drain.

### Notch and Weir Method

This requires the insertion of a V notch plate in the drain at a location where the downstream discharge can be a free fall. These plates can be cut out from stainless steel (SS) or Teflon sheets of nominal thickness of about 2 mm and inserted tightly into the drain and the gaps can be closed by a mixture of clay and cement in equal proportion mixed to a thick consistency and smeared on the downstream side. The V notch is the best chosen such that the angle subtended is 90 degrees.

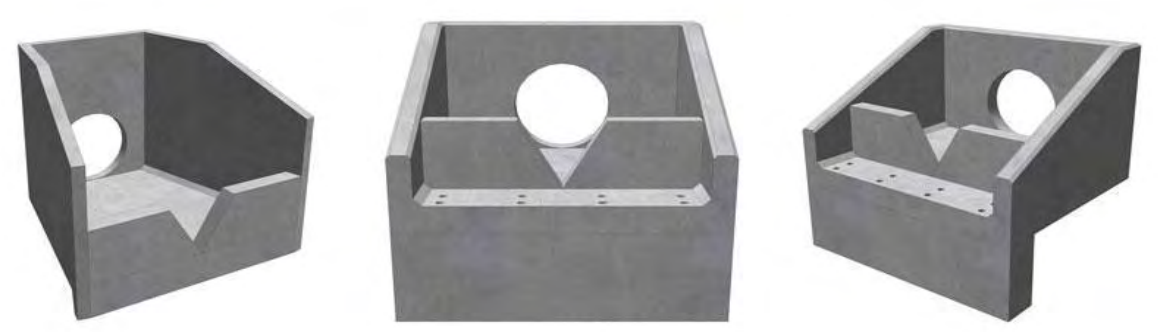


**Figure 21: V Notch in a drain**

*Source- Althon Limited, Norwich*

A weir is an overflow structure built according to specific design standards across a drain to measure the flow of wastewater. Equations can be derived for weirs of specific geometry which relate static head to wastewater flow. Weirs are classified into two general categories, broad crested and sharp crested.

### Rectangular Weir Method

Rectangular weir can be used if there is already an existing levelled overflow weir like the overflow culverts in irrigation canals. In smaller drains and in places where workmanship of V notch cuts is difficult, these can be used easily by cutting a mild steel or wood sheet. They are similar to the rectangular weir except that the length of the weir is smaller than the width of the drain. The depth of flow is measured over the overflow edge of the notch.

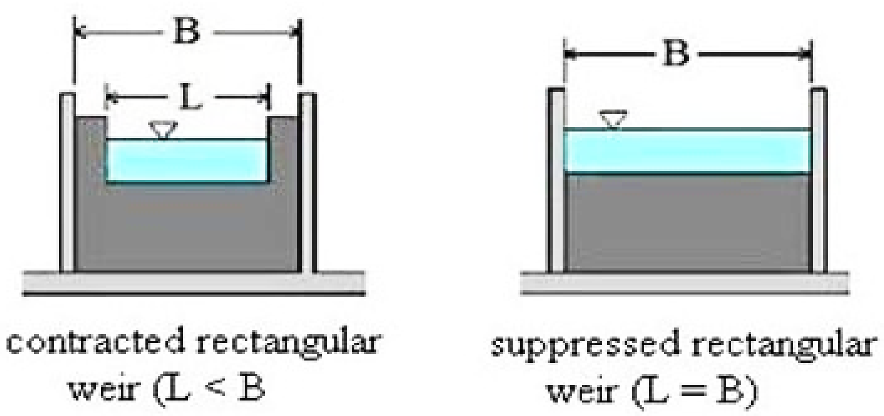



**Figure 22: Weir in a drain**

*Source- The Constructor Building ideas*

### Dilution Method

In this method, the tracer i.e., common salt and other chemicals is injected at some point along the stream, and the tracer concentration in stream water is measured at a downstream point by an electrical conductivity meter, where the tracer has become uniformly mixed with the stream water. The probe of the conductivity meter should be immersed, close to the bed of the stream or ideally at the mid depth. After injecting the salted water, the salt starts spreading itself out while travelling downstream. At a certain point downstream, it will have filled the width of the stream. For a given volume or rate of injection, greater stream discharges will result in greater tracer dilution and lower concentrations measured at the downstream site. Equations based on the mass balance principle are applied to compute the stream discharge.

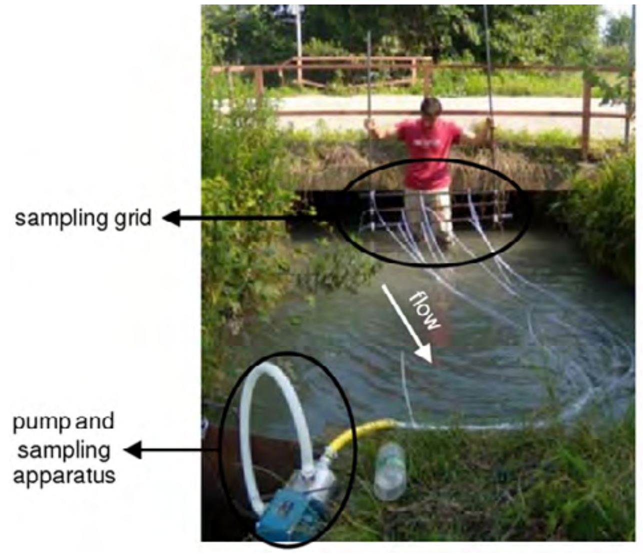



**Figure 23: Salt Dilution Method**

*Source- C. Comina et. al, 2013*

The method of flow is easy to accomplish, accurate (<±7%), and reliable for a wide range of stream types. Using this method, stream flow can be measured in less than 10 minutes and very little equipment is needed. The total streamflow, assuming that the streamflow was constant over the test, is

### Flow measurement sheet

Volume of sewage generated should be measured by any of the above methods for more accurate value. The flow measurement plan should be made showing the names of drains, discharge carried by them, location points of their outfalls into the water body, points of their interception and STPs into which diverted should be prepared. For proper data generation and actual values for designing of STPs or intercepting drains flow measurement sheet should be maintained. Actual present flows should be recorded three times: Pre-monsoon, during monsoon and after monsoon. If this is not feasible, flows may be recorded in dry weather before the point of outfall into the water body for at least one month. Samples should be taken on a day in every week for diurnal variation on hourly basis for twenty-four hours. Considering a four-week month, three sample days are to be taken on weekdays, whereas the fourth one on an off day i.e., Sunday.

If the drain has been intercepted for treating the sewage, the discharge diverted to the STP should be measured. Data on the flows measured in the past should also be collected and reported.

Details of the quantity of sewage reaching STPs through sewers may be collected from the records of STPs for the last 3 years. In the absence of records, the same may be measured in dry weather. The copies of this measurement sheets should be a part of DPR for more clarity on design calculation.

### 7.4.2 Interception and Diversion Components

Interception and Diversion project refers to intercepting the surface/subsurface drains before they reach to the disposal point and divert the flow in them to the treatment facility.

Interception and diversion of drains for different weather flow condition is as below:

- Dry weather flow
- Wet weather flow
  - Deep tunnel systems

**Dry Weather Flow**

Dry Weather Flow (DWF) refers to the wastewater flow in a sewer system during periods of dry weather with minimum infiltration. The dry weather flow is also called "sanitary sewage". It mainly consists of domestic sewage and industrial wastewater, wastewater from public facilities and ground water infiltration.

Dry weather overflows should only occur under exceptional circumstances, such as plant or equipment failure. Dry weather overflows represent a discharge of untreated wastewater to the environment and as such are likely to be highly offensive and environmentally damaging. Wastewater agencies must ensure that their systems have adequate capacity for dry weather flow. Mechanical installations such as pumping stations should be fitted with standby pumps and backup power supplies, if appropriate, to minimise the risk of failure.

The dry weather flow or the quantity of sanitary sewage depends upon the following factors

- Rate of water supply
- Population growth
- Type of area served
- Infiltration of groundwater

$$DWF = 80\% \times L \times P + I + E$$

Where:
L= Domestic water consumption per head,
P= Population connected to the sewer,
I= Infiltration in to the pipes,
E= Industrial discharges

**Wet Weather Flow**

Wet Weather Flow (WWF) consists of dry weather flow and the storm water flow. It is generally estimated when the combined sewerage system has been adopted. When rainfall takes place, a part of it infiltrates or percolates into the ground surface while the remaining flows over the land. It has been the practice in the past to tolerate wet weather overflows because they are difficult to control and the discharge is partly diluted by stormwater runoff. With increasing environmental awareness, this is no longer acceptable.

The wet weather flow depends upon the following factors:

- Permeability of the ground
- Surface slope
- Catchment area
- Extent of impervious area and vegetation growth
- Rainfall intensity and duration

There are different methods to find out wet weather flow but the commonly used method is the rational method.

$$Q = K.\ A.\ I.\ Ri$$

Where:
Q= run off at wet weather flow,
K= constant,
A= catchment area in hectors,
Ai= Impervious area = AxI
Ri= Intensity of rainfall in mm/hr
I= Impermeability coefficient

The I & D project should be designed so that this sewer overflow is restricted to four times in a year. Due to rapid urbanization, leading to larger impervious surfaces coupled with irregular-high intensity rainfall leads to numerous overflows per year. Cities in developed countries are facing the problem and are solving the issue in two ways. First way to promote stormwater management at the community level. This involves use of green infrastructure in combination with grey infrastructure for managing runoff. More details about this have been provided in Section 10.4.3.

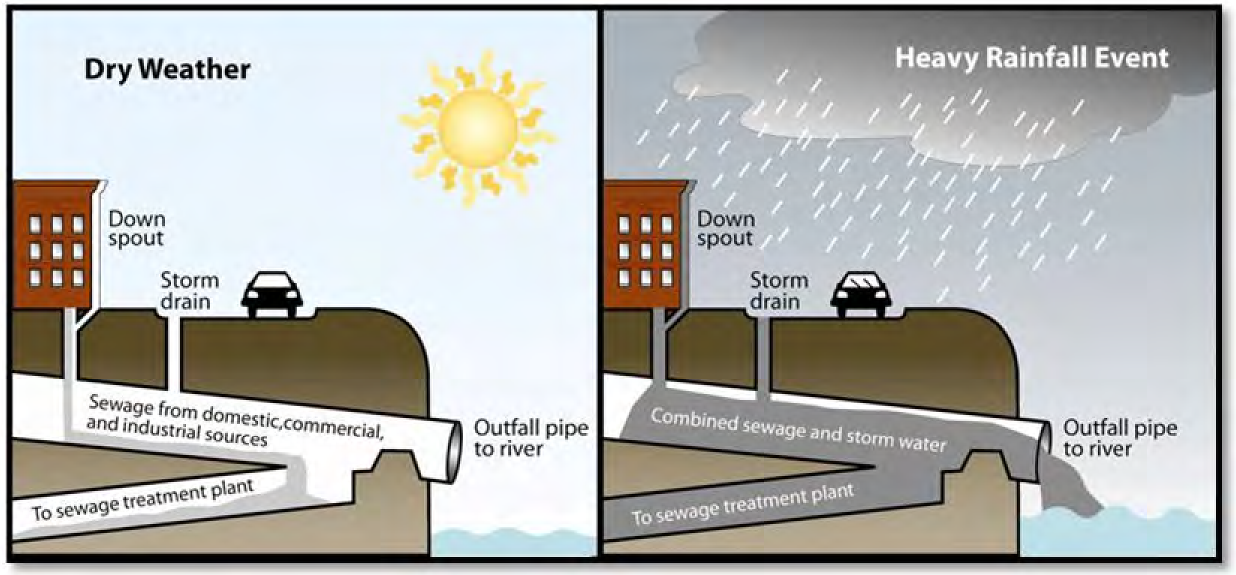



**Figure 24: Dry and Wet Weather Flow**

*Source- Akron Waterways Renewed*

### Deep Tunnel Systems

Deep tunnel systems are used to convey water, raw sewage, stormwater, floodwater, and combined sewer overflows (CSOs) in many urbanized communities and large cities around the globe. Deep tunnel conveyance can be via gravity or siphon. Just like all integrated sewer systems, no deep tunnel system is ever the same. It depends on the location, space available, purpose, and how the tunnel will work within the existing sewer system.

With this method a large-diameter tunnel is constructed deep under the city. Wet weather overflows are directed into the tunnel through vertical shafts, and are later pumped out for treatment and discharge. The tunnel can be designed to also act as a transport system, bypassing existing chokes and avoiding the need for costly system amplification within the city streets.

Deep tunnel is a solution where large diameter tunnels (up to 7m) are constructed at the depth of 30-60 m. Alternatively, large surge tanks are built underground where the overflow is collected. Post storm, the stored wastewater is then pumped into the STP and treated over a period of days. Although these solutions have numerous advantages in countries like Singapore and the US, they tend to be cost intensive and economically not feasible for most of the cities in India.

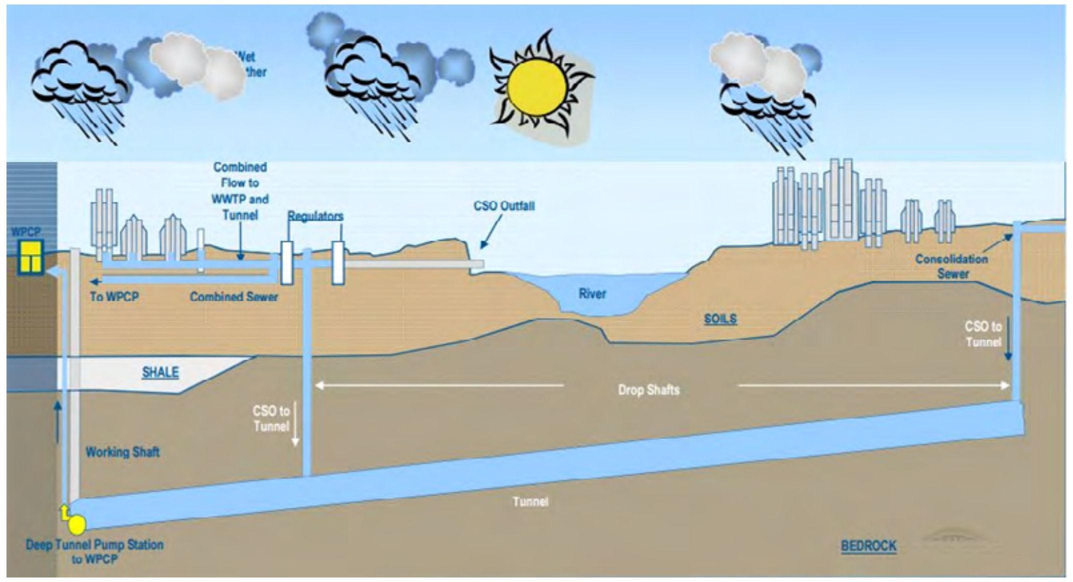



**Figure 25: An overview of deep tunnel systems for CSO control**

*Source- Water Environment Federation, 2018*

### Interception and Diversion project

Interception and Diversion projects on the surface drain involve various components which are important to complete diversion work in proper and required manner. In tapping and diverting work of drains various components are involved which are as follows:

- Interception Channel
- Weir gates
- Overflow weir
- Diversion drains

**Interception channel -** The channel which needs to be intercepted and diverted is known as interception channel. In case of irregular drains, this refers to the spot where the I&D project will be implemented. The interception channel shall have a guiding wall submerged into the water to divert the solids with the wastewater to the diversion drain.

**Weir gates -** A small weir with gates needs to be installed to block the flow of wastewater to go forward in the drain. The gates can be raised and lowered to increase or decrease the effective height of the weir.

**Overflow weir -** An overflow weir with a low flow discharge channel is provided adjacent to the weir and gates. This helps to release some overflow during peak hours. The discharge channel ensures a certain depth of water which does not get heated up while flowing down the concrete surface of the weir. Controlling temperature of the overflow is important as higher temperature favors algal growth as nutrients are present in the wastewater.

**Diversion drain -** The diversion drain diverts the flow into the trunk line or a sewage pumping station. The mouth of the diversion drain also has hydraulic gates to control the inflow of wastewater.

This surface drainage tapping work should be carried out near the outfall of the drains carrying untreated sewage into the river. During drainage tapping work, the design peak flow, size of the drain and Highest Flood Level (HFL) of the river should be considered. These should not be designed using empirical rainfall-runoff formulae.

During the rainy season, the sewage flowing into the drains will be supplemented by storm water. As this happens, the gates provided at the interception chamber shall be raised to allow rain water to pass through and bypass the STP for which suitable arrangements shall be made. Suitable arrangements need to be provided for removal and disposal of solids, floating materials and silt to prevent silting of diversion sewers. The location of the interception works shall take due consideration of the floodplain of the river to provide unobstructed approach for O&M. Hydraulic design shall be provided for every component of I&D works along with hydraulic flow diagram.

### Gates

Gates are installed at the weir to control the overflow into the water body or the flow into the sewage pumping station or sewerage network. With a properly operated gate, it is possible to continue to pump a quantity equivalent to the sanitary sewage flow from the combined sewer to the treatment plant even though flood conditions prevail in the stream at the sewer outlet. The maintenance of gates requires regular inspection and removal of debris drains or outlet chamber, lubrication of hinge pins and cleaning of seating surfaces.

The two gates tilting weir gates and sluice gates are recommended for I&D works. The sluice gate is to be implemented at the diversion gate. It can be operated manually or automatically (can also be controlled remotely if required). Its main function is to control the amount of water from the interception channel into the pumping station or the trunk line. The tilting weir gate is to be implemented on the interception weir. It can also be operated manually or automatically using motors. Its main function is to control the overflow into the disposal point in events such as rainfall. The main feature of this gate is it allows the water to overflow from the top. Thus, the sediments do not get washed away and better control is provided. A sluice gate is traditionally a wooden or metal plate, which slides in grooves in the sides of the guide channel. Sluice gates are commonly used to control sewage levels in STPs.

Source: Aquatic Control Engineering

**Figure 26: Tilting Weir and Sluice Gates to control flow**

**Sewer Diversion Process**

While doing diversion of sewer, environmental and community impact must be taken into consideration and the type of sewer and water flow must be considered. Many different methods are there to carry out the sewer diversion process, mostly using a potentially smelly process that involves pumping out the sewage from the manhole. Where there is a sewer main affecting your planned development, there may be a need to divert the main. Considering the urgency of preventing pollution of our water bodies and preserving our precious water resources, sewage treatment and reutilization of treated sewage need to be accorded a higher priority. So, diversion of sewers to its safe disposal is the key aspect of I&D project.

**Sewer Tapping**

The various components of sewer tapping are the diversion chamber, drop shaft, ventilation control unit, SPS or trunk line.

**Diversion Chamber -** Purpose of diversion chamber is to intercept wastewater from combined sewer. The diversion chamber is installed near the outlet of the existing combined sewer under the existing road or sidewalk. All existing combined sewers are affected by tide from canals. Therefore, high water levels must be considered to design a diversion chamber.

**Drop Shaft -** A drop shaft is a vertical length of pipe work taking a drain or pipe down to the level of a deeper drain, pipe or sewer, given that most of the early systems were hand dug it is no surprise that they took the path of least resistance. So, a drain running from a property would be installed at the minimum workable depth before passing through a drop shaft which would take the waste or storm water down to the level of the main line drainage. If the drop shaft is prior to a particularly deep sewer several properties at a time would be connected so as to save on pipe work, labour and unnecessary deep excavation works, the top of the drop shaft would be either a 90-degree bend or a square junction would be installed with the shaft being extended up to surface level for future access.

**Ventilation control unit -** Various gases are produced in sewers due to purification of organic materials of sewage. These gases are very foul in nature, cause harm to human health and corrode the sewers. The gases produced are highly explosive and may cause accidents. Due to the above difficulties, the sewers must be properly ventilated. Ventilating shaft helps to remove the foul and explosive gases produced in the sewer. They provide fresh air to the workers working in the manholes. They also help to prevent the formation of air locks in the sewage and thereby ensure the continuous flow of sewage inside the sewer. The ventilating shaft is provided along the sewer line at an interval of 150 m to 300 m. They are also provided at the upper end of every branch sewer and at every point where sewer diameter changes.

**Trunk lines -** The trunk sewer is the sewer line that receives wastewater flow from the collector sewer and conveys this wastewater either to an intercepting sewer or a treatment plant. The trunk sewer forms a significant part of a sewer network in large population or industrial centers. Small diameter pipes, also known as lateral sewers, carry wastewater from residential and commercial buildings to the collector sewer, which flows into the larger trunk sewer for onward transmission. The trunk sewer is sometimes referred to as the main sewer, although in other instances, tributary sewer lines that feed the trunk sewer are called the main sewers. Manholes form an essential part of this system as they are necessary for access to undertake inspection and repairs. The trunk sewer size is determined by the anticipated design flow for the required service area and the hydraulic characteristics of the sewer piping network.

**Sewage Pumping Station**

Sewer pumping stations also called lift stations are used to move wastewater to higher elevations in order to allow transport by gravity flow. Sewage is fed into and stored in a sealed underground pit, commonly known as a wet well. Sewage from individual houses flows into the wet well. The sewage will then sit in the well until it reaches a predetermined level. Once it reaches this level, a pump will kick in to pressurise the sewage so that it will travel out of the wet well, uphill, to a point where it enters the main sewer, or that it can then travel into the main sewer using gravity. A pump station offers convenience when installing a sewage system, and has a potential of cutting construction cost. Sewage can be pumped automatically without any human contact, which eliminates the risk of health problems.

The various components of sewage pumping stations are as follows:

- **Gate -** It is necessary to insert a gate at the entry of the sewer into the wet well. The gate shall close by lowering the gate by either hand driven or motorized gear wheel.

- **Screens -** Screens are needed to trap the floating matters like sachets, plastic milk packets, grocery bags, etc., which otherwise can lump in the impeller.

- **Grit chambers -** Grit shall be removed at the SPS to safeguard the same from causing wear to the pump impeller and inside of especially RCC pumping mains. In case of HDPE and PVC pipeline, the material of the wall does not succumb to erosion as long as velocities are between 1 m/s and 3 m/s and moderate grit content can be even pumped out directly to the STP. For almost all other pipelines the grit will erode the wall thickness and the pipes may collapse after some time.

- **Wet well -** Wet well pumping stations usually contain larger pumping units than those required for submersible type pumping stations. The pumping units are installed in the dry well whilst the sewage is stored in the adjacent wet well. Wet wells shall be designed and constructed to be as hazard free as possible, and corrosion resistant materials shall be used throughout.

- **Dredging equipment** – Dredging equipment is mainly used for the removal of sediments and debris from well. A dredge pump is a horizontal centrifugal pump and is the heartbeat of a dredge. The dredge pump is designed to take in sediment, debris, and other harmful materials from the surface floor into a suction pipe, carrying the material to a discharge site through a pipeline. The pump must be able to handle common solid fragments of various sizes that are capable of passing through the pump, minimizing downtime required for cleaning.

- **Odour control unit -** Adequate ventilation shall be provided for all pump stations. There shall be no interconnection between the wet well and dry well ventilation systems. Ventilation shall be accomplished by the introduction of fresh air into the pump station under positive pressure. The air shall be filtered to remove particulates inside the pumping station.

**Design aspects**

**Wet Well**

Size of the wet well should be based on the following:
- Flow from proposed development and any associated future development
- Capability to receive flows from surrounding areas as determined by the authorities

The volume of wet well is given by

$$\text{Volume [cum]} = \frac{T[min]\ x\ \ Q\ [\frac{cum}{min}]}{4}$$

Where,
V: Effective volume of wet well (in cubic meters)
T: Time for one pump cycle (in minutes)
Q: Pumping rate (cubic meters per minute)

$$\text{Volume [cum]} = HRT[min]\ x\ \ Q\ [\tfrac{cum}{s}]$$

Where;
HRT = 3.75 min
Q = Design peak flow

It may be difficult to construct wet wells 3.5 m deep below invert of incoming trunk sewers which themselves may be at a depth of about 5 m to 6 m below ground level. Moreover, designing and constructing the wet wells to be checked for cracking stress in high water table areas may be not only difficult but may give way to infiltration which will be a challenge to control later on. Thus, it becomes a problem of obtaining sufficient wet well volume at reasonable cost.

It is also a matter for consideration to move on to immersible pump sets in future where the submergence in sewage is not needed and the motor winding cooling is provided by an internal oil chamber around it in the example above, this will mean reducing the height of wet well below the incoming sewer by 1.2 m.



Following points should be considered while designing the wet well pumping system:
- Normal operating volume shall prevent any one pump from starting more than 3 times per hour.
- Level control is to be provided by an ultrasonic level controller or submersible transducer.
- Provide high water and low water alarm activated by ultrasonic or submersible level control systems and backup float switches.
- Locate level switch where flow from the inlet pipe will not interfere with the float.
- Design electrical service to handle the ultimate capacity of the pump station.

**Pump Configuration**

Generally, pumps of low specific speed can work with more suction-lift than the pumps of higher specific speed. With the pumps of very high specific speed as that of the axial flow pumps, not only that they would not work with any suction-lift, instead they would need positive suction head or minimum submergence for trouble free working. It is always advisable to avoid suction-lift for any centrifugal pump. In the SPS, the pumps are installed either to work submerged in the wet well itself like vertical pumps with motor above ground level and the pump in the wet well connected by a rotary shaft or installed in the dry well at such a level that the impeller will be below the level of the liquid in the wet well.

**Rising Main**

In case of water supply works, economical size of the rising main is worked out by trying out various sizes and finding out net present value of the capital costs of pipeline/pumping machinery and capitalised electric energy costs. In case of rising mains carrying sewage, it is not possible to calculate the economical size because of complexity of varying pumping rates etc.

Size of rising main selected should be such that to avoid silting, ensure velocities not less than 0.8 m/sec (barest minimum) and not exceeding 3 m/sec at any time. Rising mains must be designed for WHH (Water Hammer Head) and is also important to select the suitable class of the pipe.

**Table 15: Configuration of Sewage Pumps, based on length of rising mains**

| Length of rising main | Pumps | No. of pumps |
|---|---|---|
| Where rising main is long and where head losses are the dominant factor | Peak Flow/2 pumps | 3 nos. (including 1 standby) |
| | Non-Peak Flow pumps | 2 nos. (including 1 standby) |
| Where rising main is short and static head is dominant | Peak Flow/4 pumps | 6 nos. (including 2 standby) |

**Water Hammer**

Water hammer is an internal surge in pressure inside the pumping main when a pump suddenly stops or when a delivery valve in the pumping main is suddenly closed causing a reversal of the flow direction instantly and its forward and reverse oscillation. This phenomenon imparts a higher instantaneous pressure on the pumping main and can cause bursting depending on the magnitude which is almost entirely a function of the static lift. In general, sewage-pumping mains seldom encounter static lifts of more than about 20 m and this will not be a problem. Moreover, soft-start starters shall be used to ameliorate the situation as also spring-check or dashpot type of non-return valves to be used instead of plain swing-check valves. There are also customized protection systems from appropriate equipment vendors. The modulus of elasticity of the pipe material shall be considered when evaluating water hammer effects

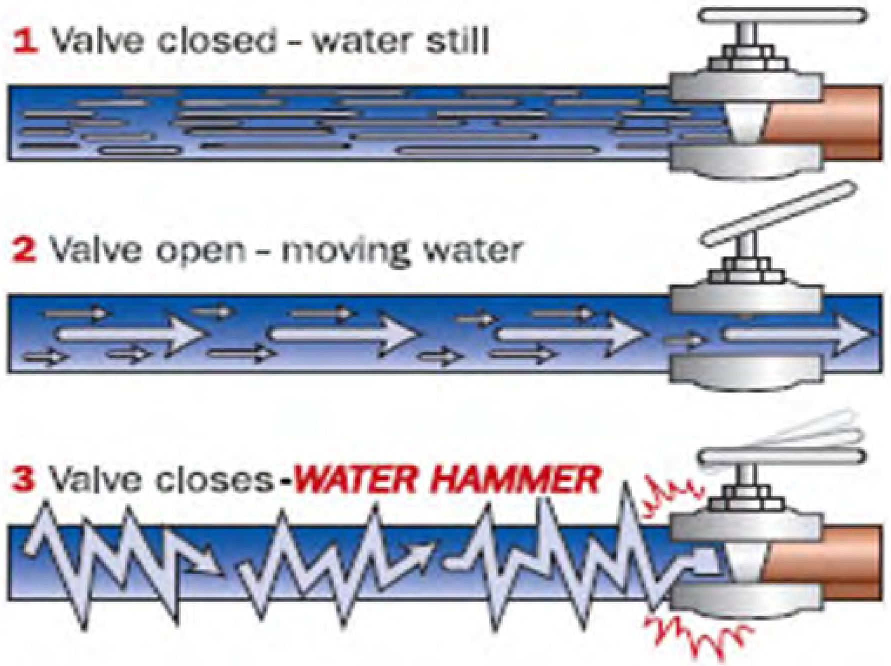



Figure 27: Water Hammer

*Source: The Process Piping*

One might wonder why water hammers are thought to be a serious problem. Recommended velocity of water in pipe network= 2-3 m/s which is mostly not possible to maintain. Though a water hammer cannot be completely eliminated, it can certainly be avoided.

### 7.5 Notes for trainer

This session give brief about the various methods to find out the design flow of sewage and sewage generation of the city. It also gives brief idea about interception and diversion project with its different components and design aspects of important components of the sewer network.

### 7.6 Bibliography


- NMCG Guidelines (2018): Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants
- CPHEEO (2013): Manual on Sewerage and Sewage Treatment Systems, Part A & B
- MoHUA (2021): Swachh Bharat Mission – Urban 2.0 Guidelines




Session

# 08

# Wastewater Treatment Technologies

# 8. Wastewater Treatment Technologies

## 8.1 Learning Objectives

- To understand the objectives and mechanisms of wastewater treatment
- To understand the different treatment stages in a wastewater treatment system
- To understand the technical aspects of non-mechanized and mechanized treatment technologies
- To understand the different sludge management units required to cater the solid stream in the wastewater treatment plant.

## 8.2 Session Plan

Duration - 60 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Wastewater Treatment | 15 min | Powerpoint presentation |
| Wastewater Treatment | 15 min | Powerpoint presentation |
| Selection of Technology | 15 min | Powerpoint presentation |
| Sewage Sludge Technology | 10 min | Powerpoint presentation |
| Q&A | 5 min | Discussion |

## 8.3 Key Facts

- Objectives of wastewater treatment should be clearly understood before considering different options for treatment.
- Non-mechanised and mechanised options are possible with respect to feasibility of the wastewater treatment system.
- Capital cost of the project should not be the driving principle for selection of wastewater treatment technology.
- Appropriate sewage sludge management is necessary for further reduction of pollution load in the environment.

## 8.4 Learning Notes

### 8.4.1 Wastewater Treatment

The principal objective of wastewater treatment is to allow human and industrial effluent to be disposed off without danger to human health or unacceptable damage to the natural environment.

**A. Objectives**

Wastewater treatment is a process used to remove contaminants from wastewater and convert it into an effluent that can be returned to the water cycle. Once returned to the water cycle, the effluent creates an acceptable impact on the environment or is reused for various purposes.

Water reclamation is the process of converting wastewater into water that can be reused for other purposes. Types of reuses include urban reuse, agricultural reuse like irrigation, environmental reuse, industrial reuse, planned potable reuse, de facto wastewater reuse (unplanned potable reuse). For example, reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater (i.e., groundwater recharge). Reused water may also be directed toward fulfilling certain needs in residences (e.g., toilet flushing), businesses, and industry, and could even be treated to reach drinking water standards. Treated wastewater reuse for irrigation is a long-established practice, especially in arid countries. Reusing wastewater as part of sustainable water management allows water to remain as an alternative water source for human activities. This can reduce scarcity and alleviate pressures on groundwater and other natural water bodies.

### B. Treatment process

Wastewater treatment processes are of different types- Physical, Biological, Chemical and Photolytic.

- Physical processes are based on the physical characteristics 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, e.g., 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 to treat the wastewater directly (e.g., UV to kill pathogens) or indirectly (e.g., Photosynthesis helps to uptake the nutrients from the wastewater in case of constructed wetlands).

### C. Design Parameters

There are different types of design parameters used to design wastewater treatment units. The importance of a few design parameters may increase or decrease from case-to-case basis.

- Organic loading (kgBOD/d, kgCOD/d)
- Solids loading (kg TSS/d)
- Volumetric loading rate (m3/d)
- Temperature (oC)
- Sludge Retention Time (SRT)
- Biomass yield (kgVSS/ kgCOD)
- Hydraulic retention time (HRT)
- Up flow velocity (m/s)
- Specific surface area (m2/m3)

### D. Wastewater Treatment Stages

#### Primary wastewater treatment

Primary treatment consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment. Some sewage treatment plants that are connected to a combined sewer system have a bypass arrangement after the primary treatment unit. This means that during heavy rainfall events, the secondary and tertiary treatment systems can be bypassed to protect them from hydraulic overloading, and the mixture of sewage and storm-water only receives primary treatment.

- **Screens -** Screening aims to prevent coarse solids, such as plastics, rags and other trash, from entering a sewerage system or treatment plant. Solids get trapped by inclined screens or bar racks. The spacing between the bars usually is 15 to 40 mm, depending on cleaning patterns. Screens can be cleaned by hand or mechanically raked. The latter allows for a more frequent solids removal and, correspondingly, a smaller design. The screening 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. It is recommended that three sequential stages of screens shall be provided, being coarse, followed by medium and followed by fine screens.

- **Grit Chamber -** Where subsequent treatment technologies could be hindered or damaged by the presence of sand, grit chambers (or sand traps) allow for the removal of heavy inorganic fractions by settling. There are three general types of grit chambers: horizontal-flow, aerated, or vortex chambers. All of these designs allow heavy grit particles to settle out, while lighter, principally organic particles remain in suspension.

#### Secondary treatment of wastewater

Secondary treatment is a treatment process for wastewater to achieve a certain degree of effluent quality by using a sewage treatment plant with physical phase separation to remove settleable solids and a biological process to remove dissolved and suspended organic compounds. After this kind of treatment, the wastewater may be called secondary-treated wastewater. Secondary treatment is the portion of a sewage treatment sequence removing dissolved and colloidal compounds measured as biochemical oxygen demand (BOD). Secondary treatment is traditionally applied to the liquid portion of sewage after primary treatment has removed settleable solids and floating material. Secondary treatment is usually performed by microorganisms in a managed aerobic habitat.

#### Tertiary wastewater treatment

The aim of tertiary wastewater treatment is to raise the water quality to domestic and industrial standards or meet specific requirements around the safe discharge of water. In the case of water treated by municipalities, tertiary treatment also involves the removal of pathogens, which ensures that water is safe for drinking purposes.

- **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).
- **Ozonation -** Ozonation is an efficient treatment to reduce the amounts of micropollutants released in the aquatic systems by wastewater treatment plants (MARGOT et al. 2011). 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.

**E. Characteristics of Wastewater**

Characteristics of wastewater must be known and the desired treatment results must be decided, before the dimensions of the vessels for the different phases can be selected.

The hydraulic load is the most common parameter for calculating reactor volumes. It describes the volume of wastewater to be applied per volume of reactor, or per surface of filter in a given time. The hydraulic retention time (HRT) indicates a volume-by-volume relation. Hydraulic loading rates are also responsible for the flow speed (velocity) inside the reactor.

Organic loading rate plays an important role in designing the wastewater treatment process. The optimum range of organic loading rate depends on the nature of the organic substrates to be added, and the type of wastewater to be treated. The permitted organic loading rate depends on the kind of reactor, the reactor temperature and the kind of wastewater. The organic loading rate takes care of the time which the various kinds of bacteria need for their specific metabolism. Organic loading influences a co-ordinated follow up of different treatment steps. Easily degradable substrate can be fed at higher loading rates, because all the bacteria involved multiply fast and consume organic matter quickly. For difficult degradable substrates, some of the bacteria species need a longer time.

The volume of sludge is an important parameter for designing sedimentation tanks and digesters. This is because the accumulating sludge occupies tank volume that must be added to the required reactor volume. Biological sludge production directly relates to the amount of BOD removed, which depends on the decomposition process. Aerobic digestion produces more sludge than anaerobic fermentation. In addition to the biological sludge, primary sludge consists partly of sludge that is already mineralised.

A waste treatment facility consists of different treatment stages combining different treatment processes. In the case of a wastewater treatment plant, after the preliminary treatment i.e., screening; the wastewater undergoes treatment in the primary stage. In the primary stage, the physical treatment processes are used to remove the easily settleable solids usually known as grit. The units which provide primary treatment are listed in the slide above. In the secondary stage, biological treatment processes remove the BOD and COD using the digestion process carried out by anaerobic and aerobic microorganisms. In the tertiary stage, the chemical or photolytic treatment process is used to disinfect the wastewater.

### 8.4.3 Wastewater Treatment Technologies

There are different wastewater treatment technologies depending upon the types of treatment units.

**A. Non mechanised treatment system**

#### Waste stabilization ponds

Waste stabilization ponds (WSPs) are large man-made basins in which greywater, blackwater or faecal sludge can be treated to an effluent of relatively high quality and apt for the reuse in agriculture or aquaculture. For the most effective treatment, WSPs should be linked in a series of three or more with effluent being transferred from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep man-made lake is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the accumulated sludge. In a series of WSPs, the effluent from the anaerobic pond is transferred to the facultative pond, where further BOD is removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%. A combination of three types of ponds in series is frequently implemented in wastewater treatment: -

- Anaerobic ponds that are two to four meters deep are used for settling of suspended solids and subsequent anaerobic digestion. The effluent flows to the facultative pond.
- Facultative ponds that are 1 to 1.8m deep allow for remaining suspended solids to settle. In the top layer of the pond dissolved organic pollution is aerobically digested, while anaerobic conditions are prevalent at the bottom.
- Maturation ponds that are 1 to 1.5 m deep allow for pathogen reduction and stabilisation. The ponds are mainly aerobic. Oxygen is supplied through algae and diffusion from the air. Pathogen reduction occurs via UV rays from the sun.

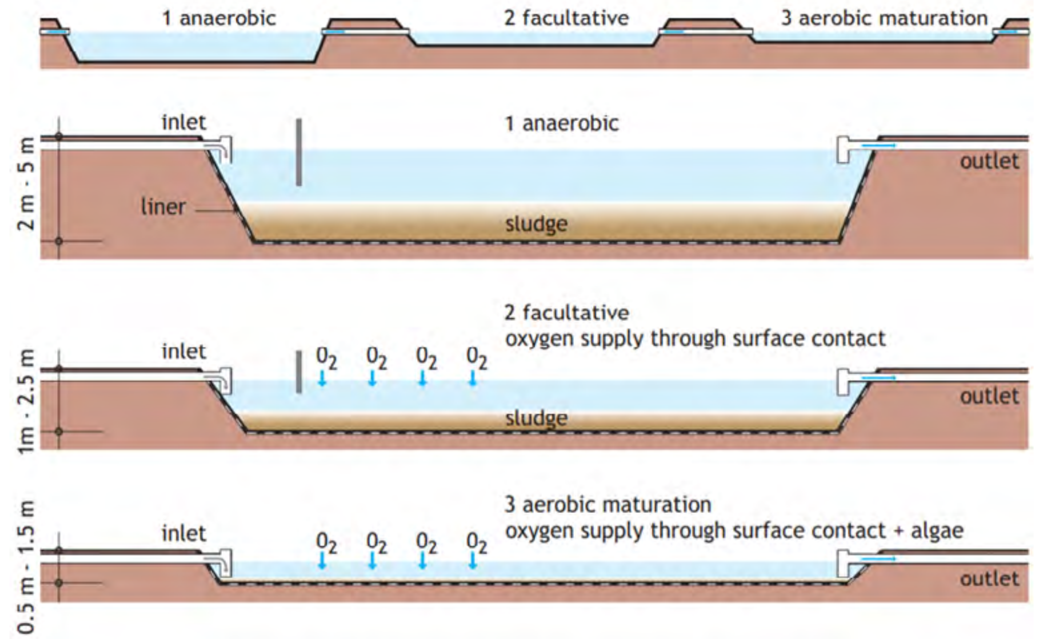



**Figure 28: Schematic diagram of waste stabilization ponds**

*Source: TILLEY et al., 2014*

WSPs are simple to build and require relatively low O&M requirements. The technology is appropriate for tropical climates, and achieves relatively high pathogen removal in the effluent. Constraints include land availability, high rate of solids accumulation if preliminary solids separation is not performed, and potential inhibition due to high salt and ammonia concentrations. The removal of sludge that accumulates in the anaerobic ponds may require heavy mechanical equipment.

#### Decentralised Wastewater Treatment System (DEWATS)

DEWATS encompasses an approach, not just a technical hardware package, i.e., besides technical and engineering aspects, the specific local economic and social situation is taken into consideration. DEWATS provides treatment for wastewater flows with close COD/BOD ratios from $1m^3$ to $1000m^3$ per day and unit. It can treat wastewaters from domestic or industrial sources. They can provide primary, secondary and tertiary treatment for wastewaters from sanitation facilities, housing colonies, public entities like hospitals, or from businesses, especially those involved in food production and processing. It can be an integral part of comprehensive wastewater strategies. The systems should be perceived as being complementary to other centralised and decentralised wastewater-treatment options. DEWATS can provide a renewable energy source. Depending on the technical layout, biogas supplies energy for cooking, lighting or power generation. It is based on a set of design and layout principles. Reliability, longevity, tolerance towards inflow fluctuation, cost efficiency and, most importantly, low control and maintenance requirements.

DEWATS usually function without technical energy inputs. Independence from outside energy sources and sophisticated technical equipment provides more reliable operation and, thereby, fewer fluctuations in effluent quality. Pumping may be necessary for water lifting. It is based on a modular, technical configuration concept. Appropriate combinations of treatment modules can be selected, depending on the required treatment efficiency, costs, land availability, etc. Its units are quality products. Though they can be constructed from locally available materials and can be implemented by the local workforce, high quality standards in planning and construction have to be met. For sound DEWATS design a good comprehension of the process of wastewater-treatment is essential. It requires few operation and maintenance skills. While most operational tasks can be carried out by the users, some maintenance services might require a local service provider. In some cases, both operation and maintenance can be delivered by a service provider. It can reduce pollution load to fit legal requirements. Like all other wastewater-treatment systems, generated solid waste (sludge) must be handled, treated and disposed of in accordance with hygiene and environmental standards. DEWATS consider the socio-economic environment of a given location. Neglecting these conditions will result in the failure of the technology.

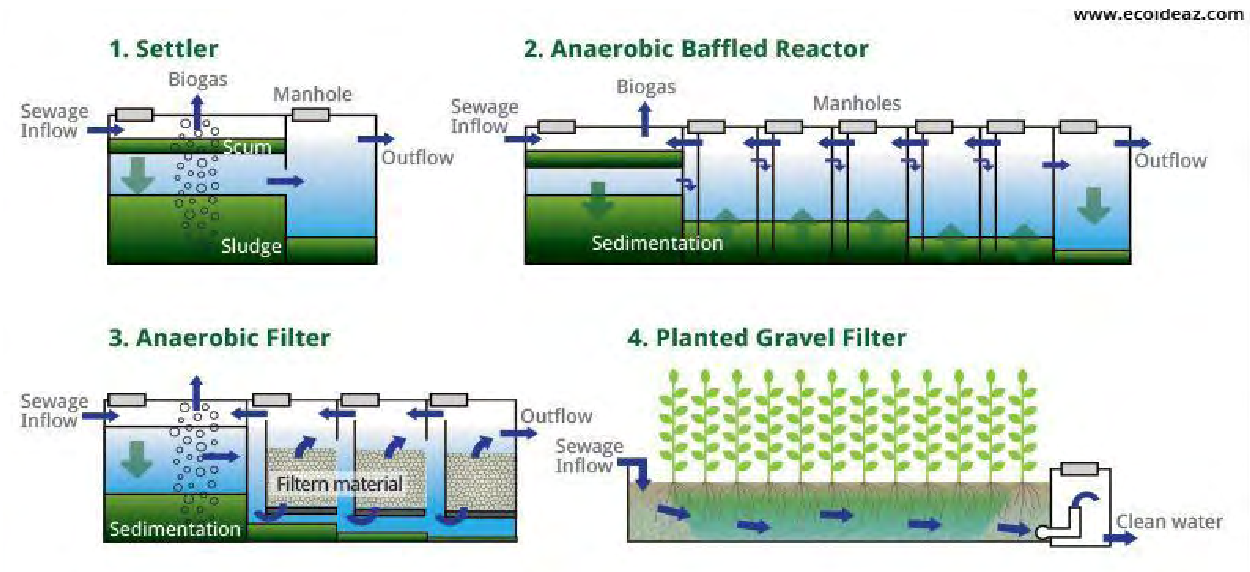



**Figure 29: Schematic diagram of DEWATS**

*Source: BORDA, Germany*

**B. Mechanised 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. Activated sludge processes are one part of a complex treatment system. They are usually used after primary treatment (that removes settleable solids) and are sometimes followed by a final polishing step. The biological processes that occur are effective at removing soluble, colloidal and particulate materials. The reactor can be designed for biological nitrification and denitrification, as well as for biological phosphorus removal. The design must be based on an accurate estimation of the wastewater composition and volume. Treatment efficiency can be severely compromised if the plant is under- or over-dimensioned. Depending on the temperature, the solids retention time (SRT) in the reactor ranges from 3 to 5 days for BOD removal, to 3 to 18 days for nitrification. The excess sludge requires treatment to reduce its water and organic content and to obtain a stabilized product suitable for end-use or final disposal. It is important to consider this step in the planning phase of the treatment plant.

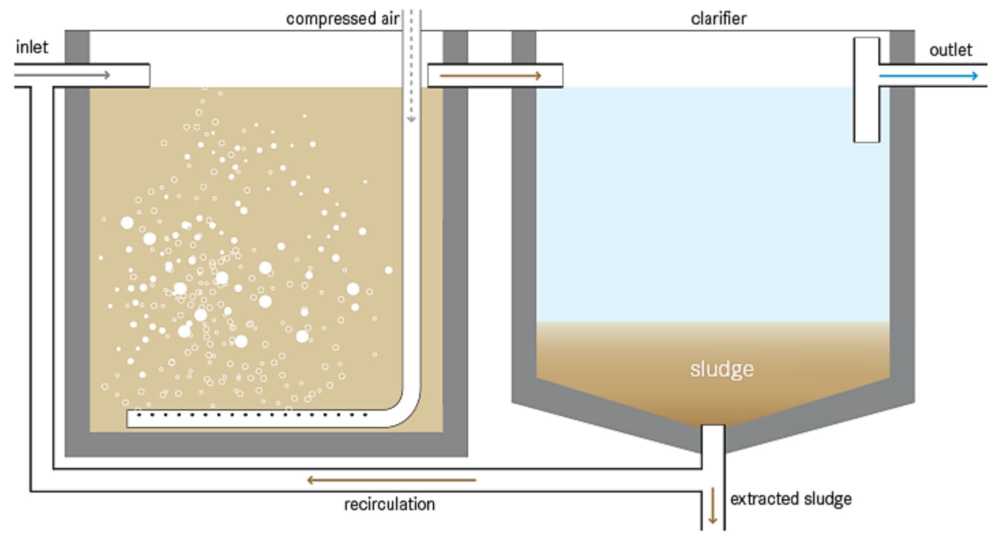



**Figure 30: Schematic diagram of ASP**

*Source: TILLEY et al., 2014*

There are few advantages of ASP, it is resistant to organic and hydraulic shock loads. It can be operated at a range of organic and hydraulic loading rates. It can reduce high percentage of BOD and pathogens (up to 99%) after secondary treatment. It highly reduces nutrients from wastewater. It can be modified to meet specific discharge limits

**Upflow Anaerobic Sludge Blanket (UASB)**

The upflow anaerobic sludge blanket reactor (UASB) is a single tank process in an anaerobic centralised or decentralised industrial wastewater or blackwater treatment system achieving high removal of organic pollutants. Wastewater enters the reactor from the bottom, and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. The sludge blanket comprises microbial granules (1 to 3 mm in diameter), i.e., small agglomerations of microorganisms that resist being washed out in the up flow because of their weight. The microorganisms in the sludge layer degrade organic compounds. Bacteria living in the sludge break down organic matter by anaerobic digestion, transforming it into biogas. An upflow velocity of 0.7 to 1 m/h must be maintained to keep the sludge blanket in suspension. Primary settling is usually not required before the UASB. Solids are also retained by a filtration effect of the blanket. The upflow regime and the motion of the gas bubbles allow mixing without mechanical assistance. Baffles at the top of the reactor allow gases to escape and prevent an outflow of the sludge blanket. As all aerobic treatments, UASB require a post-treatment to remove pathogens, but due to a low removal of nutrients, the effluent water as well as the stabilised sludge can be used in agriculture. It can reduce the high percentage of BOD which is 60 to 90 %, it produces less sludge so does not require regular desludging. It requires skilled staff, electricity and is sensitive to variable flows.

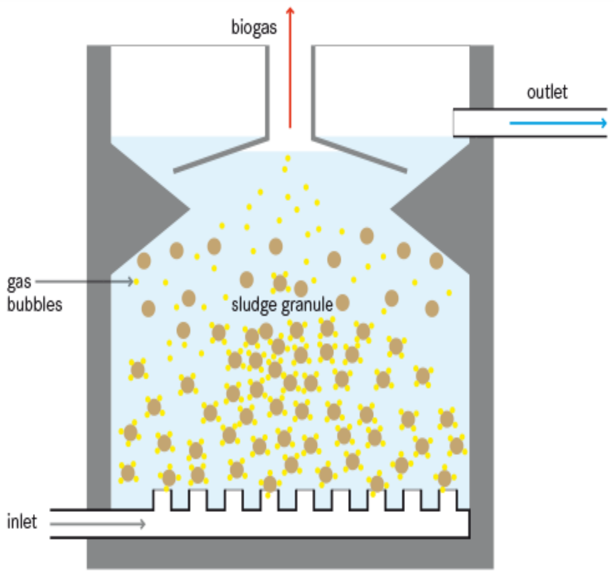



**Figure 31: Schematic diagram of UASB**

*Source: TILLEY et al., 2014*

The UASB is a Centralized Treatment technology that must be operated and maintained by professionals. A skilled operator is required to monitor the reactor and repair parts, e.g., pumps, in case of problems. A UASB is not appropriate for small or rural communities without a constant water supply or electricity. The technology is relatively simple to design and build, but developing the granulated sludge may take several months. The UASB reactor has the potential to produce higher quality effluent than Septic Tanks, and can do so in a smaller reactor volume.

**Moving Bed Bio Reactor (MBBR)**

MBBR is a highly effective biological treatment process based on a combination of conventional activated sludge process and biofilm media. The MBBR process utilizes floating media within the aeration and anoxic tanks. The microorganisms consume organic material. The media provides increased surface area for the biological microorganisms to attach and grow. The increased surface area reduces the footprint of the tanks required to treat the wastewater. The treatment process can be aerobic and/or anaerobic and operates at high volume loads. MBBR units are placed in series based on the load entering each reactor. Neutralised and settled wastewater passes through MBBR for reduction in BOD/COD. Most of the MBBR plants are provided with vertically or horizontally mounted rectangular mesh sieves or cylindrical bar sieves. Biofilm carriers are made up of high density (0.95 g/cm3) polyethylene. These are normally shaped as small cylinders with a cross inside and fins outside. The standard filling of the carrier is below 70% with a maximum specific area not more than 465 m2/m3. Generally, design load for COD-BOD removal is 20 g COD / m2d. Smaller carriers need smaller reactor volume at a given loading rate (as g/m2d) when the carrier filling is the same. HRT of the reactor is about 3 – 4 hours for effective BOD and nitrogen removal. It is advisable to use MBBR in combination with a septic tank or a pre-coagulation step as a pre-treatment unit, depending on the local conditions and input characteristics. It is a very robust and compact alternative for secondary treatment of municipal wastewater, having removal efficiency for BOD 90 – 95% (low rate) and that of 75 – 80% for high rate. Average nitrogen removal is about 85%.

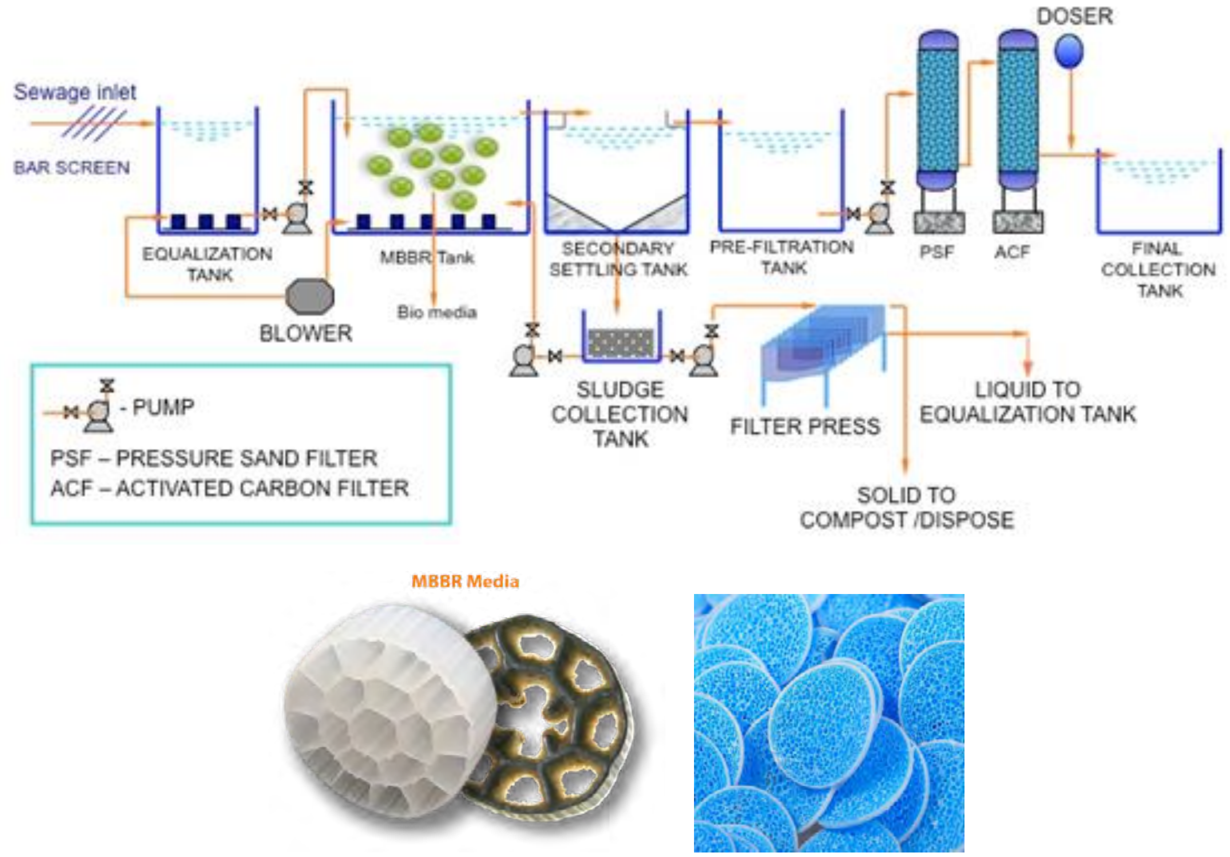



**Figure 32: Schematic diagram of MBBR**

*Source: www.ecomena.org*

A constantly operating MBBR does not require backwashing or return sludge flows. It has minimal head-loss. Coarse-bubble aeration in the aeration zone in the wastewater treatment tank provides ease of operation at low-cost. Agitation continuously moves the carrier elements over the surface of the screen thus preventing clogging. Maintenance of MBBR system includes screening, influent equalisation, clarifier system, sludge handling and integrated control system. There is no need to maintain f/M ratio as there is self-maintenance of an optimum level of productive biofilm. Skilled labour is required for routine monitoring and operations of pumps and blowers.

### 8.4.3 Selection of treatment technology

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

- Influent characteristics
- Climatic constraints
- Finance
- Performance
- Reliability
- Complexity
- Compatibility
- Environmental constraints
- Chemical requirements
- Energy requirements
- Resource requirements
- Land availability
- Treatment residual and its disposal
- Inhibiting and unaffected constituents

The application of a single technological sanitation component is not sufficient to obtain the expected goals in terms of environmental and health protection; a sustainable sanitation system has to include all the components (physical parts and actions) required for the adequate management of human waste. The best combination of technologies to build up a complete sanitation system has to be selected for a specific site.

In urban and peri-urban areas, a successful sanitation approach is made more difficult by the complexity of the urban setting compared to the rural environment; sanitation issues demand an integrated developmental approach and are strictly related to urban planning, public health, stream restoration, flooding and hydraulic issues, agriculture, solid waste management, environmental protection, resources management, economics and politics, recovery and reconstruction strategies, religion and social aspects, etc.

Presently, several treatment options are available and one can choose from these options to find the most appropriate technology for the locality under consideration. These treatment technologies have been discussed in detail in the MoHUA Manual on Sewerage and Sewage Treatment Systems, 2013. Therefore, the same may be referred for further information on suitability, designing and maintenance of these technologies. The performance-based technology comparison is carried out and presented below:

| Technologies | Effluent Quality | Coliform Removal | Nitrification Denitrification / Phosphorus Removal | Process Reliability | Land Use | Ease of Operation and Maintenance | Energy recovery | Electrical demand | Capital Cost |
|---|---|---|---|---|---|---|---|---|---|
| Waste Stabilisation Ponds | M | A | A | A | A | M | A | VG | G |
| DEWATS / DTS+CW | A | A | A | A | A | M | A | VG | G |
| Activated Sludge Process (ASP) | G | G | A | VG | G | G | VG | M | M |
| UASB Reactor | M | M | A | G | G | M | G | M | M |
| Moving Bed Biological Reactor (MBBR) | VG | VG | A | A | G | VG | M | A | M |

Very Good (VG)
Good (G)
Moderate (M)
Average (A)

**Figure 33: Performance based technology comparison**

*Source: Advisory on On-site and Offsite Sewerage Management, CPHEEO and MoHUA 2020*

**Treatment performance**

The primary criteria are that the treatment facility should be able to produce end products meeting the standards of discharge/ enduse.

**Local context**

Most important criteria are the local context. The characteristics 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, the frequency of the desludging is high; there is a possibility of having faecal sludge. In that case, stabilisation of sludge becomes important. Climate plays an 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. Ex. In cases where there is a demand for biochar, pyrolysis will be suitable treatment mechanisms for pathogen reduction.

**O&M requirement**

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

**Costs**

The CAPEX and OPEX of the technology are also criteria that are 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.

The technology comparison based on land requirement, energy requirement, capital expenditure and operational expenditure is presented below.

**Table 16: Performance- based technology comparison**

| Technology | Land Requirement (Hectare/MLD) | Energy Requirement (KWh/ML) | CAPEX | OPEX |
|---|---|---|---|---|
| DEWATS / DTS+CW | 0.16 – 0.18 | Negligible | High | Low |
| Waste Stabilisation Ponds | 0.8 – 2.3 | 10 | Moderate | Low |
| UASB Reactor | 0.2 – 0.3 | 10 - 15 | Moderate | Moderate |
| Activated Sludge Process (ASP) | 0.15 – 0.25 | 180 - 225 | Moderate | High |
| Moving Bed Biological Reactor (MBBR) | 0.05 | 282 | Moderate | High |

*(Source: Advisory on On-site and Offsite Sewerage Management, CPHEEO and MoHUA (2020))*

### 8.4.4 Sewage Sludge Management Units

Sewage sludge management describes the processes used to manage and dispose of sewage sludge produced during sewage treatment and co-treatment of faecal sludge or septage which is desludged from the on-site containment systems. Sludge is mostly water with lesser amounts of solid material removed from liquid sewage. Identification of sewage sludge handling technology and site in the STP premises is crucial for effective implementation of septage management plan. Technology assessment requires information on the following aspects of each technology:

- Land requirement
- Power requirement
- Knowledge and skills required for its operation, maintenance, and repair
- Adequacy of the supply chain for the materials and spare parts that it requires
- Overall cost, including capital and operational cost
- Environmental impact, particularly any local impact on air or water quality
- Design inflow and characteristics of the sewage sludge or FSS at the sludge handling facility
- Soil characteristics and topography
- Seasonal and climatic variations

Choices between more and less mechanized treatment technologies should take account of the management requirements of each technology, including the skills required to operate the technology and monitor its performance, the supply chains required to ensure the availability of spare parts, and the dependence of the technology on difficult tasks that are required at infrequent intervals. Choices will also be influenced by costs, particularly recurrent costs. Where financial resources are limited, it may be best to select technologies with lower operational costs, even if their discounted cost is more than that of technologies with high operational costs.

#### A. Septage Receiving Station

The primary function of a receiving station is transfer of septage from hauler trucks, preliminary treatment of septage, storage and equalization of septage flows, etc. The overall receiving station design varies with the amount of septage to be received, design of the hauler truck, type of preliminary treatment to be provided, downstream treatment & ultimate disposal, and odour considerations.

The basic aim of the receiving station is to reduce the impact & risk on the STP due to co-treatment of septage and sewage. The objectives of the receiving station are enabling safe transfer of septage from trucks to the STP, to control the O & M of the treatment plant, storage & equalization of septage flows, etc.



Following are the components of any receiving station:

**Dumping Station:** The dumping station is the initial point of reception of the septage at the receiving station.

**Screening:** Septage will generally contain various forms of untreatable debris such as rags, plastics, sticks, stones, etc. Such debris is separated from the liquid septage by a coarse bar screen. The screen provides the initial pre-treatment of septage in order to protect unit processes downstream.

**Grit Removal:** In septage, grit consists of sand, gravel & food particles that become entangled in the lighter weight organic matter & grease.

**Storage/Equalization:** Septage holding basins can be used to provide for storage, equalization, mixing & aeration of the septage prior to further treatment.

**Odour Control:** Odour problems at the septage receiving stations can be solved by proper siting & existing technologies including chemical scrubbers, filters, combustion & biological processes.

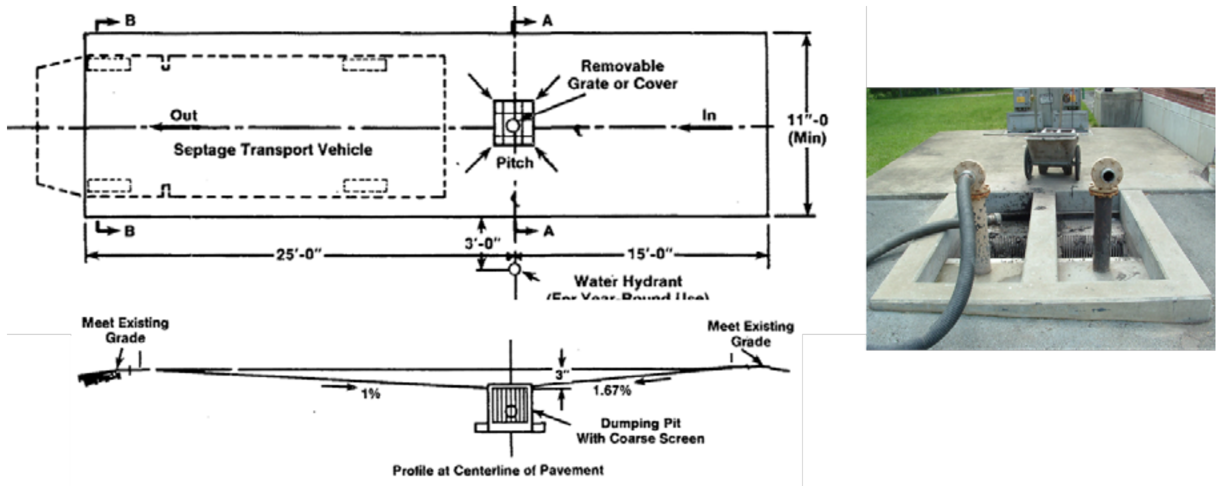



**Figure 34: Septage Receiving Station**

*Source: USEPA Handbook on Septage Treatment and Disposal*

If septage is to be co-treated with sewage, it will be necessary to construct a septage receiving station. Such a station will consist of an unloading area (sloped to allow gravity draining of septage hauling trucks), a septage storage tank, and one or more grinder pumps. The storage tank is used to store the septage so that it can be discharged to the treatment plant. The septage in the storage tank should be properly mixed by mixers, air diffusers for odour control. Discharge of septage upstream is preferable for the removal of grit and screenings. If there are no screening facilities ahead of the septage discharge facility, the septage should be transferred from the storage tank to the treatment plant with grinder pumps. In some cases, this transfer can be accomplished by gravity flow. If the septage is strong and concentrated, it can also be diluted with treated sewage while adding in STP. Chemicals such as lime or chlorine can also be added to the septage in the storage tank @ 2.4 kg/1000 litre of septage to neutralize it, render it more treatable, or reduce odours and treat the septage.

**Sewage Sludge Management Units**

**Gravity Thickener**

Thickening is when solids are condensed to produce a concentrated solids product that settles at the bottom of the tank, resulting in the relatively solids-free liquid above the solids layer. Thickening wastewater solids cuts down the volume of residuals, thereby improving the overall operation, and diminishes expenses related to storage, processing, transfer, end use, or disposal.

Gravity thickeners are similar to clarifier tanks and settling tanks that allow for suspended solids from slurries to gradually sink to the bottom of the tank. As the solids collect at the bottom of the tank, it forms into a sludge-like material that needs to be constantly removed by the use of high-powered non-clog slurry pumps for disposal. Oftentimes, this material can range from 10% to over 30% solids and is transferred to other processes including machines like centrifuge decanters which help separate the solid waste material from the liquid, effectively dewatering the slurry or sludge before transport. These pump processes are commonly seen in various industries including wastewater treatment, chemical manufacturing, and oil/food processing plants. Gravity thickeners are either continuous flow or fill and draw type, with or without the addition of chemicals. Use of slowly revolving stirrers improves the efficiency. Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery.

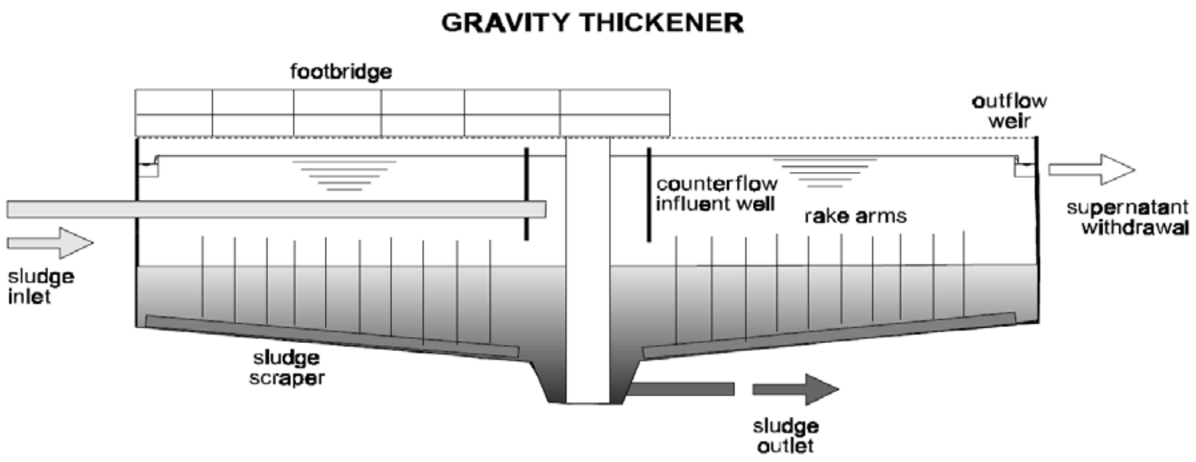



**Figure 35: Gravity Thickener**

*Source: Andreoli C. V. et al., 2007*

Greater attention to the thickener is required when thickening waste activated sludge because it has a large surface area per unit mass, resulting in low settling rates and resistance to being compacted. Sludge tends to stratify in the gravity thickener while continuing biological activity, which includes the production of gases that can cause accumulated sludge to float. Gravity thickener operation responds to changes in process temperatures; therefore, loading rates should be reduced to values at the lower end of the range when temperatures exceed 15 to 20°C, depending on the ratio of primary to secondary sludge. Higher temperatures will require additional dilution.

The following should be checked before and during operation:

- Avoid starting a thickener that contains accumulated sludge. To avoid overload, the sludge should be disposed of before starting the mechanism.
- Check and adjust the skimming mechanism to increase the amount of scum drawn into the scum box and to reduce the amount of supernatant carried with the skimming.



**Anaerobic Digester**

Anaerobic digestion is 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 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 as fats, cellulose and proteins, (2) Acidogenesis, (3) Acetogenesis and (4) Methanogenesis. The second and third stage results in 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 favourable 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. Anaerobic digestion also reduces the volume of sludge and increases the dewaterability of the sludge. Anaerobic digestion is a very sensitive process and a lot of control parameters needs to be monitored if the aim is to extract maximum methane from the FSS. Hence, O&M of anaerobic digester is high as skilled manpower with good understanding of digesters is needed.

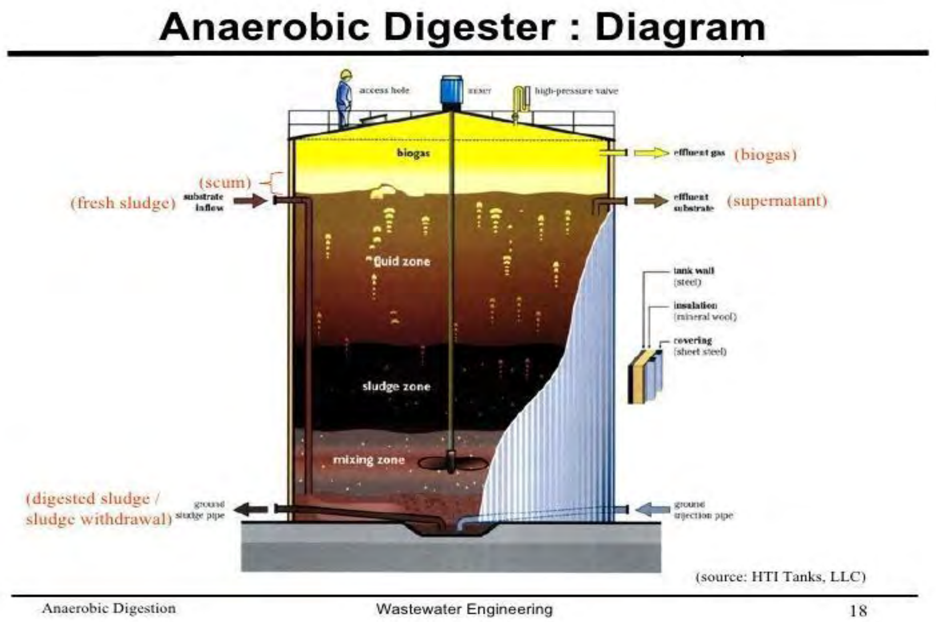



**Figure 36: Anaerobic Digester**

*Source: F.P Sheenan, University of Aberdeen, 2017*

Mechanized dewatering units have been used for dewatering of sewage sludge in the STP's. 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.

**Screw Press**

Screw press sludge dewatering machine is a kind of economic and environmentally friendly sludge dewatering equipment. It is a new type of sludge extrusion dewatering equipment by using the principle of screw extrusion, through the strong squeezing force generated by the change of screw diameter and screw pitch, and the tiny gap between the floating ring and the fixed ring, to realize solid-liquid separation. Dewatering screw press is composed of a fully automatic control cabinet, flocculation modulation box, sludge thickening and dewatering device, and liquid collecting tank. Dewatering screw press is with automatic control technology, which can realize the flocculation fully automatic operation, and continuously complete the sludge thickening and squeezing, finally return or discharge the collected filtrate liquid. Screw press are quite compact and completely enclosed. Hence there are very few concerns pertaining to bio safety or odour. Belt press, however, is available with or without enclosure. Although the press without enclosure is cheaper, allows easy inspection during its operation and facilitates access to parts during preventive maintenance; there are hazard related to odour, gases and pathogens. Advantages of screw press dewatering machine are listed below:

- Suitable for wide range sludge dewatering and can be used for oily sludge treatment.
- Operating continuously and automatically, not easy to block
- Low investment and operation cost, no secondary pollution
- Energy saving and environmentally friendly, compact design with small footprint

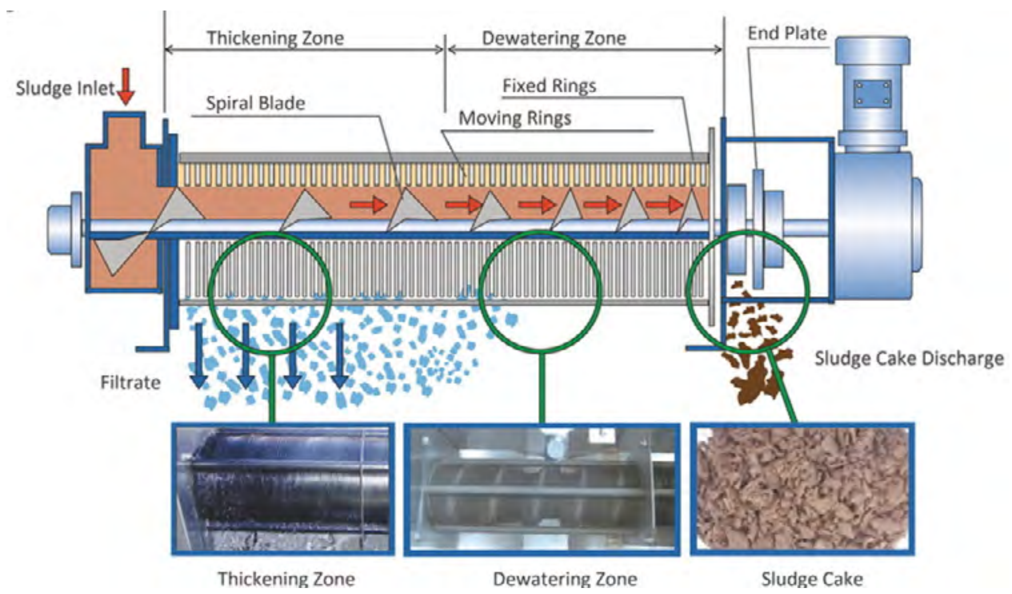



**Figure 37: Screw Press**

*Source: www.ecologixsystems.com*

### Belt Press

The belt press is an industrial machine, used for solid/liquid separation processes, particularly the dewatering of sludges in the chemical industry, mining and water treatment. The process of filtration is primarily obtained by passing a pair of filtering cloths and belts through a system of rollers. The system takes a sludge or slurry as a feed, and separates it into a filtrate and a solid cake. The belt filter is mainly used for dewatering of sludge and slurry and juice extraction from apples, pears and other fruits, as well as grapes for winemaking, etc. Belt filters are used both municipally and industrially in a range of areas including urban sewage and wastewater treatment, metallurgy and mining, steel plants, coal plants, breweries, dyeing, tanneries, as well as chemical and paper factories.

The applications of a belt filter are only limited to the sludges, slurry or mashed fruit that it can process. The sludges from municipal use include raw, anaerobically digested and aerobically digested sludges, alum sludge, lime softening sludge and river water silt. In industry, any sludge or slurry is sourced from food processing wastes, pulp and paper wastes, chemical sludges, pharmaceutical wastes, industrial waste processing sludges, and petrochemical wastes. These wastes can include mixed sludge, mineral slurry, dust sediment, selected coal washing mud, biological sludge, primary sludge, and straw, wood or waste paper pulp.

Some dewatering objectives include reducing the volume to reduce the transport and storage costs, removing liquids before landfill disposal, reducing fuel requirements before further drying or incineration, producing adequate material for composting, avoiding runoff and pooling when used for land applications, and optimizing other drying processes. Belt filters are specifically designed for each of these particular applications and feeds. Belt filters are considered simple and reliable, with good availability, low staffing, easy maintenance and a long life.

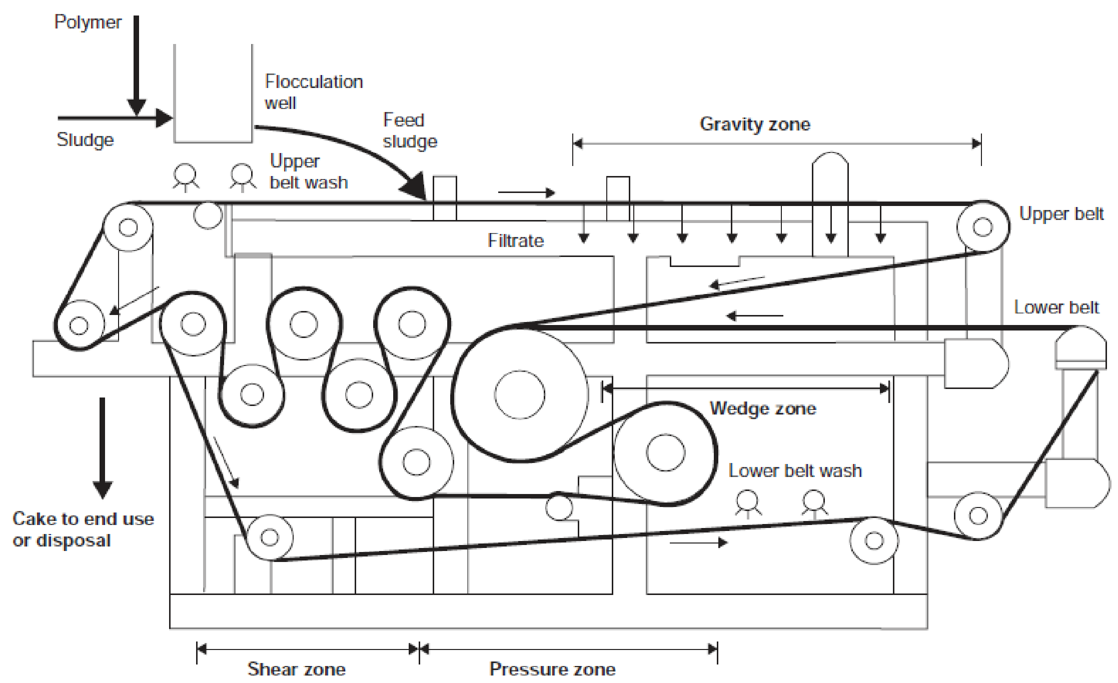



**Figure 38: Belt Press**

*Source: WEF, 2010*

### Paddle Dryer

Paddle dryers are based on externally-heated paddles (or blades) rotating in the mass of sludge solids. There are normally either two or four sets of blades which rotate together to continuously cut into and stir the sludge solid lumps into smaller particles to continuously replenish the drying surface. Paddle dryers can operate without back-mixing since the agitation provided by the rotating paddles is sufficient to avoid the formation of sticky sludge. Paddle Dryers provides a reliable and efficient method for drying of sludges either from filter press or from centrifuge. It is also used to remove hazardous volatiles. The drying process of a paddle dryer differs from that of conventional dryers. In the later, hot air (or gas) is used as a heating medium. In a paddle dryer heat is supplied by transmission of heat from the paddle shaft and jacket. Hot air is used only as a carrier to prevent evaporated vapor from condensing. Paddle dryer has lot of advantages which makes it option for sludge drying which are listed below:

- Conduction mode of heat transfer results in very high thermal efficiency
- Compact equipment – large heat transfer area packed in a small volume
- Low air requirement reduces loss of heat.
- Uniform and controlled drying
- Self-cleaning Paddles
- Minimal maintenance & Easy accessibility

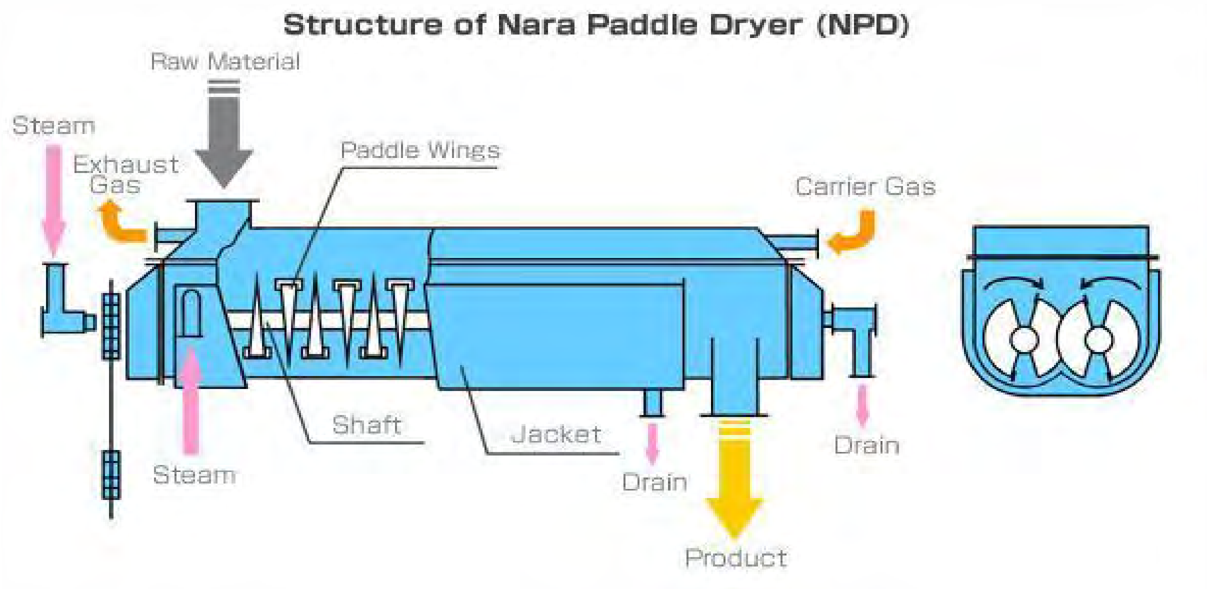



Figure 39: Paddle Dryer

*Source: www.nara-m.co.jp*

**Rotary Dryer**

Rotary dryers are a highly efficient industrial drying option for bulk solids. They are often chosen for their robust processing capabilities and their ability to produce uniform results despite variance in feedstock. Rotary dryers work by tumbling material in a rotating drum in the presence of a drying air. They can also be indirectly heated to avoid direct contact between the material and processing medium. The drum is positioned at a slight horizontal slope to allow gravity to assist in moving material through the drum. As the drum rotates, lifting flights pick up the material and drop it through the air stream in order to maximize heat transfer efficiency. When working with agglomerates, the tumbling action imparted by the dryer offers the added benefit of further rounding and polishing the granules.

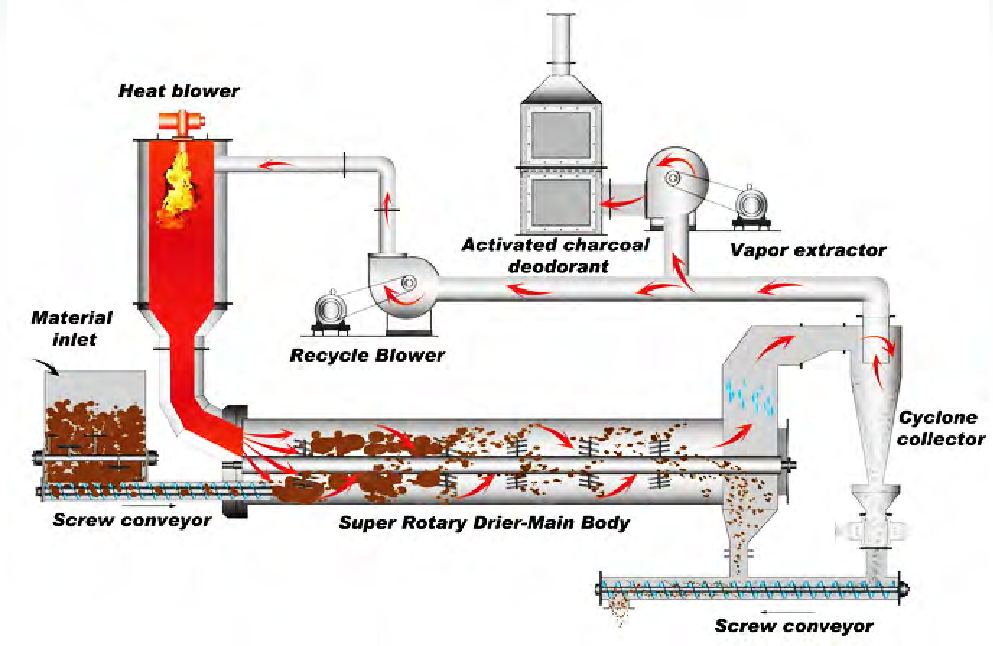



Figure 40: Rotary Dryer

*Source: www.benenv.com*

## 8.5 Notes for trainer

This session represents the various treatment technologies available for wastewater management i.e., mechanised or non-mechanised systems. The selection of treatment technology is important considering its performance and existing situation of the project area or city.

## 8.6 Bibliography


- NMCG Guidelines (2018): Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants
- CPHEEO (2013): Manual on Sewerage and Sewage Treatment Systems, Part A & B
- MoH&UA (2021): Swachh Bharat Mission – Urban 2.0 guidelines
- MoUD (2012): Guidelines for decentralized wastewater management, MoUD Centre of Excellence in DWWM

Session

# 09

# Project Management

# 9. Project Management

## 9.1 Learning Objectives

- To gain knowledge about the stages of project management and steps to be followed for holistic planning and implementation of a project.
- To understand the components and the critical points to be reviewed in a DPR.
- To understand financial modeling of the project so as to assist choosing of solution and technology.
- To realize that ultimately the project cost should be affordable to the households and shall be recovered in form of conservancy tax/fees.
- To understand project delivery methods in order to successfully implement and sustain the project.

## 9.2 Session Plan

Duration - 60 minutes

| Topics | Time | Material/Method |
|---|---|---|
| DPR Review | 15 min | Power point presentation |
| Financial Modelling | 20 min | Power point presentation |
| Project Delivery Method | 15 min | Power point presentation |
| Q&A | 10 min | Discussion |

## 9.3 Key Facts

- DPR needs to be a technology agnostic document encompassing all aspects of the project – technical, non-technical, financial, environmental etc.
- Financial modeling is key to check financial viability and long-term sustainability of the project.
- For Public Private Partnership (PPP) projects, financial modeling is necessary for fair allocation of risk in the project.
- Project delivery method helps to bind the key stakeholders of the project together.
- Correct Project delivery method, helps to complete the project time without cost escalations and sustain it for its design life.

## 9.4 Learning Notes

### 9.4.1 IWSM Project management

A step-by-step holistic and integrated planning process, not necessarily linear, is needed for all ULBs to ensure safe, hygienic and sustainable sanitation systems

**Initial findings—Pre-planning (steps 1–4)**

Emphasis on establishing evidence around the current situation of the sanitation sector in order to identify and define problem statements, underlying causes and the strategic interventions that will be required to address the problems. The output at this stage is an identification report that clarifies the objectives of the project.

The crucial decision requirements is that the project's need to be clarified by the relevant authorities.

**1. Identification of design objectives:** Typical objectives for the project could be the following either individually or in any combination as identified during the visioning exercise

- Objectives for the project could be the following either individually or in any combination as identified during the visioning process
- Achieve 100 per cent public health and hygiene
- Sustainable and affordable water and sanitation for urban poor
- Best-designated use and management of the water and wastewater resources i.e resource efficiency, reuse, recovery and sustainability
- Ecological protection, environmental flows and discharge control, natural balance and pollution abatement, climate change adaptation.

**2. Decision on planning unit**

- Emphasis on cluster-based development
- Avoid conflicts with existing projects and ensure convergence of missions and schemes for project planning and implementation
- There shall be a window for expansion in future for services and infrastructure.

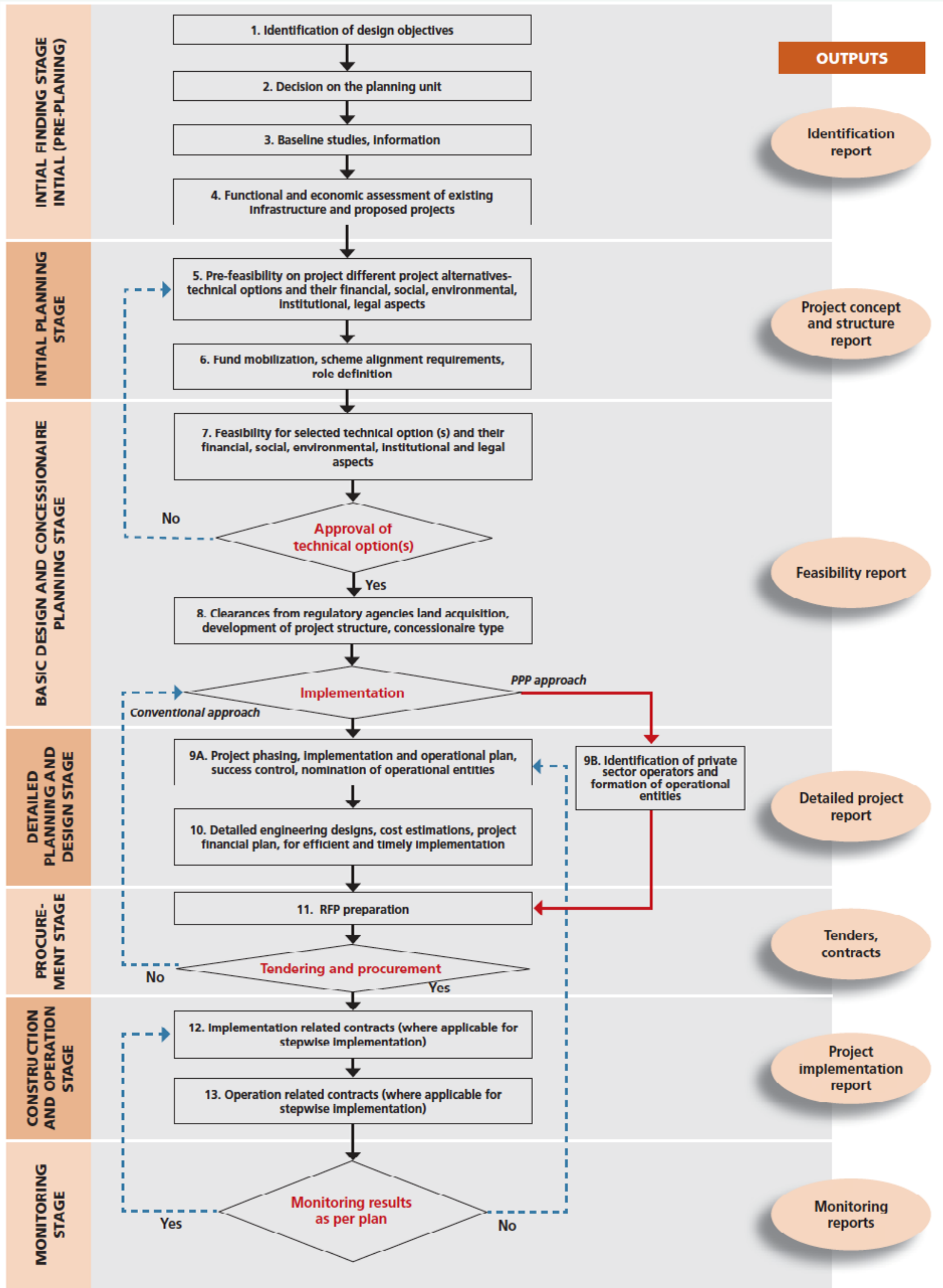
**3. Baseline studies, information:** To adopt a holistic approach to planning that prioritises human settlement's goals. Collection of baseline information is necessary for a situational analysis as well as advocacy to prioritize the region's need and requirements.

**4. Functional and economic assessment of existing infrastructure and proposed projects and proposed projects:** The ULB should form a multi-stakeholder sanitation task force which shall identify the need of the project by analysing the existing problems and further provide suggestions to address the problem.
There are two crucial steps in this stage that involve the design of a concept (approaches for decentralized sanitation, centralized sanitation or hybrid) as well as the assessment of the different project alternatives based on technical options. Following that, the role of key stakeholders is defined. Political buy-in and posing the project under government's schemes and mission is the need at the stage. Moreover, community representatives can address the requirements based on the issues raised by the dwellers. The output is a pre-feasibility report.

**5. Pre-feasibility assessment:** Pre-feasibility on different project alternatives- technical options and their financial, social, environmental, institutional, legal aspects. The ULBs shall identify the demand for the services and the design requirements based on the baseline information and data collected.

**6. Fund mobilization assessment:** It is critical that the respective ULB first assesses its financial situation, as well as its potential to mobilise internal sources of funding and district common funds. Thereafter, if any financial deficit exists, a clear statement shall be issued which shall enable to look for external sources (grants, loans, flagship missions in sanitation sector, markets) or leverage existing assets. Following that, the lender must ensure debt-paying capabilities in response to external financing and capital markets. In that case, if the respective ULB, happens to be at risk for paying debt, the ministry shall guarantee to pay the debt.





Source: Adapted from Integrated Faecal Sludge Management Guidelines, GIZ 2018.

**Design and concessionaire planning (steps 7 and 8)**

At this stage there are two key steps that involves preliminary planning for the elements of the sanitation value chain and estimation of ball park figure of the project. Accordingly, potential funding sources are identified and evaluated for the feasibility of investment. This stage also determines all clearance required to facilitate an effective implementation. The output is a feasibility report.

The critical decision requirements at this stage shall be selection of technology and related clearance for implementation.

**7. Feasibility assessment:** The ULBs shall conduct the feasibility assessment of selected technical options identified in the previous stage with respect to financial viability, institutional and governance capability, operational ease, environmental compliances and social aspect

ULBs will define the structure of the project including the operational model, financial model, mode of implementation and the related project partners or concessionaires

**8. Clearances from regulatory agencies land acquisition, development of project structure, concessionaire type:** The critical decision requirements at this stage shall be related clearance before initiation of the project to avoid legal conflict at later stages.

**Detailed planning and design (steps 9 and 10)**

There are two key steps at this stage that will result in efficient project phasing and implementation plan including the corresponding detailed design and engineering aspects. The output is a 'detailed project report'.

**9A Project phasing and implementation plan**

The work packages for tender documents will be aligned with planning units. In terms of public health and environmental concerns, there will be synergies between current services and requirement of the concerned region. ULBs may also explore the possibility for private-sector participation to identify private-sector operators, form operational entities for effective operation of standardized containment systems, and schedule emptying service and treatment facilities.

**9B Identification of private sector operators and formation of operational entities:** ULBs should also explore private-sector participation for procurement, operations and maintenance of the emptying vehicles, construction and operations of wastewater and faecal sludge treatment facility and possible reuse of treated wastewater and faecal sludge within a region as well as in nearby regions. They should create performance-based contracts such that payment is linked to private-sector performance for providing the services.

**10. Detailed engineering designs**

Detailed engineering designs for the new assets and/or retrofitting/rehabilitation of the existing assets and infrastructure should be developed, with a focus on the process design. The designs will provide details of unit capacities/dimensions, context-specific choice of material for construction and phase-wise design. Financial estimates will be based on the civil Schedule of Rates (SoR). The detailed engineering design must take into account, operability conditions, institutional and governance requisites, the legal and regulatory necessities, and the financial sustainability models. The financial risks should be clearly defined and delimited to an interval of ± 10 per cent. The work packages shall be structured as financial packages with staggered implementation schedule based on the financial implications and feasibility



**Procurement, construction and operation (steps 11 and 12)**

**11. Robust Expression of Interest (EOI) and Request for Proposal (RfP):** documents shall be developed. In accordance with the statuary rules, diligent and efficient bid with appraisal mechanisms shall be carried out based on principles of fairness, transparency, integrity, accountability, and competence.

**12 Implementation related contracts (where applicable for stepwise implementation):** The procurement process shall result in the establishment of governance structures and implementation frameworks that will guarantee safe and sustainable service delivery in the long term.

**Monitoring and evaluation (step 13):** The effectiveness of services will be monitored by the relevant authorities in accordance with national or international standards. With the goal of meeting step 1, there will be a mechanism for monitoring the implementation's aftereffects as well as service delivery. Aside from government organisations, the authorities can delegate responsibilities to national and international research think tanks, as well as the private sector as per the contract. Responsibilities may not be limited to monitoring the implementation and service delivery only.

### 9.4.2 DPR Review

DPR preparation plays an important role in planning and implementation of a project which consists of several stages of planning, implementation and management of the project. The four stages of DPR are mentioned below and each stage has its own significance. Each stage consists of certain critical points, which need to be checked before approving the DPR and proceeding with implementation of the project.

- Foundation
- Design
- Non – Technical Aspects
- Financial Modelling

#### A. Foundation

In the foundation stage, baseline survey and data assessment activity should be carried out for further planning, design and upgradation of sanitation systems in the city. The foundation stage consists of five different sections to collect the data, assess the collected data of city sanitation value chain, water and sewage generation. From preliminary data assessment it is easy to plan and choose proper and sustainable technology solutions for project execution. The five stages of foundation stage are as follows: -

- Description of project area
- Existing wastewater management
- Project area and population
- Sewage Generation
- Qualitative analysis

**Description of project area** – This section of the DPR talks about the city sanitation plan and the components of CSP which gives an idea about the existing infrastructure and information of existing plans and what needs to be considered in future. CSP gives information about current population, floating population due to various cultural, religious and tourism activities which helps to find out the fluctuation in water and wastewater flow and its generation. The numbers should be decided in consultation with the tourism departments and specified for water supply and sewerage. It also gives idea about selection of area and location for the project implementation. There are some preconditions commonly required for dissemination of any centralized project. Equivalent permanent population shall be worked out in proportion to the rate of water supply required for floating and permanent population.

**Existing Wastewater Management** – The sanitation value chain of any city or town from its source of waste generation to disposal and reuse give value to the process of data collection of any city for interception and diversion projects and STP implementation. Maps of drains, sewers, nallah no. of STPs, its source and disposal data should be perpetually collected during baseline survey which helps in planning and implementation of any sanitation project. Details about existing sanitation infrastructure and managing facilities add value to any DPR for further action in the project.

**Project area and Population** – Future population projection plays an important role in designing, planning and deciding the capacity of any treatment technology that will cater to the future population. Population projections for the base, after 10 years, mid and design years shall be made considering the past decadal growths using different methods such as:

- Arithmetical increase method
- Incremental increase method
- Geometrical increase method
- Decreasing rate of growth
- Graphical projection method
- Logistic method
- Land use and future density method

This activity of population projection shall be carried out at city level or micro level for different wards and clusters depending upon the growth potential of individual wards in consultation with the local body, development authority and city planning department. Future population, which gives a more realistic picture of city or town and acceptable, shall be adopted by giving proper justification. In major cities, slum areas, unauthorized colonies, houses and establishments have been generating substantial amounts of wastewater. Population of such areas should also be considered during estimation of population and sewage generation. Design population shall be adopted as a sum of permanent and equivalent floating and unauthorized population and shall be given for base year, 10, 15, 30 years. In case the town has been divided into a number of sewerage zones, design population in different years shall also be given zone wise.

**Sewage generation** – Quantity and quality of water supply and sewage generated in a city or town carried by water supply pipes and drains need to be measured and tested. Micro planning of the project in terms of number of drains, number of STPs and its disposal in water bodies shall give a better idea of where the generated sewage should be disposed of without populating the water bodies and environment. Considering data of seasonal variation in sewage generation shall give variation in design flow of sewage and it can be collected from the records of STPs for the last 3 years. In the absence of records, the same may be measured in dry weather. The assessment of the flows in drains and STPs can be done by a variety of methods. The choice of methods for finding out flow in drains and STP gives accuracy of calculation. Methods of calculating design flow are considered in session 2. Flow in drains and sewers varies hourly and seasonally. However, for design purposes various different factors shall be considered.

**Qualitative Analysis -** Raw sewage quality for design of STPs should be considered and shall be carried out weekly or monthly to understand the seasonal variation. The normative values of parameters like BOD and SS have been taken for influent sewage despite actual quality characteristics having been established through field investigations. Such considerations result in over design of STPs with higher cost implications. This must be avoided and actual influent quality with an appropriate mark up only be considered for design purposes. Sampling for water quality should be conducted for at least one month during dry weather to assess pollution load quantitatively and qualitatively.

### B. Design

The second and one of the important stages in preparation of DPR for projects of sanitation infrastructures is the design stage. After data collection and assessment of collected data, which helps in planning and designing of the STPs and interception and diversion projects. In this section of DPR there are five different stages to plan, design different components of STPs and sewers along with the technology selection on the basis of assessed data of the city. The five stages of design section are as follows:

- **Overall Planning –** In this section the overall planning of the project shall be done considering the city level assessed data, the development of infrastructure needed after finding out the gaps between existing and future infrastructure. The future plan pertaining to the future population projection shall be implemented which can be managed and become sustainable for further operation and providing services. Local government and private authorities should also sit together for planning and implementation to understand the assets needed for providing services and to have an ownership towards the sanitation infrastructure.

- **Interception and Diversion** – I&D of drains which outfalls in the water bodies need to be diverted through sewers to STPs for treatment and further disposal and reuse. While planning and designing of I&D project, the sizes, the invert levels, topography of towns and cities, the population projection and future infrastructure development should be considered.

- **Sewer network -** For a town that is sewered, even if partly, the existing Master Plan of sewerage of the town, sewerage zones, designs of trunk sewers, locations of sewage pumping stations and STPs will need to be referred to determine the invert levels of Diversion Sewers now being proposed. In case of towns with no sewerage system and no sewerage plan, ideally it would be desirable to prepare the Master Plan for sewerage, if not prepared earlier and carry out the design of sewerage network of sewers. However, in case it is not feasible or practical for any reason to prepare a master plan of sewerage, it is necessary to ensure that in the future when a comprehensive sewerage plan of the town is prepared and implemented, the proposed works that will come up then will be in consonance with the diversion works that are being planned now. In drainage areas where there is an existing system of interception and diversion of waste water from drains, their existing status shall be considered in a plan and in the form of a note stating the components, their details and condition etc.

- **Sewage Pumping Station** – During planning of sewage pumping station, topography, location and future infrastructure development should be considered and the proposed design should be provided considering future need for 30 years and would ultimately become a part of the town's integrated and comprehensive system of dealing with wastewater. The sizes of pumping stations and invert levels of different components shall therefore, be provided accordingly. However, considering the modular approach, pumping plants shall be provided to cater to the next 15 years and further pumps may be provided with a modular approach in a phased manner as the population grows. Various components of sewage pumping station shall be considered while designing them like raising mains and phenomena like water hammer.

- **Sewage Treatment Plant -** Sewage treatment plants shall be based on the technology which may have the natural, chemical, powered or non-powered based processes. The choice of technology option for sewage treatment is of great importance. The treatment technology and the location of STP places very important role in making of DPR. The technology selection shall be evaluated on the basis of the performance, energy requirement, resource and land requirement and overall annual cost of maintenance and manpower. The technology must fall under the guidelines of government policy and the efficiency of treatment should match the standards of CPHEEO manual and various pollution control boards of states. The most cost effective and feasible option may be selected through their life cycle cost analysis of various technologies. Provision for STPs should be made on a technology neutral basis. The technology provider may be asked to quote the rates based on the criteria such as raw sewage quality, effluent quality for reuse of effluent, availability of land and O&M cost and ease in maintenance of the STPs etc. Costs of STPs constructed elsewhere on latest effluent parameters should be given in support of estimated cost adopted in the DPR. In areas where the sewerage network coverage is low, there has been reported tendencies of the septage being dumped at the receiving chambers or the drains to the STPs causing shock loads and leading to failure of the STP's performance. Hence Septage / Faecal Sludge management practices are to be assessed and appropriate provisions need to be built in while designing the STPs.

An integrated and comprehensive scheme of management of wastewater in the town will include other aspects such as covering all the localities with sewers and connecting every household to it, dealing with non-point sources of pollution, solid waste management etc. Thus, the interception and diversion sewers, sewage pumping stations and sewage treatment plants proposed under DPR would ultimately become a part of the town's integrated and comprehensive system of dealing with wastewater. This aspect should be kept in mind while designing the infrastructure works.

### C. Non-Technical aspects

**Capacity of ULB -** Capacity is a function of two aspects, namely human resource and physical and financial resources. Human resource has been dealt with above. Physical resources imply equipping the staff deployed for this work with necessary financial resources and physical resources such as space, laboratory, tools etc. The DPR should incorporate the requirement of these resources for proper operation and maintenance and management of the project.

**Environmental Sanitation Management Plan -** The I&D and STP projects have generally favourable impact on the components of the social environment. some components are assessed to be adversely affected; a management plan must be prepared to keep the values of the component within acceptable limits. The following steps to be considered for impact management plan:

- Baseline study of environmental parameters
- Environmental impacts
- Environmental Management Plan (EMP) and its cost consideration

**Governance and Accountability Action Plan -** The Governance and Accountability Action Plan (GAAP) is to minimize accountability risks. Specific arrangements shall be proposed to mitigate these risks and to ensure that funds are used effectively and efficiently. The main purpose of the GAAP is to ensure that objectives are achieved with avoidance of all kinds of internal and external risks. This GAAP summarizes the mitigation measures being taken as a part of program. The mitigation measures are grouped into three categories:

- Implementation Arrangements
- Transparency and Citizen Voice
- Grievance Redressal

**Communication and Outreach Plan** – The local authorities and state authorities may employ a number of projects executing agencies for different types of projects. The local authorities must explore the possibilities of Public Private Partnership (PPP) departmental implementation of projects, existing state/central government undertakings or setting up a special purpose vehicle to implement these projects. Various stakeholders for implementation of infrastructure, maintaining it according to the byelaws and collecting proper taxes and governance and accountability should be appointed to keep the project sustainable for the design period.

**Capacity building -** Impart training to the identified personnel of the agency that owns the project and has the responsibility for its proper functioning. Successful project preparation, implementation and management need the human power with diverse expertise in the various domains of knowledge like technical, scientific, social sciences, communication, financial and economics, institutional, administrative and legal department with relevant experience in similar works. Skill acquisition is achieved through education, training and experience.

**Quality Control and Assurance Plan -** I&D and STP projects are implemented mainly for the preservation of natural resources and these are necessary for the benefit and welfare of the public. The benefits of involving the public in the decision-making process are immense. It greatly helps in increasing public understanding of pollution abatement and subsequently defusing conflicts on government action by generating support of beneficiaries.

### D. Financial Modelling

Another important stage which needs to be considered in DPR preparation is financial plan and management of the project. This stage includes funding and financial assistance for land acquisition to management of the project after handing over to local authorities. Entire project sustainability and success depend upon proper financial modelling.

**Capital cost**

Capital cost includes cost of land acquisition, cost of various electromechanical components and its implementation and installation, cost of establishment of treatment units. For economic calculation the value of land remains the same over years and thus, land has unlimited lifetime. However, the price of land is never stable. It usually goes up in times of growth and may go down in times of political turbulence. In reality, the actual availability of land is more important than the price. Land is likely to cost more in areas with a high population density and vice versa. The choice of treatment system is severely influenced by these facts. Construction cost varies from region to region with adverse effects due to cost inflation as well.

**Operation and maintenance cost**
Running expenses include the cost of personnel for operation, maintenance and management, including monitoring. It also includes the cost required for electricity consumption to run STP plants on a regular basis. Running cost also include the cost of various consumables to maintain plants and to maintain safety hazards at STPs. Annual O&M cost beyond the 1st year is to be worked out by compounding present cost with general price index/inflation, which may be taken as 5% on Manpower and 2% on Chemicals. However, no escalation is to be considered on Power. Preventive maintenance or repairs needed after a few years' initial operations are often lost sight of. This is an important element of overall O&M cost and must be provided for appropriately. The DPR must clearly reflect the component-wise and total funds needed for O&M and how and where from these would be provided.

**Life cycle cost assessment**
The most cost effective and feasible option may be selected through their life cycle cost analysis of various technologies. This analysis should include capitalized costs, less revenue from resource recovery, recycling, by-product utilization etc. Ease of O&M, time required to construct and for achieving the desired objectives and costs of mitigation of any adverse environmental impacts must be considered on the costs assigned for the alternatives. Best option arrived from the LCC analysis should be selected and details should be presented in the DPR. Standard methodology for calculating life cycle costs should be adopted. With little additional and dedicated efforts, sewage treatment could be converted into a resource generation activity to partly meet the O&M costs. Treated sewage and sludge are both rich in nutrients and, therefore, can be suitably marketed as biological manure. It is necessary for the local bodies to enlarge the property tax base and utilize the additional revenue generated to meet the O&M cost. There could be several other ways for local bodies to raise revenue towards O&M costs through taxes from pilgrim/tourist/floating population visiting the city, undertaking plantation on municipal lands and generating revenue etc.

**Fund management**
The DPR incorporates a detailed projection of the costs and revenues expected during the projected lifespan of the operation phase. The principal input to this comes from operational costs. The DPR would include a recommendation schedule for ensuring adequate flow of funds for the timely completion of the project with adequate provision for normal contingencies. The DPR would also include for the project phase a recommended system of monitoring & control of the financial progress of the project, vis-a-vis the physical progress. The system is an essential ingredient for adequate financial control during the execution & the termination phase of the project.

### 9.4.3 Financial Modelling

#### A. Components of Project Cost
The project cost of any waste management project includes its capital or investment cost, the cost which is spent on initial establishment of any project. Other important cost component is operation cost, the cost which runs or operates the project regularly and maintains the project to keep it functional for the life span of the project. Another cost is maintenance cost, this cost keeps the project maintained and functional if any sudden breakdown comes or needs any replacement of the components of the project.

**Investment cost**
These are costs which occur initially for construction of a project or implementation of any facilities. For the project phase, the DPR shall provide an estimate of the phase requirement of capital. The DPR would include a recommendation schedule for ensuring adequate flow of funds for the timely completion of the project with adequate provision for normal contingencies.

**Operation and maintenance cost**
These are usually recurring costs required to operate and maintain assets and facilities. e.g., staff, electricity, chemicals, administrative costs, etc. The DPR shall incorporate a much-detailed projection of the costs and revenues expected during the projected life span of the operation phase. The principal input to this comes from operational costs. The other financing costs include depreciation, interest on long-term loans and short-term working capital loans, writing off pre-operative & preliminary expenses, guarantee commission, etc.

#### B. Life cycle cost
Life-cycle cost analysis (LCCA) is a method for evaluating all relevant costs over time of a project, product, or measure. LCC is a valuable technique which is used for predicting and assessing the cost performance of the project. The purpose of LCC is to quantify the life cycle cost for input into a decision making or evaluation process. It takes into consideration all costs including first costs, such as capital investment costs, purchase, and installation costs; future costs, such as energy costs, operating costs, maintenance costs, capital replacement costs, financing costs; and any resale, salvage, or disposal cost, over the lifetime of the project or product. LCCA is thus an engineering economic analysis tool useful for comparing the relative merit of competing project alternatives. Life cycle cost analysis is an assessment method for estimating the performance of materials and services considering their impact on environment, from extraction of raw materials to the end-of-life disposal/recycling stage. Standard methodology for calculating life cycle costs should be adopted.

Life cycle costs of different systems should be compared to make the project cost efficient and reliable to maintain till it's designed life or year. The Life cycle costing methodology has the following steps: -

- Determining life cycle cost analysis objectives
- Defining the scope of the system
- Choosing the effective estimating life cycle costing model
- Obtaining all essential data and making the appropriate inputs to the selected model
- Computing total life cycle cost
- Formulating life cycle cost analysis results

Where,
C = Initial cost
R = Present value of replacement cost
A = Present value of annually recurring, operating, maintenance and repair cost
M = Present value of non-annually recurring operating, maintenance and repair cost
E = Present value of energy costs
S = Present resale value or residual value or salvage value

**C. Cost inflation**

It is easy to measure the price changes of individual products over time, human needs extend much beyond one or two such products. Individuals need a big and diversified set of products as well as a host of services for living a comfortable life. They include commodities like fuel, utilities like electricity and transportation, and services like healthcare, labour etc. Inflation aims to measure the overall impact of price changes for a diversified set of products and services, and allows for a single value representation of the increase in the price level of goods and services in an economy over a period of time. As a currency loses value, prices rise and it buys fewer goods and services. This loss of purchasing power impacts the general cost of living for the common public which ultimately leads to a deceleration in economic growth.

In projects of wastewater management, the cost of various materials of construction rises due to inflation and which affects the project cost of implementation, operation and maintenance. So, while making DPR the cost of the project shall be calculated considering cost inflation of products for the design and life cycle period of project. Inflation also affects the demand and supply ratio of goods and material. Inflation can be construed as either a good or a bad thing, depending upon which side one takes, and how rapidly the change occurs.

**D. Net Present Value**

Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. Net present value (NPV) is a method used to determine the current value of all future cash flows generated by a project, including the initial capital investment. It is widely used in capital budgeting to establish which projects are likely to turn the greatest profit. Net present value, or NPV, is used to calculate today's value of a future stream of payments. If the NPV of a project or investment is positive, it means that the discounted present value of all future cash flows related to that project or investment will be positive, and therefore attractive. To calculate NPV you need to estimate future cash flows for each period and determine the correct discount rate.

The formula to calculate NPV

$$NPV = ((Cash\ Flow)/(1+i)^t) - Initial\ Investment$$

Where,
i =Required return or discount rate
t =Number of times periods

NPV is used in capital budgeting to compare projects based on their expected rates of return, required investment, and anticipated revenue over time.

**E. Equivalent Annual Cost**

Equivalent annual cost (EAC) is the annual cost of owning, operating, and maintaining an asset over its entire life. EAC is often used by organisations for capital budgeting decisions, as it allows an organisation to compare the cost-effectiveness of various assets that have unequal lifespans. EAC allows planners who are involved in preparation of DPR, to compare the net present values of different technologies over different regions and areas, to accurately determine the best option. Equivalent annual cost (EAC) is used for a variety of purposes, including capital budgeting. But it is used most often to analyse or compare different technologies with different lifespans, where costs are the most relevant variable.



Other uses of EAC include calculating the optimal life of a project, determining if contracting or ownership of a project is the better option, determining the magnitude of which maintenance costs will impact a project, determining the necessary cost savings to support before investing in new project components and determining the cost of keeping existing equipment.

**F. Conservancy Tax**

A conservancy tax is sufficed to provide for the collection, removal and disposal, by municipal agency, of all excrementitiously and polluted matter from privies, urinals, and cesspools and for efficiently maintaining and repairing municipal drains. Sanitation tax is a tax collected by an urban local government for provision of sanitation services. The sanitation tax is collected through property tax bills or water bills. Local governments use the proceeds of sanitation tax for providing various sanitation services. This tax is different for different states considering the sanitation facilities they have and the administrative authority. The ULB should impose adequate sanitation tax to cover the cost of sewerage and sanitation services. Whereas efforts should be made for cost recovery from the beneficiaries who get doorstep service, the shortfall in funds should be made good from general sanitation tax, which should be adequately imposed as a matter of policy by the ULBs. This conservancy tax is not adequate to recover O&M charge fully but partially to at least maintain the facilities.

**Sinking fund**

A sinking fund is a fund containing money set aside or saved to pay off a debt or bond. An organisation or authority that issues debt will need to pay that debt off in the future, and the sinking fund helps to soften the hardship of a large outlay of revenue. A sinking fund is established so the local authority of the city can contribute to the fund in the years leading up to the bond's maturity. A sinking fund helps companies that have floated debt in the form of bonds gradually save money and avoid a large lump-sum payment at maturity. In wastewater projects, money to be deposited into this fund include transfers from the water and sewer fund, money received for wastewater general facility charges received in the water and sewer capital development fund and transferred to the wastewater debt sinking fund, and any other legally authorized funds to be used for the wastewater utility. Any interest earnings on moneys invested from this fund shall be deposited into such fund.

### 9.4.4 Project Delivery Method

Project delivery method are the methods used by different authorities or organisations for smooth and hurdle free implementation of any project in terms of cost, on ground implementation, its operation and continuous maintenance.

For smooth implementation of such plans, the government authorities or owners of the project need to involve other private parties and enter into contracts with them. Such models are designed to facilitate speedy and cost-efficient completion of the projects. There are two main types of method used for project delivery:

- Engineering, Procurement and Construction (EPC)
- Public-Private-Partnership (PPP)

Engineering, Procurement and Construction (EPC) is an arrangement of implementing / executing a project and a type of contracting arrangement between Owner and company made responsible for all the activities from design, procurement, construction, to commissioning and handover of the project to the owner. The funds are in place.

PPP is Public-Private-Partnership and is basically a business relationship between a private sector (company) and a government agency for the purpose of completing a project that will serve the public. PPP is normally used to fund, finance, build (Capex), and operate projects. Different types of PPP Contracts are mentioned below:

- Build-Operate-Transfer (BOT)
- Build-Own-Operate (BOO)
- Build-Operate-Own-Transfer (BOOT)
- Buy-Build-Operate (BBO)
- Design-Build (DB)
- Design-Build-Finance (DBF)
- Design-Construct-Maintain-Finance (DCMF)
- Management agreements
- O&M or Annual Maintenance Contract (AMC)

**Build-Operate-Transfer** is an arrangement in which the private entity undertakes construction work, operates it for a certain period of time, andis taken back by the government. It is generally used for discrete assets rather than full networks.

**Build-Own-Operate** is a model in which the ownership remains with the private party and it continues to operate that project. It is often used for water treatment or power plants.

**Buy-Build-Operate,** in this model the government sells the facility to the private entity. The private party renovates and operates the facility.

**Build–own–operate–transfer (BOOT) -** A BOOT structure differs from BOT in that the private entity owns the works. During the concession period, the private company owns and operates the facility with the prime goal to recover the costs of investment and maintenance while trying to achieve a higher margin on the project. BOOT has been used in projects like highways, roads mass transit, railway transport and power generation.

**Design-Bid-Build (DBB) or Design-Award-Build (DAB) -** In Design-Bid-Build, owner develops contract documents with an architect or an engineer consisting of a set of blueprints and detailed specification. Bids are solicited from contractors based on these documents; contract is then awarded to the lowest responsive and responsible bidder. This is the traditional model for public sector infrastructure projects.

**DBB with Construction Management (DBB with CM**) **-** DBB with Construction Management is a modified version of the Design-bid-build approach With partially completed contract documents, an owner will hire a construction manager to act as an agent. As substantial portions of the documents are completed, the construction manager will solicit bids from suitable subcontractors. This allows construction to proceed more quickly and allows the owner to share some of the risk inherent in the project with the construction manager.

**Design-Build** is a type of PPP model in which the private party has an additional responsibility of designing the framework of the project. It reduces time and complications and helps the public entity save money as only a single party is involved. It burdens the private party with an additional responsibility.

**Design-Construct-Maintain-Finance** is a framework in which the private party designs and constructs the project, and then is leased back the property.

**Management agreements-** Under management agreement the public entity transfers the management of the asset, business, property etc. to the private party for a particular period.

**Operations and Maintenance** is an arrangement where the private party takes the responsibility of maintaining and operating the public property/project for a specific amount of time with certain obligations which are specified in the operation and maintenance agreement.

PPP model one party is a government or public sector enterprise and the other is a private party while the same is not true for the EPC model which can have two private entities as parties to the contract. Also, there is a difference between how the two models work.

In the PPP model, the government invites bids over this project and grants the project to the entity with the cheapest bid. The project would be financed by the government. Now, if there arises a situation in which there is a delay in the project, the private entity will have to solve the problem which would involve costs. Now it will have to pitch in a new bid to get compensated for the costs incurred. It will have to deal with the lethargic government machinery in order to get the new bid approved. But, in an EPC model the government would call for individual bids for engineering expertise, procurement of raw materials and the actual construction work. This would in turn increase the efficiency of the project as different parts of the project would not be interrelated and the private party would not have to deal with the political issues. The government would deal with the complications that arise. The PPP model may seem better in complex infrastructure projects, the EPC model has many advantages over it.

Risk allocation in different methods with its advantages are mentioned in this part of the module. In the case of the EPC model, all the three risks are directed towards the government/client. To reduce this risk, PPP models are used. In case of BOT, all the three risks are upon the private party/contractor. However, projects done through this model usually face opposition as they are looked upon as privatization of services. In some projects such as waste management the return on investment is relatively less; hence it is difficult to find financing institutions. Hence, an improved version known as Viability Gap Funding was introduced. Here, the financing risk was shared by the government for meeting the investment cost. However, the risk of revenue collection and O&M still lies with the private party. In cases where it is ensuring collection of revenue consistently from the beneficiaries**,** projects face issues with O&M and the quality-of-service declines over a period of time. To overcome this difficulty, Annuity Model is used, where the government bears the risk of revenue collection. The collection is made through property tax etc. and transferred to the private party through escrow account. In India, the new HAM is a mix of BOT Annuity and EPC models.

The latest model known as HAM tries to mitigate all the issues and are considered as fair by experts. In this case, similar to the Viability Gap Funding Model, the portion of the initial investment cost is borne by the government (usually 40%) and the rest is borne by the private party. The revenue collection risk is borne by the government and carried out similar to the Annuity Model. The O&M risk is with the private party. However, there are certain disadvantages too in this model. While calculating future payments certain assumptions for inflation rate and discount rate are made. If these rates change due to certain events such as pandemic or natural calamity, the project can quickly become financially non-viable for the private party incurring huge losses. Since, maximum risk is borne by the private party, it is expected that at the end of the project the party is able to get good returns on its investment. Thus, in order to attract private players in HAM, the good margins need to be considered.

## 9.5 Notes for trainer

This session gives a brief about stages in preparation of DPR, that DPR shall be a technology agnostic document encompassing all aspects of the project – technical, non-technical, financial, environmental etc. This session also gives a brief about how financial modelling of any project is important to check financial viability and long-term sustainability of the project. The proper selection of project delivery methods plays an important role to complete the project within the time without cost escalations and sustain it for its design life.

## 9.6 Bibliography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Session

# 10

# Operation & Maintenance and Sustainability

# 10 Operation & Maintenance and Sustainability

## 10.1 Learning objectives

- To plan the operation and maintenance of wastewater management system.
- To understand the requirements of O&M in case of drains, I&D system and STPs.
- To understand the importance of public awareness and participation.
- To understand the aspect of combined sewer overflow and its control methods.

## 10.2 Session plan

Duration - 45 minutes

| Topics | Time | Material/Method |
|---|---|---|
| Operation and Maintenance (O&M) | 15 min | Power point presentation |
| Public Awareness and Participation | 10 min | Power point presentation |
| Reducing combined sewer overflow | 10 min | Power point presentation |
| Q&A | 10 min | Discussion |

## 10.3 Key facts

- O&M plan is an important document and needs to holistically cater to all the tasks that need to be performed by the operator to keep the plant operational.
- Monitoring of the processes at the treatment facility helps in early detection or completely avoid issues and challenges at the treatment facility.
- Public awareness and participation is the key for achieving 100% sanitation and to ensure personal hygiene in the community.
- The control methods for reducing combined sewer overflow can be adopted in the case of India for the management of urban drains. Excessive wet weather flow conditions lead to overloads in the sewer system, hydraulic surcharge of pipes, flooding of basements and larger combined sewer overflow events.
- The control methods for reducing combined sewer overflow can be adopted in the case of India for the management of urban drains.

## 10.4 Learning notes

### 10.4.1 Operation and Maintenance (O&M)

Sanitation system maintenance functions are most often neglected and given attention only as emergency arises. Adequate budgets are seldom provided for supervision, manpower and equipment, unlike the case for maintenance of other utilities like electric cables, telephone cables, gas and water mains. Such neglected attitude towards sanitation infrastructure maintenance is found even in large cities. Considering the health hazards that the public at large has to face, it is appropriate to provide sufficient funds, proper maintenance, regular supervision and safety aspects to take care of men, material, equipment and machinery required for efficient maintenance

Maintenance of the sanitation system consists of the optimum use of labour, equipment, and materials to keep the system in good condition, so that it can efficiently accomplish its intended purpose of collection and conveyance of sewage.

For proper operation and maintenance of sanitation systems, O&M plan needs to be properly made considering the O&M of each sanitation system components, proper guidelines, operational tools for maintenance, safety measures and equipment's during maintenance activity, etc.

### A. Operation and Maintenance Plan

O&M plan should be made to see there is no failure in the internal parts of the systems; it may damage the extensive property and may affect the entire function of the system and its components.

Maintenance plan helps to protect the capital investment and ensures an effective and economical expenditure in operating and maintaining the sanitation facilities. It also helps to build up and maintain cordial relations with the public, whose understanding and support are essential for the success and keep the project sustainable for years. The ULBs must ensure that sanitation systems are given their due importance to improve the sanitation condition in the country.

For wastewater management system, it is essential to include following points in the O&M plans for proper, successful and sustainable management of project:

- Technical specifications and engineering drawings of wastewater systems
- Manufacturing details and operational guidelines with proper tools for maintenance
- Allocation of Manpower and their roles and responsibilities
- Activity chart of O&M weekly, fortnightly, monthly and yearly
- Occupational safety and hazard during O&M activity
- Maintaining regular records for every activity
- Regular monitoring and analysis of system efficiency
- Availability of material required for monitoring, analysis and maintenance
  - Consumables
  - Contact details of stakeholders
- Emergency supplies and services

Sewers and sewage treatment plants are the major components of wastewater management systems. Sewer collection systems are intended to be a reliable method of conveying sewage from individual discharge to sewage treatment plants. Regular monitoring and supervision are the techniques used to gather information to develop operation and maintenance programmes to ensure that new and existing collection systems serve their intended purposes on a continuing basis. Supervision and monitoring are necessary to do the following:

- Identify existing or potential problem areas in the collection system
- Evaluate the seriousness of detected problems
- Locate the position of problems
- Provide clear, concise, and meaningful reports to supervisors regarding problems

The purpose of regular supervision and monitoring is to prevent leaks from developing in the sewers and identify existing leaks to be corrected. A designer's mistake and the failure in construction are directly responsible for many of the sewer failures. Due to age, deterioration of the material of the sewer by attack of hydrogen sulphide or other chemicals, settlement of foundations and leaking joints may result in the structural failure of the sewer. It takes a very long time from the onset of the first initial defect to the collapse of the sewer. A crack or a leaking joint will allow subsoil water and soil mixture to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer.

### B. Maintenance Planning

Standard records are essential to sewer maintenance planning, practices and methods. From an analysis of daily and monthly records, the work is scheduled. Plans are made to make necessary yearly repairs so as to take first things first in their importance of benefit to the whole. Emergency breakdowns and repairs will change a yearly preventive maintenance schedule. By the use of charts and diagrams showing accumulative performance and comparison of work, maintenance crews can be transferred from an operation where they are ahead of schedule, to the emergency work requiring immediate consideration. This gives flexibility to maintenance personnel. Every phase of maintenance operation needs to be taken into consideration from the disposal of waste at the house connection lateral to the final discharge from the treatment plant.

Preventive or routine maintenance should be carried out to prevent any breakdown of the system and to avoid emergency operations to deal with clogged sewer lines or overflowing manholes or backing up of sewage into a house or structural failure of the system. Preventive maintenance is more economical and provides for reliability in operations of the sewer facilities. Emergency repairs, which would be very rare if proper maintenance is carried out well, also, have to be provided for. Proper inspection and preventive maintenance are necessary.

The above information showcases two main types of maintenance:

- Preventive Maintenance
- Breakdown Maintenance

The preventive maintenance program is essentially scheduled for inspection tasks designed to determine the effectiveness of the preventive maintenance program as well as the overall condition of the sanitary collection system. Inspections are both manual, for manholes and short sections of pipe, and closed-circuit television (CCTV) for more detailed examination of the interior of the collection system pipelines. Additionally, CCTV provides videotape for future reference and comparison.

The breakdown maintenance is also called as sudden maintenance and is designed to respond to a failure in the system, such as a blockage. Additionally, breakdown maintenance would provide for system rehabilitation, repair or replacement based upon the regular condition assessment of the collection system.

The maintenance procedure sheets should be prepared for each treatment unit and should consist of all the information mentioned below:

- The list of tasks which need to be performed for complete maintenance of the unit.
- The frequency of the action, certain activities such as oiling and greasing might have to be done on a weekly basis whereas checking of overhauling of the equipment needs to be done in each quarter.
- Tools required for performing the tasks need to be mentioned clearly.
- A step-by-step procedure to do the task needs to be mentioned.
- Exactly what needs to be inspected and what the situation means should be checked and recorded into the log book.

### C. Operation and maintenance requirements

O&M of drains, sewers, sewage pumping stations and sewage treatment plant plays a vital role in proper and sustainable project management of sewerage system.

**Table 17: O&M Activities of wastewater management components**

| Wastewater Management System Components | | O&M Activities |
|---|---|---|
| Surface drains | Lined / Unlined<br>Opened / Covered<br>Screens | Periodic cleaning of solid waste and grit, Removing unwanted vegetation |
| I&D/ Sewer Systems | Gates, Overflow Weir, Interception Channel, Diversion Drain, Sewer lines | Inspections, Periodic cleaning using jetting machine, vacuum/ dredging machine, Greasing of gates and valves and anti-rust treatment. |
| SPS and STP | Civil, Electromechanical, Electrical and Plumbing | Daily operations, Preventive maintenance, Inspection and control measures, Monitoring and record keeping |
| Drains | Lined / Unlined<br>Opened / Covered<br>Screens (at intervals) | Cleaning of Screens (Weekly)<br>Cleaning of Drains (Regular Intervals) |

Wastewater management systems cleaning using hydraulic or mechanical cleaning methods needs to be done on a scheduled basis to remove accumulated debris in the pipe such as sand, silt, grease, roots and rocks. If debris is allowed to accumulate, it reduces the capacity of the pipe and blockage can eventually occur resulting in overflows from the system onto streets, yards and into surface waters. Roots and corrosion also can cause physical damage to sewerage systems. Wastewater management systems cleaning works require usual implements like pick axes, manhole guards, tripod stands, danger flags, lanterns, batteries, safety lamps, lead acetate paper, silt drums, ropes, iron hooks, hand carts, plunger rods, observation rods, shovels etc.

Wastewater management systems cleaning work calls for the special equipment and devices like a portable pump-set running on either diesel or petrol engine, rope and cloth balls, sectional sewer rods, a sewer cleaning bucket machine, a dredger, a rodding machine with flexible sewer rods and cleaning tool attachments such as augers, corkscrews, hedgehogs and sand cups, scraper, and hydraulically propelled devices such as flush hags, sewer balls, wooden bail and sewer scooters, sewer jetting machine, gully emptiers and pneumatic plugs.

#### 1. O&M of Open Drains, Interception and Diversion Components or Sewer Systems

**Cleaning and installation of bar screen**

A bar screen can be a manual or mechanical filter used to remove large objects, such as rags and plastics, from wastewater. It is part of the primary filtration flow and typically is the first, or preliminary, level of filtration, being installed at the influent to a wastewater treatment plant. They typically consist of a series of vertical steel bars spaced between 1 and 3 inches apart.

Bar screens come in many designs. Some employ automatic cleaning mechanisms using electric motors and chains, some must be cleaned manually by means of a heavy rake. Items removed from the influent are called screenings and are collected in dumpsters and disposed of in landfills. As a bar screen collects objects, the water level will rise, and so they must be cleared regularly to prevent overflow. Screens must be installed at certain interval on the surface drains to arrest the solid waste from moving ahead and clogging the drain. The solid waste shall be raked regularly depending upon the screenings collected. The community must be sensitized regarding hazards of disposal of solid waste in the drains. The drain shall also be cleaned regularly to remove the grit and unwanted vegetation if any. These tasks are to be performed using mechanical instruments shown on the subsequent slides.

The screen should be installed with a) the inclination of 45-degree, b) the standing platform for raking/cleaning activity c) the proper access path with safety rails for safe movement of the workers.

**Table 18: Cleaning of Screen**

| Cleaning of screens | |
|---|---|
| Frequency | After stipulated number of dumping cycle |
| Tools | Screen raking rod and appropriate PPE Gum boots, Gloves, Helmet |
| Procedure | • Stand on the raking platform. Make sure that you are comfortable and stable.<br>• Use the raking rod to rake the screen- starting from the bottom to the top.<br>• Push the screenings onto the slotted part of the platform and allow the water to drip back into the screen channel.<br>• Once the dripping stops, push the screenings into the tipper or bin<br>• Clean the raking rod with water using the water hose before storing back<br>• Once the bin is full, dispose off the screenings properly. |
| Inspection | Inspect the raking rod and PPE before starting the task |

**Inspection of Sewer System Components**

Documents and data that can give information on the status of sewer facilities are necessary for operation and maintenance of the facilities. However, enormous time and costs are necessary for examining and inspecting the overall information on sewer facilities that extend over a wide area. It is recommended that a preliminary inspection be implemented to acquire with comparative ease documents and data that can be used to decide the facilities to be examined/inspected and their priority, and then decide the facilities to be finally examined and inspected for effective acquisition of data. The methodology is to first acquire the basic information through preliminary inspection for the examination and inspection of the facilities in a given length or area of the sewers.

During the preliminary inspection of the sewerage system, subsidence, collapse, and overflows on the roads on which sewers are laid should be confirmed. Deformation or damage to facilities and deposits of sand and silt are to be confirmed during observation from the manhole. If damage or possibility of damage to the facility or if any of the abnormalities listed below are confirmed during the preliminary inspection, the facility manager should examine and inspect the relevant locations for the following:

- Corrosion, wear, damage or crack in the facility
- Water infiltration
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole
- Abnormal odours
- Clogging and overflowing

If an abnormality is detected during preliminary internal inspection or externally noticed from outside, the maintenance engineer should judge the urgency and the content of the abnormality, and then make a proper inspection and study.

### Inspection of Closed Drains / I&D / Sewer System Components

It consists of an extendable operating rod at the front of which a camera and light are fitted. This arrangement is inserted in the manhole from the ground, and the inspector on the ground observes a monitor and inspects the internal parts of the pipe through the camera. The features of direct visual inspection are compared with those of inspection by TV camera and shown below.

**Advantages**

- The inspection is easy and observations can be made in a short period. Moreover, the data of inspection can be recorded as images.
- Since the inspector works above ground, there is no chance of oxygen deficiency or accidents by fall, and the work is safe.

**Disadvantages**

- The scope of inspection is limited to the area around the mouth of the pipe
- Offset in the horizontal direction or fine cracks cannot be detected
- The condition of the side surfaces in the sewer pipe cannot be grasped

Pipes that can be inspected by CCTV have inside diameters ranging from 150 mm to 900 mm, but large diameter pipes may also be inspected by CCTV. The TV camera may be the traveling type or the towed type. Either the direct method (taking panoramic shots of the overall scene) or the side view method of taking local shots of only abnormal locations may be used.

The features of TV camera inspection are:

- By opening a manhole at one location, inspection using the traveling TV camera is enabled
- Continuous inspection up to a maximum distance of 100 to 200 m (cable length) is possible
- The connections of the lateral sewer and main sewer and defective locations should be photographed by the side view method.

CCTV Camera Inspection Record - Abnormalities detected in the pipeline during the CCTV camera inspection should be recorded on video tape or as photographs, according to the judgment criteria. The inspected results should be recorded in the inspection record.

### Mechanised Cleaning of Drains / I&D / Sewer System Components

There are three types of cleaning processes including hydraulic, mechanical, and chemical cleaning techniques. In those mechanical and hydraulic cleaning of sewers is a cost-effective method of removing material that interferes with the proper operation of the sewer. The objective is to remove all material clinging to the interior surface of the pipe so that the sewer pipe can carry full pipe flow without any restrictions that might result in blockages due to reduced pipe capacity.

### Hydraulic cleaning

The hydraulically propelled devices take advantage of the force of impounded water to effectively clear sewers. The efficiency depends on the hydraulic principle that an increase in velocity in a moving stream is accompanied by a greatly increased ability to move entrained material. The transporting capacity of water varies as the sixth power of its velocity. Several techniques of hydraulic cleaning such as:

- sewer balls
- sewer scooter
- flush bags

### Mechanical cleaning

The mechanical cleaning also has many technologies such as manila rope and cloth ball, sectional sewer rods, sewer cleaning bucket machine, dredger, rodding machine with flexible sewer rods, scraper, jetting machines, and suction units.

### Chemical cleaning

Several chemicals and application methods are available to kill and retard the regrowth of roots in the wastewater collection system. Methods of application include foaming, dusting and liquid application. Special equipment is required for all three application methods. If the problem is roots alone, chemical treatment is a very cost-effective method of cleaning. Grease can also be cleaned from sewers by the addition of chemicals or by bioaugmentation (addition of bacteria to speed up the breakdown of grease). Various chemicals are available, such as enzymes, hydroxides, caustics, biocides, and neutralizers, for removing and/or controlling grease build-ups. The effectiveness of a particular chemical depends largely on the exact nature of the problem and site-specific circumstances. In most cases, these compounds tend to be an expensive method of treatment if they are applied routinely on an ongoing basis. If the grease is not removed at the source, it can create additional problems downstream at the pumping stations and treatment plants. An effective grease control ordinance is an important part of any service program.

### 2. O&M of Sewage Treatment Plants

Before clearing a large septic stoppage, be sure to notify the operator on duty at the downstream STP. Septic stoppages develop when the sewer has been blocked for considerable time and/or the air temperature is hot. Under these conditions, the wastewater and organic solids turn black and smell like rotten eggs. If a large diameter sewer is blocked and a large volume of sewage backs up in the pipes, there might not be sufficient fresh water arriving at the treatment plant to dilute the septic sewage. When a large volume of septic sewage reaches the STP, the treatment processes may fail to do their intended job. By notifying the operator in advance of the location of the stoppage and approximate volume of septic sewage flowing towards the STP, the operator can be alerted and can prepare to minimize the impact on the treatment processes.

## D. Asset Management

All the electromechanical components such as dewatering or drying equipment etc can be termed as assets for the treatment facility and needs special attention to avoid breakdown. Asset management refers to the management of these electromechanical units. An asset management plan should contain all the information about its cost and installation procedure. If any special specific spare parts which might require longer time to procure or costly should be known to the operator. The tools and supplies required to carry out the maintenance should be stored separately. Replacement cost of spares should also be indicated so that the operator can plan for the expenses in advance.

### Preventive maintenance

It refers to the maintenance that needs to be carried out to reduce the likelihood of equipment failure. The regular preventive maintenance needs to be performed when the equipment is still functional so that it does not breakdown unexpectedly causing disruption of the operations. For eg., Sludge from sewers can be disposed of along with grit and sludge of the STP or the sludge and silt can be co-disposed in an eco-friendly manner with Municipal Solid Waste.

**Cleaning of equipment's**

It includes the regular cleaning of equipment's such as screens, grit removal systems, solid handling facilities etc. During the routine cleaning operations discussed in this chapter, many manholes should be opened and used for high-velocity cleaning or flushing of sewer. Manhole Inspection form detailing its location, condition, and any problems observed should be completed. If this is done each time a manhole is opened during cleaning operations, over a time the database for these structures will include up-to-date information on a high percentage of them and allow better decisions to be made in regard to routine maintenance, repair, or rehabilitation. If pieces of broken sewer are removed, a TV inspection may be needed and repairs may need to be made on the broken sections of pipe

**Inspection and monitoring**

Regular sampling and analysis are required to understand the processes and performance of the treatment units. The records of it have to be maintained by the operator for any troubleshooting requirements.

### E. Monitoring and record keeping

The key objective of the monitoring at the sewerage system is to understand the process and performance of the sewerage units and components. Monitoring also serves as an early detection of any issue or failure. Monitoring plan with appropriate infrastructure, equipment in the laboratory, skilled personnel and finance. Different methods of monitoring are visual or sensory (odour) inputs, field (on site) testing or elaborate analysis in the laboratory.

Record keeping is a mart of monitoring activity. Record keeping is in different forms and might have to be done by different persons. For example, the operator's logbook needs to be maintained by one or more operators appointed at the treatment facility. The reception log book should be maintained by the receptionist at the septage receiving station. Disaster or emergency response record helps to record the accidents happened at the facilities. These are required in case the facility goes for ISO certification. The preventive and corrective maintenance records are kept for electromechanical components to understand the right time to place orders for spares etc. Compliance's report is necessary and are to be produced in the case to pollution control board from time to time. Such record keeping helps to trace the issues, challenges and solutions for overcoming them. This documentation becomes of utmost importance, then the operators are changed during shifts or O&M contract is awarded to the new party.

When marking records, remember that someone else will be referring to them. The more complete the record, the easier the next operation becomes since there is a history of this sewer.

### F. Chain of Custody

Chain of custody is a method which is used while performing sampling of influent and effluent for different treatment units. The custody forms contain all the necessary information regarding the samples. It also contains instructions for laboratory personnel, which might be useful for analysis of the samples. If the custody of the samples is given to another person, then this form becomes important as it ensures there is no loss of information between the person taking samples and the person analysing the samples in the laboratory.

To reflect the inspection and testing results in appropriate O&M of piping facilities, the test results should be recorded and stored in the proper format.

**Inspection Sheet**

When inspections and examinations are implemented, an inspection sheet should be prepared and recorded as shown in Figure 41.

<table>
<tr><td colspan="4">Inspection Sheet</td><td>No.</td></tr>
<tr><td colspan="2">Location<br>(Manhole No. etc)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td rowspan="5">Inspection items</td><td>Manhole cover</td><td colspan="3">Abrasion, backlash, difference in level, invaded pavement, damaged, location unknown</td></tr>
<tr><td>Inside of manhole</td><td colspan="3">Corrosion, damage to the floor, infiltration, metal steps corroded, inferior pipe end, rubbish, odour</td></tr>
<tr><td>Pipe</td><td colspan="3">Corrosion, damage, coupling displacement, inadequate inclination, infiltration, roots of trees, earth, sand and mortar, road subsidence</td></tr>
<tr><td>House inlet</td><td colspan="3">Cover (no damage), difference in level, corrosion, damage, damaged invert, earth and sand, location unknown, odour</td></tr>
<tr><td>Lateral</td><td colspan="3">Damage, displacement, earth and sand, road subsidence</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td colspan="2">Inspection Result</td><td colspan="3"></td></tr>
<tr><td colspan="2">Follow up actions</td><td>□Necessary<br>□Not necessary</td><td colspan="2">□Contracted<br>□ Self</td></tr>
<tr><td colspan="2">Date of order</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of schedule</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of completion</td><td colspan="3"></td></tr>
<tr><td colspan="2">Remarks</td><td colspan="3"></td></tr>
<tr><td colspan="2"></td><td colspan="3"></td></tr>
</table>

**Figure 41: Inspection Sheet (Source: CPHEEO Manual, Part B – O&M, 2013)**

**Logbook**

Dedicated bound logbooks will be used for field data collection including but not limited to sampling, measurements and observations. Logbook entries should be objective, factual, and free of personal feelings or other terminology which might prove inappropriate. All pertinent field activity information will be recorded contemporaneously when observed or collected to prevent a loss of information. The logbook should be used to record daily work results, which can be used in the O&M of piping facilities. Then the daily record should be summarized in monthly reports. The format of the monthly report is shown in Figure 43.

| Daily Report | | | | | | | | Date | Weather | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Receipt No. | Receipt date | Location: address | Work description | Inspector | Tool/Material | Remarks | | |
| Response to complaint / breakdown | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | 4 | | | | | | | | | |
| Trunk cleaning | Diameter (mm) | | | | | | | Name of cleaned area | | Daily total |
| | Crew A | | | | | | | District: | | person |
| | Crew B | | | | | | | | | person |
| | Removed sand volume | | | | | | | System No: | | $m^3$ |
| | Cleaned distance | | | | | | | | | m |
| Manhole | Direct works | Name of place repaired | Name of drainage area | System No. | Entrusted works | Name of place repaired | Name of drainage area | System No. | Tool/Material | Daily total |
| | Work description | | | | Work description | | | | | |

Figure 42: Daily report

*Source: CPHEEO Manual, Part B – O&M, 2013*

| Monthly Report | | | | | | | | | | DateWeather | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Response to complaint / breakdown | Category | 1.Lateral | 2.Inlet | 3.Manhole | 4.Ground subsidence | 5.Odour | 6.Others | Total | | | | |
| | Number | | | | | | | | | | | |
| Trunk cleaning | Diameter (mm) | | | | | | | | | | | Total |
| | Direct crew | | | | | | | | | | | |
| | Entrusted crew | | | | | | | | | | | |
| | Removed sand | | | | | | | | | | | |
| | Cleaned distance | | | | | | | | | | | |
| Manhole repair | Manhole type | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Special | Direct | Entrusted | Total |
| | Cover replaced | | | | | | | | | | | |
| | Ring repaired | | | | | | | | | | | |
| | Barrel repaired | | | | | | | | | | | |
| | Noise | | | | | | | | | | | |

Figure 43: Monthly report

*Source: CPHEEO Manual, Part B – O&M, 2013*

### 10.4.2 Occupational Health and Safety

**Need for establishing Emergency Response Sanitation Unit (ERSU)**

The Government of India is committed to ensure that no person needs to enter any sewer or septic tank, unless absolutely inescapable in the interest of greater public hygiene. The employer implied in the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act/ Rules, 2013, who engage the sanitation workers for cleaning of sewers and septic tanks do not have adequate knowledge (particularly the private firms and individuals) and resources to ensure safe entry into the hazardous confined spaces which causes untoward accidents. It is therefore important to establish and maintain an adequately equipped professional entity to ensure quick resolution of maintenance and management issues of the sanitation sector.

**Objectives of ESRU**

The main objective of the ERSU is to provide a professional, well trained, motivated and appropriately equipped workforce for the maintenance and management of sewers and septic tanks, thereby eliminating the deaths caused by entry of workers into sewers and septic tanks without proper PPEs & training and nonadherence to security protocols.

**Salient Features of ERSU**

a) Emergency Response Sanitation Units will be set up in major cities which have Municipal Corporation and/or Water & Sewer Board (in whatever local name) and in capital cities of each State/UT. The ERSU shall be responsible to meet sanitation emergency requests from all smaller towns within a cluster say 75 KM radius.

b) The Emergency Response Sanitation Unit shall be generally based on the structure of the Fire Services/ Fire Brigade; It will be provided a dedicated 3 or 4 digit registered telephone number (RTN)/ hotline. This RTN will be common for all ERSUs in the State/ UT.

c) Normal cleaning/ suction of sewer/ septic tanks which does not require entry of a person into sewers/ septic tanks/ nallahs may be undertaken by contractors/ vendors as well as by the empanelled PSSOs (without any effect on their primary task with ERSUs). For this too, available technology may be deployed and SUY funds made available.

**Personal Protective Equipment**

PPEs are very crucial for the better health and safety of the sanitary workers. ULBs should provide the workers with personal protective equipment or if private operators are involved, ULBs should ensure through contract that the private operator provides the same to the persons on duty. Basic PPE includes helmet, goggles, mask, boots and torch. Use of PPE should be made mandatory and should be strictly monitored by the city and appropriate action should be taken for noncompliance. It is essential to make the workers primarily handling septage aware of health hazards if PPE is not used.

**Health Requirements of Cleaning Employees**

Persons considered for employment in confined spaces shall be physically fit and capable of understanding training given.

Those with the undernoted disabilities shall not be recruited for this type of work and those who contract these should cease to be employed in this capacity:

- Fits, blackouts or fainting attacks, heart disease or disorder;
- High blood pressure;
- Asthma, bronchitis or a shortness of breath on exertion;
- Deafness;
- Meniers disease or disease involving dizziness or loss of balance;
- Claustrophobia or nervous or mental disorder;
- Deformity or disease of the lower limbs limiting movement;
- Chronic skin disease;
- Serious defects in eyesight; and
- Lack of sense of smell.
- Only routine medical examination is required.

### 10.4.3 Public Awareness and Participation

The benefits of involving the public in the decision-making process are immense. It greatly helps in increasing public understanding of pollution abatement and subsequently defusing conflicts on government action by generating support of beneficiaries.

An expert agency with the right kind of background and experience may be engaged to formulate public participation strategy. Two types of outcomes are expected from this activity. The first one is public participation and through it agreement on complex issues like house connections, water conservation at household levels, proper collection of garbage so that it does not choke sewers/drains, sharing increased burden of O&M cost, proper layout of sewerage systems and location of STPs, diffusing conflicts, if any, on programme components etc. This can be best achieved through consultation at various stages of project formulation and implementation. The second one is increasing public understanding about the programmes through awareness. This should be achieved through workshops, seminars, street plays, city runs and riverside walks. Active involvement of students and teachers in schools and colleges can greatly help achieve the objectives. Public can also play the role of a watchdog in supervising project implementation and operation and maintenance which would help improve the quality of the programme.

**Objective**

- The objective of public education, awareness and participation programme should be to ensure that the communities get aware about the activities as:
- There is a need for the programme to intercept the drains that carry the wastewater of the town into the waterbody and treat it before it is finally discharged and that they will derive multiple benefits from it. The benefits need to be specified.
- Though there will be recoveries in the form of compost and nutrient rich water and electricity, still there would be additional costs in O&M and these costs may have to be borne by them
- The communities are effectively involved in all stages of the project cycle from conceptualization, to preparation, to finalization, to implementation and finally O&M. Such involvement will generate a sense of ownership of the programme among the stakeholders.
- To keep the stakeholders and citizens informed of the progress of the project at all stages, a website with updated information about important features of the project may be created and arrangements made to send replies to project related queries.

Public Awareness & Public Participation should be a front-end activity of the project.

**Target Audience**

- Local influential/Community leaders
- Local ULBs & NGOs
- School teachers and students
- Elite groups and organisations like Rotary Club, Lions club
- Representatives of industry and commerce
- Leaders of trade unions and organisations like safai karamchari sanghs,
- Representatives of political parties including the elected office bearers and members of local bodies
- Representatives of media

**Communication Methods**

There are a variety of media and communication methods that exist, each with its own advantages and disadvantages. The use of a combination of several media at the same time can reinforce the necessary messages. Person to person contact carried out through community members, who are already convinced of the truth of the message, is usually the most effective means of communication.

A provision of 2%-3% of the project cost may be made for generation of public awareness and securing public participation. Various communication methods for awareness generation and involvement of public in project are as follows:

- Use of print media
- Use of TV / Radio / Cinema Halls / Website
- Streat plays / Puppet shows
- Posters / Pamphlets / Hoardings
- Use of public transport system
- Communication through school activities / Curriculum
- Involvement of NCC / NSS / Scouts
- Involvement of religious leaders / practitioners / associations
- Involvement of NGOs / CBOs
- Corporate Social and Environmental Responsibility
- Door to Door Communication

### 10.4.4 Reducing Combined Sewer Overflow (CSO)

Combined sewers are designed to carry both sanitary and stormwater flows in the same pipe, and when these collection systems over flow, a combined sewer overflow (CSO) event occurs. Combined sewers are the only collection systems with an issued permit to cover their overflows. Wastewater treatment plants connected to combined sewers often become overburdened during CSO events, resulting in inefficient treatment or untreated sewage bypass directly discharged into rivers, streams or other waterways. Either situation poses a threat to water quality, aquatic life, human health and properties and also contributes to the biological, chemical and aesthetic pollution of the waterway.

Combined sewer systems are designed to convey sanitary sewage and stormwater through a single pipeline system to a sewage treatment plant. During excessive rainfall, the capacities of the pipelines and treatment plant are often exceeded, causing overflows at one or more “relief points” in the system. Unless properly controlled, excess stormwater flows into the sewer pipes. To avoid sewage backups, sanitary sewage and stormwater mixtures from CSO events are discharged directly into nearby rivers, lakes and harbours without treatment.



**A. Catchment Characteristics**

Watershed assessment is a critical component of a watershed-based approach to managing receiving waters. Watershed assessment is needed to develop both protection and restoration strategies, identify priorities, and adjust management prescriptions based on trend analyses. Both rapid and extensive assessments can be performed to determine water body status and trends.

The loss of water bodies significantly reduces the absorptive capacity of a basin. The loss of any green cover—including forests and agriculture—to built-up concrete also reduces porosity. Unplanned built-up areas are almost completely impervious, which means they do not allow water from rainfall to percolate into the ground. Rather, these surfaces lead water to rush through the landscape - creating increased runoff during storm events. Fully built-up areas contribute to runoff volumes of more than 5 times than areas with natural ground cover for the same amount of rainfall. Compared to the natural condition, the time over which the peak volume of runoff is generated after a rain event decreases. This creates very little lag time between the beginning of a storm event and when water begins rushing towards water bodies or stormwater channels in large quantities. Stormwater infrastructure designed for an area when the land cover was considerably more permeable than today, will inevitably fail to accommodate larger runoff volumes with shorter lag times. Going forward, the investment needed to physically increase the capacities of all gray stormwater infrastructure pipes and channels is cost-prohibitive. Rather, the municipality should try to reduce runoff volume and increase lag time by leveraging the landscape as part of its stormwater infrastructure strategy.

This means protecting landscapes that naturally slow down or store water and integrating landscape functions into designed stormwater systems. This way, the natural functions of delaying and storing water to release into the aquifer can be replicated within the urban fabric.

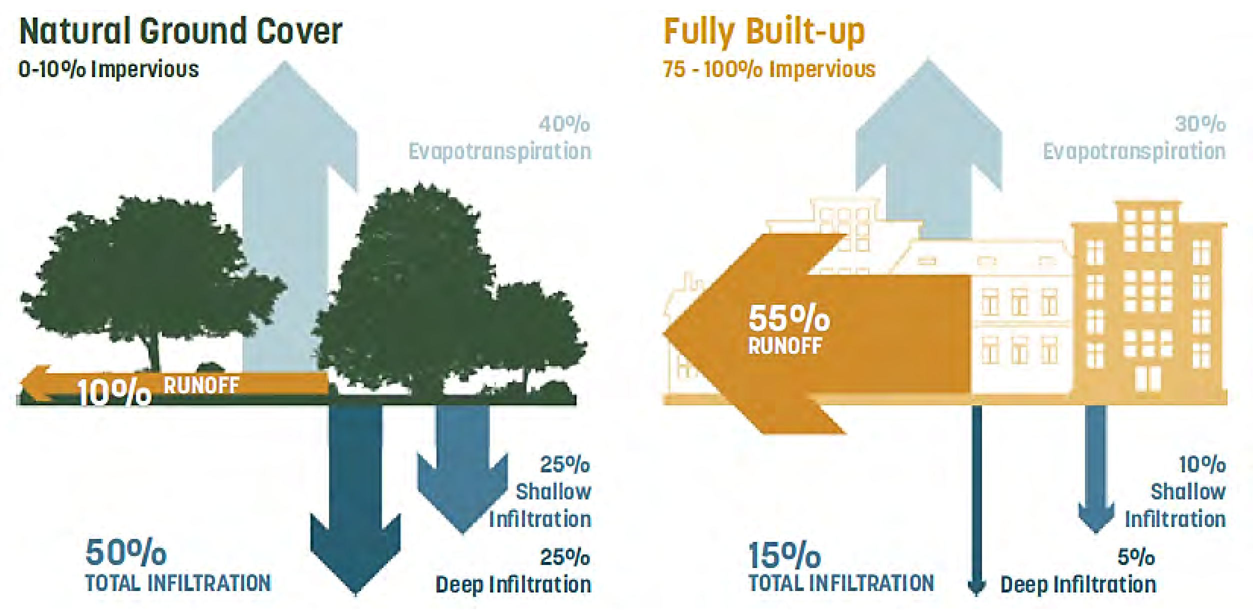



**Figure 44: Natural and Urban Catchment**

**B. Runoff Hydrograph**

**Gray Infrastructure** is sized for a pre-determined catchment area and water is meant to be quickly piped away. Channelling water through gray infrastructure creates potential chokepoints and disrupts the water cycle. Gray Infrastructure is invisible to city’s residents and only makes its presence felt when it fails. Scaling up gray Infrastructure to handle extreme conditions is a prohibitively expensive approach without any benefits of public real improvements or natural recharge. Grey Infrastructure refers to the drainage systems such as combined sewers or storm water sewers in place to manage urban runoff. In this hydrograph, it can be observed that the discharge peak in urban catchment is significant as compared to that in natural catchment. It should also be observed that the peak occurs before the discharge peaks in case of natural catchment. Increasing the capacity of gray infrastructure is prohibitively expensive and remains invisible to the general public. Traditional gray infrastructure incurs higher maintenance cost over time than Landscape infrastructure. Accounting for losses from flooding, solely relying on gray infrastructure does not pay off in the long run.

**Natural greenery** and water bodies within the watershed are integrated with gray infrastructure to slow water down. Decentralized systems are more resilient to failure and create more points for rainfall to recharge the aquifer. Landscape approach to infrastructure uses creative ways to manage water while improving the public realm. Leveraging green infrastructure and other natural methods to manage runoff can significantly lower upgrading and maintenance costs of stormwater infrastructure. Green infrastructure refers to soft systems put in place to delay, release, filter or store the runoff. It can be observed that this time, the peak is significantly lowered and also it occurs later than it did before. Thus, it can be inferred that, (a) scaling up gray infrastructure to handle extreme conditions is a prohibitively expensive approach without any benefits of public realm improvements or natural recharge and (b) leveraging green infrastructure and other natural methods to manage runoff can significantly lower upgrading and maintenance costs of stormwater infrastructure. A well-integrated and decentralized Sponge Network is more resilient to flooding and increases the liveability and value of neighbourhoods. This increases property values or encourages new development which in turn brings in more revenue for the city - essentially subsidizing investments towards the landscape.

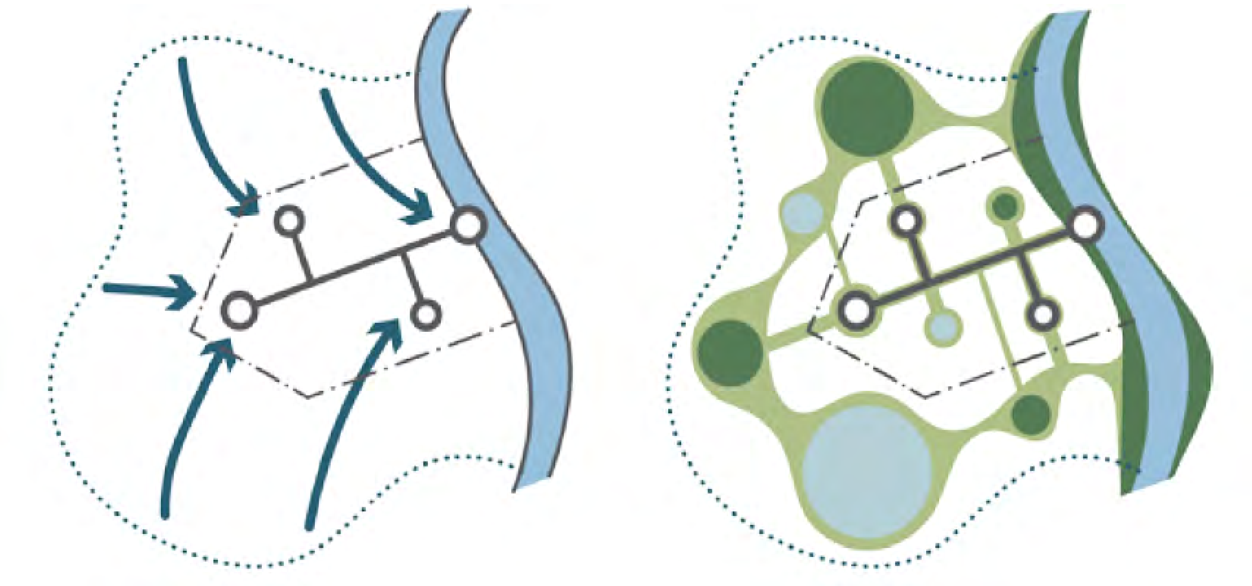


**Figure 45: Gray and Green Infrastructure**

*(Source: Biswas, S.K., et. al., 2019)*

### C. Runoff Control Mechanisms

The four principles of the runoff control mechanism can only be realized through the protection and restoration of landscapes and the creation of a comprehensive but distributed landscape Infrastructure network.

- Protect
- Delay
- Store
- Release

**Protect** requires protecting the city's green spaces and water bodies from development, encroachment, and pollution. Natural systems that have been compromised by encroachment or pollution have to be restored into fully functioning systems. No designed system can replicate the benefits and complexities of uncompromised natural systems. As such, they need to be protected.

**Delay** is a vital principle to mitigate the risk of flooding after a storm event or cloudburst. 'Delay' requires the presence of landscapes or landscape infrastructures to slow down rain water runoff so it does not overwhelm stormwater drain inlets, canals, rivers, and other water bodies. Natural ground cover, trees, topographic variations, and landscape infrastructures can all delay stormwater, leading to lower peak flows, increased lag time, and potential reduction of flood-related losses.

**Store** is a critical principle to effectively remove the risk of water scarcity by making the most of extreme storm events during the monsoons. Cities can get its water from a handful of distant reservoirs that often reach their capacity before the end of the monsoons. The creation of a distributed network to store water through rainwater harvesting in buildings and the creation of holding ponds, tanks, and micro-reservoirs can ensure greater water availability closer to places of consumption.

**Release** refers to the management of runoff and surface water flows in a way that recharges the aquifer without polluting it. Many of the city's households rely on the aquifer for drinking water. The overexploitation of the aquifer has not only caused water scarcity but increases the risk of saltwater infiltration and land subsidence. 'Release' requires overflow from storage structures to go into the aquifer, the protection of natural aquifer recharge zones, and ensuring the groundwater is pollution-free.

### D. Control Measures

There are a number of landscape infrastructure components that allow built-up areas to manage stormwater runoff in ways that partially, if not completely, replicate natural ground cover conditions. This toolkit organizes the components into typologies that correspond with the urban systems that can be retrofitted and improved.

- Household level
- Community level
- City level

**Household level -** collect components like rainwater harvesting, green roofs, and detention tanks since they can be implemented atop or around buildings.

- **Rainwater harvesting** is collecting the run-off from a structure or other impervious surface in order to store it for later use. Traditionally, this involves harvesting the rain from a roof. The rain will collect in gutters that channel the water into downspouts and then into some sort of storage vessel. Owing to the efforts of Mr. Raghavan of 'Rain Centre,' the biggest breakthrough came in 2002, when the city passed legislation that made it mandatory for every building in the city to harvest rainwater. Although the practice is in place for over two decades, it is seen as a mere legal obligation with shortcomings pertaining to its efficiency. The proposed RWH typologies improvise over the existing system to optimize its efficiency and improve spatial quality. The three typologies in the section vary in scale and cost, giving implementing land owners or tenants more flexibility. The diagrams below depict how rainwater collection systems can be as simple as collecting rain in a rain barrel or as elaborate as harvesting rainwater into underground storage units to supply for the entire building demand. The interventions also illustrate how the systems can be designed effectively to add value to the public realm.

- **Green roof** is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. The large surface area of the system can absorb the rainwater, hold them before releasing the excess into the aquifer through down spouts. Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, mitigating the heat island effect etc. Below are depictions of the two types of green roof systems. 'The Container gardens' (Roof garden) on the left side is a less complex system on roofs, where plants are maintained in pots/trays. The pots are connected to a drainage system that removes excess water through down spouts. The system is economically viable and can be easily installed in Apartment towers. 'The Drainage Plate' system (Simple/Deep Green Roof) on the right side is under-drained with waffled plastic sheets called drainage plates. Water is retained within pockets on the upper sides of the plates while excess water flows through small holes and spills over the edges to be carried off the roof. A separation fabric over the top of the plates retains growing media while allowing water to drain freely. This system is well suited for large roof areas of institutional and corporate buildings.

- **Detention tanks** are meticulously articulated aesthetic landscapes for holding and storing rainwater. The system comprises of a sunken space that is integrated within the courtyards or the small open spaces of large buildings. The detention tanks act as holding ponds that retain the water for short periods of time before discharging them into an underground storage unit. The tanks are fed by a comprehensive drainage system that collects runoff from various parts of the building. On the right, is a depiction of how the entire system can be effectively designed as a composite landscape entity through the use of open gutters, that channelize the water into planter boxes and then finally into the storage unit underground. The design possibilities are endless and left to the choice of the implementing stakeholder. These resilient landscape infrastructures also serve the purpose semi-public spaces for small events, gatherings and social interactions within these buildings.

**Community level -** to a number of components that delay stormwater and increase infiltration opportunities along street medians or edges, sidewalks, and curb sides or intersections.

- **Bioswale** channels are vegetated and maintained swales specifically designed to convey stormwater at a low velocity, promote natural treatment and infiltration. Bioswale channels are more resilient, aesthetic, and low-maintenance alternatives to underground storm sewers or lined open channels. Bioswale channels can effectively convey and treat stormwater from roadways and other impervious surfaces. They can be implemented along roadways or on medians where the drainage area, topography, soils, slope and safety issues are conducive to its function. Bioswale channels effectively reduce peak discharge and provide infiltration opportunities compared to hardened channels. They can provide up to a 10-20% runoff reduction when designed for certain development conditions.

- **Sidewalk planters** (also known as rain gardens or bioretention gardens) uses vegetation and inventive drainage design to slow down and potentially infiltrate runoff flows from roads and sidewalks. They can be accommodated within a number of design variations that respond to the conditions of the street and sidewalk. Sidewalk planters can effectively slow down stormwater while improving the streetscape experience. Sidewalk planters have the following components: inflow design, pre-treatment, ponding area, overflow, filter/soil media, and underdrain. Good inflow design will ensure stormwater inlet at rates that prevent ponding and avoid erosion. Pre-treatment using plants is necessary to prevent roadside pollutants from infiltrating into the aquifer. The ponding area should be designed to accommodate 10-year flood events while an overflow mechanism ensures water from extreme flood events can enter the stormwater drains. Well-designed sidewalk planters can reduce the load on the stormwater system and mitigate flooding during most cloudburst events.

- **Tree Trenches** is a system of tree pits that are interconnected by a shared infiltration structure. Tree pits allow individual trees to grow in a healthy manner within constrained urban areas such as sidewalks. Planting a single tree creates multiple benefits for urban areas including purifying the air, reducing the heat island effect, creating wildlife habitat, buffering wind and noise, and increasing property values. In terms of stormwater management, trees reduce runoff through the interception of rainfall and evapotranspiration. Tree trenches are an advanced tree pit system created by digging a trench along the sidewalk, lining it with permeable geotextile materials, filling it with stone or gravel, and finally bringing in the soil and the tree. A special stormwater inlet brings runoff flows into the tree trench where water is stored in the empty spaces between the stones. The tree roots absorb the water while it slowly infiltrates through the bottom. During extreme flood events, a bypass system leads runoff directly into the existing stormwater network.

**City level -** consist of interventions that create ponds, wetlands, rain gardens, or sunken plazas within green or urban public spaces.

- **Constructed Ponds** are an effective way to reduce runoff volumes and improve storage capacities within urban neighborhoods while dramatically improving the public realm. Constructed Ponds can have varying design variants and demand fairly large open spaces to become an infrastructural amenity as well as a public space. Constructed Ponds, also called Stormwater Detention Ponds, can be designed to have water pooled permanently, for extended periods of time after a rain event, or temporarily for the extents of a single storm event. Detention ponds by definition do not allow infiltration. However, if soil conditions allow for it and runoff pollution is adequately treated within the pond design, they may fulfill the function of Release as well. Constructed Ponds can offer habitat benefits if the design encourages the use of native wetland plants and strategic ponding during rain and drought cycles.

- **Constructed Wetlands** replicate the hydrological and ecological functions of wetlands within an urban environment. They are primarily designed as a shallow, submersible areas that can detain and treat stormwater runoff. However, well designed Constructed Wetlands can become true assets for neighborhoods and the city at large if they begin to offer some of the ecosystem services found in natural wetlands including water filtration. Unlike Constructed Ponds, Constructed Wetlands should be able to withstand a thirty-day drought at summer evaporation rates without completely drawing down. As such, most Constructed Wetlands will retain water while allowing minimal or slow water infiltration. The design of Constructed Wetlands should support the growth of wetland plant species and circulate water in ways that prevent stagnant water. This will prevent the breeding of species like mosquitos and lead to the creation of healthy habitats for native species within the urban fabric.

- **Bio infiltration Basins** or Raingardens function as bioretention gardens described in S.2 Sidewalk Planters with specific components including inflow design, pre-treatment, ponding area, overflow, filter/soil media, and underdrain. However, Bio infiltration Basins differ from Bioretention Gardens or Detention Ponds in that their main function is to encourage infiltration. Bio infiltration Basins use vegetation and topography to delay and detain water, and their sub-surface design encourages slow release into the aquifer. The Basin should be able to fully dewater the total volume of runoff within 48 hours of a storm event. As such, the maximum contributing drainage area for Bio infiltration Basins should typically be less than 5 acres. Bio infiltration Basins can only be sited above soils with an infiltration rate of greater than 13 mm/hr and where the bottom of the system is at least 1.2m away from the seasonal water table height. Bio infiltration Basins should have the capacity to remove hydrocarbons, trace meters, and other roadside toxicants from at least 25% of the runoff volume. In areas with infiltration of more than 50 mm/ hr, additional sedimentation basins or other upgrades should be incorporated to filter at least 50% of the runoff volume. Bio infiltration basins cannot be designed to filter high levels of toxicity and pollution. As such, they cannot be sited near pollutant hotspots and drinking water wells.

### E. Control Measures Application

- **Household level -** The built form in an urban infrastructure can greatly contribute to the green building capacity; and the larger goal is to foster the green development performance across all sections of the urban region with highest efficiency. Hence, Green Building typologies of varying scales, involving a wide spectrum of stakeholders and building types are proposed. The Green Building Infrastructures are factored on parameters including cost, structural considerations, efficiency etc, which will inform the implementing stakeholders in decision making based on their capacity. The RWH systems are the easiest to realize and hence they should be incorporated across all building types/use in the urban fabric. Green Roofs and Detention Tanks are more substantial investments, so the suitability matrix identifies large institutional and corporate buildings as suitable candidates for implementing them.

- **Community level** – Community level green infrastructure depends on their respective capacities to handle stormwater runoff and should be based on the contributing drainage area and the hydrologic group of the in-situ soil. Water flow path along Bioswale channels should be designed to maximize the time water spends in the swale. Sidewalk planters or rain gardens require a 0.75m - 1.2m deep planting soil bed, a surface mulch layer, and a 0.3m deep surface ponding area where the ponding area is calculated based on the size and perviousness of the contributing drainage area. Tree pits can meet local drainage if the landscape infrastructure planning considers the storage capacity of the soil voids in the cavity created for the root ball of the tree and the ponding area. The infiltration of the in-situ or engineered soil must be a minimum of 50mm per hour.

- **City level** – City level green infrastructure are the most compelling landscape infrastructure typologies in terms of their impact on improving the public realm and the habitat potential of the city. Existing open spaces in cities can be converted into green infrastructure with strategic regrading efforts, planting designs, and co-ordination with the existing stormwater network. The resulting transformation can create enormous political and community goodwill while improving the resilience of urban neighbourhoods. As such, green infrastructure should be prioritized as pilot projects when possible. Soils with high infiltration rates are suitable for Bio infiltration Basins while other typologies could be constructed on any soil type. Implementation budgets for these projects should account for the role of design in their success as multi-functional infrastructures

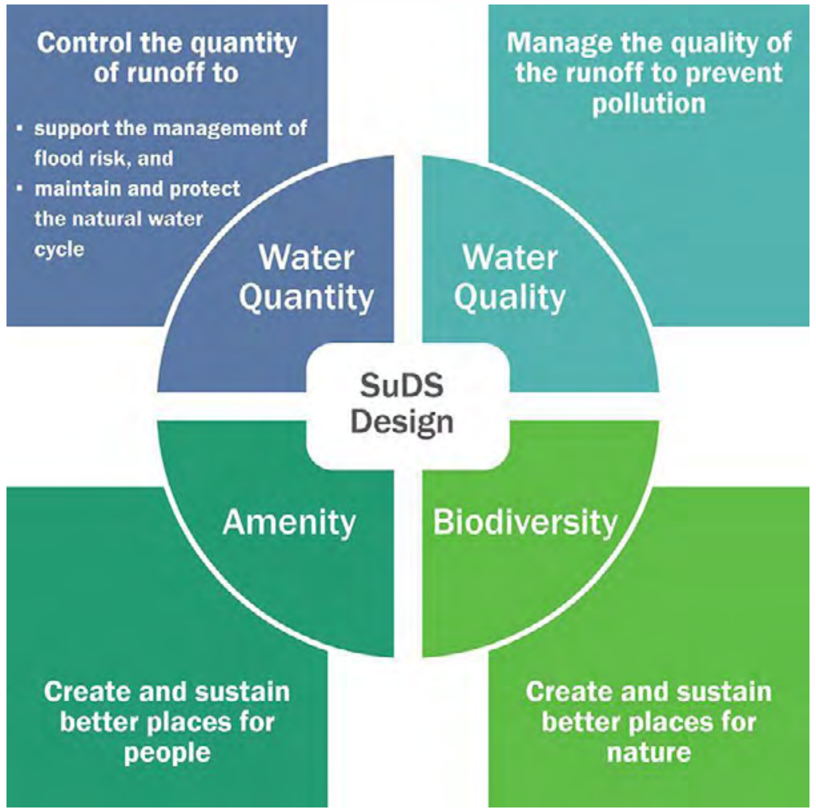
The control measure application graph summarizes the performative abilities and implementation considerations of all the Green Landscape Infrastructure typologies. This serves as a decision-making tool for stakeholders to evaluate which Green Landscape Infrastructure is most appropriate or feasible.

### F. Stormwater Management

Many urban cities continue to experience an increase in the intensity and frequency of floods, with further escalations projected as a result of climate change and rapid urbanization. In urban areas, the management and drainage of storm water presents a serious challenge. The high urban density within cities and resultant soil sealing has led to a reduction in the potential of water infiltration in the ground, which increases run off water and flood risk. Climate change modifies the water cycle, leading to changes in rainfall patterns.

The traditional solution to cope with excess rainwater in western cities has been piped drainage systems. These are mainly single-objective oriented designs that often no longer have the capacity to keep pace with on-going urbanisation and the impacts of climate change, and frequently involve high construction, maintenance, and repair costs. While such approaches have certainly reduced the damages incurred from flooding events during the past two centuries and are arguably still necessary for extreme flood events in the future, alternative approaches that accomplish these aims and offer additional benefits are progressively being pursued. Given these conditions, one increasingly utilised solution for managing flood risk by dealing with water at the source is sustainable urban drainage systems (SUDS).

In order to mitigate against floods, control diffuse pollution and reverse habitat fragmentation, less restrictive and more flexible drainage strategies that also serve with other Green Infrastructure elements, the Sustainable Drainage System (SuDS) stormwater management approach is a solution to the above problems. The SuDS stormwater management approach has been a better solution to tackle excess flooding thantraditional drainage methods. However, the current SuDS design and planning practise is site-specific and, hence, limits the potential to provide amenity and biodiversity enhancements across the entire catchment ecosystem. Consequently, this design and planning practise is unable to contribute to reversing habitat fragmentation.



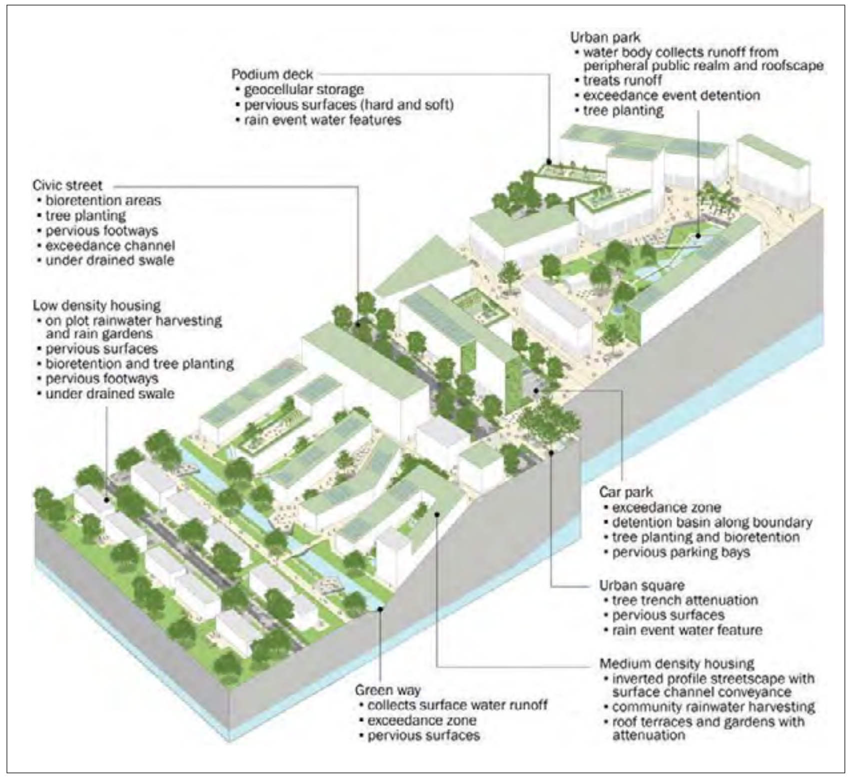




**Figure 46: SuDS concept for Stormwater Management**

*Source: Ballard et al., 2015*



Overall, the SuDS stormwater management approach, in terms of flooding, can be used to compensate for the loss of pre-development, permeable lands by providing extra capacity to temporarily store stormwater runoff and release the water gradually in a controlled manner. The SuDS approach, if implemented correctly, can potentially reduce flooding and erosion of the receiving natural water bodies, and protect wildlife habitats.

## 10.5 Notes for trainer

This session talks about O&M of various wastewater management system components. It is recommended to have a discussion with the participants on integrating O&M with planning and design, asset management, monitoring and record keeping of wastewater management system components. It also talks about the importance of public awareness and public participation and involvement in projects. The session also aware participants about how to reduce combined sewer overflow.

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Notes

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NIUA is a premier national institute for research, capacity building and dissemination of knowledge in the urban sector, including sanitation. Established in 1976, it is the apex research body for the Ministry of Housing and Urban Affairs (MoHUA), Government of India. NIUA is also the strategic partner of the MoHUA in capacity building for providing single window services to the MoHUA/states/ULBs.

## 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—DESIGN MODULE** PART B: LEARNING NOTES