Wastewater
Recycle and Reuse

TRAINING MANUAL

ClimateSmart Cities Assessment Framework
Water Management
Wastewater Recycle and Reuse

TRAINING MANUAL

ClimateSmart Cities Assessment Framework

Water Management

Ministry of Housing and Urban Affairs
Government of India

Climate Centre for Cities

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag
Executive Summary

On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events (storms, floods, heatwaves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually.\(^1\) Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of CSCAF. The training on the ‘wastewater recycle and reuse’ under the thematic areas of Water Management in the CSCAF.

---

Wastewater recycling and reuse are essential services to be provided in a city. With increasing population and urbanisation, water stress and scarcity of water emerging as one of India’s most challenging threats, it is crucial to recycle waste water and reuse it appropriate use. The objective of the module is to

- Present the current water and wastewater related challenges in urban India.
- Understand the performance evaluation approach of the assessment framework and provide guidance on how to perform better.
- Illustrate the approach and technologies applied for wastewater treatment and reuse.
- Provide insight on rules and standards for recycling and reusing waste water along with some of the innovations and best practices adopted by cities.
Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training
The training manual is designed for urban local body authorities and decision makers to plan, design and implement of wastewater treatment/ recycling systems. Besides, the module can also be used by training institutes to further the capacity building of ULB authorities, engineers, consultants and others. A pre-requisite for this training is to have a basic knowledge of wastewater and wastewater mechanisms. The training will be conducted in English, so understanding language may be necessary.

This manual gives an outline of the topics covered in training, and the link to further reading. The manual has seven components:
- Current Scenario on wastewater treatment
- Indicator: Wastewater treatment recycling and reuse
- Wastewater management approach and strategies
- Technological options
- Rules and Regulations
- Finance and Budgeting
- Best practices

This manual can be used as a reference note to get insights on wastewater treatment and reuse. It has briefed the topics mentioned above and provides links for further reading. Participants can refer to this document before and after the training sessions to equip themselves with knowledge on the relevant subject. It will also help them engage more effectively during the training sessions and identify any queries that they can ask to the facilitator.

The learning outcome of training includes:
- Appraise participants to a broad overview of the technical and regulatory framework for wastewater recycling
- Introduction to the indicator, 'Wastewater recycle and reuse'. Assess and evaluate their options to enhance wastewater treatment and move forward in CSCAF performance.
- Understand different approaches (centralised vs decentralised) for planning wastewater treatment systems
- Understand the appropriateness of onsite and offsite sanitation systems; and centralised and decentralised sanitation systems.

As this is a short online training, details of all technologies and applications are not covered. The training is intended to serve as an impetus for the CSCAF assessment by increasing the volume of wastewater treated, recycled and reused. Thus, this training provides a broad overview of insights and approaches rather than prescriptive tasks or recommendations on technology.
Waste: Waste is any item beyond use in its current form and discarded as unwanted. It can be solid or liquid with respective management methods.

Sanitation: Sanitation generally refers to providing facilities and services for the safe disposal of human urine and faeces.

Solid waste is 'Waste' generated by households and of a similar nature generated by commercial and business establishments, industrial and agricultural premises, institutions such as schools and hospitals, public spaces such as parks and streets and construction sites. Generally, it is non-hazardous wastes composed of food waste, garden waste, paper and cardboard, wood, textiles, nappies (disposable diapers), rubber and leather, plastics, metal, glass, and refuse such as ash, dirt and dust (source: https://unstats.un.org/sdgs/metadata/files/Metadata-11-06-01.pdf)

Wastewater: When water is used once and is no longer fit for human consumption or any other use, it is considered liquid waste. Wastewater can be sub-categorised as industrial and domestic:
- Industrial wastewater is generated by manufacturing processes and is challenging to treat.
- Domestic wastewater includes water discharged from homes, commercial complexes, hotels, and educational institutions. Wastewater in this manual refers to domestic wastewater generated from toilets, bathing, washing, cleaning, community stand post/hand pumps etc.

Grey Water: Wastewater generated from bathing, washing, general cleaning, laundry, as well as from community stand post, well, hand pumps etc.

Black Water: wastewater generated from toilet/latrine containing faecal matter. Such water contains a very high amount of pathogens compared to greywater.

Yellow Water: Urine with or without flush water is termed as yellow water.

Night soil: human excreta.

Storm Water: Storm water indicates rainfall runoff from roofs, roads and other surfaces

Sludge: it is the settled solid matter in semi-solid conditions. The term sewage sludge is generally used to describe residuals from wastewater treatment systems, while the term Septage describes the residuals from septic tanks.

Effluent: wastewater that flows out of a treatment system (septic tank in this module). It is partially treated.

Sources: CEPT CWAS, UNICEF, CPHEEO, NIUA, CSE, SuSaNa
• **Faecal sludge:** Faecal sludge is the solid or settled contents of pit latrines and septic tanks.
  ✓ **Septage:** settled solid matter produced in septic tanks is termed as Septage.
  ✓ **Scum:** impure matter like oil, hair, grease and other light material that float at the surface of the liquid in a septic tank.
  ✓ **Faeces:** Faeces refers to (semi-solid) excrement without urine or water.
  ✓ **Leachate:** is the liquid part of mixed wastewater separated through gravity or filtration from the solid component. It required further treatment prior to disposal
  ✓ **Soak Pit/soakaway/leach pit:** It is a covered porous walled chamber that allows liquid waste to infiltrate the surrounding ground.
  ✓ **Septic Tank:** An underground tank that treats wastewater by a combining 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.
  ✓ **Sewer:** is an underground carriage system/network transporting liquid waste from the household level to the disposal/treatment unit. The system carrying only wastewater (black and or greywater) is termed a sanitary sewer system, while that carrying storm water is termed storm water sewer. There is a combined sewer that carries combined waste..
  ✓ **Ecological sanitation:** It is a form of sanitation that involves re-use of human faecal waste/wastewater and its nutrient back into the local environment, thus avoiding pollution of land, air and water resources.
  ✓ **Pathogen:** an organism capable of causing disease.
  ✓ **The aerobic process** is the process that relies on microorganisms that thrive under aerobic conditions i.e. where plentiful oxygen is available
  ✓ **Anaerobic digestion** is a collection of processes by which microorganisms break down biodegradable material without of oxygen.
  ✓ **Biodegradable:** Any organic material that microorganisms can degrade into simpler stable compounds.
  ✓ **Non Bio-degradable Waste:** Any waste that micro-organisms cannot degrade into simpler stable compounds.
Executive Summary iv
Glossary of Terms vii

1. Wastewater recycling and reuse 2
   1.1 Existing scenarios and gaps 4
   1.2 Aligning with the ClimateSmart Cities Assessment Framework 6

2. Institutional framework 8
   2.1 Legal provisions and Acts 8
   2.2 Policies and Guidelines 9
   2.3 Standards 10

3. Implementation strategies 12
   3.1 Concept in practices 12
   3.2 Planning and Design 14
   3.3 Implementation strategy 16
   3.4 Funding 19
   3.5 Wastewater recycle and reuse 21
      3.5.1 Reuse Potential 21
      3.5.2 Benefits of Reusing treated wastewater 22

4. Interactive Exercise 24
   4.1 Additional offline exercise of participants 28
5. Case Study
5.1. Alandur Sewerage Project: Successful Innovation and Partnership 30
5.2. Tiger Bio Filter Sewage Treatment Plant at Vasantrao Bagul Udyan, Pune 32
6. List of additional materials 34
7. Annexures 38
List of Figures

Figure 1: Wastewater Recycle and Reuse ................................................................. 1
Figure 2: Water Scenario in India ........................................................................ 3
Figure 3: Water scarcity and stress projection in India ....................................... 4
Figure 4: Wastewater generated and treated in major cities ............................... 5
Figure 5: Climate Smart City Assessment Framework (NIUA) ............................. 7
Figure 6: A typical flowchart of wastewater treatment process ......................... 13
Figure 7: Typical Treatment process of wastewater ........................................... 14
Figure 8: Broad parameters for planning and design of wastewater infrastructure ................................................................................................................. 14
Figure 9: Parameters for selection of appropriate technology for wastewater treatment ................................................................................................................. 15
Figure 10: Service chain in wastewater treatment and recycling ........................ 16
Figure 11: Planning strategies for wastewater treatment systems ........................ 18
Figure 12: Schematic diagram of ASP technology ................................................. 31
Figure 13: Different type of technologies for wastewater treatment 1 ................ 38
List of Tables

Table 1: Progression Level in CSCAF ................................................................. 6
Table 2: Difference between centralised and decentralised systems.................. 17
Table 3: Advantages and Disadvantages of On site systems............................. 18
Table 4: Stakeholders and their roles .................................................................. 19
Table 5: Government Schemes and Funding Options for ULBs ......................... 20
Table 6: Participants exercise: Technologies of containment and conveyance ....... 28
Table 7: Participants exercise: Technologies of treatment .................................... 28
Table 8: Participants Exercise: End use purpose and products ............................ 28
Table 9: Various functions of different components of treatment systems ............ 39
Table 10: Advantages and disadvantages of various onsite treatment systems ....... 40
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASP</td>
<td>Activated Sludge Processes</td>
</tr>
<tr>
<td>BCM</td>
<td>Billion Cubic Metre</td>
</tr>
<tr>
<td>BOD</td>
<td>Biological Oxygen Demand</td>
</tr>
<tr>
<td>CMD</td>
<td>Chennai Metropolitan Development</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>CPCB</td>
<td>Central Pollution Control Board</td>
</tr>
<tr>
<td>CPHEEO</td>
<td>Central Public Health and Environmental Engineering Organization</td>
</tr>
<tr>
<td>CSCAF</td>
<td>ClimateSmart Cities Assessment Framework</td>
</tr>
<tr>
<td>CSR</td>
<td>Corporate Social Responsibility</td>
</tr>
<tr>
<td>DEWATS</td>
<td>Decentralized Wastewater Treatment System</td>
</tr>
<tr>
<td>DeLWM</td>
<td>Decentralized Liquid Waste Management</td>
</tr>
<tr>
<td>DeSWM</td>
<td>Decentralized Solid Waste Management</td>
</tr>
<tr>
<td>DeWaM</td>
<td>Decentralized Waste Management</td>
</tr>
<tr>
<td>FIRE</td>
<td>Financial Institution Reform and Expansion</td>
</tr>
<tr>
<td>FRP</td>
<td>Fibre Reinforced Plastic</td>
</tr>
<tr>
<td>GHG</td>
<td>Green House Gas</td>
</tr>
<tr>
<td>HH</td>
<td>House Hold</td>
</tr>
<tr>
<td>HRIDAY</td>
<td>National Heritage City Development and Augmentation Yojana</td>
</tr>
<tr>
<td>JJM</td>
<td>Jal Jeevan Mission</td>
</tr>
<tr>
<td>Mg/l</td>
<td>Milligram/Litre</td>
</tr>
<tr>
<td>MLD</td>
<td>Million Litres per Day</td>
</tr>
<tr>
<td>MoEFCC</td>
<td>Ministry of Environment, Forest and Climate Change</td>
</tr>
<tr>
<td>MoHUA</td>
<td>Ministry of Housing and Urban Affairs</td>
</tr>
<tr>
<td>NAPCC</td>
<td>National Action Plan on Climate Change</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
</tr>
<tr>
<td>O &amp; M</td>
<td>Operation &amp; Maintenance</td>
</tr>
<tr>
<td>PMAY</td>
<td>Pradhan Mantri Awas Yojana</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td>PVC</td>
<td>Poly Vinyl Chloride</td>
</tr>
<tr>
<td>RCC</td>
<td>Reinforced Cement Concrete</td>
</tr>
<tr>
<td>RDF</td>
<td>Refuse Derived Fuel</td>
</tr>
<tr>
<td>RWA</td>
<td>Resident Welfare Association</td>
</tr>
<tr>
<td>SBM (U)</td>
<td>Swachh Bharat Mission (Urban)</td>
</tr>
<tr>
<td>SHG</td>
<td>Self Help Group</td>
</tr>
<tr>
<td>SPCB</td>
<td>State Pollution Control Board</td>
</tr>
<tr>
<td>SUDD</td>
<td>State Urban Development Department</td>
</tr>
<tr>
<td>SUWSSB</td>
<td>State Urban Water Supply and Sewerage Board</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td>TNUIFFSL</td>
<td>Tamil Nadu Urban Infrastructure Financial Services Limited</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>ULB</td>
<td>Urban Local Body</td>
</tr>
<tr>
<td>WSSB</td>
<td>Water Supply and Sewerage Board</td>
</tr>
</tbody>
</table>
Figure 1 Wastewater Recycle and Reuse, World Bank Group

**WASTE WATER FROM WASTE TO RESOURCE**

Worldwide, the majority of wastewater is neither collected nor treated. Wastewater is a valuable resource, but it is often seen as a burden to be disposed of. This perception needs to change.

80% of global wastewater is released to the environment without adequate treatment.

**WASTEWATER TREATMENT PLANT**
(Water Resource Recovery Facility)

**TREATED WATER** for:
- the energy sector, such as cooling water for power plants and process water for mines
- industrial processes, such as in the textile and paper industry
- irrigation (agriculture, urban parks, etc)
- recreational use
- replenishing aquifers
- drinking water

**SLUDGE**
- Anaerobic Digester
- Biogas can be used to generate energy (heat and electricity), which can be used at the plant and/or sold.
- Biosolids are nutrient rich and can be used as fertilizer in agriculture, to recover degraded areas or as feed, among others.
- Carbon Credits: waste water treatment plants can get carbon credits for generating renewable energy.

**PHOSPHORUS**
Can be recovered and used as fertilizer

Improved wastewater management offers a double value proposition if, in addition to the environmental and health benefits of wastewater treatment, financial returns are also possible. Resource recovery from these facilities in the form of energy, nutrients, reusable water, and biosolids represent an economic and financial benefit that contributes to the sustainability of these systems and of the water utilities operating them.

These resources can generate additional revenue streams for the operator, paying part or all of the operation costs, thereby contributing to the sustainability of the water system.

Wastewater recycling and reuse

The consistent increase in the growth rate of India’s population and unprecedented urbanization has led to an increase in the demand for water.¹ The Asian Development Bank projects that by 2030, India will have a water deficit of 50%.² Currently, as per Central Public Health and Environmental Engineering Organisation (CPHEEO), the average water supply in urban local bodies is 69.25 LPCD against the service benchmark of 135 LPCD. This indicates a vast gap between the demand and supply of water in the urban areas.

The problem of access to safe drinking water and sanitation facilities in urban areas of India is also a significant concern. In this context, appropriate reuse of treated wastewater can support in meeting the water demands to an extent.³ However, there is a lack of wastewater treatment facilities to treat the wastewater of a growing population. The lack of sufficient infrastructure, services and funds to support the water and wastewater treatment facilities required for an urban area exacerbate the problem. Moreover, the drainage and solid waste collection services are not adequate in most urban areas. The systems are poorly planned and designed or operated without adequate maintenance. The use of natural capacities of soil and vegetation (green infrastructure) can be applied to absorb and treat wastewater. Natural systems are more cost-effective and require low building, labour and maintenance costs.

¹ Nathaniel B Dkhar and Qazi Syed Wamiq Ali, India’s rampant urban water issues and challenges, The Energy and Resource Institute (TERI), 2018
³ Arun Kumar and Kirti Goyal, Wastewater Treatment and Reuse in India: Current Perspective and future potential, Science Direct, 2020
Figure 2 Water Scenario in India

METRO CRISIS
India’s urban population is set to grow massively over the next three decades—a major problem, since existing supplies of water are already insufficient to meet demand.

40% of India’s population is projected to live in urban areas by 2050, up from 31% per cent in 2011.

31% of urban households lack access to piped water or public tap water.

67.3% of urban Indian households are not connected to a piped sewage discharge system.

48% of the urban water supply in India comes from groundwater, according to the Centre for Science and Environment.

THE SUPPLY GAP
Average quantity of water supplied by urban local bodies in India:
69.25 litres per person per day

Required quantity of water to be made available in the cities:
135 litres per person per day

THE 30 CITIES MOST AT RISK
A Water Index report projects that the following cities will face a grave water risk by 2050 due to sharp increases in population:
1. Jaipur
2. Indore
3. Thane
4. Vellore
5. Srinagar
6. Rajkot
7. Kota
8. Nashik
9. Visakhapatnam
10. Bengaluru
11. Kolkata
12. Ahmedabad
13. Jaipur
14. Mumbai
15. Lucknow
16. Hubli–Dharwad

KEEPING IT FLOWING
While 80% of households in India’s cities have water sources within their premises, the challenge is to keep them flowing:

Outside dwellings but within premises:
24.6%

Less than 200 metres:
13.8%

200 m-500 m:
3.2%

500 m-1 km:
1.2%

1 km-1.5 km:
0.5%

More than 1.5 km:
0.6%

Within dwellings:
56.1%


1.1. Existing scenarios and gaps
Low provision of facilities for wastewater treatment, ineffective treatment of wastewater and existing treatment facilities working below par contribute to the discharge of partial or untreated wastewater and are responsible for more than 80% pollution in surface waters in India (CPCB, 2007). Only 200 cities/towns in India have a partial sewerage network; only 32.7% of the urban population (25.78 of the total 78.9 million households) have access to sewer despite investments over 11 plan periods up to 2012 (Census, 2011). Sewage treatment capacity is 30% of what is required in class I and class II cities. It is further exacerbated because existing treatment capacity is underused, with capacity utilization estimated to be about 66% of existing sewage treatment facilities (ibid).

Decreasing per-capita water availability and increasing pollution of fresh-water resources are enormous challenges as India continues to grow economically. In urban areas especially, water resources are under significant pressure due to high water-demand patterns. The situation is worsening with rising demand due to increasing urbanisation. Almost 80 per cent of water supply to municipalities flows back into the ecosystem as untreated wastewater, which is a critical environmental and health hazard. An estimated 38354 million litres per day (MLD) sewage is generated in major cities of India, but

---

6Performance Evaluation of Sewage Treatment Plants under NRCD. CPCB. 2013. (https://cpcb.nic.in/openpdf/file.php?id=UmVwb3J0RmlsZXMvMjlfMTQ1ODExMDE5Mi9OZXdjdGVtXzE5NV9TVFBfUkVQT1JULnBkZg)
the sewage treatment capacity is only 11786 MLD. Similarly, only 60% of industrial wastewater, primarily large scale industries, is treated.

Figure 4 Wastewater generated and treated in major cities

Figure 4 shows that there is a wide gap in terms of treatment infrastructure across all the cities. As of August 2017, Delhi generated nearly 4400 million litres of sewage per day. The Indian capital territory produced more sewage than any other city in the country that year. Among all the municipal corporations across the most populated cities, the sewage generation exceeded the treatment capacity. As this training is focused on helping ULBs to move forward in CSCAF ranking, the module is mainly designed to:

1. Understanding approaches and strategies to plan and design wastewater treatment facilities, including sewerage network; and
2. Understanding the essential functions of different technologies and their suitability in application in different scenarios.
1.2. Aligning with the ClimateSmart Cities Assessment Framework

The importance of wastewater recycling and reuse as an indicator is emphasized because freshwater resources are depleting rapidly, and climate change has impacted the availability and replenishment of water sources. This indicator stresses the conservation of existing water resources and opportunities to tap into recycling and reuse potential.

The assessment for this indicator is based on the percentage of wastewater that is being recycled and reused, adhering to CPCB standards. The higher the percentage of wastewater treated by the city (against the baseline), the higher the performance.

Based on this formula the performance evaluation levels may be derived using following table.

<table>
<thead>
<tr>
<th>Progression Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence</td>
<td>No Reuse</td>
<td>&lt; 5% Treated wastewater recycled and reused</td>
<td>5 to &lt;10% Treated wastewater recycled and reused</td>
<td>10 to &lt; 20% Treated wastewater recycled and reused</td>
<td>&gt;= 20% Treated wastewater recycled and reused</td>
</tr>
<tr>
<td>Score</td>
<td>0</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
</tr>
</tbody>
</table>

Hence, this module will focus on enhancing the capacity of ULBs to treat and reuse wastewater by addressing the challenges and guiding enabling measures to achieve desired objectives.
Figure 5 ClimateSmart Cities Assessment Framework

- Total electricity consumption in the city
- Total electrical energy in the city derived from renewable sources
- Fossil fuel consumption in the city
- Energy efficient street lighting in the city
- Green building adoption
- Promotion of green buildings
- Urban biodiversity
- Clean Air Action Plan (Planning and Implementation)
- Level of Air Pollution
- Clean Air Action Plan (Monitoring & Enforcement)
- MOBILITY & AIR QUALITY 20%
- ENERGY & GREEN BUILDINGS 25%
- URBAN PLANNING, GREEN COVER & BIODIVERSITY 25%
- WATER MANAGEMENT 15%
- WASTE MANAGEMENT 15%
- ClimateSmart Cities Assessment Framework 2.0

- Energy-efficient wastewater management system
- Energy-efficient water supply system
- Flood/water stagnation risk management
- Wastewater Recycling and Reuse
- Water Resources
- Water Recycling
- Water Use/Wasting
- Extent of wet waste processed
- Scientific Landfill availability & operations
- Landfill / dumpsite scientific remediation
- Waste minimization initiatives undertaken by the City
- Extent of dry waste recovered & recycled
- Extent of non-revenue water
- Wastewater recycle and reuse
- Flood/water stagnation risk management
Institutional framework

2.1. Legal provisions and Acts
While there are no specific legal provisions relating to urban sanitation, there are several provisions relating to sanitation services. The responsibility for the planning and delivering of urban services, including sanitation, lies with urban local bodies under local municipal laws and the 74th Constitutional Amendment Act, 1992. The 12th Schedule of the Act sets out a list of critical issues for the urban local bodies, including amongst other things:

1. Urban Planning
2. Regulation of land-use and construction of buildings;
3. Water supply for domestic, industrial, and commercial purposes;
4. Public health, sanitation, conservancy, and solid waste management;
5. Protection of the environment and promotion of ecological aspects; and
6. Slum improvement and upgrading.
7. Municipal Bylaws

These enable local bodies to discharge their functions and typically include, for example, a requirement for property owners to discharge wastewater without causing a nuisance; and an obligation to discharge wastewater into sewers where available. There are, however, no specific provisions for the safe removal, cartage, and disposal of septage in urban areas.¹

Water (Prevention & Control of Pollution) Act, 1974 is comprehensive legislation regulating agencies responsible for checking on water pollution and ambit of pollution

control boards both at the centre and states. Under Water Act 1974, Sewage or pollutants cannot be discharged into water bodies, including lakes, and the state pollution control board must intervene and stop such activity.

The Environment (Protection) Act, 1986: This Act applies in principle to every establishment, agency, or individual discharging any pollutant into the environment. ‘Pollutant’ includes treated or untreated sewage. In principle, municipalities must to comply with discharge norms for effluent released from sewage treatment plants and pay water cess under the Water Cess Act, 1977.

2.2. Policies and Guidelines

The National Environment Policy (NEP), 2006 builds on the various earlier policies that had addressed the environment’s challenges and need for sustainable development prior to this policy. One of the objectives of the policy is to protect and conserve critical ecological systems and resources.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT): Aimed to provide basic services (e.g., water supply, sewerage, and urban transport) to households and build amenities in cities to improve the quality of life for all, especially the poor and the disadvantaged.

National Urban Sanitation Policy (NUSP), 2008: Aimed to transform all urban areas into community-driven, totally sanitised, healthy, and liveable city and town, ensuring and sustaining good public health and environmental outcomes for all citizens.
The Manual on Sewerage and Sewage Treatment (CPHEEO), 2013: The Manual on Sewerage and Sewage Treatment of the Central Public Health and Environmental Engineering Organization, Ministry of Housing and Urban Affairs (formerly known as, Ministry of Urban Development (MoUD)), sets out technical norms for best practice in on-site sanitation and wastewater management. The manual covers planning, design, and construction aspects for various technical options; it also includes operation and maintenance aspects and safeguards to prevent water pollution under different soil and groundwater conditions.

2.3. Standards
Besides these Acts and statutory provisions documents, there are many relevant Indian Standards and Codes of Practice notified by the Bureau of Indian Standards that guides the planning, design and implementation of various components of the value chain of wastewater recycling and reuse. The most relevant include the following:

1. IS 1172:1993 – Basic requirements for water supply, drainage, and sanitation.
7. IS 10261:1982 – Requirements for settling tanks (clarifier equipment) for wastewater treatment.
8. IS 13496:1992 – General requirements for suction machines for cleaning sewers, manholes and so on.

In addition, MoHUA (then MoUD) prepared a document entitled 'Technical Guidelines on Twin-Pit Pour-Flush Latrines' in 1992, which broadly follows the lines of IS 12314:1987 on leach pit construction in rural areas.

All Indian Standards’ codes represent a standard of good practice and therefore take the form of recommendations. They are not mandatory unless made so under contract conditions, and some are routinely ignored, for example, the recommendation for the construction of soakaways, dispersion trenches, and biological filters to deal with the outflow from septic tanks; and for the regular desludging of septic tanks using specified equipment.
3. Implementation strategies

3.1. Concept in practices

Typically, the uncollected wastewater is either treated with onsite sanitation systems like a septic tank or disposed-off in lakes, rivers or even on the ground without any treatment. Figure 6 showcases a typical process of handling wastewater in India. However, collected wastewater may undergo primary or secondary treatment where the Sewage Treatment Plant (STP) facility is available. In a few instances, treated water may be reused after secondary treatment or subject to tertiary treatment. Often, collected water may also be disposed of without treatment in the absence of such a facility within the city.

A typical process involves primary and secondary wastewater treatment, which is shown below (Figure 6). Different systems employ primary or up to secondary treatment methods. For advanced use of treated water (like disposal in water bodies or domestic and drinking water use), tertiary and advanced purification treatment can be adopted.

The primary treatment involves screening and sedimentation to remove large solid particles from wastewater. Secondary treatment may use physical, biological and chemical processes to remove smaller and tiny particles and further reduce the contaminants. Use of biofilms, activated sludge, secondary sedimentation, coagulation, and other chemical treatment processes are common in secondary treatment. Tertiary or advanced treatment processes are used to remove micro contaminants, dissolved salts and solids, chemical contaminants, foul odours etc, so that treated water can be reused for various purposes. Chemical-based methods, membranes, Ultraviolet process, Ozonisation, Oxidation are standard processes in this stage. Use of one or more processes can be determined by the quality of influent and end use purpose after treatment.
Figure 6 A typical flowchart of wastewater treatment process

1Image Source: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/industrial-waste-water
3.2. Planning and Design

To plan or design a sanitation system with sewerage and treatment systems, three broad sets of information and parameters need to be considered.² This includes

³Adapted from Guidelines for Decentralized Wastewater Management, IIT Madras, MoHUA, 2012
1. Site condition and site potential for installing and commissioning the designed wastewater treatment plant. It considers the environmental and social concerns while selecting the site.

2. Design criteria including type of treatment projected handling capacity, phase-wise development (if needed) and estimated design period. It considers the technological options and demography to be catered, and

3. Components of the treatment process itself, which will be crucial for determining the appropriate and optimal processes in line with other two sets of information – site potential and design criteria.

Further, the parameters for selecting technology for wastewater treatment should be most appropriate and aligned with the sustainable development approach. It can be broken down into three broad parameters: environmentally sustainable, economically affordable and socially acceptable.

Figure 9 Parameters for selection of appropriate technology for wastewater treatment

In short, multiple criteria and parameters play a crucial role in determining the appropriate strategy and process involved in designing and implementing wastewater treatment and recycling. The influencing factors on deciding on the most appropriate wastewater treatment system may include the following:

1. Scale of the project
2. Physical characteristics of the site such as geohydrology, topography etc.
3. Planning considerations like land use planning, population projections, industrial and infrastructure projects etc
4. Management capabilities – present and future, and availability of skill and technology

---

4Image Source: https://www.mdpi.com/2079-9276/6/2/22/htm
5. Appropriate technology to serve the purpose and objectives of treatment, reuse
6. Legal compliance requirements
7. Social acceptance in terms of acceptable hazards and environmental implications
8. Financial status, funding mechanism and opportunities
9. Environmental impact of the project

3.3. Implementation strategy
Implementation strategy should consider all service chain stages, including generation, onsite treatment, collection/containment, conveyance, offsite treatment, and disposal/reuse.

These stages have to be considered in an integrated manner as there may be different appropriate solutions catering to different stages. For example, the most suitable solution for containment or conveyance may not fit best into the treatment system needed to achieve the reuse objective. Thus, the system has to be designed keeping in mind the ultimate objective use of treated water.

To plan sewerage and treatment systems, we can adopt a combination of four broad level strategies. Onsite Systems are the measures where the containment or treatment of wastewater is done near the source, and usually, there is no need for long conveyance systems. When such systems are designed at the institutional or small cluster level and cater to the treatment and reuse needs locally, they are characterised as decentralised systems.

*Image Source: World Health Organization and UN-HABITAT, 2018*
On the other hand, offsite systems typically serve large areas where wastewater is directed to a common treatment plant. When such systems typically serve large areas or populations, it is also called a centralised system. The difference between centralised and decentralised systems is explained in table 2.⁶

Table 2 Difference between centralised and decentralised systems

<table>
<thead>
<tr>
<th></th>
<th>Decentralized</th>
<th>Centralized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment &amp; Installation/</td>
<td>• Currently, even decentralized treatment systems have gained efficiency in</td>
<td>• High treatment efficiency of the conventional treatment system.</td>
</tr>
<tr>
<td>Construction</td>
<td>treatment.</td>
<td>• The larger infrastructure is required and higher time is required for</td>
</tr>
<tr>
<td></td>
<td>• Smaller solutions, faster to implement</td>
<td>construction/installation.</td>
</tr>
<tr>
<td></td>
<td>• Re-use of treated waste is easier to manage due to lower conveyance</td>
<td>• Re-use of treated waste also require higher conveyance</td>
</tr>
<tr>
<td></td>
<td>• Easy to pilot new technologies</td>
<td>• The pilot of New technologies require meticulous planning for success</td>
</tr>
<tr>
<td></td>
<td>• May require lower energy and pumping</td>
<td>• Require high energy and pumping, mainly considering larger conveyance.</td>
</tr>
<tr>
<td></td>
<td>• Ease in expansion and the modular system can be done</td>
<td>• Expansion in the existing system may be difficult.</td>
</tr>
<tr>
<td>Managerial Aspects</td>
<td>• The number of treatment units are more, but conveyance is reduced.</td>
<td>• A smaller number of treatment units required. So easier to manage.</td>
</tr>
<tr>
<td></td>
<td>The higher number of treatment units/systems to be managed, but managing</td>
<td>But conveyance to centralized place (transport/pipelines) require high</td>
</tr>
<tr>
<td></td>
<td>conveyance is reduced considerably.</td>
<td>monitoring and maintenance</td>
</tr>
<tr>
<td>Financial Aspects</td>
<td>• Reduced conveyance infrastructure</td>
<td>• Higher infrastructure cost mainly considering higher conveyance of waste.</td>
</tr>
<tr>
<td></td>
<td>• Reduced O &amp; M for conveyance</td>
<td>• Usually, require higher energy/fuel-intensive technologies and pumping/</td>
</tr>
<tr>
<td></td>
<td>• Low energy-intensive technologies possible and thus reduced/no energy</td>
<td>conveyance, leading to higher investment as well as higher operation and</td>
</tr>
<tr>
<td></td>
<td>consumption and thus very low O &amp; M costs</td>
<td>maintenance costs.</td>
</tr>
<tr>
<td>Location &amp; Social Acceptance</td>
<td>• Customarily, located near human settlement. Needs acceptance due to issues</td>
<td>• Typically located far from human settlement, so no significant acceptance</td>
</tr>
<tr>
<td></td>
<td>like odour, aesthetics etc near the settlement.</td>
<td>issues by the community.</td>
</tr>
<tr>
<td>Community Participation</td>
<td>• Higher participation in the community required</td>
<td>• Lower participation of community required</td>
</tr>
</tbody>
</table>

⁶Adapted from presentation by Dr. Markus Starkl published in Develoment.asia
Centralised systems are typically offsite systems. i.e. the waste must to be conveyed to the treatment plant, which may be at a distance. However, Decentralised systems may be onsite and offsite (but at a smaller distance). Advantages and disadvantages of onsite systems can be summarised as follows:

Table 3 Advantages and Disadvantages of On-site systems

<table>
<thead>
<tr>
<th>Advantages of onsite systems</th>
<th>Dis-advantages of onsite systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Less environmental disturbances.</td>
<td>▪ Policies not well established.</td>
</tr>
<tr>
<td>▪ Nil or minimal sewer pipelines.</td>
<td>▪ Standardization of the systems is difficult.</td>
</tr>
<tr>
<td>▪ Maintained by individual households/establishments.</td>
<td>▪ Individual households/establishments bear O &amp; M cost.</td>
</tr>
<tr>
<td>▪ Power requirement is nil or minimal.</td>
<td>▪ Improper maintenance leads to significant environmental consequences.</td>
</tr>
<tr>
<td>▪ Maintenance of the treatment system is effortless.</td>
<td>▪ Individual components will not be able to meet the discharge standards.</td>
</tr>
</tbody>
</table>

Annexure 1 gives list of different technologies in wastewater management.

The roles and responsibility of various stakeholders also differ according to planning approach and scale of the systems. This can be summarised in Tabel 3:

MoHUA is mandated to define policies regarding urban sanitation, along with financing large programmes which are implemented in partnership of States. State-level Urban Development Department (SUDD) may also be drafting policies at the State level. Projects may also be financed independently or jointly by SUDD and State-level Water Supply and Sewerage Board (WSSB/SUWSSB) and Urban Local Body (ULB). WSSB is also mandated to implement the project. State or Central Pollution Control Board may do the performance quality control and monitoring.

7Source: CPHEEO, Guideline on Decentralized Wastewater Treatment Bharat Mission- Gramin, Manual for District Level Functionaries, 2017
Table 4 Stakeholders and their roles

<table>
<thead>
<tr>
<th>Category/Roles</th>
<th>Policy</th>
<th>Capital Investment</th>
<th>Implementation</th>
<th>Effluent Standard</th>
<th>Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Scale Centralized or semi</td>
<td>MoHUA</td>
<td>MoHUA</td>
<td>SUWSSB</td>
<td>CPCB</td>
<td>SPCB</td>
</tr>
<tr>
<td>decentralized</td>
<td>Sbdd</td>
<td>SUDD</td>
<td>WSSB</td>
<td>SPCB</td>
<td></td>
</tr>
<tr>
<td>Small Scale - In-situ/ decentralized</td>
<td>MoEFCC</td>
<td>Builders, Developers, Real Estate Companies</td>
<td>Builders, Developers, Real Estate Companies</td>
<td>CPCB</td>
<td>SPCB</td>
</tr>
<tr>
<td></td>
<td>Sbdd</td>
<td>Institutions</td>
<td>Institutions</td>
<td>SPCB</td>
<td>ULB</td>
</tr>
<tr>
<td></td>
<td>SPCB</td>
<td>Private Business</td>
<td>Private Business</td>
<td>ULB</td>
<td></td>
</tr>
</tbody>
</table>

However, for small scale independent projects, Ministry of Environment, Forests and Climate Change (MoEFCC) policy directives may be followed. Generally, financing and implementation of small scale projects is done by private players, builders, developers etc. However, effluent standard should confirm to CPCB/SPCB or even ULB directives.

3.4. Funding

Financing wastewater treatment systems and sewerage networks may involve different stakeholders for different projects. It may include:

1. Public funding through government programmes like Swachch Bharat Mission and Namami Gange
2. Shared expenses by community or user fee-based like institutional and RWA projects
3. Private finance like NGO funding, CSR funding or investment by enterprises and entrepreneurs like
4. Partnership models wherein two or more agencies collaborate for financing like the Alandur Sewerage project

For ULBs, different options of securing funding for new or expansion of sewerage and treatment systems are given below. However, depending on the focus and criteria laid in the scheme, all the options may not apply to all the cities.

---

8 Large scale systems refers to city level systems or systems catering to large population and area, generally with treatment capacity of over 1 MLD
9 Small scale systems refers to systems catering to cluster, society or institutions, generally with treatment capacity of less than 1 MLD
Table 5 Government Schemes and Funding Options for ULBs

<table>
<thead>
<tr>
<th>Program</th>
<th>Funding Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atal Mission for Rejuvenation and Urban Transformation (AMRUT)</td>
<td>AMRUT 2.0 is launched for 5 years from 2021-22 to 2025-26 with aim to make cities water secure and enhance circular economy through recycling of wastewater in 500 cities in India. It targets 100% coverage of household sewerage/septage management with 2.64 crore sewer/septage connections. Funds are allocated or decentralized sewerage systems, recycling and reuse of treated water. Under Reforms Agenda for AMRUT 2.0, reforms on water conservation envisages recycle of treated wastewater to meet 20% of total city water demand and 40% of industry water demand in aggregate at State level. Total indicative outlay for AMRUT 2.0 is ₹ 2,77,000 crore including central share of ₹76,760 crore over five years.</td>
</tr>
<tr>
<td>Smart City Mission</td>
<td>Each city will create a Special Purpose Vehicle (SPV), headed by a full-time CEO, to implement the Smart Cities Mission. Centre and state government will provide crore funding to the company, as equal contribution. The company has to raise additional funds from the financial markets. Under Smart City Mission, component of water management including wastewater recycling, storm water management and energy efficiency in wastewater treatment.</td>
</tr>
<tr>
<td>Pradhan Mantri Awaas Yojana (PMAY)</td>
<td>The mission will support construction of houses upto 30 square meter carpet area with basic civic infrastructure. States/UTs will have flexibility in terms of determining the size of house and other facilities at the state level in consultation with the Ministry but without any enhanced financial assistance from Centre. Slum redevelopment projects and Affordable Housing projects in partnership should have basic civic infrastructure like water, sanitation, sewerage, road, electricity etc. ULB should ensure that individual houses under credit linked interest subsidy and beneficiary led construction should have provision for these basic civic services.</td>
</tr>
<tr>
<td>Swachchh Bharat Mission (Urban) 2.0</td>
<td>SBM 2.0 focusses on Garbage free cities and maintaining and enhancing Open Defecation Free (ODF). The SBM-ODF+ and SBM-ODF++ protocols build upon the ODF protocols while keeping true to its provisions, so as to provide a platform for cities and towns to improve sanitation sustainability. These protocols are incremental in nature and reflect on-ground realities present in India.</td>
</tr>
</tbody>
</table>

Source: 2016, Handbook on Decentralized Wastewater Treatment, National Institute of Urban Affairs, New Delhi
<table>
<thead>
<tr>
<th>Program</th>
<th>Funding Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jal Jeevan Mission (JJM)</td>
<td>JJM focus on tap connectivity for water supply to every household by 2024 thus helping enhance water availability for sanitation. Mission also has components for water treatment facilities and grey water recycling. Total estimated cost of JJM is Rs. 3.60 Lakh Crore. The fund sharing pattern between Centre and State is 90:10 for Himalayan (Uttarakhand, Himachal Pradesh) and North-Eastern States, 100:0 for UTs and 50:50 for rest of the States.</td>
</tr>
<tr>
<td>Namami Gange Programme</td>
<td>Under National Mission for Clean Ganga (NMCG), projects for expansion and enhancement of sewerage network and in-situ sewage treatment options have been sanctioned. In the budget for the financial year 2020-21, Government of India has proposed an allocation of Rs.1,600.02 crore for the Namami Gange Programme.</td>
</tr>
<tr>
<td>15th Finance Commission</td>
<td>The 15th Finance Commission has allocated Rs 1.5 lakh crore in grants to urban local bodies (ULBs) in India for the next five years comprising 100% outcome funding of Rs 26,000 crore for million-plus urban agglomerations tied to water and sanitation. The remaining cities to receive an allocation of Rs 83,000 crore in aggregate, with 60 percent of the funds tied to performance on water and sanitation and balance being untied.</td>
</tr>
</tbody>
</table>

3.5. **Wastewater recycle and reuse**

3.5.1. **Reuse Potential**
Collection, treatment and reuse of municipal wastewater provides an opportunity for environmental rehabilitation and meeting the increasing water needs of different economic sectors. In addition to recycled wastewater becoming an additional and valuable water source, there are opportunities to recover nutrients and energy from wastewater.

It is estimated that if 80% of urban wastewater could be collected and treated by 2030, there would be a total volume of around 17 billion m³ (BCM) per year; an increase of around 400% in the volume of available treated wastewater. This 17 BCM of treated wastewater resource, if captured, treated safely and recycled, is equivalent to almost 75% of the projected industrial demand in 2025 (MoWR 2006) and almost a quarter of the total projected drinking water requirements in the country.

---

3.5.2. Benefits of Reusing treated wastewater

Model Building Bylaws 2016 mandates wastewater recycling and reuse for “all building having a minimum discharge of 10,000 litre and above per day. The recycled water should be used for horticultural purposes”. Handbook on Service Level Benchmarking by MoHUA proposes benchmark of 20% extent of recycling and reuse of sewage for urban areas.

There are several benefits to wastewater recycling for cities, industries, agriculture and others, which are explained here:

1. An additional source of water: Recycled wastewater reduces freshwater demand within the city and for industries and agriculture. This option is generally less expensive than other options to augment existing water supplies from distant water sources or expensive treatment such as desalination. Using treated or untreated wastewater for agriculture has also been historically prevalent in India; however, there is a need to understand the economic, environmental, social and health implications of using untreated wastewater and mitigating any deleterious effects from its use. In coastal areas, reclaimed wastewater (discharged to the sea) is an additional resource to meet irrigation demand, and in upstream locations, the use of reclaimed water in agriculture frees up freshwater for domestic and industrial consumption. By 2030, treated wastewater from Class I and II cities can meet about a quarter of the current industrial water demand.

2. Source of revenue for utilities: Utilities, with well-functioning STPs, are in a position to sell the treated effluent to industrial customers depending on the need and availability of other water sources. Utilities may charge these industrial customers for this recycled wastewater based on the required level of treatment provided and quality of wastewater. Therefore, it is desirable therefore, that cities, whenever possible, should promote the use and sale of recycled wastewater to industrial customers, even making this practice mandatory through changes in the state/local regulations.

3. Reduction in groundwater pumping requirement: The use of treated wastewater for irrigation also can to reduce groundwater irrigation, hence pumping and the associated energy requirement, GHG emissions, and associated costs. An estimated 1.75 million MWh of electricity, which is equivalent to reducing about 1.5 million tonnes of CO2e (tCO2) GHG emissions can be avoided by reduced pumping every year in India.

While treated wastewater presents potential economic and environmental benefits to consumers (industrial, agricultural), city governments and states—an assured and reliable water supply, the nutrients present in the wastewater, and avoided costs of groundwater pumping—utilities and state/city governments will need to develop more sustainable business models. These models should aim at different user categories—industry, agriculture, institutions/commercial establishments—which in collaboration with partner agencies ensure financial viability, follow water allocation rules and support peri-urban agriculture.
Interactive Exercise

The interactive exercise is designed on the MIRO Board, allowing multiple users to engage in exercise simultaneously while the moderator to controls the level of engagement and use of specific tools.

This online exercise is designed for participants to understand
1. Influencing factors for selecting various options across service chain of wastewater treatment system – containment, conveyance, treatment and reuse; and
2. understand suitable options for various phases of the service chain.

Exercise 1: This part of the exercise is about understanding factors that influence the decision on the containment and conveyance of wastewater and faecal sludge. A table consists of rows of various restrictive parameters like hilly terrain, high groundwater, rocky strata, cold region etc. while in columns, participants have to drag and drop notes with various options of containment (like soak pit, septic tank etc) and conveyance (sewer line, small bore, vehicle pump etc).
There are three exercises within this session to achieve the objectives.

<table>
<thead>
<tr>
<th>EXERCISE 1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CONTAINMENT</th>
<th>CONVEYANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HILLY/ UNDULATING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH GROUND WATER TABLE / COASTAL CITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NARROW STREETS / HIGH DENSITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROCKY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXTREME COLD CLIMATE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLAINS / MURRUM / LOW GROUND WATER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Settler tank
- Shallow channels
- Small bore pipes
- Sewer line
- Septic tank
- Small vehicle pump
- Truck decant
- Bio digester
- Soak pit
- Root zone
**Exercise 2:** This exercise is about different types of treatment systems. Rows have broad treatment systems like natural systems, mechanical systems, co-treatment options, partial systems (primary and secondary treatment) and complete systems (including tertiary systems). Participants have to select treatment systems from sticky notes and place them in appropriate rows.

<table>
<thead>
<tr>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermi worms filter</td>
</tr>
<tr>
<td>Reed beds</td>
</tr>
<tr>
<td>DEWATS</td>
</tr>
<tr>
<td>Membrane based batch reactors</td>
</tr>
<tr>
<td>Drying bed</td>
</tr>
<tr>
<td>Constructed wetland</td>
</tr>
<tr>
<td>Activated sludge</td>
</tr>
<tr>
<td>Sequential batch reactor</td>
</tr>
<tr>
<td>Bio digester</td>
</tr>
<tr>
<td>Submerged aeration</td>
</tr>
<tr>
<td>Soil bio technology</td>
</tr>
<tr>
<td>Faculative aerated lagoon</td>
</tr>
</tbody>
</table>
**Exercise 3:** This exercise relates to various reuse options after treatment and related processes required to suit reuse purposes. Here rows are marked with broad processes like pathogen removal, nutrition recovery, liquid reuse and solid reuse. Participants have to select end-use options like energy pallets, fertilisers etc, given in sticky notes and place them in appropriate rows. At the end of each exercise, briefly discuss challenges and opportunities related to selecting of appropriate technology and processes in each value chain stage in their respective cities. At the end of all three exercises, summarise the main learning points.
4.1. Additional offline exercise of participants

Fill in the blank cells of table with appropriate technologies and processes:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Appropriate technologies and processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Containment</td>
</tr>
<tr>
<td></td>
<td>Conveyance</td>
</tr>
<tr>
<td>Hilly or undulating terrain</td>
<td></td>
</tr>
<tr>
<td>High ground water table</td>
<td></td>
</tr>
<tr>
<td>Coastal area</td>
<td></td>
</tr>
<tr>
<td>Rocky strata</td>
<td></td>
</tr>
<tr>
<td>Extreme cold climate</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Appropriate treatment technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural systems</td>
</tr>
<tr>
<td></td>
<td>Mechanized or hybrid systems</td>
</tr>
<tr>
<td>Partial systems (allows Primary and Secondary treatment only)</td>
<td></td>
</tr>
<tr>
<td>Full or advanced systems (allows primary, secondary and tertiary treatment)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reuse Processes and treatment objectives</th>
<th>End use products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathogen removal</td>
<td></td>
</tr>
<tr>
<td>Nutrition recovery</td>
<td></td>
</tr>
<tr>
<td>Liquid reuse</td>
<td></td>
</tr>
<tr>
<td>Solid Reuse</td>
<td></td>
</tr>
</tbody>
</table>
Case Study

5.1. Alandur Sewerage Project: Successful Innovation and Partnership

Alandur is a small municipality adjacent to the Chennai Metropolitan Development (CMD) Area with a population of 146,000 (Census 2001). Slums and squatter settlements constitute about a quarter of the total population. Before the project, almost 95 per cent of families had household toilets with individual septic tanks discharged into open drains where much of it stagnated due to low flows, causing odour and offering sites for mosquito breeding. While the municipality provided a septage removal service, there was no treatment facility, and waste was disposed of in low-lying areas beyond the municipal limits.

The Alandur sewerage project, initiated in 1996, was the first project in India using a PPP framework (Build-own-transfer (BOT) format) and presents a unique case in the area of PPP in urban sanitation sector.¹

Sewerage component included the following:
1. a sewerage network consisting of the main sewer line, branch sewer line and inspection chamber (manholes);
2. construction of a sewage pumping station;
3. a Sewage Treatment Plant with Activated Sludge Process (ASP) technology; and
4. Low-cost sanitation

The construction of the underground sewerage system was done through an engineering, procurement and construction contract, and the STP was constructed on a BOT basis. The

¹Ministry of Finance, Government of India, Toolkit for improving PPP Decision Making Processes (pppinindia.gov.in)
Municipality carried out the O&M of the sewerage system, including sewer lines, pump houses, and pumping plants. The project's financing was done uniquely by collecting one-time deposits from users who financed 40% of the project cost. Other financing mechanisms included loans (46%), Capital grants (11%) and connection fees (3%). Public awareness and support were sought through an extensive communication campaign.

Figure 12 Schematic diagram of ASP technology

2Source: https://www.slideshare.net/A3SEnviroConsultants/stp-plants-technology-by-a3s-enviro-consultants
To plan this complex and politically challenging project, local body worked in partnership with the Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL), the state asset management company and with USAID’s Financial Institution Reform and Expansion (FIRE) Project. A sewerage network consists of the main sewer line, branch sewer line and inspection chamber; a sewage pumping station, a sewage treatment plant, and low-cost sanitation. In the initial phase the plant treated 12 MLD of sewage supplied to it by the municipality. The ultimate capacity was to be 24 MLD. Eventually, the project connected 32,000 users and 43 per cent of the slum households in the city took individual connections. A notable feature is the tariff structure, developed on full user charge recovery with cross-subsidies for the poor. The municipality collects differential user charges based on the size of the property.

5.2. Tiger Bio Filter Sewage Treatment Plant at Vasantrao Bagul Udyan, Pune
Before the project, wastewater from three slum colonies located 1 Km upstream of Bagul Udyan was disposed into Ambil Odha Nalla, and further nalla was mixing up with Mutha River, contaminating water source. This project was taken up to control water pollution and reuse treated water for public facility.

Project Details:
- Location of treatment plant: Vasantrao Bagul Udyan, Pune
- Areas catered: 3 slum colonies (i.e. Sanjay Nagar, Sandhya Society and Gavali Wada) catering to 3000 HHs
- Capacity: 500 KL/D
Operational Since: 2017
- Areas of Site: 400 sq.m.

Key stakeholders:
The project was conceptualised by private player, which was then taken up by Urban Local Body and implemented through agency with expertise in this domain. Thus it also showcases Public Private partnership in sector in a unique way.

Financials:
Investment Cost: 1.25 crore
Operation & Maintenance Cost: Rs. 8.91 lakh/year

Type of technology used:
Bio-filtration technique, based on vermi-filtration, pressure sand filter and activated carbon filter was used in this project. The technique is environmentally friendly as it requires less operational land. The treatment system contains filter media with specially bred earthworms, which helps degrade organic waste from wastewater at a rapid rate. This helps in eliminating the need for forced aeration using a blower. The worms convert organic matter into valuable compost, which can be directly used as a fertilizer.

The unique set-up of the treatment plant introduces a "trickling" action of the wastewater as it passes through the bio-media and dissolves oxygen into it. The inorganic waste in the water is removed by physical filtration and digested and metabolized by the earthworms and microorganisms. Treated wastewater is used in gardening, irrigation and construction sites.

Benefits of project:
Project has not only helped in reduction of pollution load of fresh water sources, but have also demonstrated environment friendly approach and technology for wastewater treatment and reuse at decentralised level.
List of additional materials

6.1. Documents

- NIUA & Ministry of Housing and Urban Affairs, Solid Waste Initiatives in Urban India, A Compendium, 2019
- Centre for Science and Environment, Decentralized Wastewater Treatment and Re-use: Case studies of implementation on different scale – community, institutional and individual building; New Delhi, 2014
- ICCO and CDD Society, Linking Climate Sanitation and Climate Change: Evaluation GHG emissions and vulnerability: the case of Valsad, 2014
- CPHEEO, Guideline on Decentralized Wastewater Treatment Bharat Mission- Gramin, Manual for District Level Functionaries, 2017
- Ministry of Environment, Forest and Climate Change, Notification on Solid Waste management Rules, 2015
- EAWAG Aquatic Research & The International Water Association, Compendium of Sanitation Systems and Technologies, 2nd Revised Edition
- Planning Commission, Govt. of India, Report of the Task Force of Waste to Energy, May 2014

Arun Kumar, Kirti Goyel, Water Reuse in India- Current perspective and future potential, ScienceDirect.com, August 2020

World Bank, Water and Sanitation Program (WSP); International Water Management Institute (IWMI), Recycling and reuse of treated wastewater in urban India: A proposed advisory and guidance document, 2016

6.2. Articles

Government of India, Ministry of Environment, Forest and Climate Change, Loksabha unstarred question no. 2541, updated on 28th May 2018

Order Of The National Green Tribunal Regarding Effluent Discharge Standards For STPs, 30/04/2019 Updated on 8th May, 2019


6.3. **Webpages**

- [http://agricoop.nic.in/sites/default/files/Vermicompost%20Production%20Unit.pdf](http://agricoop.nic.in/sites/default/files/Vermicompost%20Production%20Unit.pdf)
- [http://vikaspedia.in/energy/energy-production/bio-energy/biogas#section-8](http://vikaspedia.in/energy/energy-production/bio-energy/biogas#section-8)
- [https://ghgprotocol.org/sites/default/files/Waste%20Sector%20GHG%20Protocol_Version%205_October%20202013_1_0.pdf](https://ghgprotocol.org/sites/default/files/Waste%20Sector%20GHG%20Protocol_Version%205_October%20202013_1_0.pdf)
- [https://nrega.nic.in/Netnrega/WriteReaddata/Circulars/1569SuggestiveEstimatesFarmPondNADEPandVermiCompost.pdf](https://nrega.nic.in/Netnrega/WriteReaddata/Circulars/1569SuggestiveEstimatesFarmPondNADEPandVermiCompost.pdf)
- [https://iopscience.iop.org/article/10.1088/1755-1315/16/1/012033](https://iopscience.iop.org/article/10.1088/1755-1315/16/1/012033)
Annexures

Annexure 1: Different types of technologies for wastewater treatment

Figure 13 Different type of technologies for wastewater treatment¹

¹Image Source: World Health Organization and UN-HABITAT, 2018
### Annexure 2: Functions of different components of wastewater treatment systems

#### Table 9 Various functions of different components of treatment systems

<table>
<thead>
<tr>
<th>Principal purposes of Unit Processes</th>
<th>Unit Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grit Removal</td>
<td>Grit chambers</td>
</tr>
<tr>
<td>Removal or grinding of coarse solids</td>
<td>Bar screens</td>
</tr>
<tr>
<td>Odour control</td>
<td>Per chlorination, Ozonation</td>
</tr>
<tr>
<td>Gross solid-liquid suspension, BOD reduction</td>
<td>Plain primary settling</td>
</tr>
<tr>
<td>Gross Removal of soluble BOD and COD from raw wastewater</td>
<td>Biological treatment</td>
</tr>
<tr>
<td>Removal of oxidized particulates and biological solids</td>
<td>Plain secondary setting</td>
</tr>
<tr>
<td>Decomposition or stabilization of organic solids, conditioning of sludge for dewatering</td>
<td>Anaerobic sludge digestion</td>
</tr>
<tr>
<td>Ultimate sludge disposal</td>
<td>Sludge drying beds, land disposal, land reclamation</td>
</tr>
<tr>
<td>Removal of colloidal solids and turbidity from wastewater</td>
<td>Chemical treatment, sedimentation, mixed-media filtration</td>
</tr>
<tr>
<td>Phosphate removal</td>
<td>Chemical coagulation, flocculation and settling</td>
</tr>
<tr>
<td>Nitrate removal</td>
<td>Ammonia stripping</td>
</tr>
<tr>
<td>Removal of suspended and colloidal materials</td>
<td>Mixed-media filtration</td>
</tr>
<tr>
<td>Disinfections</td>
<td>Chlorination, UV treatment</td>
</tr>
</tbody>
</table>
# Annexure 3: Details of various onsite treatment systems

## Table 10 Advantages and disadvantages of various onsite treatment systems

<table>
<thead>
<tr>
<th>Type</th>
<th>Kind of Treatment</th>
<th>Use of type of wastewater</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic Tank</td>
<td>Sedimentation, Sludge Stabilization</td>
<td>Wastewater of settleable solids, specially, domestic</td>
<td>Simple, durable, underground so requires little space</td>
<td>Low treatment efficiency, effluent not odourless</td>
</tr>
<tr>
<td>Imhoff tank</td>
<td>Sedimentation, sludge stabilization</td>
<td>Waste water of settleable solids</td>
<td>Durable, less space required as underground, colourless effluent</td>
<td>Less simple than septic tank, needs regular de-sludging</td>
</tr>
<tr>
<td>Anaerobic filter</td>
<td>Anaerobic degradation of suspended and dissolved solids</td>
<td>Pre-settled domestic wastewater of narrow BOD/COD ratio</td>
<td>Simple and fairly durable, high treatment efficiency, little space required as underground</td>
<td>Costs in construction,</td>
</tr>
<tr>
<td>Baffled septic tank</td>
<td>Anaerobic degradation of suspended and dissolved solids</td>
<td>Pre-settled domestic wastewater of narrow BOD/COD</td>
<td>Simple and durable, high treatment efficiency, less space required as underground</td>
<td>Longer start-up phase than anaerobic filter</td>
</tr>
<tr>
<td>Root zone treatment</td>
<td>Aerobic degradation of dissolved and fine suspended solids, pathogen removal</td>
<td>Suitable where settleable solids and suspended solids already removed by pre-treatment</td>
<td>High treatment efficiency, can be merged with landscape, no odour</td>
<td>High space requirement, requires higher maintenance</td>
</tr>
<tr>
<td>Anaerobic pond</td>
<td>Sedimentation, anaerobic degradation and sludge stabilization</td>
<td>Strong/medium wastewater</td>
<td>Flexible and simple in construction, little maintenance</td>
<td>Large space required, odour is always there, vector breeding possible</td>
</tr>
<tr>
<td>Aerobic pond</td>
<td>Aerobic degradation, pathogen removal</td>
<td>Pre-treated domestic wastewater</td>
<td>Simple in construction, high pathogen removal, fish farming possible</td>
<td>Large space requirement, vector breeding and odour possible</td>
</tr>
<tr>
<td>Type</td>
<td>Kind of Treatment</td>
<td>Use of type of wastewater</td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bioremediation</td>
<td>Use of different microorganisms to reduce pollutant load</td>
<td>Can be used of industrial (heavy metal and others) as well as domestic waste</td>
<td>Efficient, cost effective and environmental friendly processes can be developed</td>
<td>Large scale implementation remains challenge due to different experimental conditions and target pollutants</td>
</tr>
<tr>
<td>Phytorid</td>
<td>Engineered wetland system to reduce organic load</td>
<td>Domestic wastewater, food, dairy and textile industry wastewater</td>
<td>Decentralised, low maintenance, non mechanical, non electrical</td>
<td>High Space requirement, Not suitable treating industrial waste</td>
</tr>
<tr>
<td>Bio Gas Unit</td>
<td>Anaerobic digestion through micro organism and generation of mainly methane</td>
<td>Biogas/ methane produced is used as fuel for burning or creating electricity; slurry can be used as soil fertilizer</td>
<td>Simple, durable, reduction of solids to be handled; excess sludge production on the basis of biodegradable COD in anaerobic treatment is significantly lower compared to aerobic processes</td>
<td>Requires strict monitoring due to sensitive micro organisms in it, require high amount of waste for gas optimum gas production Needs good workmanship while construction/ installation as leakages can bring down efficiency</td>
</tr>
</tbody>
</table>

Source: Adapted from presentation by Prof. Arunabha Majumder Emiritus Fellow, School of Water Resources Engineering Jadavpur University