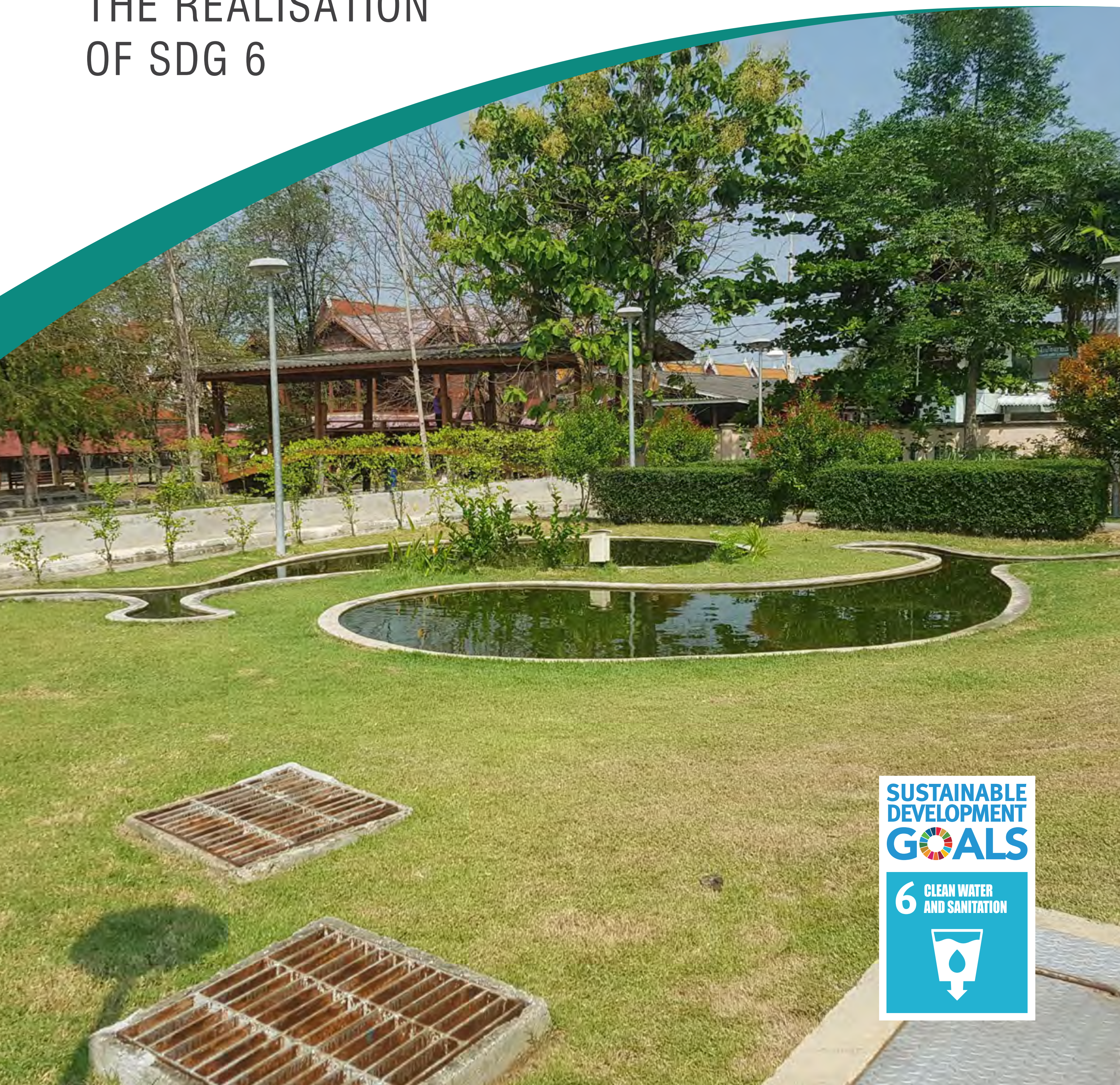
DECENTRALISED WASTEWATER MANAGEMENT IN ASEAN

TRAINING MODULES FOR THE REALISATION OF SDG 6



SUSTAINABLE DEVELOPMENT GOALS
6 CLEAN WATER AND SANITATION

DECENTRALISED WASTEWATER MANAGEMENT IN ASEAN: TRAINING MODULES FOR THE REALISATION OF SDG 6

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Foreword

Cities and municipalities in the Association of Southeast Asian Nations (ASEAN) face critical challenges in pursuing Sustainable Development Goal 6 (SDG 6), which includes ensuring universal access to water and sanitation coupled with sustainable management. Effective execution of Decentralised Wastewater Management (DWM) is critical to the success of this endeavour. Hence, designing standard training modules for sanitation planners, water professionals, and other pertinent stakeholders in the ASEAN region is imperative to achieve this objective.

These training modules, as explained in 'Decentralised Wastewater Management in ASEAN: Training Modules for the Realisation of SDG 6', serve a dual purpose. First, they enhance the knowledge and technical capabilities of those helming this initiative, thus increasing the efficiency and effectiveness of DWM implementation at the local level. Second, by standardising these modules, a uniformity in approach and quality of implementation of DWM across diverse geographical and cultural landscapes within the ASEAN region is ensured.

The importance of DWM in the context of ASEAN cannot be overstated. DWM presents a sustainable, cost-effective, and adaptable solution to the region's unique challenges regarding water and sanitation management. By empowering local stakeholders with the necessary skills and knowledge, we not only inch closer to achieving SDG 6, but also contribute to the broader objectives of public health, environmental protection and socio-economic development within the ASEAN region.

Hence, these training modules are tasked with the critical role of driving progress and transformation in the ASEAN region, by enabling the region's journey towards sustainable water and sanitation management, aligning with the global goals of SDG 6.

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This publication was made possible by generous funding from the Government of Japan through the JAIF. We would also like to express our sincere gratitude to the ASEAN Secretariat for their tremendous support, coordination and guidance, which were essential in ensuring the smooth and successful implementation of this significant regional initiative.

The final design of this Training Modules was completed with the strong support and dedicated efforts of all relevant members from the Asian Institute of Technology, led by Prof. Thammarat Koottatep, and with a significant contribution from Suraj Pradhan. Additionally, we wish to express our appreciation to the reviewers of this practical guide, including national focal points of the ASEAN Working Group on Water Resource Management, project technical advisors led by Dr. Ebie Yoshitaka from the National Institute for Environmental Studies (NIES) and the ASEAN Secretariat, for their reviews, insightful comments and feedback on this guidebook.

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Abbreviation

ABR	Anaerobic Baffled Reactor
ADB	Asian Development Bank
AIT	Asian Institute of Technology
ASEAN	Association of Southeast Asian Nations
BCR	Benefit-cost Ratio
BMGF	Bill and Melinda Gates Foundation
BOD	Biochemical Oxygen Demand
BORDA	Bremen Overseas Research and Development Association
CBA	Cost and Benefit Analysis
COD	Chemical Oxygen Demand
CSDA	City Service Delivery Assessment
CWIS	City-wide Inclusive Sanitation Services
CWIS SAP	City-wide Inclusive Sanitation Services Assessment and Planning
DWM	Decentralised Wastewater Management
EEM	Environmental Engineering and Management
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
IR	International Relations
O&M	Operation and Maintenance
SDGs	Sustainable Development Goals
SFD	Shit Flow Diagram

TP	Treatment Plant
TSS	Total Suspended Solids
UN	United Nations
UNICEF	United Nations Children's Fund
WASH	Water, Sanitation and Hygiene
WB	World Bank
WHO	World Health Organization
WSP	Waste Stabilization Pond

INTRODUCTION

During the development of a country with limited financial resources, sanitation is often neglected and other priorities frequently overshadow the country's agenda (World Bank, 2008). During 2005–2020, most Southeast Asian countries implemented initiatives that resulted in significant improvement in terms of access to improved sanitation. However, these countries continue to face multifaceted issues concerning the improvement of wastewater management. Many developing countries have failed to use centralised wastewater treatment to its full capacity and to subsequently address issues of severe water pollution and associated risks to human health; this can attributed partly due to the requirement of large initial investment for the construction of centralised wastewater treatment facilities and collection systems (Bao, Canh, & Mitra, 2020). Hence, affordable alternative approaches or solutions that can be employed by developing countries are needed. A decentralised wastewater treatment approach has recently been successfully demonstrated in several member nations of ASEAN (hereinafter referred to as 'ASEAN countries'), including Indonesia, Laos, the Philippines, Thailand and Vietnam, especially in rural and peri-urban settlements, as a short- and long-term solution in addressing the challenges of water pollution (Bao, Canh, & Mitra, 2020). However, the Decentralised Wastewater Management (DWM) approach is often avoided in the ASEAN region due to the local emphasis on large-scale wastewater treatment infrastructures (Sotelo, Satoh, & Mino, 2019).

To disseminate and promote the DWM approach to a larger audience (policymakers, wastewater and sanitation planners, government officials and wastewater and faecal sludge management (FSM) professionals), comprehensive capacity building and training modules have been developed for a city-wide inclusive sanitation approach and solution for the ASEAN region. This will not only increase awareness and comprehension of wastewater issues but also play a crucial role in reducing domestic wastewater-related constraints in the ASEAN region.

Objectives

The training modules presented in this document aim to equip water and sanitation professionals, decision-makers and sanitation planners in ASEAN countries with the basic knowledge and skills necessary to effectively implement a DWM approach, thereby facilitating the achievement of Sustainable Development Goal 6 (SDG 6), which pertains to access to clean water and sanitation.

Target audience

The training modules were developed for water policymakers, wastewater and sanitation planners, relevant government officials, private consultants, wastewater and FSM specialists and sanitation service providers. The training modules aim to guide local and national policymakers and experts in the development of appropriate strategies and policies, and that of institutional, legal, financial and environmental frameworks for sustainable DWM and FSM services. Additionally, these modules aim to equip trainees with a better understanding of the most significant drawbacks and limitations of existing sanitation approaches, as well as alternative and optimal solutions for improving the performance of sanitation services in the region.

Expected outcomes after the training

Upon completing the training modules, the participants will be able to:

- Understand the fundamentals and benefits of DWM in the context of achieving SDG 6 regarding providing clean water and sanitation services;
- Identify suitable implementation scenarios for DWM systems;
- Select suitable technologies and design appropriate DWM systems;
- Plan, manage and monitor the operation and maintenance (O&M) of the DWM systems;
- Analyse and adopt the best practices of ASEAN nations;
- Develop and implement DWM strategies in their respective countries to meet SDG 6 objectives.

Training methods and tools

- The training modules can be used to provide instruction through a combination of lectures, workshops, case study analyses, group discussions and field visits to facilitate hands-on learning and practical application of the concepts presented in the modules.
- The use of the variety of methods and tools outlined in these modules will ensure a comprehensive and engaging learning experience for participants. Some of these include:
  a. Lectures and presentations by field experts;
  b. Interactive workshops and group activities;
  c. Case study analyses and problem-solving exercises;
  d. Field visits to the DWM facilities and projects;
  e. Panel discussions and Q&A sessions with practitioners and policymakers;
  f. Role-playing and simulation exercises;
  g. Peer-to-peer learning and knowledge exchange;
  h. Individual or group assignments and assessments;
  i. Online resources, readings and multimedia materials for self-paced learning.

By incorporating these diverse learning methods and tools, the training modules aim to equip participants with a well-rounded understanding of DWM and its potential to advance water and sanitation outcomes in their respective countries. The training will also provide opportunities for networking, collaboration and knowledge exchange among water and sanitation professionals in ASEAN countries, fostering a community of practitioners dedicated to achieving SDG 6 through effective DWM implementation.

TRAINING MODULES

Module 1. Introduction to Decentralised Wastewater Management (DWM)

1.1. Overview of SDG 6: Water and sanitation

Access to improved sanitation is essential for ensuring public health and well-being. According to the Sustainable Development Report 2022, while the entire population of Singapore has access to improved sanitation, 99.6% of the population of Malaysia and more than 90% of the population in Brunei Darussalam and Thailand have access to improved sanitation. Hence, although access to basic sanitation services has increased in ASEAN countries, most of these countries are not on track to meet the SDG sanitation target. This indicates that substantial progress is required for the ASEAN region's overall development.

Table 1. Population of ASEAN countries with access to basic sanitation (as of 2020)

Country	Value (%)	Rating	Trend
Thailand	98.7	🟠	⬆
Philippines	82.3	🟢	⬆
Singapore	100	🟠	⬆
Indonesia	86.5	🔵	⬆
Myanmar	73.6	🔴	➡
Malaysia	99.6	🟠	-
Lao PDR	79.7	🟢	⬆
Brunei Darussalam	96.3	🟠	-
Vietnam	89.2	🔵	⬆
Cambodia	68.8	🔴	⬆
Timor-Leste	56.8	🔴	➡

(Source: Sustainable Development Report, 2022)

🟠 SDG achievement 🔵 Challenges remain 🟢 Significant challenges remain 🔴 Major challenges remain

⬆ On track ➡ Stagnating - Data not available

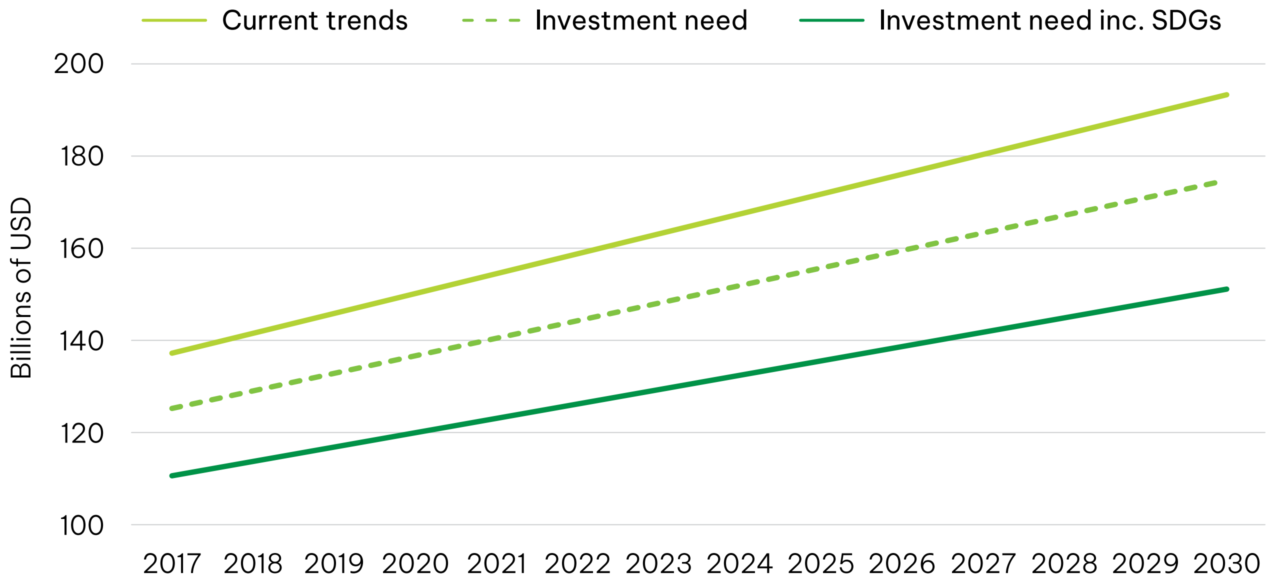
In Southeast Asia, decentralised wastewater treatment is reportedly the predominant wastewater treatment system. Most countries in the region favour decentralised wastewater technology in rural areas and centralised wastewater technology in urban areas. Due to the availability of funding and community participation, Lao PDR and Timor-Leste for instance, favour decentralised wastewater treatment systems for rural and urban settlements. Other nations, including Indonesia, Malaysia, Thailand and the Philippines, are planning to implement centralised wastewater systems in urban areas. Cambodia and Myanmar also favoured centralised wastewater systems but restricted their use to urban and tourist areas.[1]

1.1.1. Investment gap for the SDGs

The majority of Southeast Asian countries show significant infrastructure investment gaps. To achieve SDGs, till 2030, ASEAN countries need to invest an additional USD 35 billion annually in infrastructure (Figure 1). Cambodia and Myanmar have infrastructure investment gaps of 78% and 186%, respectively, while Singapore shows an investment gap of only 0.3%. Increasing infrastructure investment is essential for the national development of ASEAN nations as they currently require an average of 53 billion USD per year until 2030 to finance and address the water and sanitation deficit.[2]

1 Sotelo T. J., Satoh H., Mino T. (2019). Assessing wastewater management in the developing countries of Southeast Asia: Underlining flexibility in appropriateness https://doi.org/10.2965/jwet.19-006

2 Inclusive Sanitation Needed to Address Service Gap in Asia and Pacific. https://www.adb.org/news/inclusive- sanitation-needed-address-service-gap-asia-and-pacific



** Figures do not include estimates for Lao PDR and Brunei.*

Figure 1. ASEAN Infrastructure Investment Gap (Total, in billions of USD)
(Source: IMF, 2018)

The annual investment gap in water and sanitation in developing nations is estimated to be 487 billion USD (UNCTAD, 2023). According to the WB, *'we are around $114 billion short of achieving the UN SDG 6 on water'*[3] thus indicating that 114 billion USD per year is required from now until 2030 to attain the clean water goal of SDG 6 (UNCTAD, 2023). By 2030, Malaysia, Indonesia, the Philippines, Thailand and Vietnam alone will need to invest 1.3 trillion USD towards SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry, Innovation and Infrastructure), with an estimated shortfall of 538 billion USD (ASEAN, 2021). Furthermore, the funding gap for WASH is estimated to be roughly two-thirds of the total investment needed, or 487 billion USD, given that WASH funding needs are just over three times the historical financing trend (UNCTAD, 2023). Additionally, a 114 billion USD estimate was made for meeting the entire capital cost of WASH needs (UNCTAD, 2023). SDG 6.1 and 6.2, that address WASH needs, constitute only a small percentage of the total funding required to achieve SDG 6.

3 IWA. https://iwa-network.org/water-financing-and-partnerships-fundamental-to-achieve-sdgs/

1.1.2. Regional water security

The United Nations (UN) has defined water security as 'the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability'.[4]

Temperature fluctuations and weather unpredictability are increasing the pressure on water supplies in nearly every ASEAN country. Droughts and water shortages affected an estimated 66 million people in the ASEAN region over the past three decades. Bangkok's tap water became salty in 2020, when the Chao Phraya River's water level dropped too low to prevent salt intrusion.

Further, multiple water-related risks and dangers have threatened the lives of millions of people residing in megacities such as Bangkok, Jakarta and Manila. For instance, in 2019, thousands of households in Manila lost their water supply as the water level in dams dropped below the critical level. When water infrastructure and sanitation services cannot keep up with rapid urbanisation and population growth, water pollution levels increase uncontrollably. Human waste, industrial pollutants and raw sewage are frequently dumped untreated into natural water sources, thus negatively impacting human health and well-being. Several regions are susceptible to typhoons, floods and other natural disasters, which adds to the complexity of the situation. Recent heavy rainfall in 2020 and 2022 in Jakarta and Thailand's southern provinces triggered massive flooding, displacing thousands and causing significant human suffering. Similarly, Malaysia is currently experiencing issues that can be traced back to the Peninsular Malaysia tropical depression of 2021. The ASEAN Secretariat predicts that fresh water demand will increase by one-third by 2025 and double by the end of the 21st century (Maniam, Poh, Htar, Poon, & Chuah, 2021).

4 UN 'Water Security'. https://www.unwater.org/publications/what-water-security-infographic

Additionally, Figure 2 compares the percentage of Southeast Asia's urban population to that of the rural population regarding access to improved water sources in 2020. Thailand attained 100% access to at least limited water services in both urban and rural areas (Maniam, Poh, Htar, Poon, & Chuah, 2021). In countries such as Cambodia, Laos, Myanmar and Timor-Leste, an urban-rural divide remains, as shown in the graph below. Moreover, in 2020, Cambodia and the Philippines had significantly lower populations using safe drinking water than the global average (74.3%)—27.8% and 47.5%, respectively—as compared to that of 93.8% and 100% in Malaysia and Singapore, respectively.[5]

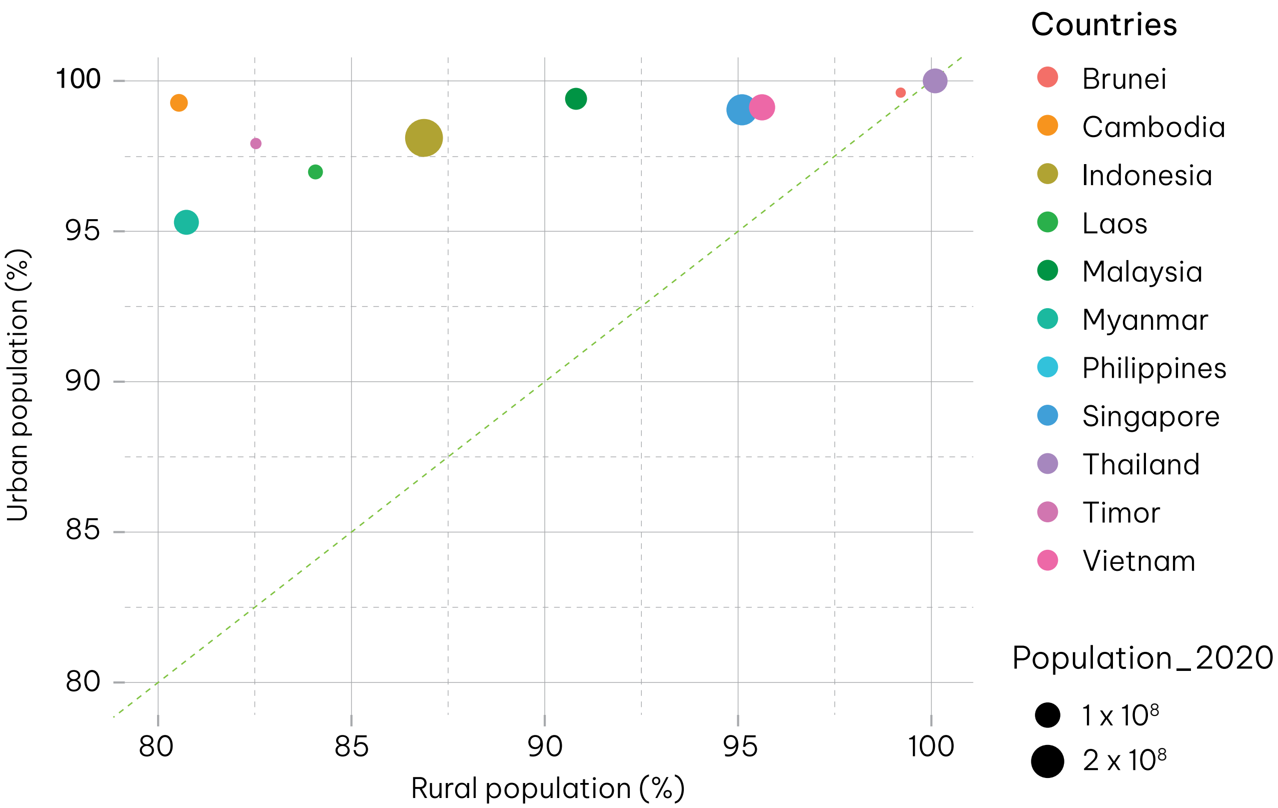


Figure 2. Urban and rural populations (%) with access to improved water sources in 2020 in Southeast Asian countries (excluding Singapore as it has zero rural population) *(Source: Maniam, Poh, Htar, Poon, & Chuah, 2021).*

5 Water Literacy in Southeast Asian Context: Are we there yet? https://doi. org/10.3390/w13162311

1.2. Significance of appropriate domestic wastewater management in ASEAN

Figure 3. Location map of ASEAN countries
(Source: ASEAN, 2022)

1.1.3. Regional disparities

Brunei Darussalam

In all major cities in Brunei Darussalam, owing to the national housing scheme, centralised sewage systems are the most prevalent. The surrounding populations that are served and/or connected by a centralised sewerage system are exempt from payment for the service. However, in peri-urban and rural areas, where there is no centralised sewerage system, septic tanks are predominantly used in the residential, public, commercial and industrial sectors. The private sector is responsible for septic tank provision. As of 2019, 59% of the population of Brunei Darussalam had access to a centralised sewerage system and 34% of the population had access to septic tanks (UNHCR, 2020). It has been reported that the development of a public–private partnership is crucial for promoting and expanding the maintenance of decentralised wastewater treatment facilities, sludge removal and performance testing and quality assurance of decentralised wastewater treatment facilities (NIES, 2020).

Cambodia

The typical Cambodian sanitation system consists of an on-site (pit latrine or tank) and off-site component (the sewer and drainage network). Before discharging wastewater into sewerage systems comprising sewers and open canals, pre-treatment is common in both urban and peri-urban areas. Outside the sanitation service coverage area, on-site systems are prevalent among households. Despite the existence of an institutional framework, the definition of responsibilities of public health, drainage and sanitation management for ensuring sanitation is insufficient. Actual urban sanitation conditions are extremely poor as a result of poorly designed sanitation systems that provide little or no effluent treatment or pre-treatment. Generally, sewage sludge is dumped into the environment without appropriate treatment.

Indonesia

Indonesia's wastewater management includes both on-site and off-site systems, including individual and community-based wastewater collection and treatment facilities; public services and facilities that are designed to extract, handle, transport and treat septic tank sludge; and, centralised sewage systems comprising public sewer networks and wastewater treatment plants. Although more than 80% of the population has access to basic sanitation, safe collection and disposal of domestic wastewater and faecal sludge (FS) continues to be rare. In urban Indonesia, only 1% of wastewater (WEPA, 2021) and 4% of FS are collected and treated in a safe manner (Harahap, Suprayogi, Gunawan, & Widyastuti, 2021). In rural Indonesia, wastewater is neither collected nor treated (WEPA, 2021). Organic load from domestic wastewater is the most significant contributor to river pollution, particularly in large cities (Harahap, Suprayogi, Gunawan, & Widyastuti, 2021). Approximately 70% of Jakarta's water pollution is caused by organic pollutants from domestic wastewater (Harahap, Suprayogi, Gunawan, & Widyastuti, 2021). It was estimated that in 2015, Indonesia ranked the second highest in terms of open defecation, with 12.9% of the population still practicing open defecation (Sari, et al., 2022). In 2021, the estimated population of Indonesia was 288.22 million— of which 32.77 million continue to practice open defecation (Sari, et al., 2022). Thirty-three out of 34 provinces in Indonesia are not yet verified as open defecation free (ODF) areas (Sari, et al., 2022). This issue is frequently side-lined and not prioritised by the government and society. While the number of decentralised wastewater treatment systems has increased in Indonesia, these systems are not operating effectively due to underutilisation.

Lao PDR

Geographically, 70% of Laos comprises mountainous terrain, with numerous remote and isolated communities. Most households in Laos utilize on- site sanitation systems, such as a pour-flush toilet connected to a septic tank or soak pit. There is a growing concern that faeces and coliforms from latrines and septic tanks are contaminating the groundwater. Only a small portion of urban areas are served by sewerage facilities. Additionally, the country’s frequent exposure to extreme weather events and natural disasters, such as floods, makes it vulnerable to climate-related issues and affects its water security and sanitation infrastructure. It is estimated that Laos loses approximately 2.8%–3.6% of GDP due to the impact of flooding on the government operations, businesses and households (UN-Habitat, 2023). Despite obstacles, the country declared Bolikhamxay as the first province free of ODF in 2020 (SWA, 2020). Seven out of 10 households in the country have access to basic sanitation facilities (the coverage increased from 57% in 2012 to 71% in 2017) (SWA, 2020). The rate of ODF decreased from 38% in 2011/12 to 24% in 2017 (SWA, 2020).

Malaysia

Malaysia’s wastewater management consists of on-site systems—including individual septic tanks, communal septic tanks and pits—in addition to off-site systems that include a sewer network connected to public and private sewage treatment plants. Indah Water Konsortium (IWK) is the country's primary operator of sewage systems, with a service area of 88,741 km2 covering 25 million people. IWK operates and maintains 6,745 wastewater treatment facilities, 1,188 pumping stations and 19,134 km of sewer network (WEPA, 2021). Furthermore, the country has 10,773 public and private treatment facilities (WEPA, 2021). The country's sludge treatment uses both mechanised and non-mechanised systems, including belt presses, centrifuge decanters and filter presses, as well as geobags, sludge lagoons and drying beds. Currently, there are no tertiary treatment systems in Malaysia. The performance of automated sewage treatment plants is superior to that of non-mechanised facilities. The nation is transitioning from non-mechanical to mechanical systems with improved equipment. However, the low sewerage tariff has resulted in mechanical systems being unfeasible for long-term operation due to the high operational and maintenance costs. Additionally, the growing trend of private developers handing over sewerage infrastructures to public operators has created a quality assurance risk that impacts treatment operation and procedure.

Myanmar

In Myanmar, domestic wastewater is usually released into storm water drainage facilities and natural water sources. Both urban and rural areas of Myanmar have inadequate wastewater and sanitation services: large urban areas such as Yangon, Mandalay and Nay Pyi Taw have inadequate wastewater management services, and these services are significantly worse in the low-income areas of the country. In addition to the central business districts, none of the above-mentioned three cities operate conventional wastewater and sewerage collection and treatment. In Yangon, only 7% of the population has access to a treatment facility that manages wastewater and sewage waste (WEPA, 2021). The sludge from this facility is used as fertiliser, while the treated water is discharged into the Yangon River. For the remainder of the city, vacuum trucks transport septic tank waste to treatment ponds. Vacuum trucks in Mandalay transport sewage from septic tanks to oxidation ponds. After evaporation, the remaining sludge is used as fertiliser. However, despite having a population of approximately 1.2 million, the city lacks a central treatment system (WEPA, 2021). In Nay Pyi Taw, septic tanks or pit latrines with slabs are the predominant containment systems (WEPA, 2021). There is a centralised wastewater treatment facility serving a population of 10,000 in Wannatheikdeed Quarter (IGES, 2016), whereas a newly developed area is served with a treatment facility with a capacity of processing a volume of wastewater of 1,600 m^3/day (covering only 20% of the population of that area) (WEPA, 2021).

Philippines

The Philippines, like most Southeast Asian nations, heavily relies on on-site sanitation systems. Only 5% of the population is connected to a sewerage system (WEPA, 2021). The majority of households use flush toilets that are connected to septic tanks. However, only 10% of all generated wastewater is appropriately treated (WEPA, 2021). Manila's 43 sewage and septage treatment plants serve 9% of the country's population, or millions of residents (WEPA, 2021). The discharge of untreated domestic wastewater is the primary source of water pollution in the country (based on the BOD loading), accounting for 33% of all water pollution sources (WEPA, 2021). Due to insufficient treatment infrastructures, the high demand for water is met with limited supply; additionally, increasing volume of pollutants and hazardous wastes, including increasing amounts of solid waste, has been a major challenge for the Philippines (WEPA, 2021). Therefore, the government should allocate a specific budget for research and development; additionally, facilitating a rapid increase in stakeholders' access to updated and new information is key for developing appropriate policies (WEPA, 2021).

Thailand

Thailand, with a population of 64 million, produces 9.7 million cubic metres of domestic wastewater daily. In Thailand, blackwater from toilets undergoes preliminary treatment in on-site sanitation systems at individual residences, which serve as the basis of sanitation. The greywater and effluent from on-site sanitation systems are subsequently channelled to the sewer network or drains, where 27% of the channelled fluids are treated by 105 centralised wastewater treatment plants and safely disposed of into receiving water bodies, and 73% is disposed of in the open environment (PCD, 2019). Although every household uses an on-site sanitation system, the existing FSTP can only treat 13% of FS, and the rest is released into the open environment (PCD, 2019). The type of on-site sanitation used depends on the social and economic conditions of the community. For instance, in newly developed housing estates, commercial watertight septic tanks are the norm, whereas in urban slums, typically located along canal corridors, cesspools, pit latrines and natural vegetative drainage dominate. In older homes, cesspools are the most prevalent on-site sanitation system.

Figure 4. Bang Pla treatment plant, Samut Sakhon province, Thailand
(Source: Suraj Pradhan, 2020)

Vietnam

The majority of urban and suburban households in Vietnam are equipped with storm drainage systems that are connected to septic tanks to form a combined sewerage system. It has been estimated that 60% of urban septic tanks are connected to sewer or drainage systems (EMW, 2019). The predominant system employed is septic tanks. As of 2019, Vietnam had 30 operational centralised wastewater treatment plants, with another 33 plants undergoing construction (EMW, 2019). Despite the planning and construction of wastewater treatment plants, most facilities rarely operate at full capacity. Less than 30% of the generated domestic wastewater is treated appropriately, and the remaining amount is discharged into water sources (WEPA, 2021). Efforts have been made by both central and local governments, including donor agencies, to improve environmental protection, particularly in large cities and provinces such as Hanoi, Da Nang and Ho Chi Minh City (WEPA, 2021). However, the issue of surface water pollution remains and continues to intensify due to contamination from organic substances, nutrients and microbial species (WEPA, 2021) since these areas receive large amounts of untreated or partially treated wastewater from both domestic and industrial sources. Moreover, although private companies in the country do not have legal access to landfills, they frequently dispose of collected untreated wastewater in landfills or in open areas.

Figure 5. Wastewater treatment, Phan Thiet, Vietnam.
(Source: Suraj Pradhan, 2019)

1.2.1. Major factors contributing to improved sanitation

The primary responsibilities of the central and local governments are the creation of an effective and sufficient legislative and regulatory framework, and the allocation of funds, respectively. Sanitation initiatives encompass significantly more factors than hardware distribution; thus, the regulatory framework must describe the protocol for the institutionalisation process within the public domain at both horizontal and vertical levels (Ulrich et al., 2009). The delineation of roles and collaboration across several ministries and departments (public works, environment, health, etc.) and their distribution at the local and national levels warrant particular attention. The crucial significance of sanitation programmes in the integral development of a region should be understood by both regional and municipal administrations (Ulrich et al., 2009). Establishing and implementing sanitation objectives and the schedules to meet these objectives should be in accordance with national laws, regulations and standards. Monitoring and effective coordination between relevant governmental organisations should be ensured at the regional and municipal levels (Ulrich et al., 2009). In most cases, the local government is in charge of providing sanitation facilities. During the implementation of sanitation objectives, the government must accomplish the following: raise community awareness, make decisions by closely consulting representatives of affected communities, develop implementation schemes, allocate funds, oversee implementation, establish sludge treatment systems and ensure programme sustainability (Ulrich et al., 2009). Plans for sanitation need to be created in close conjunction with local communities. Sanitation projects typically fail without the active participation of households because the general population's awareness and sanitation practices are the foundation of good hygiene. Community participation is crucial to guarantee consistent use, ongoing upkeep and funding of sanitation facilities (Ulrich et al., 2009). In addition to providing high-quality hardware, private sector businesses must guarantee ongoing operation and maintenance of sanitation facilities (Ulrich et al., 2009). Models of public-private partnerships can guarantee the installation and upkeep of sanitary infrastructure on a broad scale (Ulrich et al., 2009). Non-governmental organisations are responsible for initiating and facilitating the development and execution of sanitation projects in numerous nations. They initiate campaigns to raise awareness, assist in community decision-making, create channels of contact between the public and local government and sometimes even serve as service providers or implementing agencies. Their responsibilities are determined by the institutional competencies and profile of each participating organisation as well as the regional characteristics of the project area (Ulrich et al., 2009).

(1) Adequate access: This is defined by the physical proximity of the latrine from one's residence, the number of people that use the latrine and the ease of use for special groups such as women and girls, the elderly and disabled people.

(2) Hygienic or sanitary latrine: This is defined as easy access to sanitary and hygienic latrines that are operational throughout the year. A sanitary and hygienic latrine separates faecal matter from the environment (including people, insects and rodents) and contains no excreta in or around the latrine.

(3) Adequate use: This is defined as consistent and hygienic use of a sanitary latrine by all household members when they are in or around the house, throughout the entire year.

(4) Reliability: This refers to the continued serviceability of a latrine. It relates especially to regular or routine O&M activities, including pit-emptying services, upgrading (if desired and if necessary) and replacement.

(5) Environmental protection: This implies that there are no problematic environmental impacts such as faecal contamination of land and/or water due to the provision of sanitation facilities, and FS is disposed of or used for productive purposes.

(6) Handwashing with soap: This refers to the regularity of handwashing with soap following defecation and before handling food.

(7) **Political support and commitment:** Although these are often lacking, they are considered crucial components to ensure ongoing success of a sanitation project. It is necessary to leverage policy reform, allocate adequate resources and make appropriate use of budgeted resources to ensure continue support to a sanitation project.

(8) **Demand creation and advocacy for behavioural change:** This includes promoting a lasting change in social norms that favour the adoption of hygiene- and sanitation-sensitive behaviours, thus creating a demand for services and supplies that underpin the changed behaviour.

(9) **An enabling environment includes the following:**

- Broad and long-term political commitment;
- A well-developed sanitation strategy and policy framework;
- A clear and well-aligned institutional framework at the central and decentralised levels;
- Sufficient number of dedicated personnel with adequate skills;
- Monitoring and evaluation systems to support learning and monitor programme outcomes.

(10) **A supply chain:** This includes a well-developed and competitive supply chain which addresses the increased demand for sanitation-related services across the full sanitation life cycle—including construction, maintenance, upgrading and emptying.

(11) **Incentives and finance instruments:** These include appropriate and well-aligned financial resources which support service provision.

(12) **Safe and final disposal:** This also includes productive uses of FS.

1.3. Principles and benefits of Decentralised Wastewater Management

(a) Sewered vs. Non-Sewered

Sewered sanitation is also referred to as sewer systems, sewerage systems, sewers, networked sanitation and connected sanitation. This is defined as a sanitation system that transports wastewater via a network of pipes to another location for treatment, reuse, or discharge. Seweraged sanitation refers to a network of underground pipes, pumping stations and treatment facilities which collect and transport wastewater and sewage from homes, businesses and other facilities to a central treatment plant for treatment and disposal.

Non-sewered sanitation, also known as on-site sanitation, is a sanitation system which collects and stores excreta and used water on the site they are produced. The FS must be transported away from the site for treatment, utilisation, or disposal. FSM involves the safe storage, collection, transportation, treatment and final use or disposal of FS. FSM is concerned with on-site sanitation systems. In areas where centralised sewer systems are not feasible, non-sewered sanitation can be an efficient and cost-effective method for managing human waste and wastewater. However, ensuring that waste is collected, treated and disposed of in a manner that safeguards public health and the environment requires meticulous planning, management and supervision.

(b) Conventional centralised vs. Decentralised Wastewater Management

Conventional centralised wastewater management

Large sewer systems with high-tech centralised wastewater treatment plants have contributed to the improvement of human health and the reduction of wastewater's impact on the environment. However, they require vast quantities of water, high construction and operation costs, energy and chemical consumption and stringent management requirements. Hence, while the conventional system for waste collection and transport may be comprehensive, it is also extremely resource intensive. Therefore, the high initial investment and substantial O&M costs of this system prevent its widespread adoption in cities of all sizes.

Decentralised system

A decentralised system depends on on-site sanitation technologies used for waste treatment. Scum and sludge are usually mixed at the point of generation, and both are emptied together into the septic tank or any other 'containment' system. However, for the treatment of scum and sludge, some distinct technologies are used. This system is suitable for housing clusters, since it can be used to collect wastewater from a small cluster of homes and subsequently transport it to a treatment facility.

Application of decentralised wastewater treatment systems

- This system is typically installed on properties where the available land area is insufficient to accommodate an on-site treatment system.
- This system can be employed when the financial cost of constructing conventional centralised treatment facilities is not feasible.

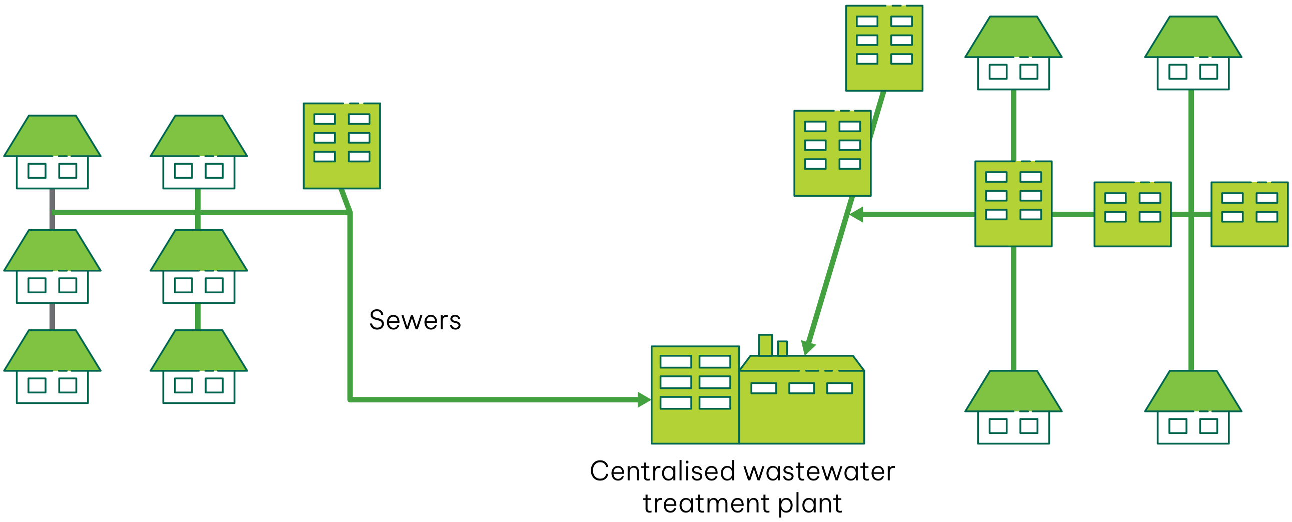


Figure 6. Conventional centralised wastewater treatment approach

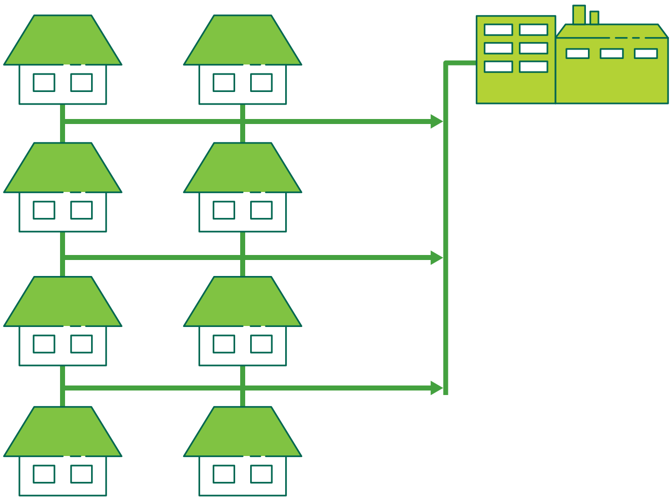


Figure 7. Decentralised wastewater treatment approach

Why is Decentralised Wastewater Management approach significant?

DWM consists of a variety of approaches for the collection, treatment and reuse of wastewater for individual or clusters of homes or businesses and communities. As part of DWM, an evaluation of site-specific conditions is performed to determine the appropriate type of treatment system for each location. These systems are a part of the permanent infrastructure and can be managed as standalone facilities or be integrated with centralised sewage treatment systems. They provide a range of treatment options, ranging from simple, passive treatment with soil dispersal, commonly referred to as on-site systems, to more complex and mechanised approaches such as advanced treatment units that collect and treat waste from multiple buildings and discharge it to natural water resources or agriculture fields/ soil. They are typically installed at or near the point where wastewater is generated.

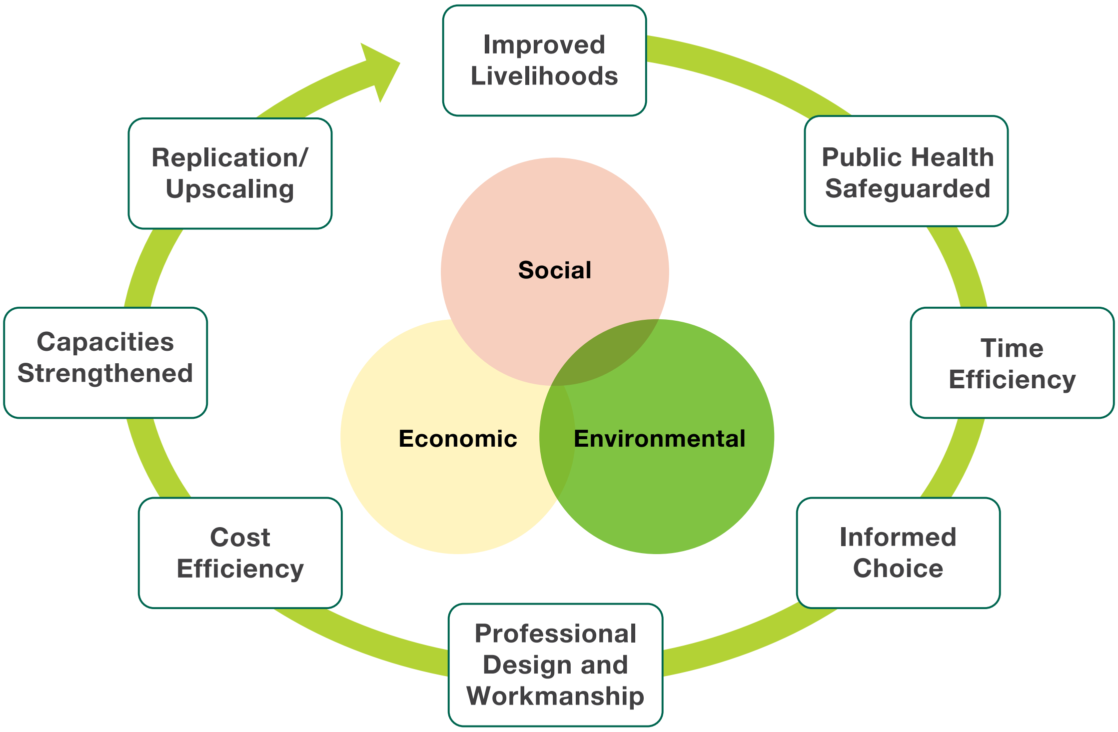


Figure 8. Benefits of DWM based on social, economic and environmental dimensions
(Source: UNESCAP & AIT, 2015)

Some major characteristics of decentralised wastewater treatment systems are as follows:

- They treat wastewater flows ranging from 1–1000 m^3/day per unit.
- In addition to technical and engineering aspects, the specific local economic and social situation should be considered when selecting decentralised wastewater treatment options.
- There is a provision of primary, secondary and tertiary wastewater treatment solutions for residential, community and commercial areas.
- DWM is complementary to other approaches, especially conventional centralised wastewater treatment options; it is an integral part of comprehensive wastewater management strategies.

- Depending on the technical configuration, biogas produced by decentralised wastewater treatment solutions (in the case of anaerobic digesters) can be used as a renewable energy source.
- The main characteristics of DWM include reliability, durability, inflow tolerance, cost effectiveness and most importantly, simple maintenance requirements.
- DWM facilitates independence from external energy sources, leads to more reliable operation and less variation in effluent quality. However, pumping may be required to lift water in decentralised wastewater treatment systems.
- The appropriate combinations of treatment modules can be selected based on the required treatment efficiency, costs, land availability, etc.
- Although decentralised wastewater treatment systems can be constructed with locally accessible materials and implemented by the local labour force, planning and construction quality standards must be met.
- These systems require operators with simple O&M skills. While most operational tasks can be performed by the users themselves, certain maintenance services may require the assistance of a local service provider. In some instances, the same service provider can provide both O&M services.
- These systems enable the reduction of pollution load, thus complying with regulations. The handling, treatment and disposal of generated sludge must comply with international and/or national standards (Ulrich et al., 2009).

Advantages of Decentralised Wastewater Management

a. Cost effectiveness

- The requirement for an underground sewer system is eliminated or partially required.
- Low capital and O&M expenses due to limited mechanical and electrical system complexity.

b. Environmentally sound

- Reduction/elimination of electric energy consumption.
- It is odourless and can be constructed in a liveable area.

c. User acceptance

- Minimal O&M costs and requirements because fewer personnel are required.
- Simple and efficient user participation and involvement (e.g. in decision-making and O&M).

d. Flexibility

- It can be constructed relatively easily in remote locations by using locally accessible materials and skills.
- It can be constructed in accordance with household, cluster and community scales (NIUA, 2019)

Disadvantages of Decentralised Wastewater Management

Although policymakers accept the decentralised approach, the lack of a comprehensive capacity to plan, design, implement and operate decentralised wastewater treatment systems hinders its widespread implementation. In many developing countries, there are insufficient institutional arrangements and a limited framework for promoting the DWM approach. Existing issues regarding institutional capacity under a centralised approach, such as lack of technical support and other capacity building measures, are simply transferred to this new approach. Due to the absence or insufficiency of a formal institutional framework for a decentralised approach, efforts to implement DWM systems are likely to remain fragmented and unreliable (NIUA, 2019). Therefore, the introduction of this new approach requires considerable coordination among the government, private sector and civilians. This approach must be compatible with locally available knowledge and skills, as even the simplest technologies frequently fail when O&M requirements are neglected.

1.4. Exercises

(1) What is DWM and how does it differ from other pre-existing paradigms?

(2) Why should such an approach be adopted, especially in the context of ASEAN?

(3) Why do you think the conventional sanitation approach has been predominant in past years?

(4) Why do you think sanitation solutions have been more technology-focused and less holistic in all pre-existing paradigms?

(5) Why do we need to change our conventional approach to sanitation? How will this change affect the provision of sanitation services? What are the potential benefits of this change? How will it change public perception and response to public health issues? How will this change affect the development and implementation of sanitation technologies?

(6) Do you agree that it is imperative to change the way in which sanitation is handled if we are to meet SDG 6 goals and targets for sanitation by 2030?

(7) Please share your views regarding the impact of the decentralised approach in terms of the SDG 6 sanitation targets.

Module 2. Key components of Decentralised Wastewater Management

DWM exists at different levels on the sanitation ladder; geographically, it ranges from the household to city district level (UNESCAP & AIT, 2015). However, a case study of the development of sanitation in Indonesia revealed that decentralised systems are a stepping stone towards city-wide centralised facilities (UNESCAP & AIT, 2015). Although improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact, the sanitation ladder only considers the far-left hand side (containment) of the sanitation service chain and focuses on selected technologies rather than on the overall function of a sanitation system (UNESCAP & AIT, 2015). Therefore, the majority of problems related to appropriate domestic wastewater management arise from a lack of consideration of the other components of the sanitation value chain.

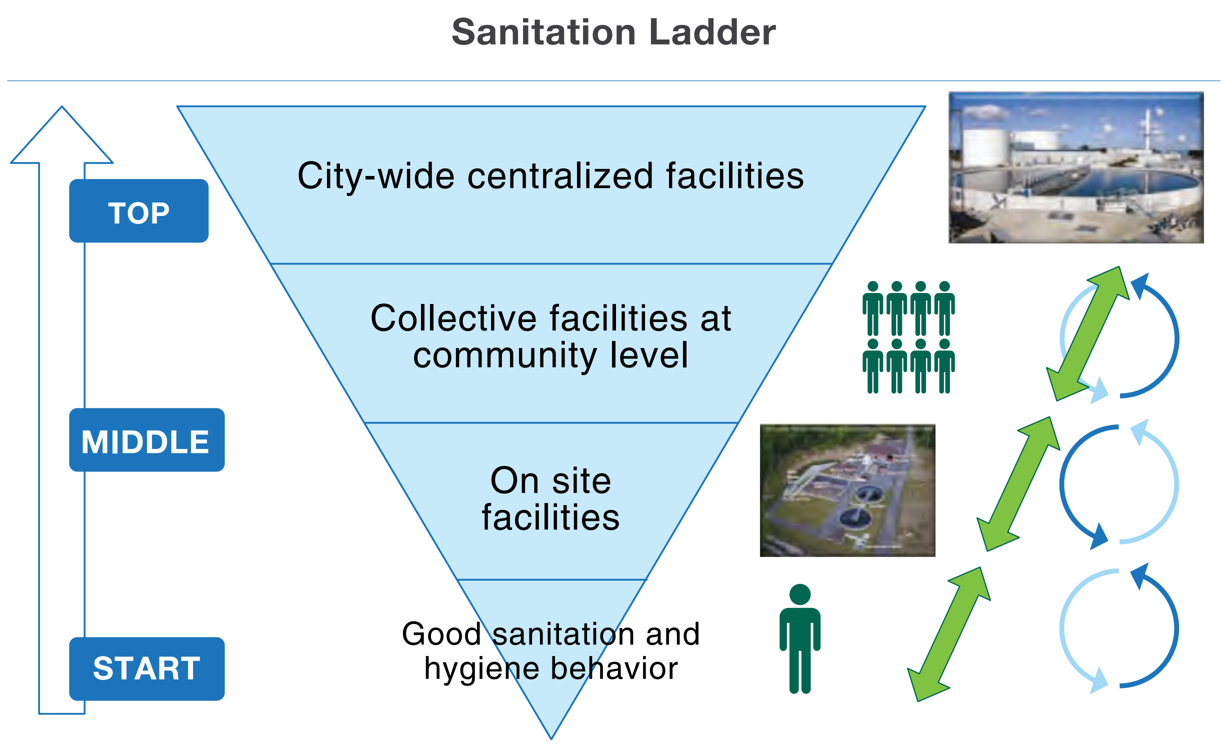
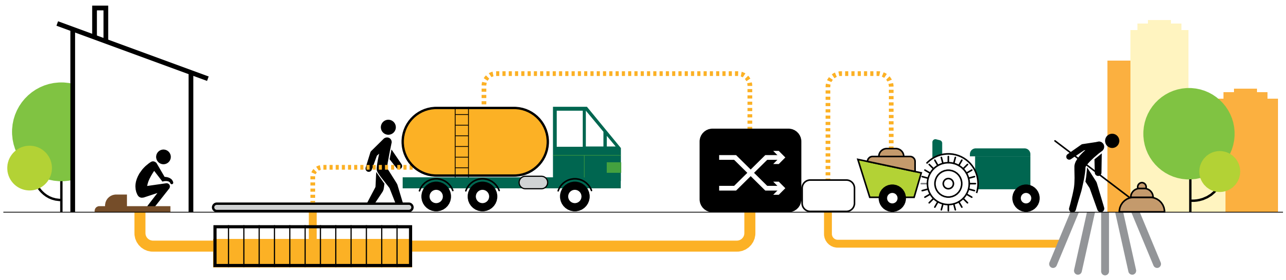


Figure 9. Different levels on the sanitation ladder

(Source: UNESCAP & AIT, 2015)



Toilet	Containment storage/ Treatment	Conveyance	Treatment	End use/ Disposal	
Without quality toilets that everyone uses, families and communities are at increased risk of disease, anxiety and violence.	Without proper onsite containment or treatment, water used for drinking, recreation and agriculture can be contaminated.	Workers without adequate protections face life-threatening risks when emptying pits and septic tanks and cleaning sewers. Waste spilled or dumped before treatment puts whole communities and food supplies at risk.	Communities are put at risk when untreated wastewater and sludge pollute beaches, drinking water, and water sources used for irrigation of food crops.	Drinking or coming into contact with untreated water perpetuated the cycle of infection - especially of intestinal worms and diarrhoea.	If wastewater and sludge are used safely, valuable water, nutrients and energy can be returned to the circular economy.

Figure 10. Major components of the sanitation value chain
(Source: UNICEF, 2022)

2.1. On-site treatment systems

An on-site treatment system is commonly referred to as a sanitation system in which excreta and wastewater are stored, collected and/or treated on the property they are produced. Therefore, at the location of the groundwater used for drinking, a risk assessment should be conducted to ensure that there is sufficient vertical (a minimum distance of 1.5 m) and horizontal distance (a minimum distance of 1.5 m) between the base of a permeable container, soak pit, or leach field and the local water table and/ or source of drinking water. When a tank or pit is equipped with an outlet, the effluent should be directed to a soak pit or leach field. It must not discharge into an open drain, a body of water, or the open ground. Furthermore, treatment systems can be designed to handle various types of wastewater. For instance, on-site systems can handle a mixture of greywater and blackwater, greywater alone, or blackwater alone. When products from storage or treatment in an on-site containment technology are handled for final use or disposal, risk assessments should be conducted to ensure that workers and/or consumers observe safe operating procedures.

2.2. Cluster or community treatment systems

These treatment systems are designed to serve a group of houses or businesses. A cluster collects wastewater from two or more dwellings or buildings that are under some form of common ownership. There may be a need for more than one plant to serve the entire community. They provide the community with the flexibility to continue with on-site treatment based on the settlement density. They transport the wastewater to a treatment and dispersal system located near the community. Cluster systems are prevalent in rural subdivisions.

2.3. Collection and transportation

Manual or mechanical collection and transport can be used to remove wastewater and FS and transport them (for example, via vacuum trucks) to treatment facilities or disposal sites. However, whenever possible, motorized transport and emptying should take precedence over manual transport and emptying. The risks of handling wastewater and/or FS and standard operating procedures should be communicated to all employees. Specifically, when manual emptying is required, all workers should wear personal protective equipment (such as gloves, masks, hats, full overalls and enclosed waterproof footwear).

2.4. DWM treatment technologies

Regardless of the source (such as wastewater from sewer-based technologies or FS from on-site sanitation), both liquid and solid components must be treated before final use or disposal. The treatment facility should be designed and operated in accordance with the end use/ disposal objective and should use a risk assessment and management strategy to identify, manage and monitor system-wide risks. Typically, a biogas digester or settler can serve as the primary treatment unit in a typical modular of dentralised wastewater treatment system configuration. The secondary anaerobic treatment unit is often an anaerobic baffled reactor (ABR) used in conjunction with an anaerobic filter (AF). Certain systems incorporate tertiary treatment in the form of a planted gravel filter (PGF). Post-treatment can occasionally occur in an aerobic polishing pond. The precise arrangement and allocation of modules differs throughout systems and is customised to meet the specific needs and circumstances of many communities. The list of technologies, successful case studies and details of the technologies are discussed below and in Modules 4 and 6.

Basic treatment methods

Treatment methods	Removal methods	Technologies
Physical treatment	Screening	Screening
	Filtration	Filtration
	Differences in specific gravity	Sedimentation/flotation separation
	Heat energy	Evaporation/drying
	Electric energy	Electrolysation
	Osmotic pressure	Reverse osmosis membrane
Chemical treatment	Oxidation reaction	Oxidation
	Reduction reaction	Reduction
	Metathesis reaction	Neutralization/flocculation
Physio- chemical treatment	Interface potential	Coagulation-sedimentation/ Coagulation-flotation
	Adsorption	Activated carbon adsorption
	Ion exchange	Ion-exchange resin
	Electrochemical reaction	Electrolysation
	Supercritical reaction	Supercritical oxidation
Biological treatment	Aerobic decomposition	Activated sludge method
	Anaerobic decomposition	Anaerobic digestion
	Anaerobic-aerobic decomposition	Denitrification/enhanced biological phosphorus removal

2.5. Reuse and resource recovery

Wastewater and sludge inherently pose risks to hygiene and health, emphasizing the critical need for their proper management. Ensuring safety for both the environment and human populations necessitates the implementation of comprehensive precautions. The selection of the most appropriate technology and system for disposal and reuse hinges on various factors, including the characteristics and intended reuse of the final product, whether it be biogas or a byproduct like dried sludge from earlier sanitation processes.

The decision-making process must also incorporate considerations of available skills and capacities, alongside geophysical, socio-cultural, financial, institutional, and regulatory contexts. These factors collectively guide the choice and configuration of technologies for the effective disposal and reuse of wastewater and sludge.

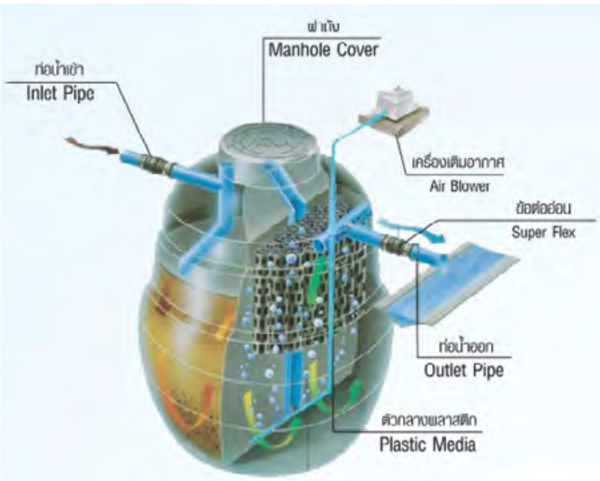
Figure 11. Emptying, Senegal.
(Source: Ashreya Krishna Shrestha)

Ultimately, the determination of the optimal approach for disposal or reuse is influenced by the potential applications, local environmental conditions, legal and regulatory requirements, and the treatment technology's efficacy. This careful selection and design process ensures the safe disposal or beneficial use of treated residues, safeguarding public health and the environment.

2.6. List of technologies adopted in different locations

The concept that "more expensive systems incur higher costs" is highlighted by offering prospective users a range of options for sanitary facilities and services. This approach allows users to eliminate alternatives that are not relevant to their specific situations. Below is a snapshot overview, presenting various technologies applied across different geographical locations. It includes details on costs, advantages and disadvantages, and treatment efficiency, among other factors.

(1) Aerated septic tank [6, 7]

	The aerobic treatment system is a modern option that is similar to septic systems in that both treat wastewater using natural processes. However, the aerobic system supplies oxygen to the tank by using an air pump or blower to facilitate the microbial activities in the septic system. The compartment of the tank can be constructed by using both concrete and fibre glass structures. The benefits of this system include odour avoidance, ability to remove organic matter and nutrients at the required standard and reduction of methane gas. However, a power supply is needed to operate the air pump in this system. Some companies also provide air pumps that can be operated by using energy from solar panels, thus making them an environment- friendly alternative for human waste treatment.
Stage of technology	Commercial
Application level	Household, community, Institution
Geographical location:	Urban residential area, Rural residential area
Unit capacity or Treatment Capacity	1.6–2.7 m^3/d

6 Aqua Nishihara Corporation Limited (2015, May 5). AQUA SEPTIC BIOFILM (STBF). Instruction for package wastewater treatment systems, 07–67.

7 Tilley, E. (2014). Compendium of sanitation systems and technologies. Eawag.

Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: 89-92%
O&M Requirement	• Regular air pump maintenance • Air diffuser cleaning and changing
Capital cost and investment cost	950 USD/system
	Products, materials
O&M cost	30 USD/year
	Energy costs, O&M cost
Durability/Lifespan	15 years
Manufacturer/Products name/ Brand	Fibertech Co., Ltd., Aqua Nishihara Corporation
Reviewed countries of application	Thailand, Myanmar, Laos, Cambodia, India and Bangladesh
Countries of product available	Thailand
After sale services	N/A

Advantages	Disadvantages
• It is convenient and space-saving • It is easy to install, and time-saving • It treats wastewater efficiently by adhering to the wastewater standard. • It has the necessary certification regarding its functioning in accordance with ISO 9001.	• Low reduction of pathogens and nutrients • Risk of clogging, depending on pre- and primary treatment • Removal and cleaning of the clogged contact media is cumbersome

(2) Solar septic tank[8, 9]

	A solar septic tank (SST), an innovative decentralised wastewater treatment system, was constructed and tested at the household scale in a community in central Thailand and Southeast Asia. The SST is a modified conventional septic tank with a solar-heated water system facilitated by a solar panel to create a temperature higher than the ambient temperature inside the septic tank. The enhancement of temperature promotes the biodegradation of organic matter and methane formation. Furthermore, the increased temperature has a significant effect on the settleability and degradation of biological solids and pathogen inactivation. The SST is suitable to apply for the treatment of blackwater with high-strength organic content since it is a highly rated degradation system. The advantages of this system include reduction of sludge accumulation, high removal efficiency and high pathogen inactivation. However, there are some disadvantages of using the SST, for example, it requires energy to heat the system and demands large rooftop area for the installation of the solar heating device.
Stage of technology	Pilot
Application level	Household, community, Institution
Geographical location:	Urban residential areas, rural residential areas

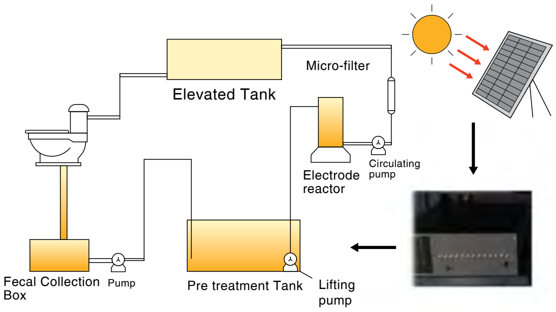
8 Koottatep T., Connelly S., Pussayanavin T., Khamyai S., Sangchun W., Sloan W., Polprasert C. (2020). 'Solar septic tank': Evaluation of innovative decentralised treatment of blackwater in developing countries. Journal of Water, Sanitation and Hygiene for Development.

9 Connelly S., Pussayanavin T., Randle-Boggis R. J., Wicheansan A., Jampathong S., Keating C., Ijaz U. Z., Sloan W. T., Koottatep T. Solar septic tank: Next generation sequencing reveals effluent microbial community composition as a useful index of system performance. Water.

Unit capacity or Treatment Capacity	0.5 m^3/d
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: 83 % COD removal: 88 % N removal: 40 % Pathogen: 99.9 % (3 log reduction) reduction in *E. coli*
O&M Requirement	• Regular desludging • Periodic assessment of the heating supply component
Capital cost and investment cost	2,500 USD and Products, materials and installation costs
O&M cost	50 USD/year Energy, operational, maintenance and repair costs
Durability/Lifespan	Around 20~30 years
Manufacturer/Products name/ Brand	Pilot stage of the Asian Institute of Technology (AIT)
Reviewed countries of application	Thailand, Cambodia, India
Countries of product available	Thailand
After sale services	N/A

Advantages	Disadvantages
• It shows improved effluent quality • It exhibits inactivation of pathogen in effluent >10^3 log (99.9%) • It reduces sludge accumulation, thus extending the desludging period • It shows increased bio-gas production, and generates reusable water for agriculture	• Energy is required to heat the system • A large rooftop area is required for the installation of solar heating devices

(3) ECO-SAN toilet[10, 11]



ECO-SAN or solar-powered toilet has been developed by CALTECH as an innovative technology that employs electrochemical reaction supplied by solar energy for chemical oxygen demand removal and pathogen inactivation via chlorine disinfection and recycling of disinfected and clarified water for use as toilet flushing water. This system utilises an array of mixed-metal oxide semiconductor anodes with stainless steel cathodes, which can be powered by photovoltaic (PV) panels for decentralised toilet wastewater treatment.

Stage of technology	Commercial (Small number of piloting)
Application level	Community, Institution
Geographical location:	Urban residential areas, rural residential areas, emergency cases
Unit capacity or Treatment Capacity	4-5 m^3/d
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	COD removal: 85% N removal: 87% Pathogens: 99.99% (4 log reduction) reduction in total coliform
O&M Requirement	• Cleaning and changing electrodes • Regular emptying twice a year • Replacing membrane filters

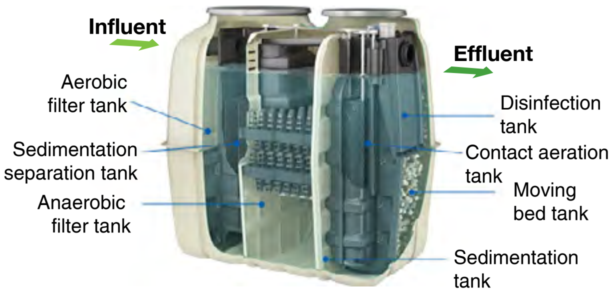
10 Huang X., Qu Y., Cid C. A., Finke C., Hoffmann M. R., Lim K., Jiang S. C. (2016). Electrochemical disinfection of toilet wastewater using wastewater electrolysis cell. Water Research, 92, 164–172.

11 http://www.eco-san.cn/e_main.html / https://sanitation.ansi.org/EcoSanToilet

Capital cost and investment cost	N/A
	-
O&M cost	5,840 USD/year (Based on maximum 800 flush per day)
	Energy, operational, maintenance and repair costs
Durability/Lifespan	10 years
Manufacturer/Products name/ Brand	Yixing Eco-Sanitary Manufacture Co.,Ltd.
Reviewed countries of application	USA, China, South Africa
Countries of product available	USA, China
After sale services	N/A

Advantages	Disadvantages
• Potential water savings compared to flush toilets • It minimizes the risk of ground water contamination • It facilitates pathogen destruction • It is suitable for high water table and rocky areas	• Proper O&M requires training of local operators • In this system, faecal matter needs to be further treated

(4) Johkasou[12, 13]

	**Description:** Johkasou is an on-site sanitation system that is widely employed for treating domestic wastewater in Japan. Different models are sold in the markets depending on the intended use. This technology combines several processes for treating domestic wastewater and discharging high-quality effluent. Although there are various types depending on the scale and desired treatment performance, a Johkasou unit typically comprises separation, anaerobic filter, aerobic moving bed, sedimentation, and disinfection chambers. The system can remove organic matter and nitrogen and inactivate pathogens.
Stage of technology	Commercial
Application level	Households, Institution
Geographical location:	Peri-urban residential areas, rural residential areas
Unit capacity or Treatment Capacity	Ranging from 5 to 5,000 person equivalents or more
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	• BOD removal: up to 90% or more • N removal: T-N in the effluent can be reduced to less than 20 mg/l (depending on treatment process)

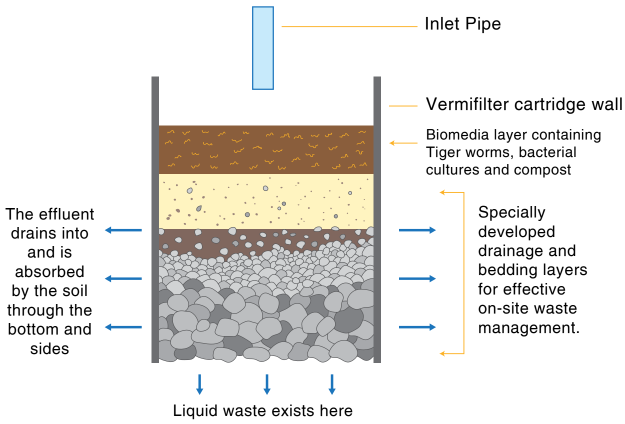
12 Yoshikawa N., Shimizu T., Amano K., Nakajima J. (2019). Evaluation of greywater reclamation and reuse system in a Japanese university building. Journal of the Asia-Japan Research Institute of Ritsumeikan University, 1, 44–55.

13 https://www.kubota.com/products/johkasou/lineup/kz/index.html / https://www.adb.org/sites/default/files/publication/743241/adbi-cs2021-04.pdf

O&M Requirement	• Desludging once a year • Annual requirement of solid chlorine tablets for disinfection • Cleaning, adjustment, inspection and changing of spare parts are necessary.
Capital cost and investment cost	2,550 USD
	–
O&M cost	30 USD/year
	Operating cost
Durability/Lifespan	30 years
Manufacturer/Products name/ Brand	Kubota Corporation, Japan
Reviewed countries of application	Asia (e.g. Cambodia, Indonesia, Laos, Thailand, Vietnam)
Countries of product available	Asia
After sale services	N/A

Advantages	Disadvantages
• It has a compact size and uses advanced technology • It is less vulnerable to natural disasters • It treats wastewater and night soil (faecal sludge) • It disinfects effluents appropriately • It generates easily reusable treated water and sludge	• It has a high initial investment cost • It requires energy for operation

(5) Vermicomposting toilet[14, 15]



Worm-based sanitation systems ('vermifilters') provide an alternate sanitation solution because they can reduce the solids in the system due to the net loss of biomass and energy when the food chain is extended. This approach can reduce both the frequency of emptying and the size of the sanitation system. Furthermore, worms are able to reduce pathogens to the level where the waste can be safely applied to land, along with generating the by-product vermicompost, which is dry, thus facilitating easy handling and transportation.

Stage of technology	Commercial/Application
Application level	Households, Institute
Geographical location:	Peri-urban residential areas and rural residential areas with long-term use
Unit capacity or Treatment Capacity	1.2 kg/d (when liquid part is filtered by bedding)

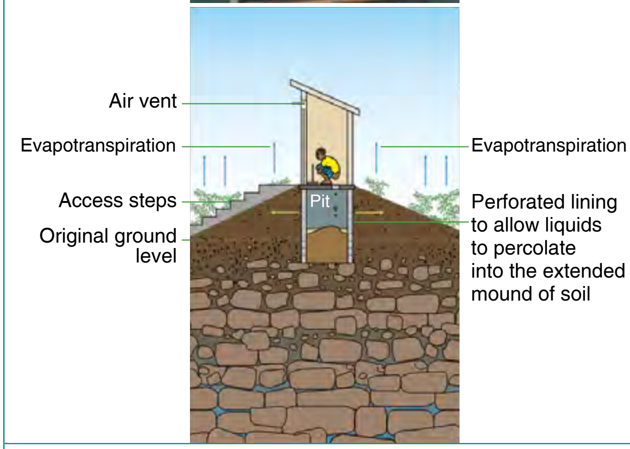
14 Furlong C., Gibson W. T., Templeton M. R., Taillade M. Kassam F., Crabb G.,...Patankar R. (2014, December). The tiger toilet: from concept to reality, IWA specialist conference on municipal water management and sanitation in developing countries. Organized by the International Water Association, Bangkok, Thailand.

15 Furlong C., Templeton M. R., and Gibson W. T. (2014). Processing of human faeces by wet vermifiltration for improved on-site sanitation. Journal of Water, Sanitation and Hygiene for Development, 4, 231-239.

Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	COD removal: 87% Pathogens: 2 log reduction (reduction in total coliform)
O&M Requirement	• System monitoring every 3 months • Since earthworms needs a moist environment for survival, it is necessary to ensure that moisture is maintained in the system
Capital cost and investment cost	350 USD
	Materials
O&M cost	N/A
	-
Durability/Lifespan	10 years
Manufacturer/Products name/ Brand	TBF Environmental Solutions Pvt. Ltd.
Reviewed countries of application	India
Countries of product available	India, Africa
After sale services	N/A

Advantages	Disadvantages
• It is environmentally friendly • It requires less water usage • It is suitable for rural and remote areas • It transforms waste into fertiliser for agricultural use	• Flies are attracted to the system and odours are generated during the decomposing process • It requires a higher level of maintenance than the standard treatment system

(6) Raised pit latrine[16, 17]



Raised-pit latrines are a modified option of conventional pit latrines that are mostly employed in high water table and frequent flood-prone areas. This system aims to prevent environmental pollution and function failure.

This system can be built in the form of an earth mound, using a wooden frame, or a concrete block structure. It can either be built as an autonomous facility entirely above ground with a holding tank below the user interface or raised partially above ground, thereby reducing the risk of groundwater contamination. The raised latrine platform usually does not exceed a maximum height of 1.5 m because of the costs and user acceptance.

Stage of technology	Commercial/Application
Application level	Households, Institution
Geographical location:	Urban residential areas, rural residential areas, emergency cases
Unit capacity or Treatment Capacity	0.8 m^3/d
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: 30-40%
O&M Requirement	Frequent desludging when land is dried
Capital cost and investment cost	120 USD
	Materials

16 Kazi N. M. (2003) Sanitation strategies and technologies: Flood-prone and high water tables areas of Bangladesh. ITN Bangladesh, Bangladesh.

17 https://www.emersan-compendium.org/en/technologies/technology/raised-latrine / https://wedc- knowledge.lboro.ac.uk/resources/e/mn/059-Raised-latrines.pdf

O&M cost	N/A
	-
Durability/Lifespan	10 years
Manufacturer/Products name/ Brand	N/A
Reviewed countries of application	Flood-prone areas in Bangladesh, Brazil, Vietnam, Indonesia and Pakistan
Countries of product available	Widely available
After sale services	N/A

Advantages	Disadvantages
• It is easy to build with locally available materials • It has a low capital cost • It has a low area requirement	• It attracts flies and generates odours during treatment • It shows low treatment performance in terms of BOD reduction and pathogen • It has a higher desludging cost

(7) Omni processor[18, 19]

The Omni Processor is a decentralised waste treatment system that kills pathogens while recovering valuable resources. It starts with solid fuel combustion. FS, biosolids, or other wet waste streams enter a dryer where moisture is evaporated. At this stage, the dried solid waste is a fuel that is burned in a combustion chamber, reducing the solids to dry fly ash. The heat generated in the combustion chamber is used in a boiler to generate high-pressure, high-temperature steam. This steam is transported to a steam expander (e.g. steam engine or steam turbine), which turns on a generator to produce electricity. This electricity is subsequently used to power the entire processor, and there is often surplus electricity produced that can be sold back to the utility grid or used for other processes locally.

The exhaust steam from the expander travels back to the heat exchanger surfaces of the dryer, where it provides the energy required for drying the incoming wet waste. In transferring its heat back, the exhaust steam is condensed back to water and pumped back to the boiler, thus completing the Rankine cycle (it means that the cycle is completed in which thermal energy is efficiently recovered and reused). The water which is evaporated from the wet waste is captured. This vapour is filtered before being condensed back to water. If desired, this water can be further treated to clean drinking water standards or used for other recycled or reuse water applications. Useful heat can also be

18 Sedron Technologies' Janicki Omni Processor (J-OP): https://www.sedron.com/janicki-omni-processor/overview/

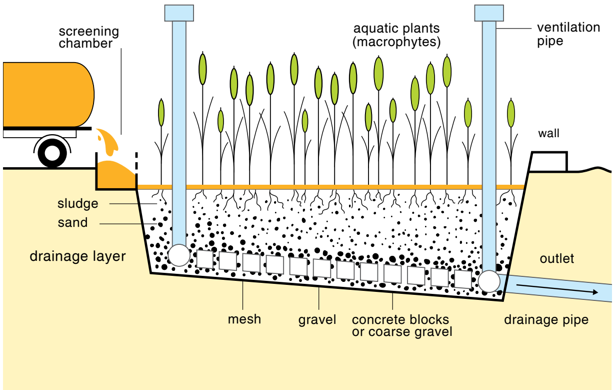
19 Janicki., P (n.d.): Omni Processor: https://swedishwaterhouse.se/wp-content/uploads/Peter-Janicki.pdf

	captured from the condenser and be used for various purposes. The Omni Processor boils the sewage at a temperature of 100°C in a drying tube to separate it into dry solids and water vapour. The dry solids are subsequently fired to turn water vapour into steam, which is used to power a steam engine and generate electricity. The steam is condensed back into safe drinking water. With the electricity generated being sufficient to power the cycle, the technology offers a self-sustaining method of power and water generation.
Stage of technology	Commercial
Application level	Community and city scale
Geographical location:	Urban residential area
Unit capacity or Treatment Capacity	92.3 m^3/d
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	The technology completely destroys FS and pathogens through combustion and fully converts sewage sludge into valuable sources such as drinking water.
O&M Requirement	The day-to-day operation needs to be monitored to provide real-time status, which includes video feeds.
Capital cost and investment cost	Capital cost: 1.5 million USD
	Omni Processor with a single-stage dryer (boiler and dryer capacity)
O&M cost	N/A
	N/A
Durability/ Lifespan	N/A

Manufacturer/Products name/ Brand	Sedron Technologies
Reviewed countries of application	Senegal and India
Countries of product available	Senegal and India
After sale services	Yes

Advantages	Disadvantages
• The Omni Processor is scalable and can serve populations ranging from the community to city level • It can operate independently of the electric grid • It employs a highly controlled thermal oxidation process in fluidised sand bed; it employs the downstream use of sorbent injection and executes particulate control via a cyclone; additionally, a filter baghouse helps in air pollution and emission	• Some odours may be present • The harsh UV and salty air of Dakar have highlighted the need for careful material selection and coating

(8) Planted drying bed (PDB)[20, 21]



PDB is also referred to as vertical constructed wetlands and sludge drying reed beds. PDB consists of porous beds comprising sand and gravel layers planted with emerging macrophytes, and involves mechanisms such as filtration, evaporation and evapotranspiration, etc. The porosity maintained by the plant root system and sludge is transformed into plant biomass. The system has prolonged desludging period of 3-5 years or more. (Planted drying bed followed by horizontal planted gravel filter and polishing pond)

Stage of technology	Commercial
Application level	Community Scale
Geographical location:	Mountainous area
Unit capacity or Treatment Capacity	12 m^3/d
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: 50-75% COD removal: 40% Total Kjeldahl Nitrogen (TKN) or Total Nitrogen (TN) removal: 35-55% Pathogens (reduction of Total Coliform, Faecal Coliforms and E-coli): 1-3 Log reduction of FC (80%-99.9%)

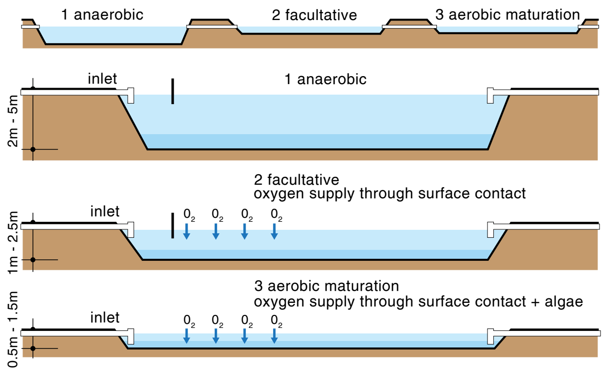
20 Illey E., Ulrich L., Luethi C., Reymond P., Zurbruegg C. (2014). Compendium of Sanitation Systems and Technologies, 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)

21 FSM for Leh: https://www.borda.org/wp-content/uploads/2018/08/BORDA_FSM_for_Leh_HF.pdf

O&M Requirement	• Simple and minimal operation; skilled staff is not required for regular and proper functioning. • The drains must be maintained, and the effluent should be properly collected and disposed of. • The plants should have grown sufficiently before applying the sludge. • The acclimation phase is crucial and requires considerable care. • The plants should be periodically thinned and/or harvested. • After 3–5 years, the sludge can be removed.
Capital cost and investment cost	Capital cost: 130,000 USD (FSTP + Truck + Land etc.) Construction cost: 68,100 USD (Approx. 6,500 USD/m^3)
	• Planted drying bed: 10 units (design size: 8m × 6m × 2m) • Horizontal planted gravel filter: 2 units (design size: 10m × 6m × 0.6m) • Polishing pond: 1 unit (design size: 5.6m dia × 1m depth) • Suction truck: 3000 L capacity
O&M cost	4,060 USD/year
	General management and supervision.
Durability/Lifespan	N/A
Manufacturer/Products name/ Brand	Blue Water Company/ BORDA / CDD
Reviewed countries of application	Leh, Ladakh, India
Countries of product available	Asia and Africa
After sale services	N/A

Advantages	Disadvantages
• It can handle high loading. It provides better sludge treatment than that in unplanted drying beds • It can be built and repaired by using locally available materials. It has relatively low capital and operating costs • Fruit or forage growing in beds can generate income. No electrical energy is required	• It requires a large land area • Odours and flies may be noticeable • It has long storage times • It is characterized by labour intensive removal • It requires expert design and construction supervision • Leachate requires further treatmentv

(9) Waste stabilization pond (WSP) [22, 23]



WSP is a large man-made water body. It usually includes anaerobic, facultative and maturation (aerobic) ponds connected in series for enhanced treatment—with effluent flowing from anaerobic to maturation stages. The anaerobic pond serves as the primary treatment pond, reducing organics and solids (BOD reduction - 60%). BOD is further reduced in the facultative pond. The top layer of the facultative pond prevails aerobically, while the bottom layer acts as an anaerobic system (BOD reduction - 75%). The maturation pond is designed for pathogen and nutrient removal.

Stage of technology	Commercial
Application level	Community Scale
Geographical location:	Rural residential area
Unit capacity or Treatment Capacity	N/A
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: 85% COD removal: 80% TKN or TN removal: N/A Pathogens reduction of TC, FC and EC: *E.coli* 3 log reduction (99.9%)

22 Illey E., Ulrich L., Luethi C., Reymond P., Zurbruegg C. (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)

23 NIUA (2019), Cost analysis of faecal sludge treatment plants in India. Life Cycle Costing and Contracting Models of FSTPs

O&M Requirement	It extremely simple maintenance activities, such as removing vegetation (to prevent BOD increase and mosquito breath), removing scum and floating vegetation from pond surfaces, keeping inlets and outlets clear and repairing any embankment damage.
Capital cost and investment cost	Capital cost: Estimated 180,000 USD
	• WSP cost is heavily influenced by land availability and the land price of each country • Cost estimation including equipment, design and land cost.
O&M cost	Estimated 500–1000 USD/year
	• Removing vegetation • Keeping the inlet and outlet clear • Repair (only when damage occurs)
Durability/ Lifespan	N/A
Manufacturer/ Products name/ Brand	University of Ghana
Reviewed countries of application	Ghana
Countries of product available	Countries in Asia, Africa, Europe and the Americas
After sale services	N/A

Advantages	Disadvantages
• It is resistant to organic and hydraulic loads • It shows high reduction in solids, pathogens and BOD • It shows high nutrient removal when combined with aquaculture • It enables job creation and food production (fish) • It has low operating cost as no energy is required	• It requires a larger area • It has high capital cost depending on the land price • Skilled manpower is needed for its design and construction • Insect breeding may occur if the pond is not designed and operated properly

(10) Vermicomposting [24, 25, 26]

The Black Soldier fly (BSF), also known as Hermetia illucens, originated in the US but is commonly found in temperate and warm climates. The fly larvae feed on decaying organic material, such as vegetables, fruits, manure, or human excreta. They generate protein and fat as an animal feed and soil conditioner as a by-product. During their larval stage, BSF larvae achieve a rapid reduction in organic waste volumes of up to 75%, together with the removal of nutrients such as nitrogen and phosphorus. This process relies on the natural growth cycle of BSF, that needs to feed only during the larval stage, and as they subsequently migrate for pupation; they do not feed anymore, even during the adult stage. Therefore, the risk of the BSF being a vector for disease transmission is extremely low because it is not attracted by decaying organic matter when it can fly. In recent years, the private sector has shown interest in BSF larvae (BSFL), with companies such as Protix (The Netherlands), AgriProtein (South Africa) and Ynsect (France) establishing commercial operations. The Worldwide Insect Feed Market analysis lists 23 BSF companies and projects their revenue to exceed $1 billion USD by 2022.

Black soldier fly larvae can consume up to 130 mg of human faeces per larva per day.

24 Dortmans B. M. A., Diener S., Verstappen B. M., ZurbruÃàgg C. (2017), Black soldier fly biowaste processing: a step-by-step guide. Eawag: Swiss Federal Institute of Aquatic Science and Technology. https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/BSF/BSF_Biowaste_Proces sing_LR.pdf

25 Verhagen J., and Scott P., (2019). Safely managed sanitation in high-density rural areas. https://openknowledge.worldbank.org/handle/10986/32385

26 ISF-UTS and SNV, Treatment technologies in practice: On-the-ground experiences of faecal sludge and wastewater treatment, The Hague, SNV Netherlands Development Organization, 2021.

	In other words, approximately 10,000 larvae are required to process the faeces from one person per day.
Stage of technology	Commercial
Application level	Community Scale
Geographical location:	Urban residential area and Urban slums
Unit capacity or Treatment Capacity	7 tonnes currently, and 200 tonnes planned
Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	• BOD removal: N/A • COD removal: N/A • TKN or TN removal: N/A • Pathogens reduction of TC, FC and EC: Pathogen reduction is achieved through the reduction of waste quantities in a controlled manner, rather than pathogen inactivation
O&M Requirement	• Routes for garbage delivery and residue pickup should be well maintained and easily accessible throughout the year • Skilled and semi-skilled professionals are required to operate a laboratory • Water and electricity supply and wastewater management options should be available. • Adequate environmental buffers, for example, open areas, trees and fences, should be maintained • The facility should be downwind from residential areas • A closed and ventilated room that provides direct sunlight is required for the rearing of larvae and mating • Sheltered area without direct sunlight for the treatment containers

Capital cost and investment cost	Capital cost: 7 million USD • The area required is approximately 500–750m^2 per tonne of dry solids processed per day with an additional 60m^2 per tonne required for a waste-receiving area and to accommodate a laboratory, office, and storage facilities. • Cost will reduce depending on the scale of the business
O&M cost	N/A Staff ranging from semi-skilled (emptiers) to skilled (engineers and researchers)
Durability/Lifespan	N/A
Manufacturer/Products name/ Brand	Sanergy
Reviewed countries of application	Kenya, EU countries and South Africa
Countries of product available	Kenya, South Africa, Saudi Arabia, South Korea, United Kingdom, EU countries, United Arab Emirates
After sale services	Yes

Advantages	Disadvantages
• It allows revenue generation for small entrepreneurs with minimal investment • It can be implemented with locally available materials	• It requires appropriate food and climate conditions that best mimic the natural habitat of the BSF • It requires a large land area • It has high operating costs • Skilled and semi-skilled professionals are required to operate a laboratory

(11) Co-composting [27, 28, 29]

	Co-composting is a biological process that decomposes and stabilises organic matter to generate valuable products (such as soil amendments) under a controlled aerobic environment. By combining FS and municipal solid waste, the benefits of each can be used to optimise the process and the output product. Co-composting is a natural process that allows good hygienisation of sludge in a relatively short time. This is due to the high temperature of 50°C–70°C reached during the thermophilic degradation process. Even for large sludge volumes, co-composting of pre-treated and thickened FS with solid waste might be a good solution. Typically, there are two types of co-composting: • Open (windrow composting – heaps in open, takes up larger space) • Closed (boxed composting – heaps in walled enclosures, less space than open composting)
Stage of technology	Commercial
Application level	Community Scale
Geographical location:	Peri-urban and rural residential areas
Unit capacity or Treatment Capacity	4 t/d

27 Illey E., Ulrich L., Luethi C., Reymond P., Zurbruegg C. (2014). Compendium of Sanitation Systems and Technologies, 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)

28 NIUA (2019), Cost analysis of faecal sludge treatment plants in India. Life Cycle Costing & Contracting Models of FSTPs

29 Co-composting of Municipal Solid Waste and Faecal Sludge in Kushtia, Bangladesh. https://www.unescap.org/sites/default/files/Waste%20Concern,%20Bangladesh.pdf

Treatment efficiencies on Carbon, Nitrogen and on Microorganisms	BOD removal: N/A COD removal: N/A TKN or TN removal: N/A Pathogens reduction of TC, FC and EC: Helminth egg: absent; Salmonella: absent
O&M Requirement	• The mixture must be carefully proportioned so that it has the appropriate C:N ratio, moisture and oxygen content. If the necessary facilities exist, it would be useful to monitor helminth egg inactivation as a proxy measure of sterilisation. • A well-trained staff is necessary for the operation and maintenance of the facility. • The maintenance staff must carefully monitor the quality of the input material and keep track of the inflows, outflows, turning schedules and maturing times to ensure a high-quality product. • Forced aeration systems must be carefully controlled and monitored. • Turning must be periodically performed with either a front-end loader or by hand. Robust grinders for shredding large pieces of solid waste and pile turners help to optimize the process, reduce manual labourand ensure a more homogenous end product.
Capital cost and investment cost	80,000 USD
	Capital cost without land cost
O&M cost	10,000 USD/year
	Salary for supervisor and labour, saw dust for compost, etc.
Durability/Lifespan	N/A
Manufacturer/Products name/ Brand	Owned by the local municipality but with a contractual agreement with the Environmental Resource Advancement Services (ERAS)
Reviewed countries of application	Bangladesh and India

Countries of product available	Countries in Asia, Africa, Western Europe and North America
After sale services	N/A

Advantages	Disadvantages
• It includes thermophilic processes and pathogen inactivation • It enables resource recovery by acting as a soil conditioner	• Highly skilled labour is required to obtain a safe compost product • It has space constraints • It requires the availability of segregated organic municipal solid waste or regular availability of dried FS

2.7. Concerns and considerations

(1) Pathogens

FS is a source of pathogens that may be transmitted during the infection cycle. To verify this transmission, it is necessary to erect barriers. To effectively mitigate risks posed by the FS, the World Health Organization (WHO) suggests a multi-barrier approach. For agricultural use, treated sludge should contain only one egg of helminth per gram of total solids (gTS). It is also recommended to avoid applying this sludge to raw food crops. Implementing drip or subsurface irrigation techniques can further reduce risks. Additionally, it is essential to restrict worker and public access during sludge application. Individuals involved in the application and handling of sludge are required to wear personal protective equipment (PPE).

To prevent potential contamination and risks to human health, it is also essential to ensure safe food preparation by cleaning and washing the raw food materials appropriately.

(2) Heavy metals

The toxicity of heavy metals poses a long-term threat to soil. Specifically, if FS from domestic sources is combined with industrial FS, the risk increases significantly.

(3) Social factors

In determining the success of FS products, social factors play a crucial role. The acceptability and attitude of individuals towards these products can significantly impact their adoption. Alternative end use products, such as biofuel or construction materials, should be considered for resource recovery if the above-mentioned FS products are deemed unsuitable as soil amendments.

(4) Suitable situations for DWM

DWM is suitable for a variety of circumstances. It is ideal for regions/areas with a high concentration of on-site systems that lack adequate wastewater pollution control measures. It can be a viable alternative when on-site systems are inadequately maintained and the costs of conventional centralised systems are prohibitive. It is also advantageous for communities located far from existing centralised facilities or in regions where freshwater is scarce. DWM is advantageous in regions/areas where reuse of treated wastewater is possible and the discharge of partially treated wastewater is restricted for environmental reasons. Additionally, it can be employed in areas where expanding the current centralised system is impractical, as well as for newly constructed or existing homes, parks, public amenities and commercial and institutional buildings.

(5) Land requirement

In peri-urban areas and provincial cities where concretisation of the surroundings has not yet taken place, treated effluent and solids need to be given preferences regarding extending into surrounding farmlands. Usually, land in these cities is cheaper and can be acquired at a lesser unit cost and can be reserved at the earlier stage of planning as the least cost technologies usually have a larger footprint.

(6) Investment costs

Investment costs are usually estimated on the basis of the preliminary estimate of the technology to be adopted. The cost of the system is also influenced by the lifetime of the hardware. Generally, civil structures (building and ground-based structures) have a life span of 20 years. Similarly, sewer networks, filter media and pipelines have a life span of 10 years, whereas connection equipment such as valves and gas pipes have an even shorter life span of 6 years. A decision matrix can be developed for technologies under consideration and their appropriateness can be weighed based on the least cost analysis and their performance.

(7) Operational and maintenance (O&M) cost

The O&M cost determines the long-term suitability of the technology under consideration. Generally, the O&M cost increases with the complexity of the technology; hence, systems requiring a high O&M cost over a long term are not suitable for areas wherein the user tariff for wastewater is not/ rarely implemented. The O&M cost for DWM includes the cost of personnel, external services such as maintenance or replacement of the components, desludging, etc. In addition to the regular staff, the hiring of an external workforce for the maintenance and repair of the treatment component incurs additional costs. Open systems such as ponds and constructed wetland require frequent monitoring than closed digesters; however, the desludging frequency and cost of open systems are lower than those of closed digesters that are compacted and heavily loaded, thus requiring a higher O&M cost.

(8) Suitability to achieve the prescribed effluent standard

Technologies that can achieve the prescribed discharge standard need to be considered first when implementing a wastewater treatment system. For example, options ranging from suspended solids removal to attached growth biological treatment to natural treatment process can be considered. However, a simple technology might not be feasible when considering a stringent discharge standard. Hence, the selection of the approach for wastewater management should be driven by the need of the local situation since conventional centralised wastewater management is not always the best solution, especially for the developing economy. Hence, DWM can be considered as an alternative in a scenario that cannot be economically served by a centralised system. In such a case, DWM can be considered as a part of the future expanded sewer network, which can be addressed in the master plan design of the city.

(9) Revision of the effluent standard

If the effluent standard is reasonably stringent considering the level of treatment despite discretization of standards based on the sectors, then simpler technologies prove to be inefficient. High-level treatment performance often includes treatment technologies with high degree of required skills and expertise for proper O&M to ensure sustainability of the system. Thus, when using high-level treatment technologies, there should be provisions for the local government to adopt their own local standards guided by scientific analysis of the locality, groundwater level, background pollutant concentration of the receiving water bodies and downstream settlement.

(10) Amendment of the building code

Most developing nations do not have the building code that is employed by developed nations such as the US, Australia, or European nations; rather, ministerial regulations serve as the building control regulation. The building control regulation specifies the need for a sanitation system at the household and the need for connection to the sewerage network, especially in urban areas. The criteria adopted in the regulation are based on the structural safety viewpoint rather than the occupancy and the wastewater volume likely to be generated. Hence, the criteria for the sanitation system scheme at the household should be designed based on the occupancy, water consumption and wastewater volume generation.

(11) Preparing a sanitation map

The geographic information system (GIS) has become an integral part of urban planning in recent years. It allows spatial- and temporal-based visualisation of urban infrastructure development based on the projected scenario. Similar to urban infrastructure mapping, sanitation mapping allows scenario analysis of the current sanitation situation, impact of poor sanitation infrastructure and impact of proposed future sanitation projects, consequently helping to prioritise the area of intervention. To develop comprehensive sanitation mapping, the following data can prove to be beneficial:

- Topography;
- Drainage and water supply;
- Existing land use pattern such as the location of residential areas, agricultural areas, water bodies and industrial zones;
- Sewer and drainage networks;
- Population density;
- Socio-economic status;
- Existing land use facilities.

It is easy to visualise the potential locations for the DWM implementation; These alternatives include:

- Locations away from a centralised wastewater treatment plant or in areas where connection to a ssewer network is not possible either due to geographical barriers or financial constraints
- Location in a peri-urban area with low population density and scattered communities
- Location with medium-range polluters, such as schools, hospitals, slumps, condominiums, housing estates, areas requiring immediate wastewater solutions, etc.
- In addition to the location for DWM systems, a comprehensive sanitation map containing all relevant data helps in the zonation of the sanitation development, including suitable areas for centralised wastewater treatment facility, decentralised wastewater treatment facility, or a combination of both.

(12) Preparing a roadmap to increase revenue and cost recovery

A preliminary survey on the willingness of the residents of a region to pay a fee for wastewater treatment and the average fee they are ready to pay needs be conducted, and backed up by Information, Education and Communication (IEC) campaigns and periodic survey over a period, the wastewater fee should be increased. Local authorities should show their willingness to charge user fees and continue to fund the balance of O&M cost not covered by the recovered user fees.

(13) Considering the market value of the treated wastewater products

The resources recovered from the wastewater treatment have market value, which needs to be considered while designing and financing the sanitation project. This value can be estimated on the basis of direct sales or the product they substitute. Once the products are recovered from the treatment system economically, mapping the demand of each product into the market could help the selection of the appropriate technology and necessary financing. For example, in the case of the Nonthaburi FS treatment plant in Thailand, the biosolids recovered from the treatment plant had a market value of 90 USD/tonnes; these biosolids have been employed partially instead of chemical fertiliser in the nearby area. Similarly, the treated effluent is being used in green spaces within the facilities; the economic value of this effluent is yet to be assessed. The economic potential of the treated effluent can be calculated on the basis of the volume of fresh water it replaced. Another product that has economic potential is biogas, which can be used to substitute other fuel products as well as eliminate the potential greenhouse gases being released into the environment.

The economic value of the treated wastewater product could help subsidise the user tariff as these resources partially compensate for the O&M expenses of the treatment plant. These potential economic sources, along with the user tariff, could be the selling point for attracting the private sector for investment in the wastewater business.

Figure 12. Wastewater treatment plant, Baatan, Philippines
(Source: Lormelyn E. Claudio, 2015)

Case study: Resource-efficient decentralised wastewater treatment systems in Dar es Salaam, Tanzania[30]

Figure 13. Wastewater treatment plant, Baatan, Philippines
(Source: UNEP / Riccardo Zennar)

30 United Nations Environment Programme (2023). Wastewater – Turning Problem to Solution. A UNEP Rapid Response Assessment. Nairobi, Kenya

A maternity hospital in Dar es Salaam, Tanzania, has implemented two decentralised wastewater treatment systems that provide wastewater treatment, subsequently generating nutrient-rich water for irrigation as well as biogas. In 2013, a system with the capacity to treat 100 m^3 of wastewater per day at a cost of 96,000 euros was adopted in this hospital. The hospital is situated in an area prone to flooding without a sewer connection. The wastewater treatment system operates without using external energy, utilising only locally accessible resources. The treated wastewater is used for hospital irrigation, and the remainder is stored for fire suppression. The biogas produced was intended for use in the kitchen; however, a lack of confidence among potential users made them reluctant to purchase biogas stoves. Although biogas production at this hospital was effective, other small-scale biogas units in the country experienced comparable difficulties. Hence, although biogas production from wastewater and FS is substantial, its usage must be well-planned and further developed.

2.8. Exercises

(1) Briefly explain the challenges of the existing sanitation infrastructure in ASEAN.

(2) What is the principle behind a DWM approach?

(3) What are the benefits of implementing DWM systems in the ASEAN region?

(4) What do you think should be included in the design process of sanitation technologies?

(5) What do you think is the near future technology design and development regarding the decentralised sanitation approach?

Module 3. Assessment and planning for DWM implementation

3.1. Step-by-step planning process for DWM implementation

It is critical to consider the entire sanitation service chain, from containment to reuse/disposal, during the planning process for domestic wastewater and FSM. This process often involves multiple stakeholders, each with distinct needs and priorities. For example, authorities seek to maintain social order while ensuring cleanliness and health. To ensure the long-term viability of domestic wastewater and FSM, it is necessary to identify and address all of these needs and priorities in the plan. This requires the involvement of all major players. Hence, early emphasis on planning is essential for this process.

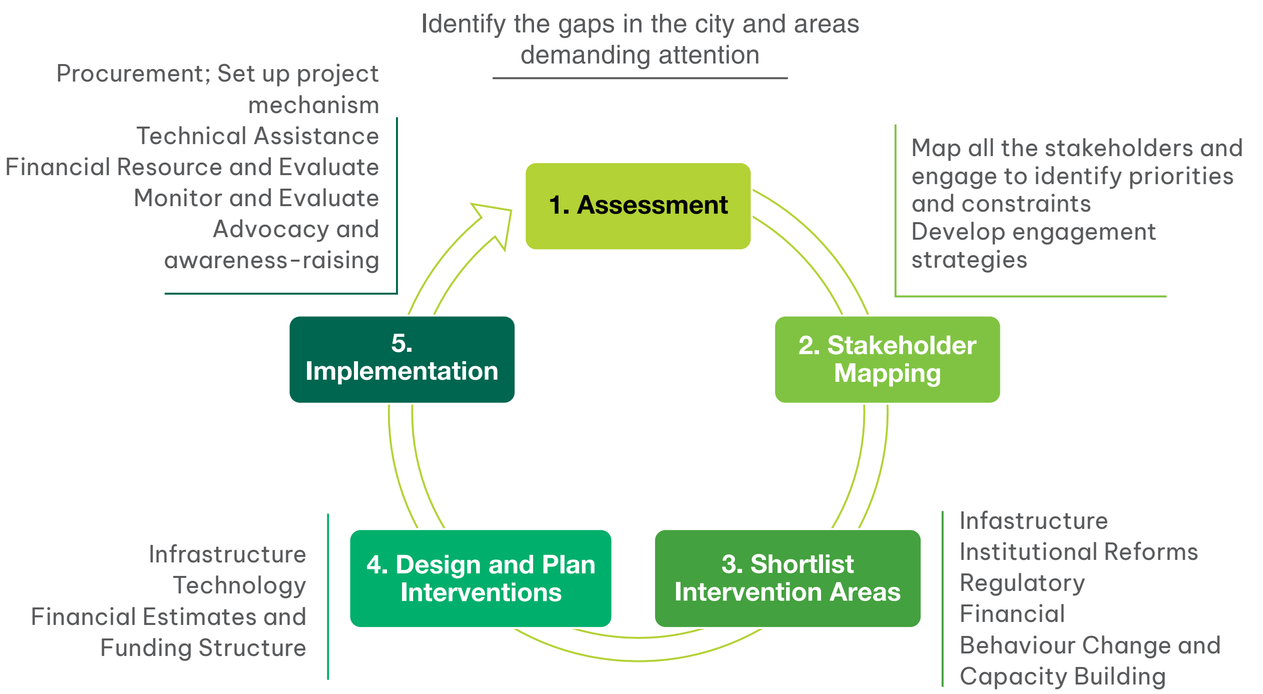


Figure 14. Step-by-step planning process for DWM implementation
(Source: Athena Infonomics)

STEP 1. ASSESSMENT OF THE INITIAL SITUATION

The first step in the project cycle is to assess the initial situation. This step lays the foundation for informed decision-making by providing baseline information. It offers a detailed overview of the current sanitation service chain visualised through a Shit Flow Diagram, and identifies gaps using the Situational Assessment Tool. This step also involves pinpointing key stakeholders and strategizing their engagement through the Stakeholder Assessment Tool. Furthermore, in this step, it is essential to recognise the existing regulatory and institutional frameworks, noting any overlaps or voids, by using the City Service Delivery Assessment (CSDA). The primary objectives of this step include establishing the context for the intervention, comprehending the prevailing situation, identifying key players, recognising potential threats and other pertinent issues, and prioritising the challenges that need to be addressed. Various tools can assist in assessing the initial situation. However, city planners often grapple with determining the best starting point and approach.

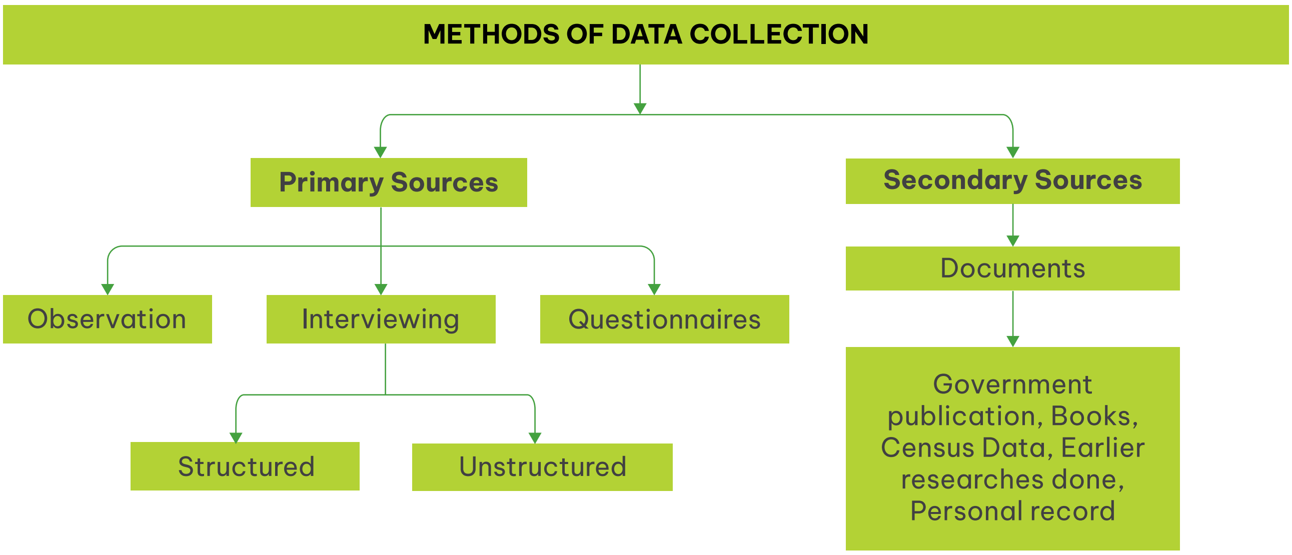


Figure 15. Various data collection methods can be used in this step.
(Source: Roeder, 2016)

Tools for the Initial Situation Assessment

(1) Shit Flow Diagram (SFD)

An excreta flow diagram (also known as a Shit Flow Diagram, SFD) is a simple advocacy and decision-making tool that illustrates how excreta 'flow' through a city. This tool attempts to trace the flow of human waste through a city's sanitation service network. Based on the contributing populations, an SFD indicates where their excreta travel, thus representing the associated public health risks. An SFD provides an overview of the outcomes of existing sanitation systems, from which sanitation priorities and solutions can be identified. For more information, please see https://sfd.susana.org.

Quantitative and qualitative data from sanitation systems and governance aspects along the sanitation service chain are required to create an SFD. When no data are available, assumptions must be made, and this report details how to accomplish this task. An SFD can be produced at three distinct levels (initial, intermediate and comprehensive) based on the objective of the analysis, the volume of data collected, the extent of stakeholder engagement and the depth of data analysis.

Example: SFD flow in Kochi, India

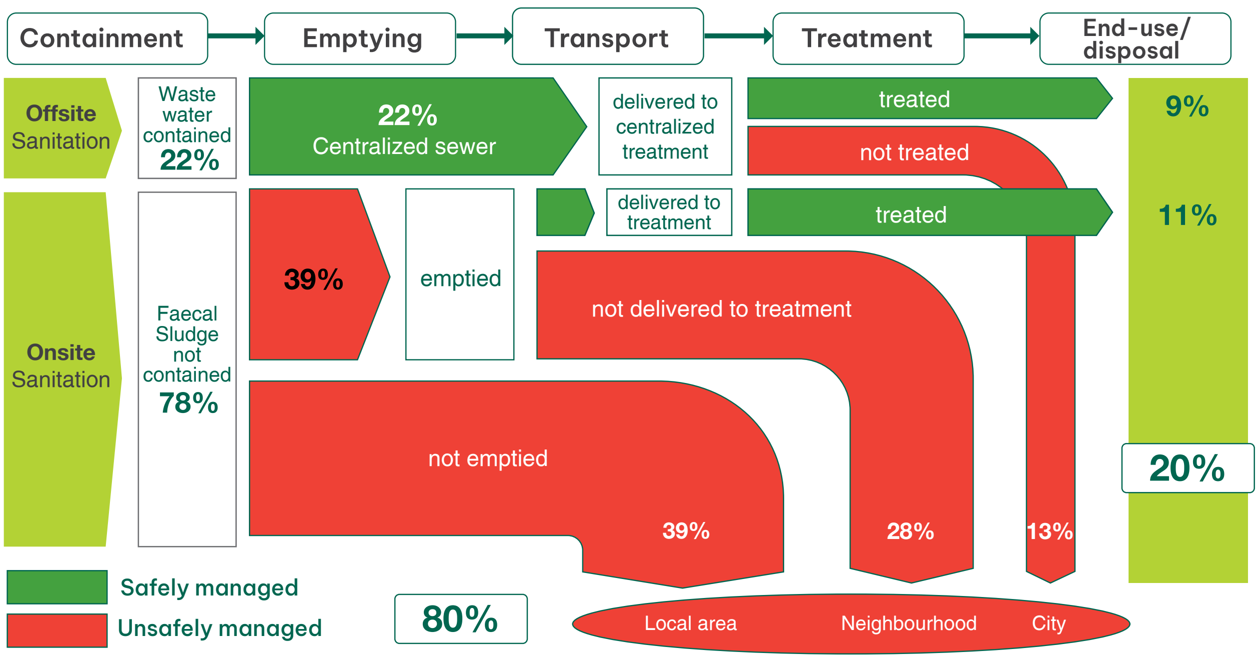


Figure 16. Shit Flow Diagram (SFD) visualises a city's sanitation challenge
(Source: Roeder, 2016)

(2) Situational assessment tool (SAT)

A questionnaire-based tool should be designed to assess the current FSM situation of an area under the jurisdiction of a municipality or department responsible for sanitation or urban planning in terms of six cross-cutting aspects: (i) infrastructure, (ii) regulatory, (iii) institutional, (iv) capacity, (v) awareness and (vi) finance and management. This tool is intended for knowledgeable users, including city planners, donors and consultants. The tool uses radar graphs (with six aspects as their axes) and colour codes (with shades of green representing a good to excellent situation, shades of yellow representing a below average to above average situation and shades of red representing an inadequate to poor situation) to present the assessment and provide the user an idea regarding the aspects that require intensive attention/interventions to improve the overall situation of FSM.

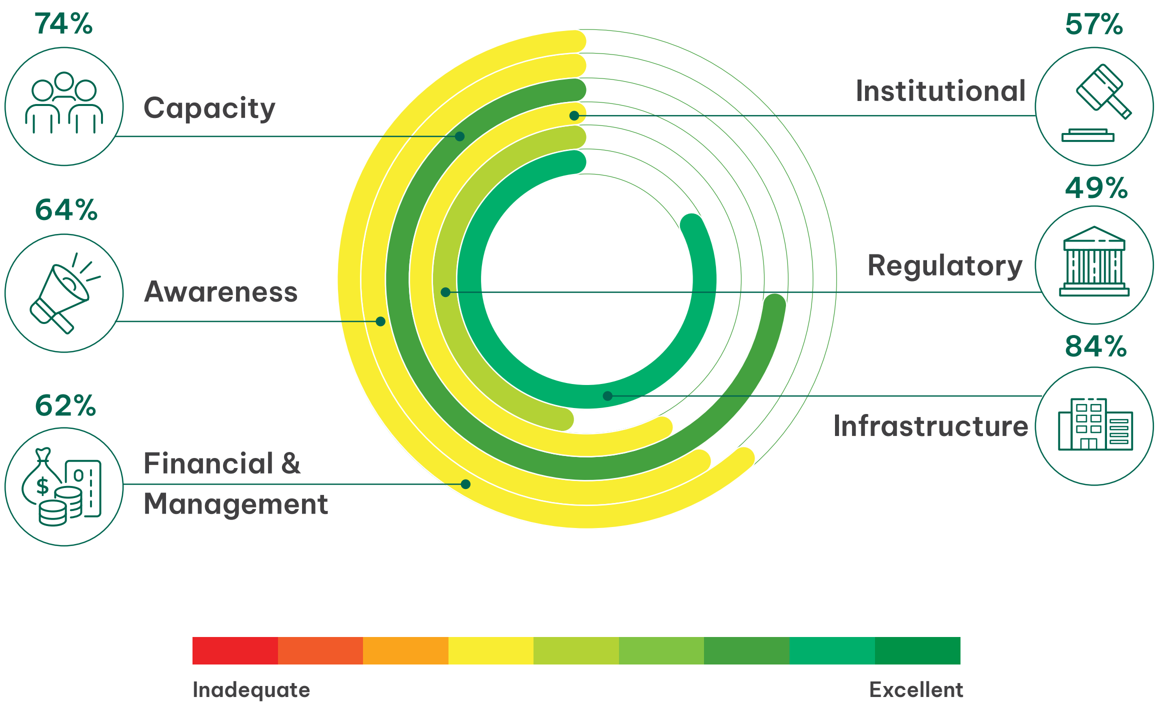


Figure 17. Example of the overall FSM situation in Mingalar Taung Nyunt
(Source: FSMA, 2024)

The infrastructure of the township in Figure 17 is overall relatively good, with excellent containment system coverage and accessibility. The containment systems are frequently emptied and the collected FS is transported to the treatment facility. The treated effluent is subsequently used for agricultural or agro-based purposes, but only for inedible crops. However, there is an inadequate number of vehicles for transporting FS, and a lack of suitable and sufficient land for disposal facilities.

STEP 2. STAKEHOLDER ENGAGEMENT AND ANALYSIS

Stakeholder analysis is the process of identifying and describing stakeholders, investigating their relationships and planning for their participation. It is a vital tool for obtaining a better understanding of the social and institutional context of a project or policy. The findings can provide early and essential information about who will be affected by the project and who could influence it (positively or negatively); which individuals, groups, or agencies must be involved in the project; and, how and which plant's capacity must be built.

Stakeholder engagement and analysis play a crucial role in the following:

- Determining who to involve and the extent of their participation;
- Understanding stakeholder influence and interests;
- Understanding interest conflicts among stakeholders;
- Identifying stakeholder relationships that should be improved and strengthened;
- Knowing how to interact with various individuals;
- Determining the most effective means of capitalising on the positive aspects of the informal sector while minimising its negative effects.

Stakeholder analysis or the Stakeholder engagement tool

For FSM projects, a stakeholder analysis tool can be used in conjunction with a participatory stakeholder analysis approach. This tool provides potential lists of FSM stakeholders as well as the criteria and method for categorising stakeholders according to their level of interest and influence. It also includes a stakeholder table dataset for documenting stakeholder information and a stakeholder matrix that identifies the four major categories of stakeholders based on the analysis. Additionally, users of the tool can obtain information regarding participation levels and communication tools for each stakeholder group. As stakeholder analysis is an iterative process, it must be repeated frequently throughout the duration of the project. Documenting all identified stakeholders and their information in the tool facilitates re-analysis and review of the stakeholders' information by the project team. The stakeholder matrix can also be used as a communication tool for meetings, either within the project team or with interested partners. Consequently, this tool primarily intends to accelerate the conventional stakeholder analysis process. For further information, please visit https://www.fsmtoolbox.com/planning.

The main purposes of stakeholder analysis are as following:

- Identifying the key constituents;
- Documenting stakeholder lists and their information;
- Evaluating stakeholder influence and interest by using multiple criteria;
- Analysing the stakeholders' interests and influence;
- Classifying stakeholders on the stakeholder matrix (based on the degree of interest and influence);
- Identifying methods for involving project stakeholders in the process.

STEP 3. REGULATORY AND INSTITUTIONAL ASSESSMENTS

The current situation and challenges that persist include: (i) ambiguous FSM-related laws and strategies, (ii) fragmented institutional setup, (iii) an emphasis on infrastructure, often neglecting organisational and financial aspects, (iv) institutional frameworks that are not tailored to local circumstances and (v) undefined roles and responsibilities in terms of regulation and enforcement. Therefore, it is vital to ensure the following:

- A regulatory checklist outlining generic regulations for households and operators throughout the service chain;
- Identifying the FSM regulations currently in place and determining missing regulations;
- Preparing an organisational chart based on the specific institutional structure of the situation to identify the involved organisations;
- Specifying the roles and responsibilities of organisations determined in the preceding step;

- Conducting a comprehensive analysis to identify gaps and overlaps between recognized FSM organisations;
- Finally, welcoming suggestions regarding any missing regulations.

Regulatory and Institutional assessment tool

The CSDA is a complementary tool for determining the causes of a sanitation situation, including an evaluation of local level policies, institutional readiness and local government capacity. It supports a systematic procedure for collaborating with stakeholders to assess the enabling environment for city-wide inclusive sanitation and for presenting the results in a straightforward manner. It also includes an Action Checklist to assist stakeholders in identifying and prioritising immediate and subsequent actions to improve the enabling environment for the delivery and sustained operation of inclusive sanitation services throughout the city.

For further information, please visit https://incsanprac.com/tools.html.

STEP 4. FEASIBILITY STUDY

The primary objective of the feasibility study is technology selection along the service chain (for instance, septic tank/pit latrine/SST at the household level, manual or mechanical or a combination of the two for FS emptying and transport, treatment technology combination based on reuse option—either fuel or fertiliser etc.). Additionally, it aims to provide assistance with alternative technology selection, design and drafting of technology, financial analysis and evaluation of the selected options for proposed technology and alternative technology, site selection, GIS, development of the project timeline, and operation and maintenance plan for the proposed option.

Feasibility Study Tool

(1) Financial and technological assessment tool

City planners/utility managers, consultants and donors are the intended audiences for the Financial and Technology Assessment Tool. This tool primarily focuses on the collection, transport and treatment of FS for improved FSM project implementation. This tool serves three primary purposes: (i) baseline assessment, (ii) selection of treatment technologies and (iii) financial feasibility evaluation. It enables users to compare various technical and financial scenarios.

The main functions of the financial and technology assessment tool include the following:

- Baseline assessment, which includes an estimation of the volume of FS produced by households, businesses and institutions. This helps to determine the required number of vacuum trucks and the capacity of the treatment plant.
- Technology evaluation, which is determined by site-specific criteria. It offers options for treating FS, such as primary, dewatering, pre-effluent, post-effluent and sludge treatment. The tool requires inputs from users regarding energy availability, flood-prone area, groundwater table, limited space, operator skill level, capital cost, O&M cost, climate conditions and priority to reuse treated FS. The tool offers contextually appropriate treatment options.
- Financial viability analysis, which calculates estimated costs for Capex (capital expenditures) and Opex (operational expenditures), cost and financing, debt, revenue, cash flow, income statement and balance sheet.

(2) City-wide inclusive sanitation services assessment and planning (cwis sap) tool

This tool helps decision-makers to compare the effects of various sanitation interventions or investments on the dimensions of equity, financial sustainability and sanitation service safety. It analyses and illustrates each potential intervention to reach low-income areas, improve the viability of service providers and increase the quantity of waste that is disposed of safely. It facilitates communication and decision-making regarding the interventions that need to be prioritised. For further information, please visit https://www.cwisplanning.com.

STEP 5. INTEGRATED PLANNING APPROACH

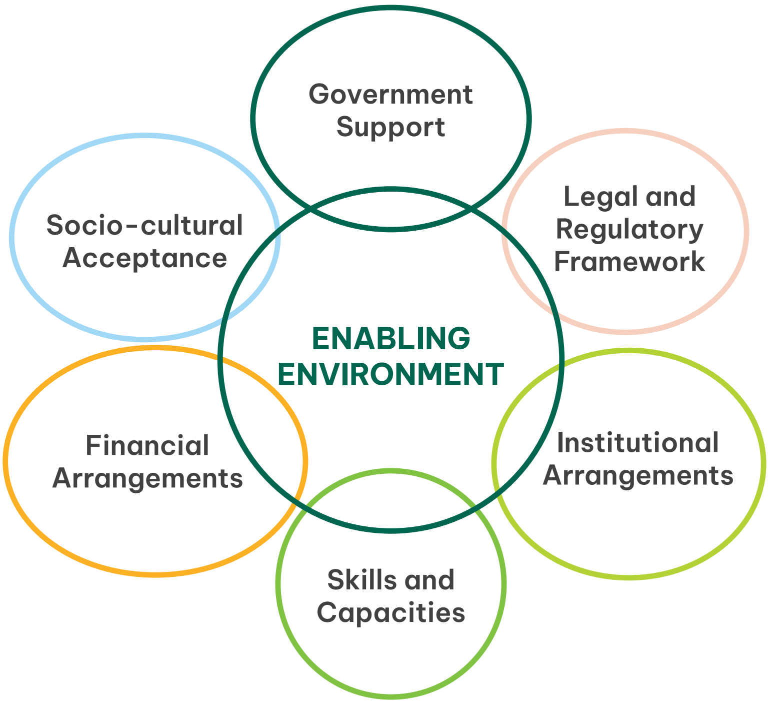


Figure 18. Enabling environment contributing to the success of FSM
(Source: Strande, Ronteltap, & Brdjanovic, 2014)

The feasibility and success of FSM are facilitated by an enabling environment. Few sanitation projects in low-income nations have been successful. Project failure is the norm and not the exception. In most instances, this is due to a lack of integrated planning. Physical infrastructure is frequently prioritised and emphasized; however, it is important to remember that technologies are only one component of the sanitation chain. Failure is typically caused by the implementation of infrastructure without consulting key stakeholders or without planning adequate operation, maintenance and financial transfers. If the enabling environment for FSM does not already exist, it must be created as part of a comprehensive plan.

3.2. Exercises

(1) Briefly explain the challenges and concerns faced during the FSM planning process in your country.

(2) What additional steps and processes can be adopted for comprehensive planning and adoption of the decentralised wastewater treatment approach?

(3) What practices and innovations are being implemented in your country that can be implemented to enforce sustainable infrastructure and sanitation principles?

(4) Describe the institutional arrangement and organisational system of sanitation in your country.

Module 4. Design and construction of DWM systems

4.1. Design principles and guidelines

The fundamental goal of wastewater treatment is to remove or significantly reduce pollutants to prevent damage to the environment and human health. Before determining the type of treatment required and the size of each unit, planners and designers must determine the following information: (i) the quality and quantity of the raw wastewater, (ii) influence of local conditions on the treatment processes and (iii) required standards to be met for final use or discharge. The quantity and quality of the pollution load, feasibility of treatment, environmental impact under local conditions and suitability of a specific wastewater for biogas production are determined by laboratory analysis. Because the quality of wastewater varies depending on the time of day and season, data analysis is never absolute. It is more important for the designers to understand the significance and normal range of each parameter than knowing the exact values. Typically, a precision of 10% proves to be sufficient.

Appropriate technology is defined as technology which is designed by considering environmental, ethical, cultural, social and economic factors. Less resource-intensive technologies are easier to maintain and have a lower total cost, with less environmental impact.

Fundamental design principles for DWM systems include the following:

- Accessibility (for women, girls, elderly, disabled and sick);
- Affordability (low-income communities);
- Land availability;
- Functionality;
- Quality;
- Long-term sustainability;
- Manageability;

- O&M requirements;
- Compliance with environmental protection regulations (having the least possible ecological impact);
- Improvements to human and ecosystem health.

Before selecting a technology, evaluating and analysing all available options for the sanitation value chain segment in question is critical. When necessary, a holistic perspective regarding the entire sanitation chain is required; for instance, if a decision-making body needs to determine which containment to implement in a certain area, it must also consider the available collection and transport system, as well as the type of treatment at the end, to maximise outputs for all segments.

4.2. Selection of appropriate technologies

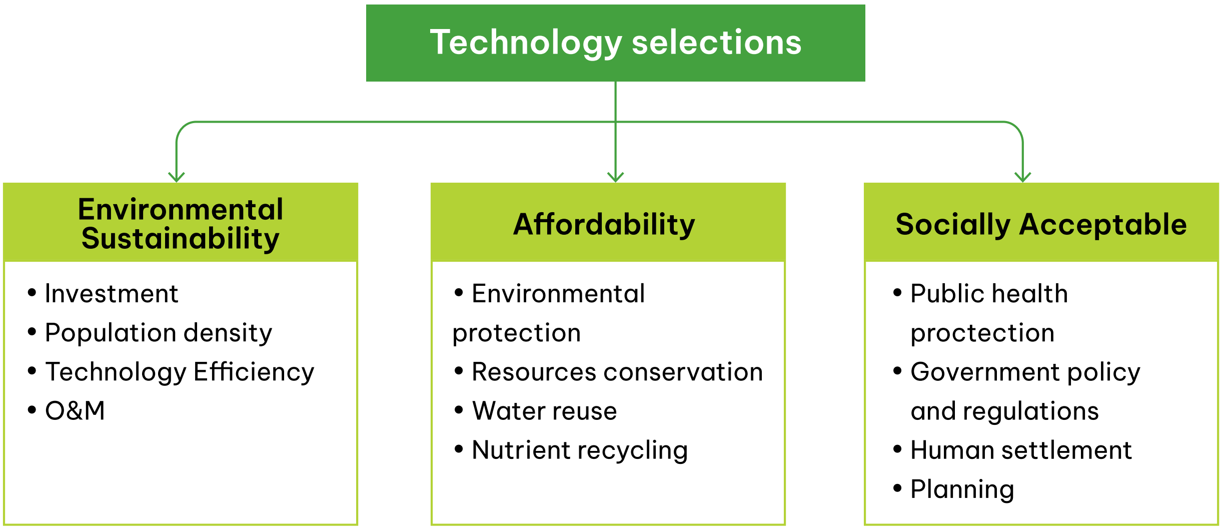


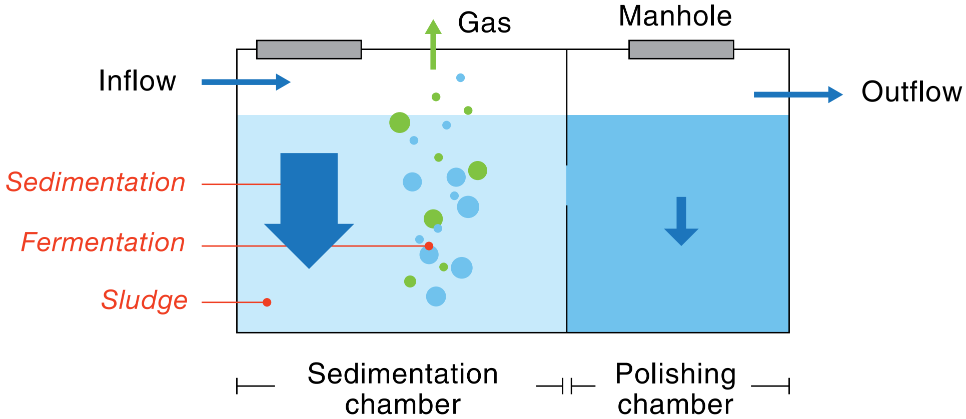
Figure 19. Criteria for the selection of appropriate treatment technologies

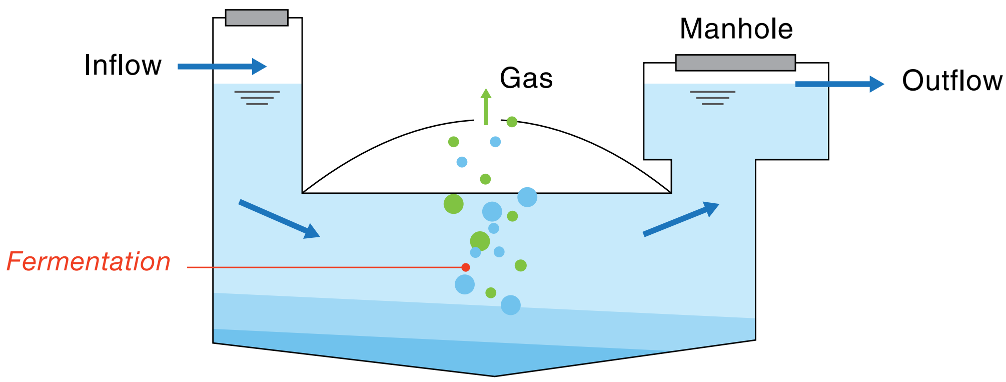
There are two types of technologies: (i) simple technologies, without energy input requirements, based on natural processes such as filtration, settling and evaporation (sludge drying bed, settling thickening tank, etc.) and (ii) complex mechanised technologies that require electrical energy (screw press, activated sludge, aerated ponds, etc.). Considering the capital investment and operational requirements, simple technologies are efficient and effective as it is simple to construct the required treatment units by using locally accessible materials; hence, simple technologies are widely adopted and used. However, a larger area may be required for these technologies. Compared with manual labour, mechanised labour is reliable and quick; however, it requires a tremendous amount of energy and capital. Spare parts are not readily available, and maintenance and operation of mechanised technologies require skilled labour. In practice, a combination of both non-mechanised and mechanised treatment technologies is used to attain the desired effluent and solids standards.

4.2.1. Examples of commonly used decentralised wastewater treatment technologies

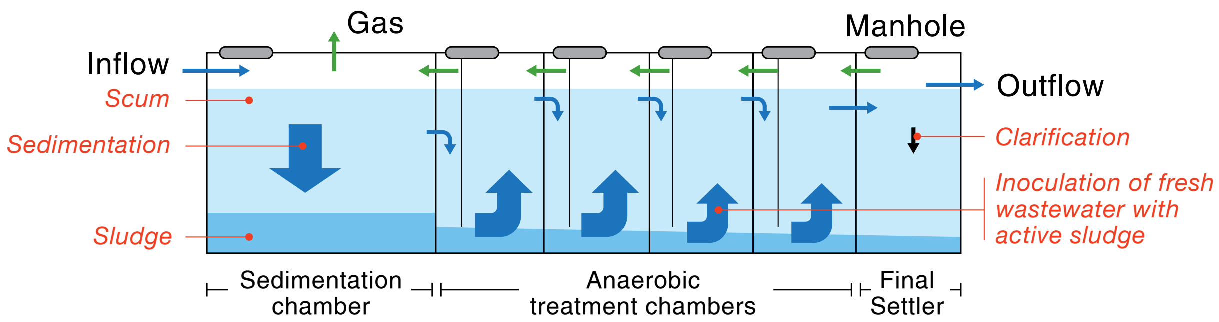
The appropriate design and technology for decentralised treatment is determined by variables such as wastewater characteristics, availability of suitable land and space, funds, expertise and compliance with environmental and social standards. As depicted in the figures, decentralised wastewater treatment technologies normally include four types of treatment systems, including aerobic (presence of oxygen) and anaerobic (absence of oxygen) treatment processes.

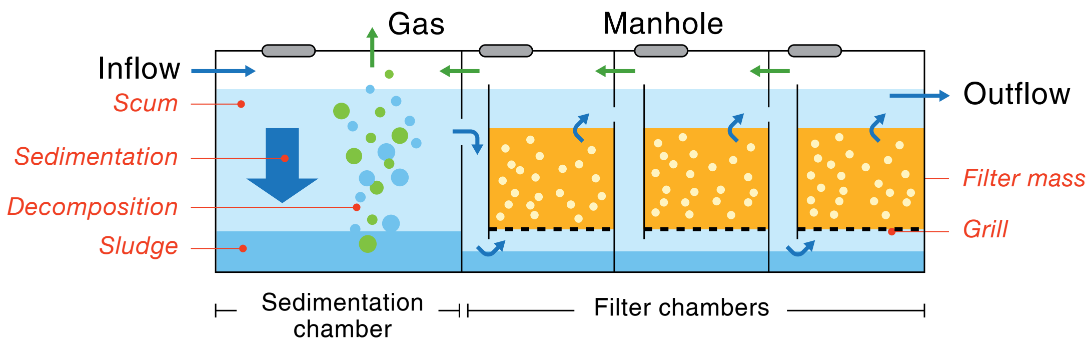
(1) Primary anaerobic treatment: Examples include sedimentation ponds, settlers, septic tanks and/or biogas digesters (ADB, 2021).



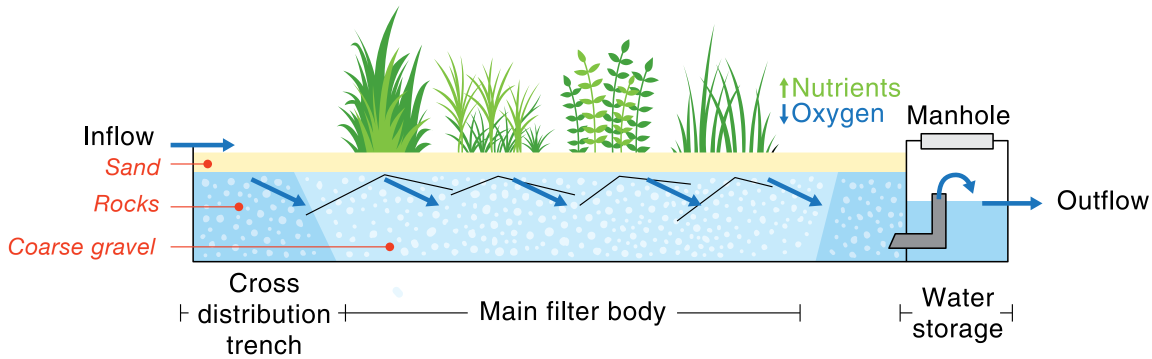


(2) Secondary treatment: Examples include ABR and AF (ADB, 2021).

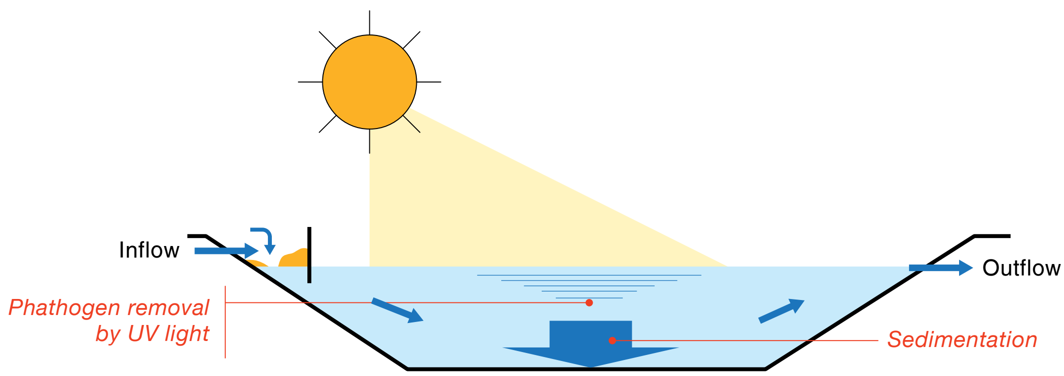




(3) Secondary and tertiary aerobic / facultative treatment: Examples include horizontal or vertical gravel filters or constructed wetlands (ADB, 2021).



(4) Post-treatment: Examples include aerobic polishing ponds and facultative pond systems (ADB, 2021).



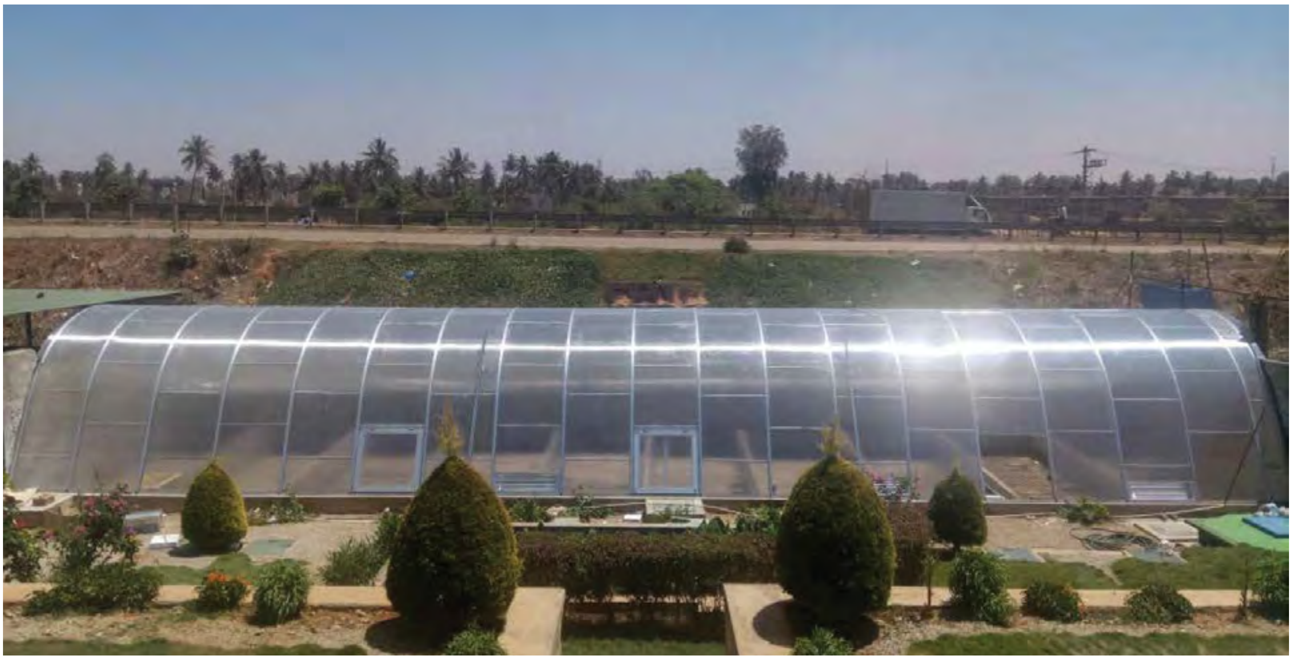


Figure 20. Greenhouse solar dryer roof arrangement over unplanted sludge drying beds for enhanced moisture removal. *(Source: Ms. Julia Knop and the CDD team)*

The following factors play an important role in the identification, selection and design of appropriate decentralised wastewater treatment technologies:

- Topography: An analysis of the topography helps determine the type of capture and containment facilities required, the type of collection and transportation system to be adopted and the location of the treatment plant (hilly areas, flooding areas, etc.); if the treatment plant is to be constructed in densely populated areas, special consideration is required for all components, particularly the placement of capture and containment facilities, type of treatment plants and collection and transportation techniques.
- Population size: This aids in comprehending the required investment and revenue streams for various available technologies and selecting the most suitable technology for a sustainable sanitation business model.
- Population income: This enables understanding the community's income trends. On the basis of their income, affordable containment facilities, collection and transportation cost fees, end product costs and dumping fees at the treatment plant are established.

- Water availability and consumption: This facilitates the selection of capture and containment facilities in the event of water scarcity.
- Type of toilets: Information regarding the type of toilets is useful for the selection of collection and transportation systems and capture and containment facilities, particularly in densely populated areas.
- Existing collection and transportation system: This enables the evaluation of performance, gaps and constraints of this system and helps to determine where to place emphasis in the forthcoming new sanitation business model.
- Policies, laws and regulations, including the regulatory framework for financial arrangements: This facilitates establishing compliance standards.
- The existing tariff and all associated costs for the entire sanitation value chain: This cost analysis is of utmost importance when establishing new collection and transportation fees.
- Social inclusion: Women's participation in the management of WASH infrastructure has been found to be effective, with guidance from elders in some communities being crucial for the adoption of a new technology/ system.
- Social considerations: For a new technology to be easily adopted by the community, social considerations must be taken into account when proposing collection and containment facilities (for public toilets: consideration of separate toilets for males and females, menstruation facilities for females and urinals for males), acceptance of treated sludge as an agricultural fertiliser, etc.

4.3. Capacity building for local construction and maintenance workforce

Capacity development for decentralised sanitation must be refocused away from centralised solutions. It is difficult to convince engineers that inexpensive decentralised treatment systems are as effective as traditional infrastructure. The political economy of large contracts and costly operations and maintenance of centralised treatment systems is also an obstacle. Therefore, a systematic approach to capacity building must be adopted, along with an integrated wastewater management strategy that includes FSM. This will provide the central government with the ability to effectively exercise and delegate authority and the development of an institutional framework will facilitate the mapping of local governments' community management responsibilities.

To enhance technical capacity and raise awareness regarding DWM, the following specific actions are recommended:

- Providing a precise definition of DWM and FSM, along with a description of their characteristics and sampling and analysis guidelines;
- Highlighting treatment characteristics and viable options, such as fundamental design principles, cost evaluation, operational guidelines and pre-selection criteria;
- Describing the quality and quantity of sludge generated by decentralised wastewater treatment systems;
- Developing customised training manuals for unskilled workers;
- Promoting the advantages and applications of the end products;
- Providing small- and medium-sized entrepreneurs with guidance on financial management;
- Providing specific technical guidance to operators of the treatment plant;
- Clarifying the complementary roles of public and private partners in DWM.

4.4. Exercises

(1) What principles govern the design of DWM?

(2) What are the most suitable or appropriate technologies under the context of ASEAN countries? What are driving factors or criteria for selecting these technologies?

(3) What are particular skills and expertise required for improving technical capacity related to DWM?

(4) What are the constraints of decentralised technologies and how can they be overcome?

Module 5. Operation and maintenance of DWM systems

To perform proper maintenance of DWM systems, first, it is necessary to understand the specifics of their maintenance. The purpose of this chapter is to provide practical and technical maintenance management information regarding DWM systems.

Operation

This involves continuous and repetitive activities involved in the operation of technical facilities, infrastructure, businesses, etc., with the goal of creating value for stakeholders (e.g. a cleaner environment, improved public health, profits, etc.).

Maintenance

This involves activities such as testing, measuring, replacing, adjusting and repairing to maintain or restore a functional unit to a specific condition in which it can perform its required functions; all actions taken to maintain or restore materials or assets to a usable condition—including inspection, testing, maintenance, serviceability classification, repair, reconstruction and refurbishment; and, the ability to ensure that an asset (plant, building, structure, surface facility, utility system, or other property) can be used continuously for its intended purpose and at its original or designed capacity and efficiency.

Maintenance mainly includes the following:

- Ensuring that the plant is working and continuously running;
- Assessing the plant function;
- Removing sludge deposits;
- Cleaning;
- Assessing the settings;
- Controlling biological performance (analysis of parameters);

- Controlling the discharge point;
- Measuring sludge levels;
- Assessing indication of desludging;
- Writing a maintenance report.

Consideration of the frequency of O&M activities

Typical O&M frequencies are shown below:

- First inspection: This involves confirming that the system is installed appropriately.
- Weekly: Visual assessment (inlet, outlet, covers, tank, ventilation pipes,...).
- Every 3 to 6 months: Cleaning mechanical equipment.
- Every 6 months:
  - Functional checks for manual and electrical devices;
  - Determination of the sludge level;
  - Effluent sampling and analysis.
- Every 12 months and/or on demand: Removing sludge.
- Every 3 to 5 years: Tightness control assessment.

It is recommended that the frequency of O&M activities should be optimised based on actual use. For example, if the number of people using the facility has increased since it was designed, the frequency of these O&M activities may need to be increased. Observing the condition at each inspection, maintaining records and organising the information will help optimise O&M activities.

Record-keeping

For maintenance and inspection, the following information must be described and maintained for a certain period:

- Date and time of work;
- Name of responsible operator (s);
- Maintenance and inspection activities;
- Water quality measurement results;

- Sludge accumulation status;
- Chemical replenishment;
- Repairs and replacement of parts;
- Cleaning.

When preparing maintenance and inspection records, it is desirable to use a format that has the following characteristics:

- Easy to complete;
- Easy to read;
- Easy to convert to an electronic format;
- Easy to tabulate.

In some cases, manufacturers may provide their own format.

Cautions

Use extreme caution when inspecting or entering the tank. Do not inspect or enter the tank alone. The natural treatment process inside the tank produces toxic gases that can be fatal to humans within minutes.

5.1. Monitoring and evaluation framework

The O&M of systems is primarily determined by the technology combination, which in turn determines the following:

- Staffing requirement;
- Levels of skills required;
- O&M costs;
- Energy requirement;
- Use of chemicals such as coagulants, grease, other consumables, etc

Example:

a) Nonthaburi FS treatment plant in Thailand.
(Source: EAWAG & SANDEC, 2015)

b) Manila septage treatment plant.
(Source: Strande, Ronteltap & Brdjanovic, 2014)

Figure 21. Sludge treatment plants in Nonthaburi and Manila.

Note:
a) This plant uses natural processes such as anaerobic digestion, evaporation and filtration, and requires less skilled labour.
b) This plant uses a mechanised screw press. The operational expense and energy demand of system b) would be significantly greater than those of system a).

5.2. Routine and preventative maintenance

5.2.1. Operation and maintenance plans of domestic wastewater and FS treatment plants

Receiving FS at a treatment plant requires two procedures: traffic control and FS discharge approval.

(1) Traffic Control

Traffic control is important at busy facilities (that frequently receive FS) where FS-carrying trucks may be competing for discharge; operational staff members are required to guide and assist drivers while unloading trucks. Traffic can be simplified through a well-designed facility layout; for example, driving through after discharging rather than turning back prevents traffic congestion and avoids conflicts and accidents.

(2) Approving FS for discharge into the facility

The impact of FS characteristics on the treatment facility is significant. FS from residential areas is relatively free of toxic chemicals, that from restaurants is high in oil and grease and that from hospitals and workshops may contain chemical toxins. In areas with a high concentration of commercial establishments, it is preferable to separate residential and commercial wastewater treatment systems. It is important to maintain a manifest form, that is, a written record of the FS delivery that traces the waste's origin, specified by the waste source location, type and volume.

Depending on the type and size of treatment facilities, O&M activities include a long list of tasks. The minimum requirements of the O&M plan are the frequency and tasks required to keep the facility operational.

Operating procedures: Most technologies necessitate cleaning screens, scraping dried sludge from drying beds, compost turning, packaging, selling, etc. Scheduled routine cleaning activities need to be conducted; further, solid waste screening and storage in a secure container until disposal is required.

Maintenance procedures: Maintenance of the treatment plant's equipment and treatment technologies will help to ensure the plant's performance and longevity. The two major types of maintenance activities include preventive and corrective maintenance. Component failure can contribute to system-wide failure or non-compliance. For example, failure of sand drying beds may result in a waste stabilisation pond with insufficient performance. Hydrant lime must be handled with care because it is an irritant. Each component must undergo preventive maintenance, which should be documented in an activity-based maintenance plan. Physical inspections should take place at regularly scheduled intervals; inspection indicators include cracked wires, broken concrete, discoloured pipe, etc. Corrosion control involves scraping rust, painting metal surfaces, locating and maintaining valves, lubricating and greasing mechanical equipment such as pumps, centrifuges, etc. and performing housekeeping tasks such as garbage collection and weed control.

5.2.2. Asset management

It is essential for treatment plant operators to perform routine and scheduled O&M tasks, emergency repairs and equipment replacement financing. Spare parts for repairs, consumables such as grease or chemicals and labour required for O&M are examples of common assets. Asset management considers the following factors: asset inventory, level of service, critical assets, life cycle costing and long-term funding strategy.

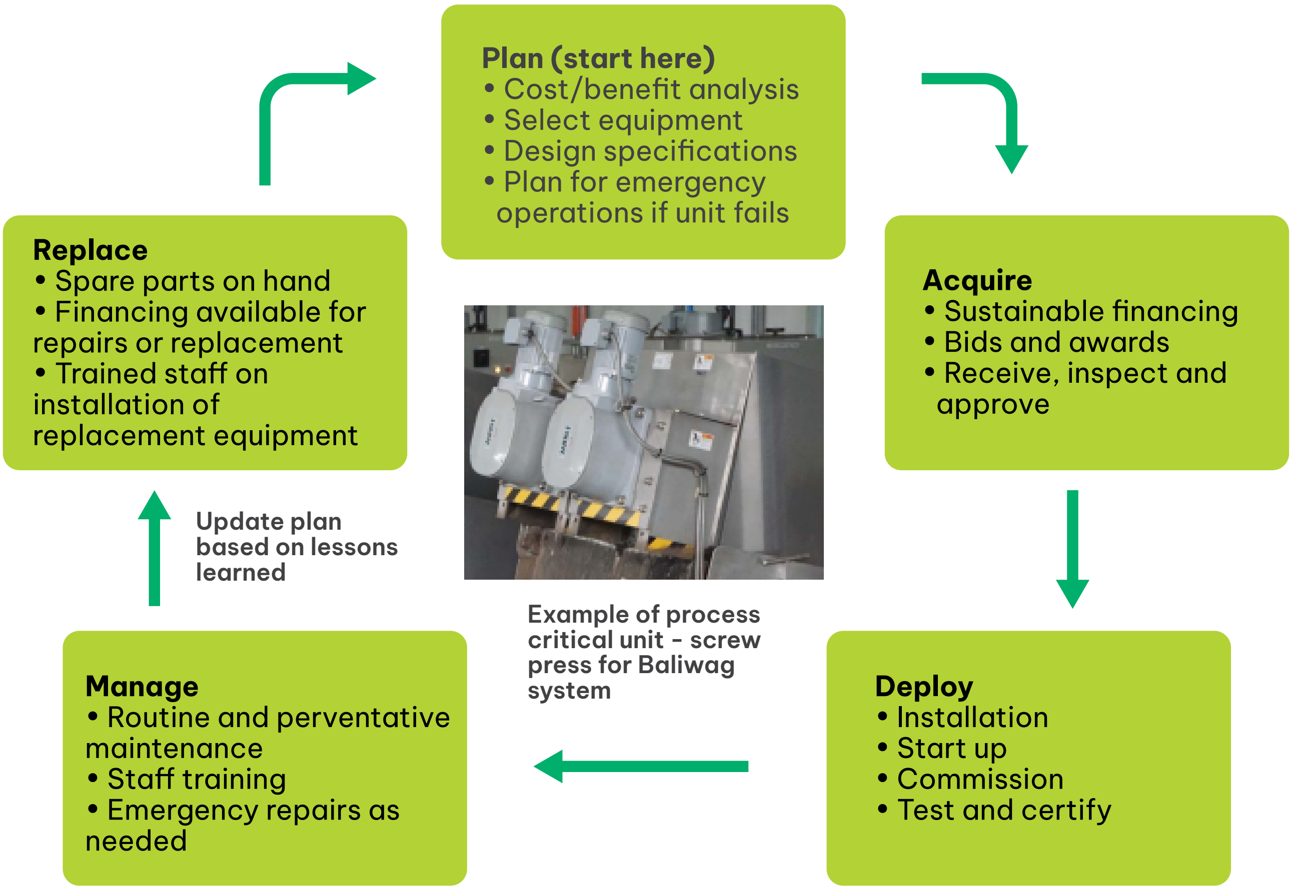


Figure 22. Asset management of critical equipment.
(Source: Bassan & Robbins, 2014)

5.2.3. Monitoring

Regular monitoring is necessary to determine whether the treatment plant is operating as intended. Monitoring may include the recording of the incoming sludge volume, which can be determined by using the manifest form discussed previously. Variation in the sludge volume assists in estimating the loading shock that a treatment plant will experience and its effect on the plant's performance. In addition to the sludge volume, monitoring of physio-chemical and biological parameters provides insight into the treatment plant's performance, effluent quality and end use products. Monitoring may involve a variety of techniques, including visual or sensory inputs, such as visually inspecting scum level, the color of sludge, odors from the system, etc.; analysis or measurements at source, such as pH, dissolved oxygen, temperature measurements; and, laboratory analysis. It is an expensive and time-consuming process that requires a proper monitoring plan; this process includes the required information, the number of samples and sampling points, the person designated to collect them, etc.

5.2.4. Record-keeping

Effective O&M programmes require precise documentation of all O&M activities, monitoring and plant operations. It is important for operators to know the history of recurring malfunctions since they perform routine assessment to optimize O&M procedures,. Examples of record-keeping include: daily operating hours, peak hours, reports, etc., disaster response and emergency recovery records, preventative maintenance records (equipment maintenance log books and store room inventory reports) and employment records (employee schedule, time sheets and injury report).

5.2.5. Administrative management

Effective management of an FSTP necessitates a well-defined management strategy that includes employee coordination, planning, supervision and capacity strengthening that is unique to each treatment plant. Administrative management consists of financial procedures which are based on operational needs—that must be monitored and devised based on actual expenses—and human resource management, a method for defining the employee's roles and responsibilities, reporting structure, etc. Each FSTP has a plant superintendent who is responsible for the plant's day-to-day management. He or she is accountable for all paperwork and correspondence; equipment maintenance and personnel supervision; coordination of the organisation's staffing and operational activities; and identifying, selecting, training, motivating and evaluating assigned personnel. The plant engineer is the technical employee in charge of ensuring overall plant efficiency, controlling operating costs and recommending technical solutions to problems encountered. It is preferable to have documentation or terms of reference for each employee at the plant that includes the job title, roles and responsibilities, minimum qualifications, knowledge required, reporting structure, etc.

(1) Responsibilities of the plant operator:

- Responsible for day-to-day plant operations, such as equipment inspections and sample collection;
- Operating aerator pumps;
- Maintaining documentation of operational activities;
- Writing field and administrative reports;
- Providing assistance with environmental investigations, field surveys and clean-up efforts.

(2) Responsibilities of the Plant maintenance technician:

- Responsible for routine and emergency repairs and maintenance of plant facilities, pumps and engines;
- Lubrication and maintenance of equipment;
- Maintaining buildings, roads and the landscape;
- Performing cleaning duties, replacing worn components, etc.

5.3. Troubleshooting and emergency response

5.3.1. Plant security and safety

There are numerous health risks associated with FSTPs, including direct contact with raw FS, the use of chemicals and their disposal, the use of large ponds or even large reactors (associated with the risk of falling) and the use of electrical equipment (associated with the risk of electrical shocks). Therefore, a treatment plant should implement safety measures such as fencing off the facilities and preventing unauthorised entry and vandalism, security discussions in employee meetings and discussions, setting up a security system and appointing responsible security staff to oversee the treatment plant, providing security training to all staff members and requiring the use of personal protective equipment (PPE) when handling equipment, sludge, etc. Smoking should always be prohibited on FSTP premises for the following reasons: 1) hand-to-mouth coordination of a cigarette can transmit disease, 2) methane accumulates in closed areas/tanks that may catch fire due to smoking and 3) flammable chemicals may also be stored in closed areas. FSTPs frequently utilise confined spaces such as anaerobic chambers and digesters. For maintenance or repairs, an operator may be required to enter a confined space; therefore, a permit from a superior must be obtained, which should include the following: operator information, time and date of work, two people for safety coordination and mandatory use of PPE.

5.4. Financing and cost recovery mechanisms for O&M

The costs of O&M determine the long-term viability of the technologies under consideration. Typically, O&M costs increase with the complexity of the technology and are unsuitable for long-term funding since wastewater user fees are rarely implemented. Personnel and external services such as maintenance or replacement of components, desludging, etc. are included in O&M expenses. The hiring of external personnel for maintenance and repair of the treatment component incurs additional expenses beyond those incurred by the regular staff. Open systems, such as ponds and constructed wetlands, require more frequent monitoring than closed digesters; however, the desludging frequency and cost of the former systems are lower than those of the latter, which are compacted and heavily loaded, resulting in a higher cost.

5.4.1. Framework for collection and transportation

Issue	Description
Key Player	1. Local administrative organisations 2. Private companies (licensed and unlicensed companies)
Value Proposition	1. FS collection service 2. Oil and grease removal/wastewater collection
Key Resources	1. Collection trucks 2. Equipment, that is, DWM cover opening equipment 3. Human resources, that is, municipality officers, operators (drivers, assistants, etc.)
Customer Segment	1. Households 2. Buildings 3. Industrial Estate
Distribution Channels	1. Service area: Within the municipality/permitted areas 2. Truck parking station: Municipality or private company office 3. Daily distance: Varies by the number of requests made, trip, location of the treatment plant (TP)/discharge area
Customer Relation Management	1. Finding new customers via community leaders, posters, name card, radio spot, etc. 2. Maintaining current customers by providing prompt services, cleanliness, affordable price, regular customers with contracts, etc. 3. Denying service to some customers due to technical problems/ long distances
Costs	1. Fixed costs: Truck and equipment costs 2. Variable costs: Fuel costs, personnel costs, license fees, treatment fees, administrative expenses, etc. 3. Other service fees
Revenues	1. Collection fee: Depending on the volume and FS fee rate 2. Other service fees: Service providers consideration and agreement
Core capabilities	1. Local administrative organisations: Money subsidised by the central government 2. Private company: Cost control

5.4.2. Framework for treatment and reuse

Issue	Treatment	Reuse
Key Player	1. Local administrative organisations 2. Private companies (licensed and unlicensed company)	
Value Proposition	Fecal sludge Treatment	Reuse of products and by-products: Depending on the treatment plant (dried sludge as fertiliser liquid as plant watering, raw water for water supply production)
Key Resources	1. Treatment plant and facilities depending on the availability of land, amount of sludge and budget 2. Equipment: Depending on the treatment technology 3. Human resources: Operators and labour	
Customer Segment	Collection and transportation provider (same organisation as treatment provider; different organisation from the treatment provider	Agriculture section including owners of vegetable gardens, orchards, flower farms
	Treatment plant location • Within the municipality area • Nearby area • No treatment plant/only disposal area	Reuse site • No delivery as the customer might pick up the product at the treatment plant
Customer Relation Management	• Finding new customers: n/a (Truck and treatment plant are usually under the same organisation. If there are available treatment plants, the collection truck will find the TP on their own) • Maintaining current customers by providing adequate capacity and low treatment fees • Denying service to some customers due to inadequate capacity	• Finding new customers by promoting product application, quality and safety • Maintaining current customers by offering adequate products that are cheap and of good quality • Denying service to some customers due to inadequate products/low product quality

Issue	Treatment	Reuse
Costs	1. Fixed costs: Investment (land and construction) 2. Variable costs: O&M costs (depends on the technology), personnel expenses, administrative costs etc. 3. Other service fees	
Revenue	Treatment fee: If the collection and treatment are from different organisations	1. Selling dry sludge 2. Profit from other reuse activities
Core Capabilities	Good location and appropriate treatment technology	Reuse technology and equipment

5.4.3. Examples of practical business models

The market opportunities within the sanitation value chain can be segmented. The primary categories of the value chain include collection and transportation, treatment, and reuse. The government plays a crucial role in developing policies that encourage private sector participation in the sanitation value chain. This can be accomplished through political prioritisation, effective legal frameworks, equitable tariff setting and the avoidance of unwarranted political interference. Weak institutional frameworks and financing policies may lead to ineffective and incompetent utilisation of available resources in the sanitation market. It is difficult to recover costs from the public budget when the demand for wastewater treatment is low. Additionally, it is difficult to attract private investments from the private sector. Demand can be generated through sanitation promotion and behaviour change campaigns, one of the most effective methods that governments can employ to empower communities and households to cover a greater portion of the costs for sanitation systems and reduce government spending (UNHABITAT, 2015). Given the importance of PR campaigns, the public sector (government, NGOs, academic institutions, etc.) should conduct location-specific demand studies to better understand what encourages or discourages households from investing in sanitation. Without stimulation from the public sector, households may frequently undervalue the advantages of engaging in hygienic behaviour (UNHABITAT, 2015). Another effective strategy to change households' behaviour is to focus on interventions in public institutions, such as schools, hotels, resorts and hospitals. Most changes in behaviour do not occur through individuals, but through introducing new habits to the next generation (UNHABITAT, 2015). Targeting affordability via financing schemes such as microcredits is another method for stimulating demand. A toilet with a septic tank is a long-term investment, and if households have the option to repay it through microcredits and loans, they are more likely to purchase this technology. To reach a large portion of the population, loans or targeted subsidies can be offered to poor households. The government can take several actions, including regulating the sector, promoting registered organisations and taking action against illegal operators.

Without a doubt, a country's national authorities must be involved in the development, dissemination and validation of policies, laws, strategies and standards which define the roles, procedures, standards and sanctions for the sanitation value chain. However, the private sector must also be considered when defining regulations, as it may offer more cost-effective measures and services and frequently fill the gap between demand and the government's capacity. In Thailand, the private sector is restricted to contract-based wastewater treatment plant operation services. In countries such as Malaysia and the Philippines, privatisation of wastewater management has proven to be effective. The Thai government has advocated for a public-private partnership (PPP) in wastewater management; however, it has not yet implemented PPP. Thongthawil Service Co. is an example of a FSTP company that is profitable because it charges a fee for the use of its treatment facility.

5.4.4. Money flow scheme

Figure 23 above shows the relationship among stakeholders within the sanitation value chain, including the household, municipality, collection and transportation and treatment plant (TP) operator. Household users are responsible for the waste they produce. In this chain, the collection and transportation company receives an emptying fee from the household and an incentive discharge payment from the treatment operator. The authority sets a series of charges for the operators to acquire the license to operate the services. Truck drivers are alerted through letters and meetings about the need for high environmental protection standards. To formalise the truck drivers' activities, the idea of an emptier license was encouraged. This license determines the handling, service quality and the number of trucks permitted to operate in a specific area.

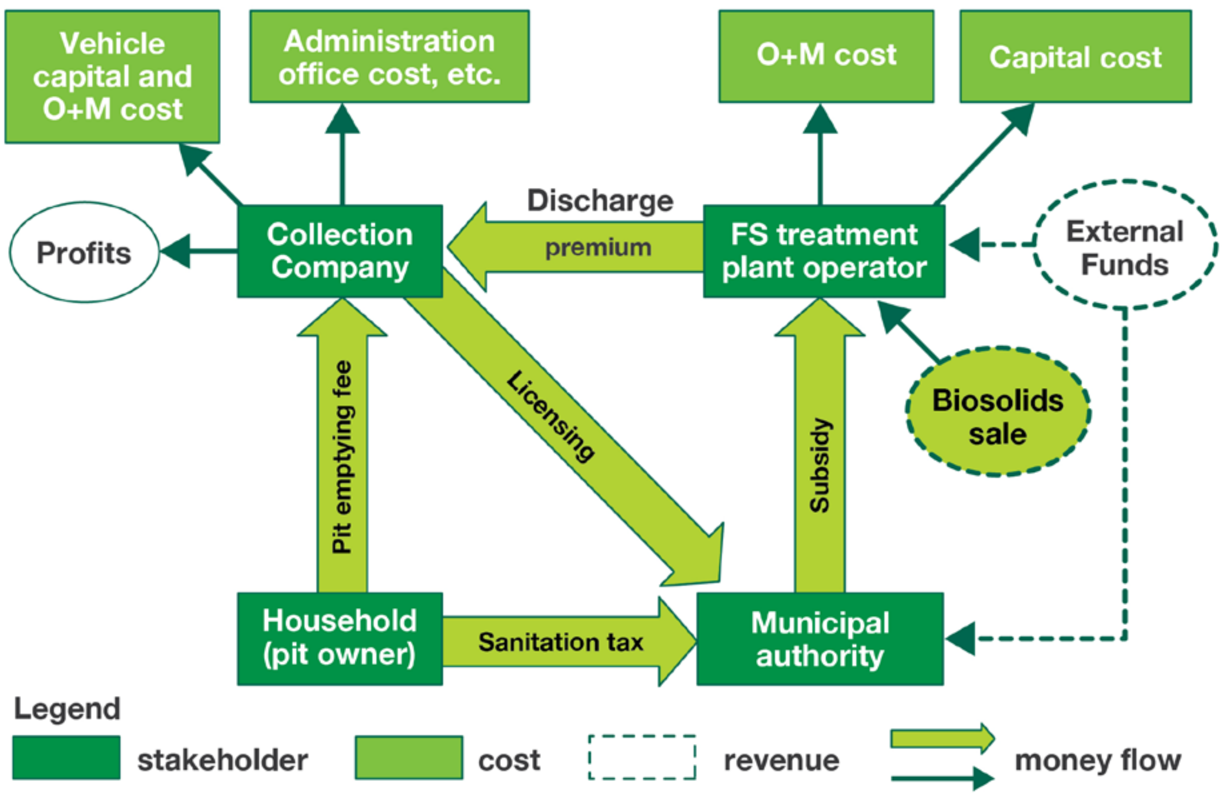


Figure 23. Relationships between stakeholders within the sanitation value chain

According to the cost of treatment plants, the financial and tariff structure should be designed as follows: collection and transportation service companies are encouraged to provide loans to treatment plants, and users' inclination to pay for sanitation services is promoted via behaviour change programmes implemented by the government. The measures consist of a structure, loans and a credit scheme for poor households, which are essential from a business and management perspective for the overall improvement of the sanitation service chain.

Subsidies and loans are crucial for many communities with low incomes. Subsidizing the cost of cleaning facilities or arranging loans could be the solution to run treatment plants for a long term and provide access to sanitation to everyone. Credit programme can also be implemented for low-income households. It should be noted that septic tanks must be emptied annually. Under the microcredit programme, emptying fees are frequently excessively high for low-income households, which prefer smaller installments throughout the year. Hence, the federal or local government should consider providing subsidies. The purpose of such a policy is to make collection and transportation services accessible and affordable to all users while retaining sufficient profit margins.

Sources of funding for domestic wastewater management and FSM may include the government budget, subsidies, loans, grants and/or individual savings. Typically, the public sector receives investment funds or grants from the government. Additionally, the private sector typically uses a personal budget to fund its own sanitation projects. However, if a personal budget is unavailable, capital financing from other sources, such as government agencies, commercial banks and non-governmental organisations, is required. Therefore, the business plan and project documentation are required for the credit to be considered and offered by the financial sources. However, the majority of collection and transportation business owners rely on personal savings or loans from informal sources such as family and friends; the reason for this is that sanitation services do not meet the criteria for bank loans.

5.5. Exercises

(1) What are the factors (which are unrelated to age) responsible for the failure of sanitation infrastructure?

(2) Discuss the challenges of sanitation infrastructure standardisation.

(3) How does acceptability play a key role when considering technology development and O&M?

(4) What and how does the cost of regular O&M of sanitation infrastructure play a role in technology selection in your country?

(5) Briefly explain the challenges of standards and regulatory frameworks regarding O&M in sanitation.

Module 6. Case studies and best practices from ASEAN countries

DWM systems have been deployed by various institutions at numerous locations in ASEAN in recent years. The experience of these cases indicates that every place needs a different strategy. A selection of good practice examples/applications is presented below. These examples are meant to be illustrative; they focus on various aspects of the implementation of sustainable sanitation solutions.

6.1. Successful DWM implementation cases observed in ASEAN countries/cities

6.1.1. Geobag unit (with co-treatment), Melaka, Malaysia

Overall regulation and management owner: Government of Malaysia

Operator: IWK

Regulator: SPAN (National Water Services Commission) (National Regulator)

Tariff: Water Services Industry Act (2006), Concession Agreement between Indah Water Konsortium / Government of Malaysia 1993. Based on the available data, IWK has been operating at a loss (due to low tariff) and has been subsidized by Government (AIT, Stantec, 2020).

On-site containment and collection

- Desludging for septic tanks is intended to be on schedule (3-year intervals); however, in reality, it only happens on demand (AIT, Stantec, 2020).
- Desludging is performed by IWK or other companies that hold permits issued by the regulator. Payment through tariff for those on the scheduled scheme, and before the provision of service for desludging (AIT, Stantec, 2020)
- Desludging is performed by vacuum tankers having a capacity of 2.5, 4.5, or 11 m^3 (AIT, Stantec, 2020).

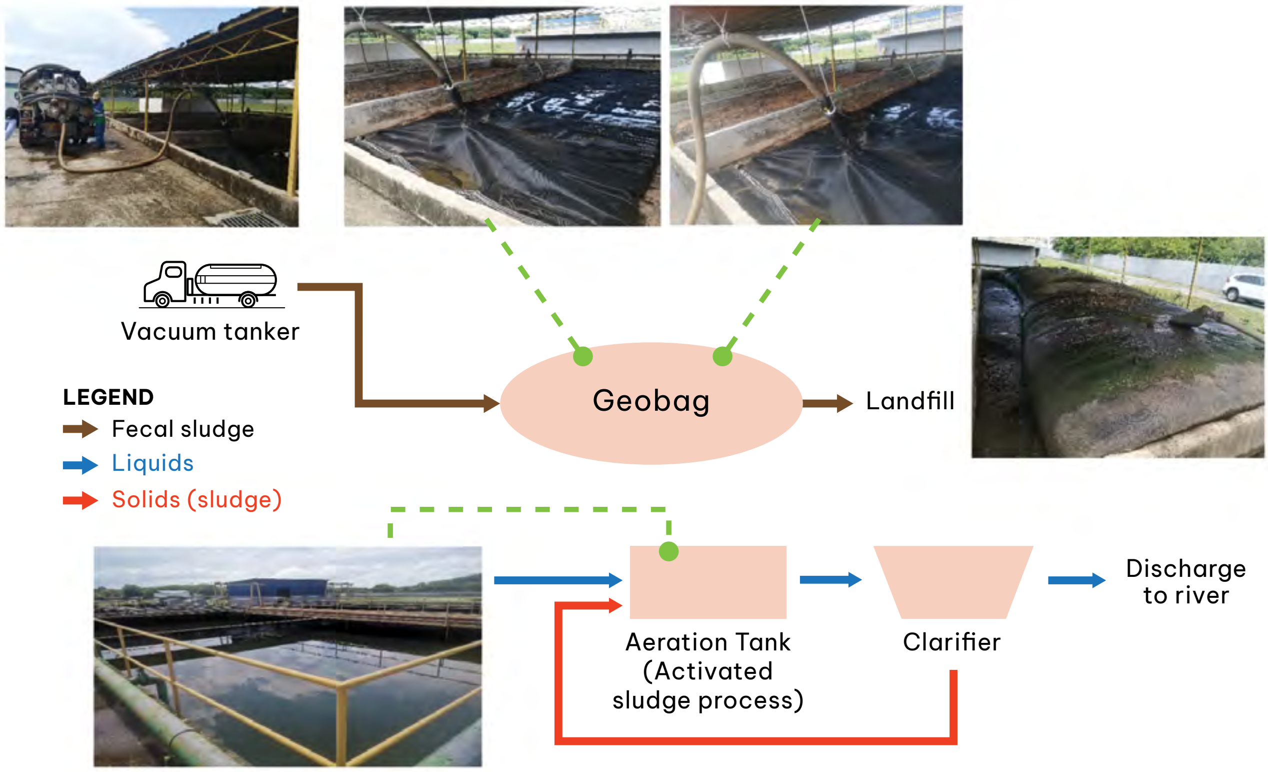


Figure 24. FSTP overview 1 *(Sources: AIT, Stantec, 2020)*

Treatment and Disposal/Reuse Process[31]

(1) Geobag: Constructed using geotextiles (polyester or polypropylene), with a pore size of 700–900 microns.

(2) The geobag capacity is $90m^3$. It receives septage intermittently, up to a capacity of $450m^3$.

(3) Discharge from tankers travels directly to the geobag, which is placed on top of the sand drying bed.

(4) Solid separation: The septage pumped into the geobag separates into solids and liquid, with the solids generally retained in the geobag, while the liquid seeps out.

(5) Filtered liquid seeps through the drying bed, and flows to the inlet of aeration tank for co-treatment; after treatment, it is discharged to the river via main drainage.

(6) A geobag can be filled with approximately five times its volume of wet sludge.

31 AIT & Stantec, 2020

(7) When the geobag is full, it is kept aside for the solids to dry and consolidate further. After a few months, the geobag is cut open and left to dry. After complete drying, the contents and the bag are disposed in landfills.

(8) Presently, there is no significant reuse of end products.

6.1.2. The case of the Thongthawil service company

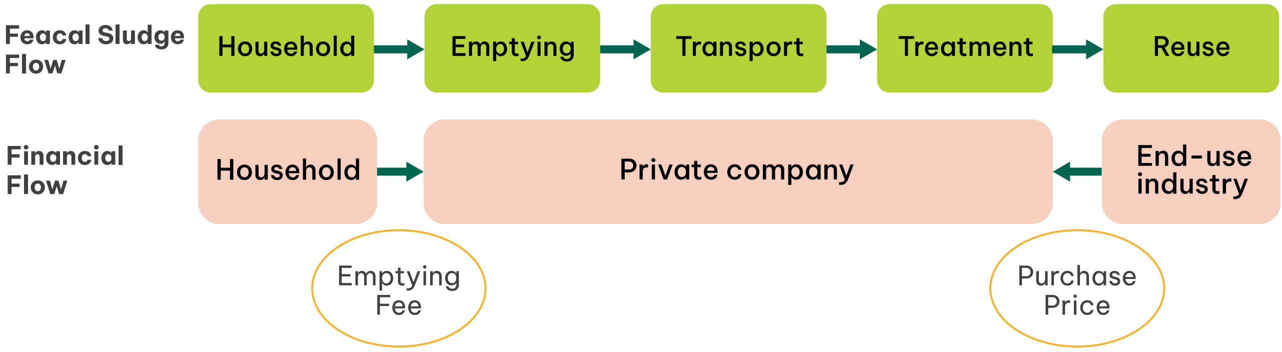


Figure 25. FS and financial flows

The Thongtawil service company is a licensed private business that operates in multiple locations within Rayong and Chiang Mai. Covering a service area of 38.90km^2, the Thongtawil service company provides collection, transportation and FS treatment services. The company offers a FS collection service in Rayong, where several industrial estates, including Maptaphut industrial estate and Eastern Seaboard industrial estate, are located. Approximately 60%–80% of its customers are from the industrial sector. The company has two 3m^3 trucks and two 6m^3 trucks with a total of five employees (two drivers, two assistants and one official). Thongtawil advertises its services on the radio and/or online. The company projects high customer satisfaction due to its dependability and popularity; however, due to high demand from industrial estate, its services are sometimes unavailable to residential customers. The Thongtawil Service Company's FSTP is an integrated system in which multiple treatment technologies are used concurrently. However, the primary system for treating FS is a covered lagoon. In addition to treating FS, by-products such as dried sludge and liquid effluent are produced. Additionally, because of the anaerobic condition, biogas is produced. In addition to using dried sludge in plantation areas, the company donates it to schools and temples. Additionally, liquid effluent is used for plant irrigation and tap water production. Furthermore, biogas from the cover lagoon is supplied to the power generator. Due to the availability of a large amount of land, the company uses a covered lagoon integrated with other treatment technologies and collects a large quantity of FS daily. The system comprises a large FSTP with a maximum capacity of 500 m^3/day and a screening unit.

Figure 26. FSTP operated by the Thongtawil service company
(Source: Asian Institute of Technology, 2018)

In Thailand, the private sector is solely responsible for the production and installation of on-site sanitation systems; however, their involvement in the wastewater treatment business is limited to O&M activities contracted by the government. Currently, more than 1,500 FSTPs cover 20% of the areas under local governments; however, only one FSTP is privately owned. This can be attributed to the government's ineffective efforts to encourage private sector investment. Additionally, the private sector will be eager to invest in the sanitation sector if the government can guarantee a return on investment. Thus, the policy must entice the private sector to invest in the FSM while developing a mechanism for contracting between private service providers and local government authorities for regularised desludging, either as a public–private partnership or as a self-owned enterprise. Thongtawil Service Co. is a great example of such a partnership. The regulation must serve as a guide for strengthening the capacities of the states and municipalities that own and operate treatment plants.

6.1.3 FS bio-fertilizer plant under the guidelines of the Royal development project, Nonthaburi, Thailand

Overall regulation and management

Owner and Operator: Nonthaburi Municipality Ownership (Public Ownership)

Regulator: Nonthaburi Municipality

Tariff: Only for desludging

Ministerial Regulation: A collection fee of 8.33 USD/m^3 to be paid by households to the service provider is specified (AIT, Stantec, 2020). The service provider needs to pay 334 USD annually to the municipality to obtain a license for FS collection, transportation and disposal (AIT, Stantec, 2020).

Relevant Legislation: Public Health Act, 1992 (AIT, Stantec, 2020)

- The local government is responsible for safe FS disposal in the area
- A license must be obtained to operate an FSM business. Violations are liable to a 6-month imprisonment and a fine of 320 USD.
- Hygienically collected FS may only be emptied in areas allotted by the local government

Business Model: Capital investment and O&M expenses are funded by the local government; while the users are charged a collection and transportation fee, there is no provision for charging users with a treatment fee. Fertilizer sales partially cover O&M expenses.

On-site Containment and Collection

Typical on-site household containment facilities include single cesspool systems (69%), double cesspool systems (23%) and commercial septic tanks (8%) (AIT, Stantec, 2020). Desludging is performed with the increasing demand by using vacuum trucks. Collection and transportation in commercial vacuum trucks with volumes of 2, 3, or 6 m3 is managed by Nonthaburi Municipality (AIT, Stantec, 2020).

Treatment and Disposal/Reuse Process[32]

(1) Discharge from trucks is screened with a manual screen to prevent large debris from entering the digester.

(2) The FS is pumped from the truck into anaerobic digesters via a screen. There exist 31 concrete reinforced anaerobic digester tanks. Each tank consists of a gas vent, manhole and gate valve (AIT, Stantec, 2020). The FS undergoes anaerobic digestion for 28 days before being discharged to sand drying beds.

(3) Digestate from the anaerobic digesters is released into sand drying beds whereby solids undergo drying for 10–14 days and the effluent is drained to the effluent collection pond. Dried solids are packaged and sold at 90 USD/tonne.

(4) Effluent collection pond: The collected effluent is treated under aerobic conditions and used within the premises for green spaces.

32 AIT & Stantec, 2020

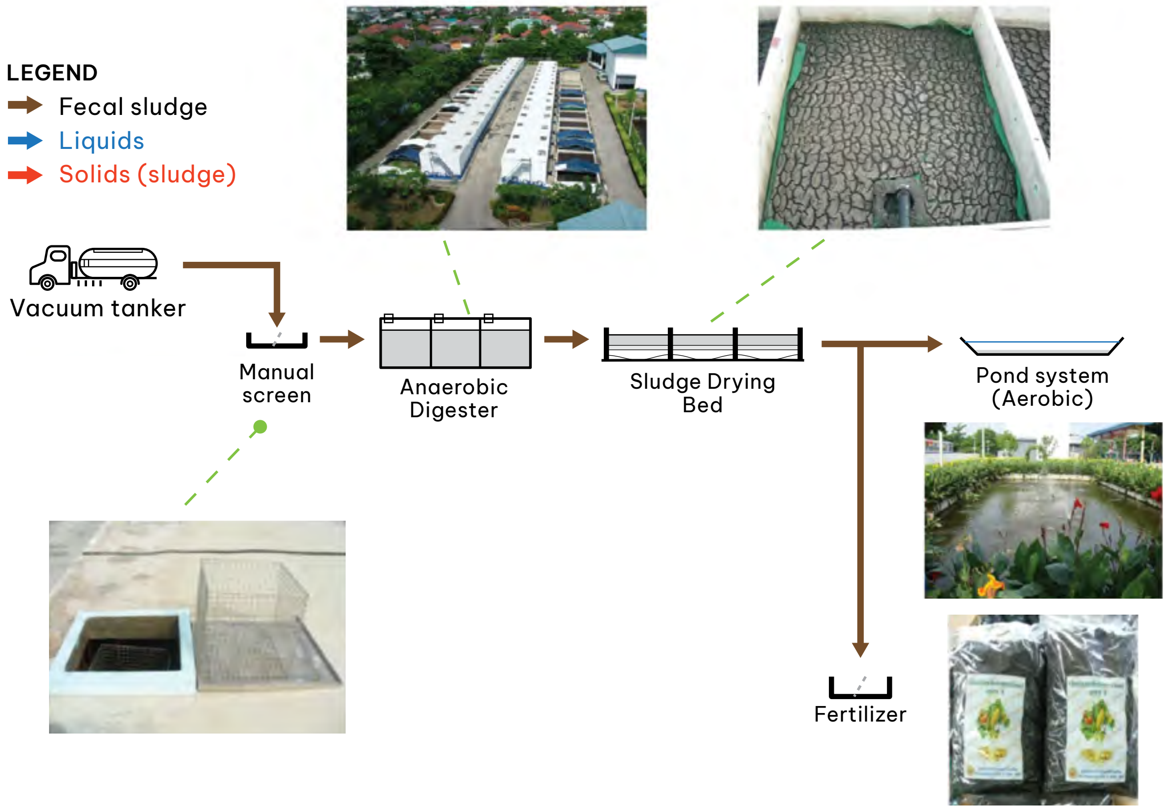


Figure 27. FSTP overview 2 *(Sources: AIT, Stantec, 2020)*

6.1.4. The National sewerage and septage management programme in the Philippines

The Philippine government approved the National Sewerage and Septage Management Programme (NSSMP) in June 2012 (UNESCAP & AIT, 2015). For the first time in Southeast Asia, a national government implemented sewerage and FSM projects to promote widespread sanitation improvement (UNESCAP & AIT, 2015). The NSSMP aims to provide local cities and municipalities with up to a 40% cost share for the implementation of sewerage projects (UNESCAP & AIT, 2015). Additionally, it aims to launch a national programme to promote FSM and the benefits of routine septic tank cleaning. The NSSMP will also offer technical assistance, targeted outreach and training to encourage and build the capacity of local officials to implement FSM programmes (UNESCAP & AIT, 2015). FSM projects are exempt from the national cost share requirement; however, they can usually be developed, run and maintained for significantly less cost. Use and service fees (tariffs) are used to divide the cost of O&M among the municipal government, private businesses and end users (UNESCAP & AIT, 2015).

6.1.5. Dumaguete City Septage Management programme, Philippines: Overall regulation and management

Owner and operator: The programme began in 2010 as a partnership between the Dumaguete City Water District and city government. In June 2019, the Dumaguete Water District terminated the Memorandum of Agreement that established the partnership as per the term of that agreement. Currently, the city government completely owns and manages the city's Septage Management System.

Regulator:

- The Department of Environment and Natural Resources (DENR) for water quality and compliance of the FSTP;
- The Dumaguete City Government for regular desludging, and enforcement of the local ordinance on sanitation
- The Dumaguete Water District (WD) for tariff collection. They subsequently remit the septage payments to the city government for a fee based on 4% of the septage tariffs collected.

Challenges:

- Changes in leadership and management in 2019 (AIT, Stantec, 2020)
- Reduction of user/septage fee by the city government from 0.04 USDm^3 (AIT, Stantec, 2020) to 0.03 USD/m^3 in October 2019, after turnover by the WD (AIT, Stantec, 2020)
- Currently, desludging is limited to the Dumaguete City area, excluding neighbouring municipalities (AIT, Stantec, 2020)

Relevant legislation and quality compliance[33]:

- **City septage ordinance.** It specifies regular desludging; it further specifies design of septic tanks, amount of user fee and modality of collection and corresponding penalties for non-compliance. The ordinance also specifies the implementation arrangements.
- **Clean water act.** This is a national law that requires all cities and municipalities to connect to a sewer system if available or have a septage management programme if sewerage is impractical. It also requires government agencies to develop and adopt the NSSMP.

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- **DENR water quality guidelines and general effluent standards of 2016.** It sets the standards for the effluent that will be discharged to water bodies.
- **Sewage collection and disposal, excreta disposal and drainage of the code on sanitation of the Philippines.**

Business model: Initial investment was co-funded by the WD and the city; subsequent capital investments and operating expenses were funded through user fees. The charging of user fees was supported by an ordinance.

On-site containment and collection[34]

Typical on-site containment for households and commercial buildings include septic tanks. Desludging was initially scheduled for every 3–5 years, but it changed to 'on demand' basis after the first round. Collection and transportation in trucks with volumes of 3–5 m^3 is managed by the city government. The WD collects the user fee, which is subsequently remitted to the city after deducting the service fee for collecting the user fee. Before September 2019, the WD collected and transported septage while the treatment facility was operated by the city. Before desludging, a preliminary visit to the site is conducted by the city treatment facility staff to verify whether or not the septic tank can be desludged, noting the presence of oil and grease or solid waste in the tanks or whether the septic tank has a manhole and is accessible. A report is prepared by the city staff. The report shows detailed data of the septic FS tank, owners, location, details of the septage trucks, technicians who conducted FS collection, dates of desludging and other relevant information.

Treatment and Disposal/ Reuse Process

A natural passive treatment process comprising anaerobic, facultative and maturation ponds, as well as PGF and wetland is also in use. Solids from the receiving tank and anaerobic ponds are air dried. The dried sludge is provide free of charge to farmers for use as soil amendment. The final effluent is discharged to the river.

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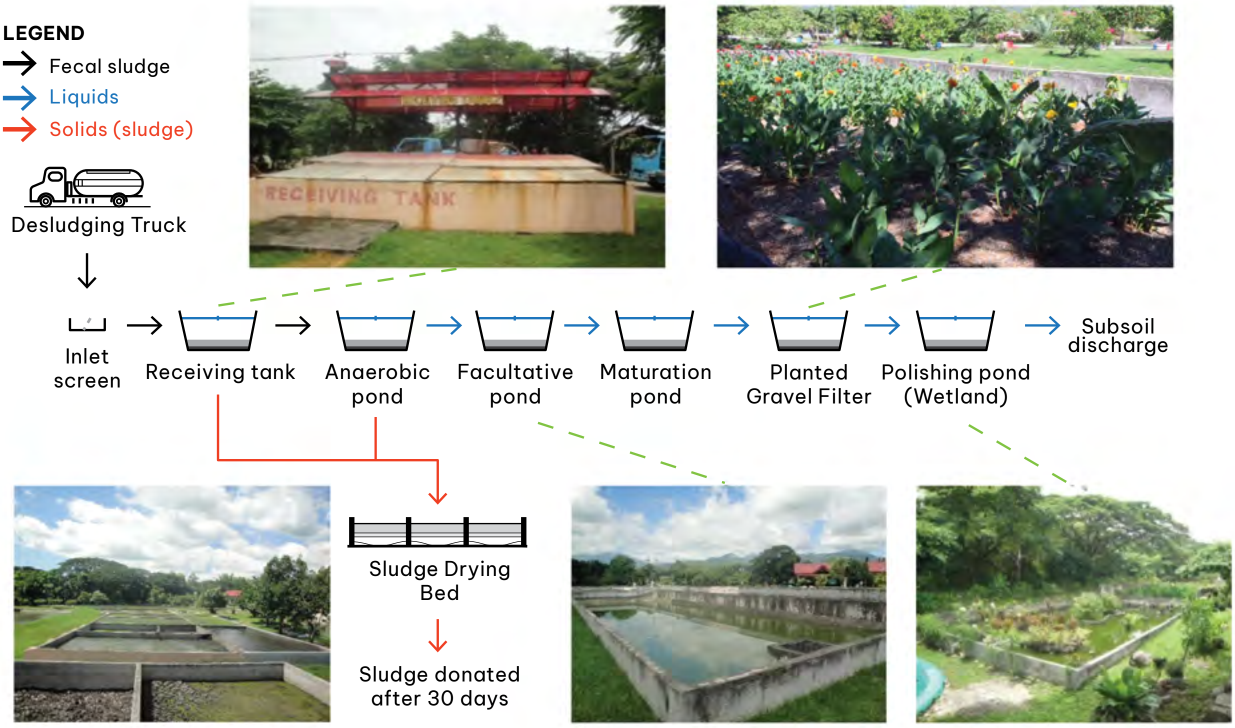

Figure 28. FSTP overview 3 *(Source: AIT, Stantec, 2020)*

6.1.6. FS treatment: Duri Kosambi, Jakarta, Indonesia. Overall regulation and management

Managing FS is the local government's responsibility; in this case, the city manages FS. The national government has regulations regarding effluent quality standards and can support via providing capital costs at times; however, this facility was paid for by the local government.

Regulator: While the district government oversees regulations, it is not particularly active. There are no specific Indonesian standards regarding FSTP effluent quality; therefore, those for wastewater treatment plants are applied to the FSTP effluent; in summary, these standards require total suspended solids (TSS) and biochemical oxygen demand (BOD) <30 parts per million (ppm) (AIT, Stantec, 2020). Currently, they also require the removal of ammonia, which is typically not achieved.

Operator: The Technical Implementation Unit, Unit Pelaksana Teknis Dinas, was specifically set up to run and manage the FSTP. It is currently financially supported by the local government; however, the is projected to become a self-sustaining entity with time.

On-site containment and collection

- On-site containment: A house septic tank (which is often poorly constructed) with a volume of 1–2 m^3 (AIT, Stantec, 2020).
- Emptying of some septic tanks is completed by the city at a price which is set by the city government laws; however, when the demand exceeds the city government's capacity, certified private companies can also provide emptying services at a negotiated rate.
- Trucks discharging the collected FS to the FSTP pay a discharge fee.
- The tank capacity of the desludging trucks that carry septage to the plant is typically 3 m^3 or 4 m^3 (AIT, Stantec, 2020).

Treatment and Disposal/reuse process

The Duri Kosambi FSTP comprises a conventional plant and mechanical plant. The conventional plant includes aerobic digesters and anaerobic ponds, whereas the mechanical plant includes a sludge acceptance plant, a sludge holding tank and screw presses. Both plants share the facilities of an aeration basin, sedimentation tank and polishing ponds.

The following section outlines the components of the mechanical plant of Duri Kosambi[35]:

(1) Receiving Station: At this station, trucks connect their hoses to a fixed coupling. There are two such couplings isolated by valves so that one truck can stage to discharge while another is discharging.

(2) Acceptance Plant: Discharge from trucks is screened for large debris and trash by using a Huber Rotamat Septage Acceptance Plant system, which removes trash, grit and fats and oils and grease. A manual screen is available as an alternative for periods of maintenance.

(3) Holding tank: FS is held in a tank to allow variations in septage quality to be smoothed out over several trucks and to allow it to be fed to the screw press at a slow constant rate. It has one surface aerator.

(4) Polymer makeup: Polymer is delivered to the site as a powder in sacks with a capacity of 25 kg. The powder is loaded manually into the hopper of a ProMinent polymer makeup system, which takes approximately an hour to create a ~0.1% solution of polymer.

35 AIT & Stantec, 2020

(5) Polymer dosing: A polymer dosing pump adds the polymer solution to the septage as it is pumped into the screw press. A known dose of polymer is automatically added, and the operator can change this dose rate by using the control system.

(6) Flocculation and screw press: The polymer mixed with the sludge forms a floc of solid, which is encouraged by gentle mixing into a small flocculation chamber provided upstream of the screw press. After a period of a few minutes in the flocculation chamber, the solids enter the screw press, which squeezes the water out of the septage through cylinder sieve. The screw press captures 80–95% of the solids in the septage.

(7) Dewatered wastewater from the septage travels to an aerated tank, followed by two sedimentation basins, before being discharged.

(8) Dewatered solids from the screw press are carried to a storage area to be contained and provided to farmers when there is a demand.

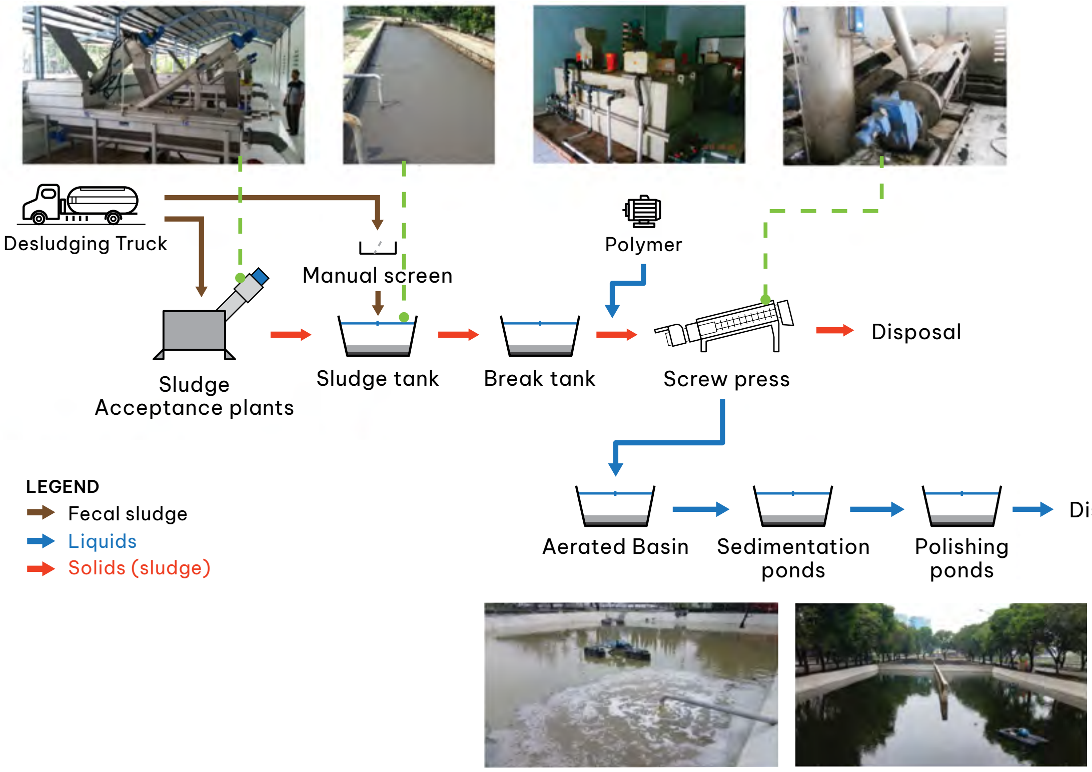

Figure 29. FSTP overview 4
(Source: AIT, Stantec, 2020)

6.2. Lessons learned and existing challenges

- Despite its critical importance, sanitation is frequently a low priority in many ASEAN countries. This is exacerbated by expansive national plans and commitments that, while being ambitious on paper, frequently contrast unambiguously with the actual local performance.
- Meanwhile, the conventional centralised sanitation approach presents a significant challenge in reality. Not only is this approach ineffective, but it also frequently results in overcapacity and poor effluent quality.
- Similarly, certain wastewater treatment facilities are underutilised. The vast capacities of these plants are not being used to their fullest extent, making them too expensive to provide a satisfactory solution to the regions they serve.
- A glaring omission exists during the integration of FSM into policies, despite the heavy reliance on On-site Sanitation Systems.
- Given the prevalence of unregulated private operators in the sanitation industry, this oversight is particularly alarming.
- In the absence of proper disposal facilities, FS is frequently dumped in the open environment, posing serious health and environmental risks.
- Moreover, the current levels of wastewater treatment are alarmingly low, especially considering the rapid population growth in many regions. This situation is exacerbated by the uncertainty surrounding water availability, a concern that is growing in urgency because of climate change.

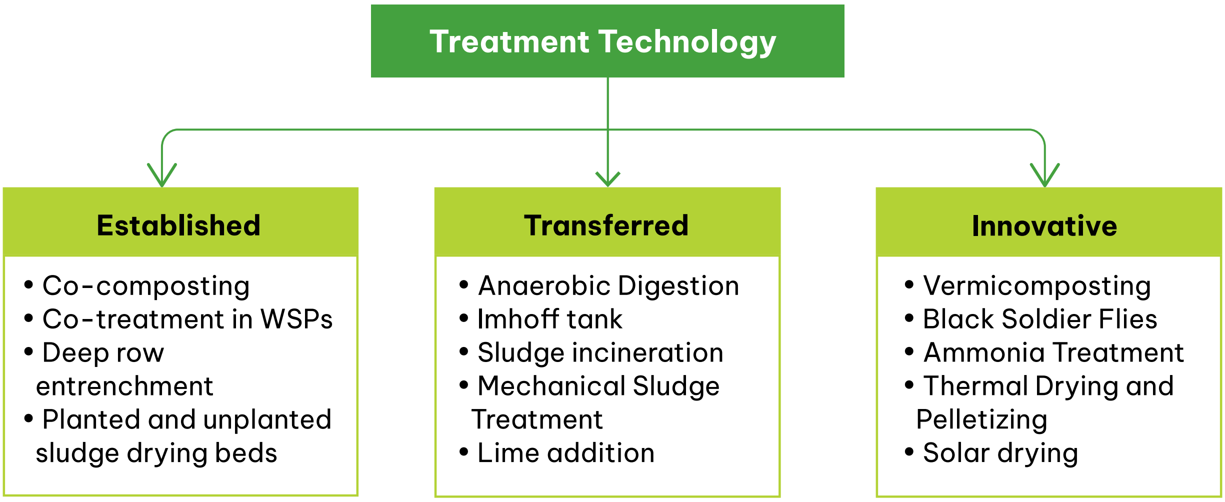

Figure 30. Categorization of decentralised wastewater treatment technologies

When discussing the future of DWM, it is essential to categorise the technologies and innovations based on their current status and potential.

Established technologies: These are the most prevalent technologies that have already demonstrated their efficacy. They have withstood the test of time and consistently delivered results in various settings, making them the apposite solutions in various situations.

Transferred technologies: These are the next category. These technologies are intriguing because their efficacy has been demonstrated in other industries, such as wastewater and solid waste management. There is a potential for these technologies to be adapted and implemented in FSM. However, they are still in the experimental phase and have yet to demonstrate their full efficacy in this context. Hence, additional testing and adaptation are required before their large-scale implementation.

Innovation is a vast and constantly evolving domain. As technology continues to develop, the potential for innovation and development in DWM is vast. This potential motivates researchers and developers to continuously push the limits of what is possible.

The following are the conclusions regarding DWM:

- To avoid conflicts of interest, policymakers, implementers, service providers and regulators should play separate roles and responsibilities (Ngamlagosi & Mutegeki, 2019).
- It is difficult for a regulatory agency for sanitation to regulate the local government authority because of the hierarchical structure (Ngamlagosi & Mutegeki, 2019). The local government is superior to the regulatory agency (Ngamlagosi & Mutegeki, 2019). The provision of regulated sanitation services should be delegated to autonomous agencies or private sector organisations (Ngamlagosi & Mutegeki, 2019).
- Institutions that set effluent standards should be separate from the agency that regulates effluent disposal services (Ngamlagosi & Mutegeki, 2019).
- In some urban areas, sewerage is managed by a utility, whereas non-sewered sanitation is the responsibility of the local government (Ngamlagosi & Mutegeki, 2019). Such fragmentation of responsibility for sanitation can lead to poor planning, exclusion of poor communities and, ultimately, reduced cost-effectiveness (Ngamlagosi & Mutegeki, 2019). Therefore, where an adequately performing utility company exists, consideration should be given to extending the mandate to cover both sewered and non-sewered sanitation (Ngamlagosi & Mutegeki, 2019).
- There needs to be collaboration among various stakeholders to address the existing gaps and overlaps of roles and responsibilities (Ngamlagosi & Mutegeki, 2019). Further, when implementing the proposed framework, collaboration is required to achieve linkages among various actors for effective results of city-wide sanitation planning and implementation (Ngamlagosi & Mutegeki, 2019).

6.3. Exercises

(1) Share and briefly provide success stories from your country in terms of sanitation infrastructure, planning and/or regulatory reformation.


SEWAGE
SEPTAGE
EFFLUENT
BIO SOLIDS

Module 7. Action planning and implementation

The current challenge that most public authorities face is to adopt and implement large-scale sanitation and treatment services. Mainstreaming the decentralised approach is one of the most essential factors for sustainable sanitation development of a nation, especially in developing countries. Therefore, it is vital to enforce a legal framework that can be efficiently enforced at the local level. A decentralised scheme must and should meet the legal standards which are defined within the regulations of the country. Unfortunately, in many developing nations, such standards are rarely met. It is often observed that developing nations refer to or adopt examples from highly developed and industrialised countries, setting unrealistic standards (Ulrich, et al., 2009). According to David W M Johnstone and Nigel Horan, *'One such issue is the importation of developed world standards with little thought of the financial consequences or little estimation of actual benefits. It is often not recognized that the current standards in the developed world result from a long period of investment in infrastructure projects during which standards progressively improved and during which society reached a higher level of affluence. Undue haste in adopting standards, which are currently too high, can lead to the use of inappropriate technology in pursuit of unattainable or unaffordable objectives and, in doing so, produces an unsustainable system. There is a great danger in setting standards and then ignoring them. It is often better to set appropriate and affordable standards and to have a phased approach to improving the standards as and when affordable. In addition, such an approach permits the country the opportunity to develop its own standards and gives adequate time to implement a suitable regulatory framework and to develop the institutional capacity necessary for enforcement'.*[36]

Hence, it is imperative to enforce and encourage a realistic legal framework covering a wide range of topics such as design standards, service providers, discharge standards, tariffs and contracts (Ulrich, et al., 2009).

36 David W M Johnstone & Nigel Horan, 1996: Institutional developments, standards and river quality: A UK history and some lessons for industrialising countries

7.1. Developing an enabling environment for DWM implementation

Creating an enabling environment for the successful implementation of a DWM strategy requires the presence of several crucial elements:

- **First, a broad and long-term political commitment is required.** This ensures that the strategy has the support necessary to be sustained over time. Additionally, it is necessary to develop a comprehensive sanitation strategy and policy framework. This provides all stakeholders with a clear road map, ensuring that their objectives and methods are aligned.
- Further, **both the central and decentralised levels require a transparent and well-aligned institutional structure.** This ensures that all entities collaborate on a unified implementation strategy. Additionally, it is essential to have a sufficient number of dedicated skilled personnel. These individuals will be the driving force behind the implementation and maintenance of the strategy.
- **Monitoring and evaluation methods are also indispensable.** Not only do these systems monitor the progress and success of the strategy, but they also provide valuable insights for continuous learning and development.
- However, it is important to note that successful sanitation projects are uncommon, especially in low-income nations. Most projects are unsuccessful. **A lack of integrated planning is a major factor in these failures.** Despite the frequent emphasis on physical infrastructure, it is crucial to recognise that technologies are only one component of a larger system.
- **Infrastructure is often prioritised without adequately consulting key stakeholders, resulting in the failure of numerous projects.** Other failures arise due to a lack of financial, operational and maintenance planning. If an enabling environment for FSM is not already present, developing such an environment must be incorporated into the strategy.
- Lastly, it is recommended to select a technology by using an elimination-based strategy. This method prioritises t**he selection of technologies based on the local context and end user interest, ensuring that the selected solutions are both relevant and sustainable**.

The city-wide inclusive sanitation (CWIS) Approach

The CWIS approach represents a paradigm shift in sanitation practices, emphasising universal access to safely administered sanitation services. As urban areas around the world continue to expand, there is a growing need for a variety of technical solutions to address the numerous sanitation challenges. CWIS leverages existing sanitation technologies and practices, enhancing them to provide more comprehensive, effective and long-lasting sanitation services. The objective of CWIS is to ensure that every urban resident has access to and benefits from sustainable and comprehensive sanitation services. This indicates that all human waste is managed safely throughout the entire sanitation service chain. The strategy is founded on four fundamental components (ADB, 2021):

- Capable institutions: Building and strengthening organisations that can effectively oversee and implement sanitation strategies.
- Safety and reliability: Ensuring that sanitation services are consistently safe and reliable.
- Equity and inclusion: Ensuring that sanitation services are accessible to everyone, regardless of their socio-economic status.
- Sustainability: Implementing solutions that are environmentally friendly and can be maintained over a long term.

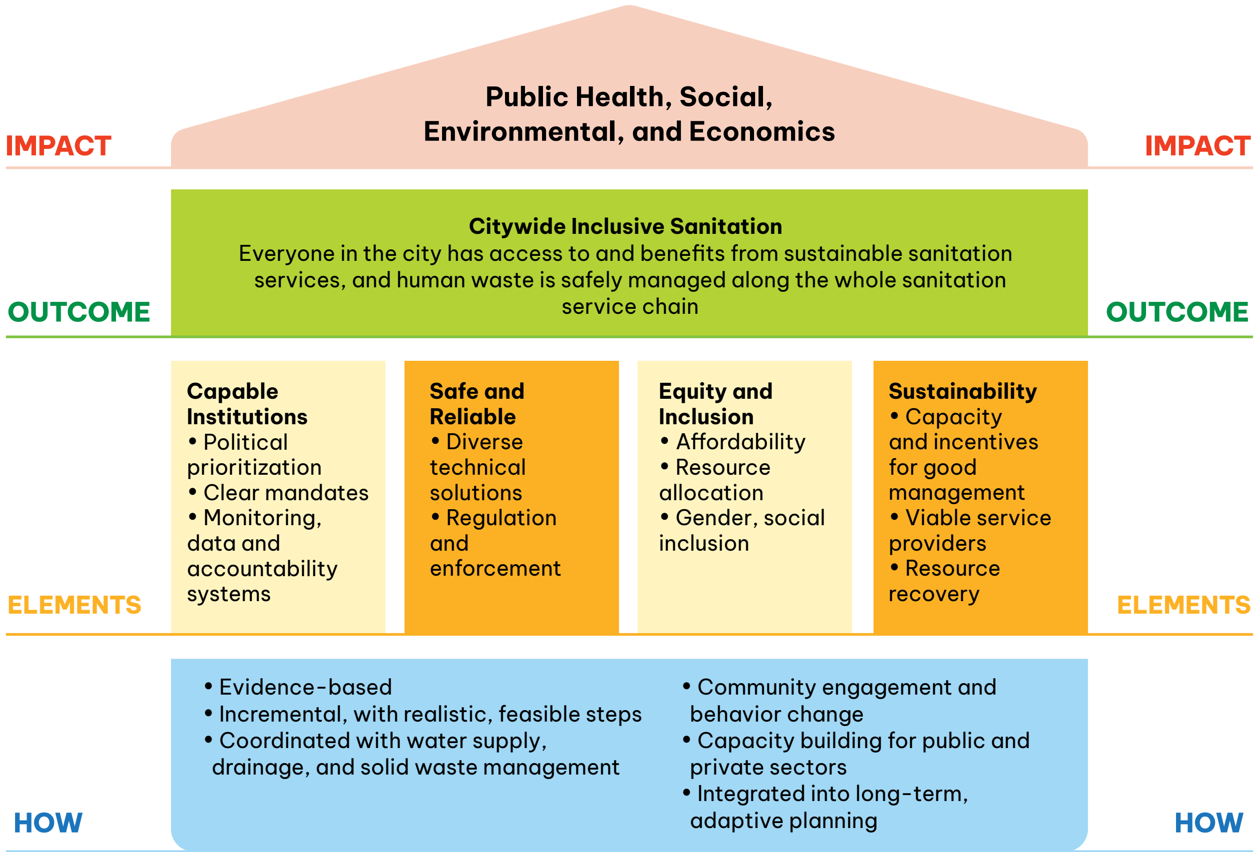

Figure 31. City-wide sanitation
(Source: ADB, 2021)

CWIS is a public service strategy with three primary characteristics: it is equitable, safe and sustainable, by bolstering the implementation of three core functions: responsibility, accountability and resource planning and management. Sanitation services should be designed on the basis of a single, all-encompassing principle, that is, they should be continuously accessible to all residents.

CWIS framework

Service Outcomes	**EQUITY** "Fairness" in distribution and prioritization of service, service quality, service prices, and use of public finance/ subsidies	**SAFETY** All human waste is managed to protect public goods* for customers, workers and all communities.	**SUSTAINABLITY** Management of revenues and resources-financial, labor, energy, water-sustain performance.
System Functions	**RESPONSIBILITY** Authority or authorities execute a clear mandate to ensure inclusive, safe sanitation services	**ACCOUNTABILITY** Performance is monitored and managed with transparency, data, incentives and penalties	**RESOURCE PLANNING & MANAGEMENT** Resources are managed to support implementation of mandate and achieve goals across time/ space

CWIS characteristics[37]

- This is a design and implementation strategy based on empirical evidence that enhances cooperation among the major sanitation actors for sustainable development by enabling an institutional and regulatory framework to accelerate sanitation services.
- It creates opportunities for institutional arrangements, regulations and accountability by providing incentives for establishing sanitation service chain management, O&M.
- It employs diverse and appropriate technical solutions that meet the needs of the users, build on existing sewered and non-sewered systems and include resource recovery and reuse techniques that are relevant and comply with standards, etc.
- It engages city leaders and stakeholder groups, including women's groups, in prioritising investment in sanitation and promotes the development of a community-based approach for short-, medium- and long-term funding for sustainable sanitation.

37 CWIS: Guidance Note (ADB, 2021)

- It enables funding for non-infrastructure components of service delivery, such as essential capacity building, household outreach and engagement and sanitation marketing.
- It integrates with sanitation planning and includes essential services such as water supply, drainage, greywater management and solid waste management.
- It promotes awareness and generates demands for activities and funding that target marginalised groups, women, minorities, informal settlements and individuals with disabilities.

7.2. Resource mobilization and partnerships

7.2.1. Policy instruments

Policy instruments play a crucial role in fostering an enabling environment that will increase access to sanitation services. Instruments such as guidance, incentives and penalties provide sanitation programme priorities through sustainable implementation. For comprehensive sanitation provision, policy instruments should be applicable to the entire sanitation service chain, including non-sewered sanitation.

Policy Instruments	
Equity	Includes policy statements, laws and budgetary allocations to be used as resources for guiding specific social groups or geographic areas to enhance equity
Integrated Water Resource Management	• Includes integrated water resource provision and water treatment system • Optimizing water infrastructure • Promoting an environmentally friendly water cycle system
Targeting Resources/ Distributed Wastewater Management System	Includes providing guidelines on where resources should be allocated with three main objectives: public health improvement, energy and water conservation and environmental protection. This will in turn help provide a full-range intervention (access to sanitation technology, promotion of hygiene behaviour and strengthening of the enabling environment), which will enable the improvement of the health status of the population.

Policy Instruments	
Reuse and Recycling	This includes reducing freshwater demand. Reduction in wastewater treatment needs is facilitated by incorporating the following treatment technologies: membranes, wetlands, sand filters and waste stabilisation ponds.
Low-impact Development	Local and decentralised measures alleviate development impacts on land, water and air by using small-scale practices; they manage storm water at the source, using simple and natural practices and make multifunctional use of the landscape and infrastructure
Financial Consideration and Water Pricing	This includes providing guidelines on tariffs and charges for services, possible subsidies to lower income households, etc.

7.2.2. Institutional instruments

An institutional instrument is defined by the laws, contracts and regulatory documents that determine the relationships between sanitation stakeholders along the service chain. In addition to defining the roles and responsibilities of each stakeholder, regulation enables regulatory institutions to monitor their activities by enforcing the law.

The case of Thailand:

- The Public Health Act of 1992 addresses the management of FS.
- The Ministry of Public Health is authorised by the same act to develop regulations for FSM.
- The Ministry of Public Health subsequently developed guidelines for FSM and decentralised the authority to provincial and local departments to manage FSM in their respective jurisdictions.
- Currently, it is the local government's responsibility to construct and operate the FSTP.

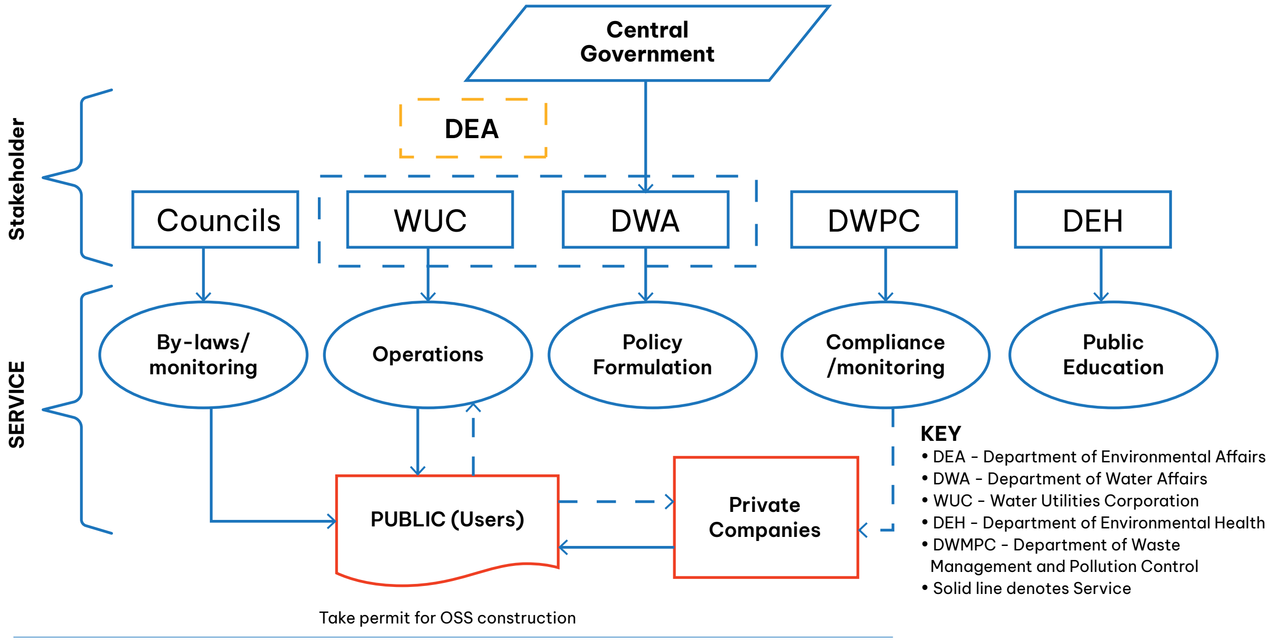

Figure 32. General process of the Legal and institutional framework for DWM implementation in Thailand.

Despite the existence of regulations and institutions, DWM implementation frequently falls short of the planned outcomes. Several variables contribute to these deficiencies:

- Initially, there are obvious responsibility gaps and overlaps, leading to confusion and inefficiency.
- There is also a severe lack of personnel dedicated to the enforcement of these regulations, which hinders the effective implementation of DWM.
- Additionally, local governments frequently lack the necessary funds and resources to effectively finance and implement FSM.
- Lastly, political obstacles can be problematic, particularly when it comes to law enforcement, because political agendas and priorities can vary from time to time.

For example:

- In Thailand, the department at the local level under the Ministry of Interior oversees the installation of the on-site sanitation system, while departments at the local level under the Ministry of Public Health oversees the FS collection and emptying.
- The Ministry of Natural resources and Environment sets the standards for wastewater effluent.
- Local governments are the actual implementing bodies; however, they often fail to enforce the standards and coordinate with departments under other ministries.

Institutional agreements

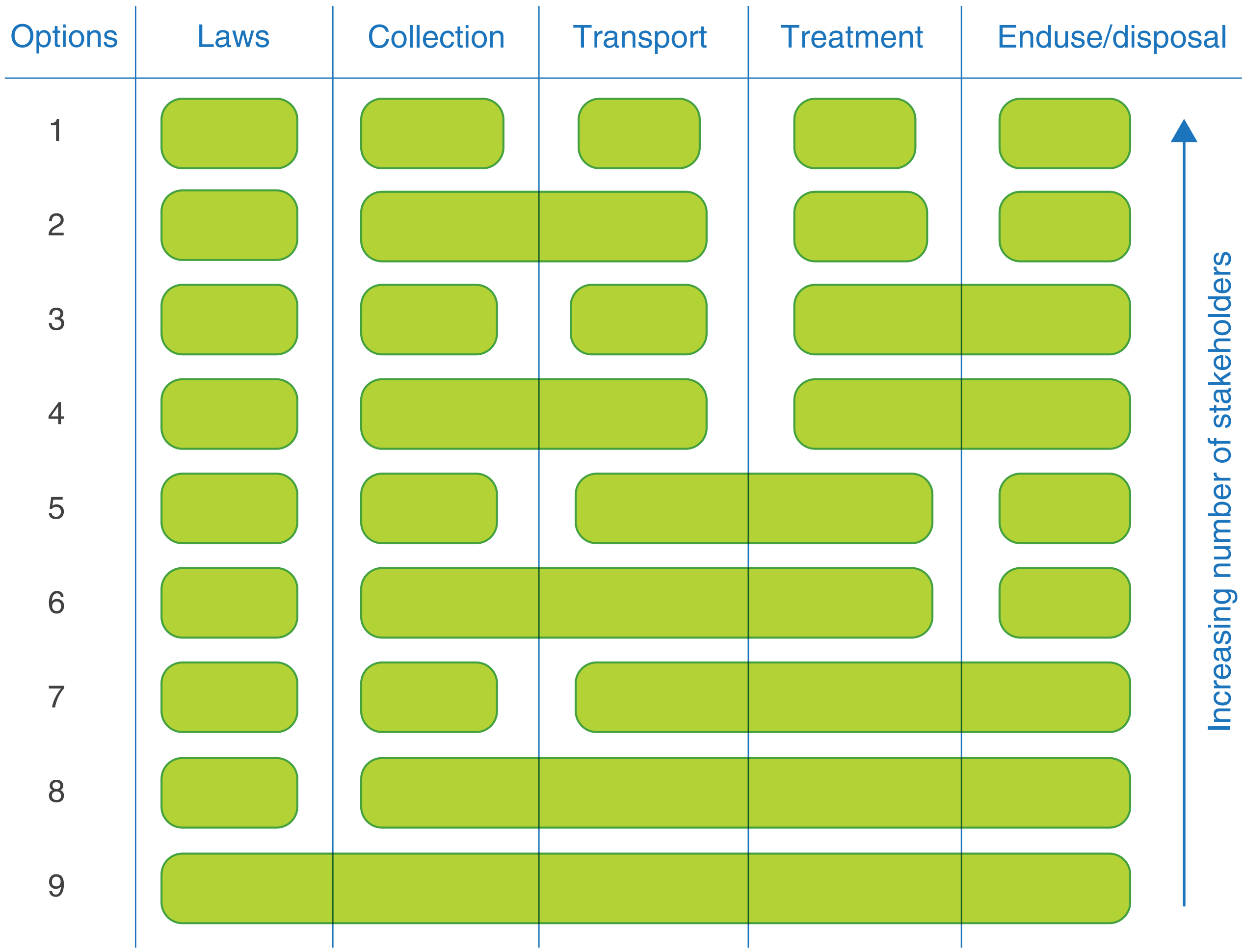

Figure 33. Schematic representation of different organisational arrangements for distribution of operational responsibilities among stakeholders (one block represents one stakeholder).

(Source: Bassan, M. (2024))

There is no one-size-fits-all solution available, and there are numerous institutional arrangements in the world (Strande, Ronteltap, & Brdjanovic, 2014). Each block represents a stakeholder and has its own advantages and disadvantages.

Option 1:

- Each block represents a service chain stakeholder.
- This option permits operational flexibility; however, enforcement, coordination and oversight are challenging.
- It allows for the creation of jobs, since emptying and transportation are performed by distinct parties.
- The need for a transfer station necessitates additional infrastructure.

Option 2:

- One stakeholder, either a private service provider or a municipality, is responsible for collection and transport.
- The treatment is administered by a separate stakeholder.
- This is preferable for motorised transport and emptying, such as vacuum trucks.
- It simplifies the flow of finances.
- The constraints of using this option is as follows: loading shock at the treatment facility makes it challenging to regulate qualitative and quantitative variations.
- In densely populated areas where truck access is a problem, congestion can be problematic.

Option 3:

- The value generated from the sale of treated FS products partially offsets the FSTP's operating expenses.
- The collection and transport of FS would face the same coordination issues as that in option 1.

Option 4:

- This is designed by combining options 2 and 3.
- One stakeholder is responsible for collection and transportation, while another is responsible for treatment and reuse.

- Each stakeholder cultivates a unique set of skills.
- One major constraint is the variation in sludge quality and quantity at the treatment facility.
- An example of this configuration is Thailand's Nong Khaem FSTP.

Option 5:

- Similar to option 1, this alternative facilitates the creation of jobs because collection and transportation are handled by distinct stakeholders.
- This is appropriate for densely populated areas where truck access is an issue.
- This has less variation in the quality and quantity of FS as a result of mixing at the transfer station.
- Transporting FS from a residence or institution to transport trucks or a transfer station can be difficult.

Option 6:

- The management of collection, transportation and treatment of FS requires a high level of managerial expertise.
- The advantage of this option is that it manages the service chain from the point of origin to treatment, thereby decreasing the number of unauthorised discharges.
- The financial flow between the end user and stakeholder in other service chains is not optimal.

Option 7:

- This is a combination of options 1, 3, and 5
- It is most effective when a transfer station already exists.
- It creates manual emptier employment opportunities in densely populated regions where truck accessibility is an issue.
- It is characterized by a complex service chain; however, it enable simple resource recovery and utilization management.

Option 8:

- This facilitates the straightforward coordination and optimisation of each component.

- One major limitation of this option is that it requires a high level of managerial expertise and financial resources.
- Example: In the Nonthaburi FSTP, Thailand, the local government funds O&M costs.

Option 9:

- This option is monopolistic and should be avoided because it prohibits transparency.

7.3. Monitoring progress and adapting to change

In recent years, the GIS has become an integral part of urban planning. It enables spatial and temporal visualisation of urban infrastructure development based on a projected scenario. Similar to urban infrastructure mapping, sanitation mapping enables scenario analysis of the current sanitation situation, the impact of inadequate sanitation infrastructure and the impact of proposed future sanitation projects; it further assists in prioritising the intervention area. For the development of comprehensive sanitation mapping, the required information is presented in section 2.7.

A DWM system is adaptable to the desired size and/or footprint. It is easily scalable to meet the needs of rapidly growing communities and can be tailored to meet specific growth objectives by planning where and how the community will expand. A DWM system typically leaves a small and minimally intrusive environmental footprint and creates green spaces in communities.

7.4. Capacity building for sustainable DWM implementation

Specific actions to build the capacity for effective implementation of DWM include the following:

(1) Capacity building for decentralised sanitation needs to be reoriented away from centralised solutions. It is difficult to convince engineers that inexpensive decentralised treatment systems are as effective as traditional infrastructure. The political economy of costly operations and the maintenance of centralised treatment systems also presents an obstacle to the implementation of decentralised sanitation.

(2) Establishing effective coordination and collaboration is necessary to develop various strategies that make information accessible at multiple times and in multiple ways.

(3) Strategies for effective implementation of DWM may include research papers, evidence summaries, policy briefs, media and advocacy, oral presentations, policy dialogues and community engagement programmes, among others. Key enablers must include personal contact/relationships with policymakers, an understanding of the policy environment, the timeliness and relevance of evidence (including cost-benefit analysis) and summarised information with clear, implementable recommendations. A nation-wide public relations campaign needs to be executed to ensure public participation, behaviour modification and promotion of sanitation and its positive effects on human and environmental health.

(4) Not just a few workshops or seminars, but state-wide capacity building initiatives are required. Short-notice transfers of municipal officers necessitate state-wide and, if possible, rural and urban administration capacity building.

(5) How to improve the knowledge and skills of stakeholders to address an immediate challenge while ensuring that longer term priorities are not neglected is a major challenge in capacity building. Urban/rural sanitation is linked to urban/rural planning and long-term sustainability of systems and the environment, managing water demand, reducing wastewater footprint and addressing inequality regarding access to sanitation and water, systems and governance.

(6) Training of trainers must emphasise the development of an understanding of the core content of DWM's capacity building training, the sequencing of sessions and the creation of practical exercises.

(7) It should be understood that the training is distinct from academic coursework and instruction. Training is used to transmit specific abilities and ways of thinking and acting. Priority is given to key messages and facts over perspectives and ideas.

(8) If sanitation is viewed as a technological challenge as opposed to a governance and municipal challenge, people will be removed from the issue. The government economy will continue to prioritise costly centralised sanitation solutions. Understanding and demanding decentralised solutions to encourage the population to pay a substantial portion of capital and operational costs as a public good requires the participation of the populace.

(9) Women are underrepresented in administrative decision-making, technological solution selection, urban and rural planning and the operation of treatment plants. Without women's participation, it will be impossible to promote decentralised solutions. Manually cleaning septic tanks and sewer lines imposes a significant burden and danger to workers. Gender equality and inclusivity must be incorporated into capacity building and training modules, not only to alert staff and consultants, but also to define implementation recommendations.

(10) State-level institutions tasked with delivering capacity building programmes are frequently understaffed. In the short term, they require DWM training modules and trainers and in the long term, they must be connected to universities and institutes for continuing development of the modules.

7.5. Exercises

(1) In your opinion, how effective is the CWIS approach regarding bringing about a change via the implementation of the sanitation action plan?

(2) How effective is your country's legal framework for comprehensive sanitation intervention? Is it practical and realistic in nature?

(3) Briefly describe the challenges and prospects of standards and regulatory frameworks in sanitation infrastructure management.

(4) Is there a need for specifications and technical standards in sanitation, and how do these impact the SDGs and the NGOs/multilateral organisations involved in the sanitation intervention for the vulnerable?


"Strengthening Capacity Development for Local Governments in ASEAN to Tackle Microplastics and Water Pollution through Decentralized Domestic Wastewater Management Approach"
(PoDIWM-2)
WELCOME DELEGATIONS FROM THE ASEAN MEMBER STATES TO THE 2nd REGIONAL TECHNICAL CAPACITY TRAINING SESSION
AIT CONFERENCE CENTRE, FEBRUARY 21, 2024
In collaboration with

Module 8. Integrating DWM with Water, Sanitation and Hygiene (WASH) programmes

Appropriate wastewater treatment and sustainable sanitation services should be incorporated into a national vision statement for short-, medium- and/or long-term strategic plans to build an overall sustainable economy.

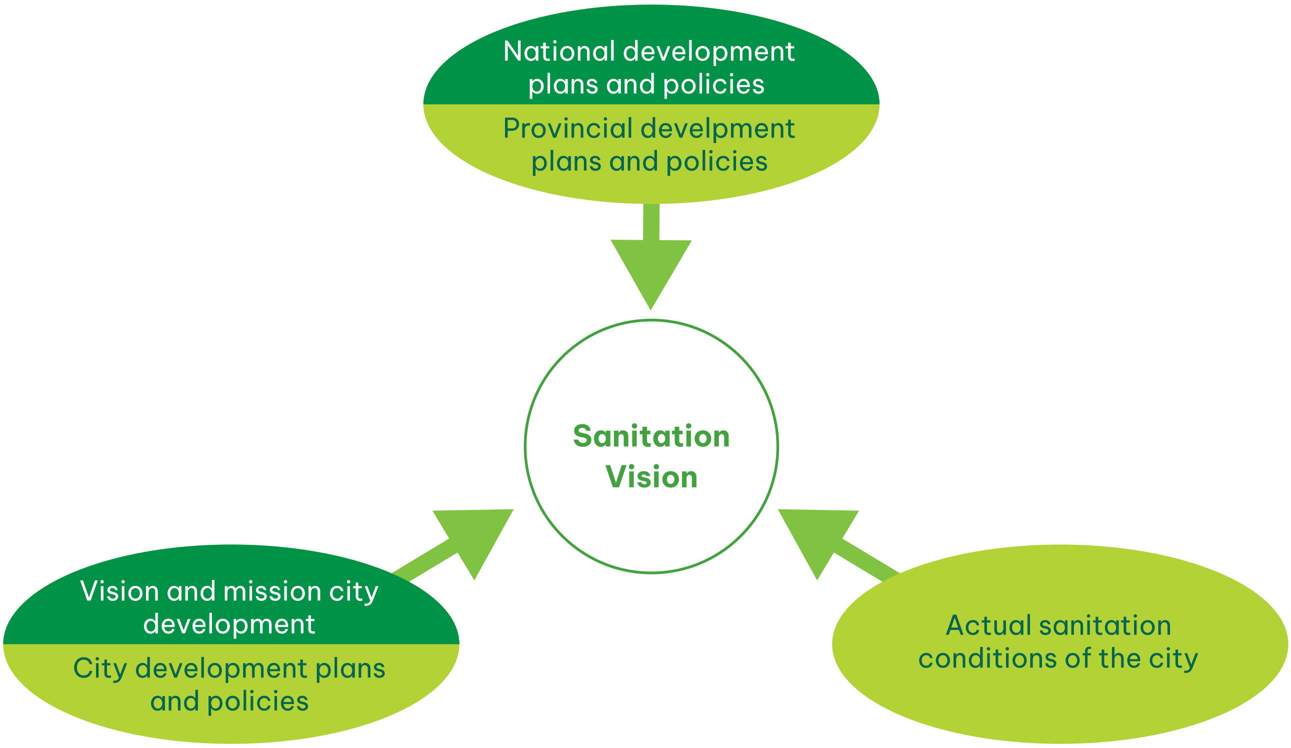

Figure 34. Connecting the city's and nation's vision

(Source: UNESCAP & AIT, 2015)

- The marketing strategy for sanitation should aim to increase the demand for sanitation, and strengthen private sector participation and the capacity to provide continuous and sustainable services.
- The sanitation service approach includes an enabling environment for progress, planning, capacity building and institutional arrangements at the municipal and provincial levels; it includes policy and strategy design at the national level and advocacy and awareness-raising at all levels (UNESCAP & AIT, 2015).

- Sanitation interventions should prioritise a sustainable approach to the delivery of sanitation services that focuses on quantity, quality, sustainability and accessibility.

Additionally, to achieve sustainable sanitation services, stakeholders should focus on the following fundamental principles:

- Financial analysis and long-term financial planning;
- Demand-driven approach;
- Comprehensive assessment of local and community needs;
- Service orientation;
- Multi-stakeholder involvement and multi-task planning (UNESCAP & AIT, 2015).

8.1. Aligning DWM and WASH goals

Traditional centralised treatment systems have large energy demands, high construction costs and high operational expenses. Due to a lack of funds and technical knowledge, the construction of a centralised system is economically unfeasible, especially in low-income regions. The installation of centralised systems is typically avoided in urban and peri-urban areas as this type of system is outfitted with an extensive network of pipes for wastewater collection and transfer. Further, as many of the machine's mechanical parts are frequently damaged, this leads to malfunctioning of the machine, negatively impacting the environment and economy. Additionally, the daily production of by-products such as sludge necessitates additional handling and management, which substantially increases the total operational costs. Realizing the drawbacks of the conventional treatment system has led to an increased emphasis on more sustainable technological systems. The use of decentralised systems as a green infrastructure system adheres to the sustainable development principle, considering their cost-effectiveness, environmental friendliness and energy efficiency. DWM systems, such as constructed wetland systems, are designed to collect, treat and enable reuse of wastewater on-site, that is, close to the source. A decentralised system offers considerable design flexibility and a modular approach that enables cost-effective and straightforward expansion to meet the required demands and needs. Additionally, the recovery of nutrients from faeces urine, and greywater, as well as their beneficial reuse—for instance, in agriculture and/or urban green spaces—reduce water pollution and ensures economical water reuse. Decentralised Wastewater Management entails not only the provision of environmentally friendly, alternative and cost-effective treatment systems, but also the extraction and reuse of elements in the treated effluents.

8.2. Intersectoral collaboration and coordination

In the ASEAN region, sanitation is typically the responsibility of multiple ministries at the national level and departments at the local level. This has led to gaps and duplications in roles and responsibilities. Inadequate interdepartmental coordination is an additional major obstacle to an integrated approach. Local entities are responsible for managing wastewater and FS in their respective communities; however, they lack the capacity to construct and operate treatment plants, and rely heavily on central funding. They cannot afford to operate and maintain centrally funded wastewater treatment plants because the local budget cannot cover O&M expenses. They have a local ordinance to collect the service fee from the user for wastewater treatment; however, the local politician's fear of losing votes has slowed the process. Local authorities lack the personnel necessary to regulate informal service providers. Additionally, private corporations are not investing in wastewater treatment facilities due to regulatory constraints and practical considerations.

Therefore, the government should establish a separate entity that bridges the multiple ministries and local departments involved in sanitation and provides complete sanitation services at the local level, including the O&M of wastewater and FS treatment systems, in addition to assisting in the upgrading of community-owned DWM. The government should develop a mechanism to formalise informal service providers and encourage private sector participation as service providers. A separate body must be established to oversee and regulate the activities of the local government and service providers. This body will continue to monitor the enforcement and transparency of tax collection.

8.3. Promoting behaviour change and community adoption

Governments are the most important stakeholders in coordinating and integrating sanitation behaviour change activities; hence, they should provide firm leadership and adequate funding. All sanitation interventions should incorporate a comprehensive sanitation promotion/behaviour change programme (including monitoring and evaluation), with all stakeholders and participants aligned around the same set of objectives and strategies. Designing effective promotion activities is necessary to influence the behaviour of the population; consequently, it is necessary to comprehend the existing sanitation behaviours and their antecedents. Noting that distinct populations will have distinct sanitation requirements, and that they will have distinct possibilities for change and obstacles to development, behaviour change interventions are most effective when they target the behaviour's antecedents. Various models and frameworks exist to assist in identifying and targeting behavioural drivers; therefore, they should be used during the intervention design process. The intervention delivery model should be thoroughly considered (standalone behaviour change versus integrated approaches; focussed versus comprehensive strategies). A successful strategy must influence adoption, adherence and long-term practice/use of safe behaviour. Programming for behaviour modification requires adequate and dedicated resources.

8.4. Ensuring gender and social inclusivity in DWM initiatives

Women, children and girls are disproportionately affected by water and sanitation problems. Frequently, women are responsible for cleaning and, in many instances, for disposing human waste. When involved in any WASH project, their contributions have been deemed valuable, particularly in the management of the provided infrastructures and the consideration of sanitation sustainability. Their participation should be highlighted on the basis of the local context. As a fundamental right, it demands affirmative action and special attention to the needs of women, girls and those in vulnerable situations, including transgender and disabled individuals.

8.5. Exercises

(1) Provide us with a brief insight regarding your country's WASH programme and its overall inclusiveness.

(2) How can the SDG 6 targets of acceptability, quality and safely managed sanitation facilities at local levels be achieved and integrated into your country's WASH programme?

Module 9. Climate resilience and environmental sustainability in DWM

9.1. Assessing the climate change impacts on DWM systems

Climate change impacts and hazards can create or exacerbate risks for sanitation services by damaging or destroying infrastructures such as pumps, toilets, treatment facilities, emptying vehicles, etc., by disrupting services such as drains, water supply, roads and electricity that sanitation services rely on, and by decreasing the accessibility and functionality of sanitation infrastructures. Predicting the exact flow of effects in sanitation is extremely difficult because of the steps in the sanitation service chain, the heterogeneity of systems in specific geographic locations and the interconnected paths in changes in behaviour, technology and/or operation that can have repercussions on the environment.

The uncertainty and/or unpredictability that climate change creates for the community and nature is another factor. Therefore, it may be impossible to predict the outcome of the sanitation sector, especially if systems are ill-equipped to handle uncertainty; therefore, requiring flexibility and adaptability regarding access to sanitation is a way to provide services. Thus, systems dynamics and continuous learning are required so that service providers and users are aware of the most suitable methods for modifying how services are delivered and accessed.

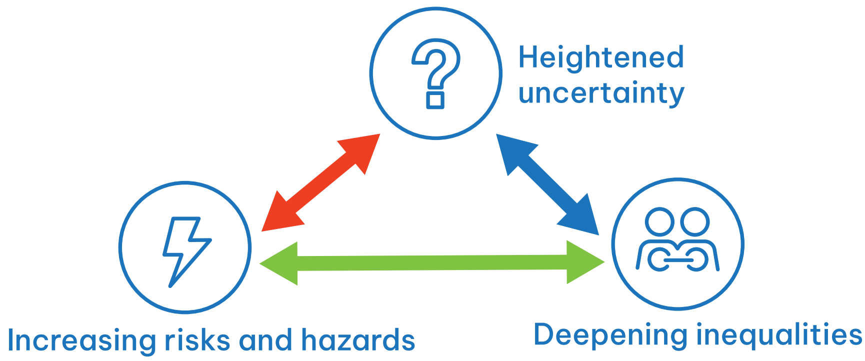

Figure 35. Perspectives on the impacts of climate change
(Source: Mills, Kohlitz, Carrard, & Willetts, 2019)

The risk hazard approach, which views the threat of climate change in terms of the physical risk that climate hazards pose to systems, is arguably the most widely held viewpoint regarding the effects of climate change. Climate change forecasts show that depending on the part of the world, there will be a variety of changes in temperatures, precipitation and sea level in the future, along with extreme weather events. These changes will result in physical dangers to urban sanitation, such as erosion, flooding, drought and rising water tables. The possibility that the sanitation system will be exposed to the hazard and the extent of the damage inflicted upon it determines the risk that these climate hazards pose to urban sanitation. The existing literature classifies risks for generating adaptations as stressors, which are long-term or chronic trends or pressures that compromise a system's stability and shocks, which are acute or short-term external changes that significantly affect people or systems (Mills, Kohlitz, Carrard, & Willetts, 2019).

9.2. Climate-resilient design and technologies

Climate-smart technology

Since 2011, several innovative WASH technologies have been developed in various contexts, making them accessible to people in less-developed countries and establishing a platform for the global sustainability of sanitation. The AIT team aims to provide technical support to develop a catalogue with a comprehensive review, including specifications regarding climate resilience (adaptation) and associated greenhouse gas emission data and energy efficiency (mitigation) for household and community selection and application. With the results of this assignment, this Climate-Smart WASH catalogue will be able to assist WASH actors in delivering the best possible outcomes for children and people in low-income countries with severe structural impediments to sustainable development by providing them with data-driven decision-making advice.

This catalogue will primarily target WASH-implementing agencies and key government representatives for water, sanitation, health and education.

Climate-Smart WASH technologies can be defined as the WASH-related technological approach in climate change mitigation and adaptation to manage the production and distribution of safe water. They (i) reduce polluted discharges to the environment, and (ii) promote good hygiene (or handwashing) practices that address the interconnected challenges of water management, environmental pollution and climate change. The self-monitoring, Analysis and Reporting Technology (Smart) solutions and innovative WASH technologies for climate resilience are covered in addition to conventional solutions.

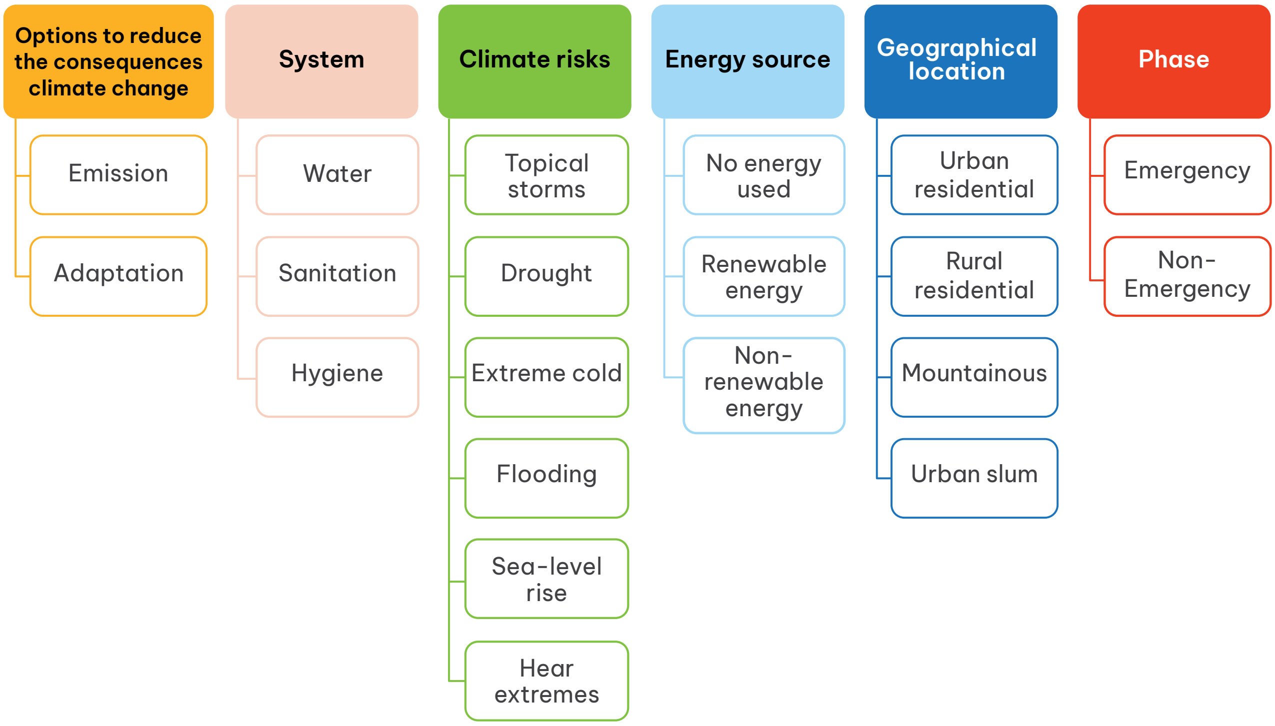

Figure 36. Categories and criteria for climate-smart technologies

Case study example: Solar septic tank (SST)

In a community in central Thailand and Southeast Asia, an innovative decentralised wastewater treatment system was developed and tested at the household level. The SST is a modified conventional septic tank with a solar-heated water system from a solar panel that produces a higher temperature inside the septic tank than the ambient temperature. This rise in temperature promotes the biodegradation of organic matter and the production of methane. Additionally, temperature has a significant impact on the settleability, degradation and pathogen inactivation of biological solids. Because of its rapid degradation rate, the SST is suitable for use with blackwater containing a high concentration of organic compounds. The advantages of this system include reduced sludge accumulation, high removal efficiency and high pathogen inactivation. However, there are some disadvantages of the SST, including the need for energy to heat the system and the need for a large rooftop area for solar heating device installation.

Climate-resilient Remarks: New WASH technology to counter the increased specific climate risks	**Yes**
	Cold climate, Flood
	This technology can be resilient to cold climate because the system can perform well with an external heated supply to facilitate organic degradation inside the system. Adaptation to flooding may be optional, which can be ensured by constructing the system in an elevated form.
Development impact: Environmental and health benefits	This system can be applied for preventing infectious microorganisms such as E. coli and Ascaris eggs from entering water bodies by means of high pathogen inactivation.
Climate risks	**Yes**
	Drought • Prolonged drought can affect the water availability for flushing; it may also result in pipe blockage and system failure.
Adaptability: Climate proof design	Drought - Securing sufficient volumes of water for flushing and operation. - Regular maintenance to avoid pipe blockage. - Construction of a system with a hand washing station and recycling water for flushing.

9.3. Promoting circular economy principles in DWM

Pillars for climate adaption[38]

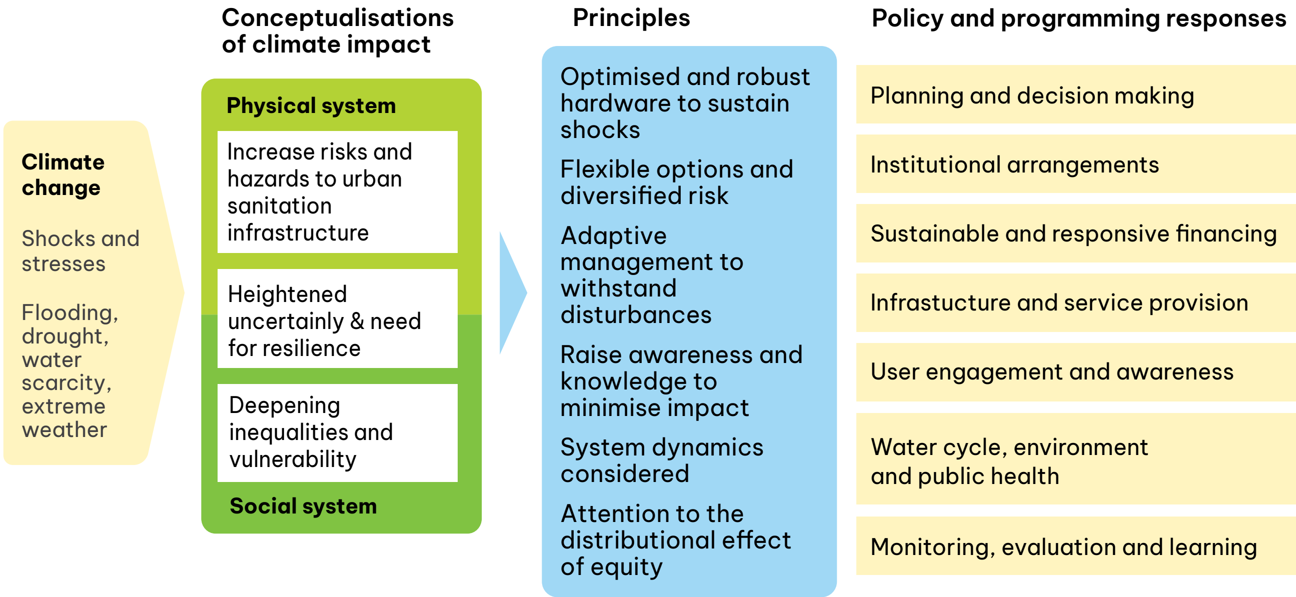

Figure 37. Principles guiding the adaptation of sanitation systems to climate change

The following principles guide the adaptation of the sanitation system to climate change:

- **Optimized and robust hardware to resist shocks.** Considering the robustness of the new hardware while ensuring the optimal operation of the existing infrastructure.
- **Flexibility and diversified risk.** Providing alternatives and strategies for infrastructure and services to decrease reliance on a single system and demand.
- **Adaptive management to withstand disturbances.** Adaptability is developed through continuous learning and environmental adaptation.
- **Raised awareness and knowledge to minimise risk.** Stakeholders need to adapt preventative measures or actions for climate hazards and uncertainty by building awareness of the risks. They need to share knowledge on how to adapt and respond to extreme conditions.

38 Considering climate change in urban sanitation: Conceptual approaches and practical implications (Mills, Kohlitz, Carrard, & Willetts, 2019)

- **Consideration of the system dynamics**. Sanitation systems are dynamic in nature, with multiple service chain steps. To consider whether the services are sustainable if one component fails due to climate hazards, a comprehensive analysis of the entire supply chain is required.
- **Attention to the distributional effects on equity.** In an era of climate change, the active and pragmatic measures required to ensure the sustainability of sanitation services are reasonable.

9.4. DWM in the circular economy

Only 3% of the water on the earth is fresh water, which is necessary for human survival (UNEP, 2023). Maintaining this limited resource's degradation is extremely important, and the water industry needs to perform better financially and environmentally. In a circular economy, circularity thinking offers a foundation for creating all-encompassing water management plans. It presents an alternative economic model that maintains the highest value of natural resources—including water sources—for as long as possible. A more circular approach to wastewater treatment is becoming more popular as a means of enhancing resilience, eliminating waste and re-establishing ecosystems. The key to converting wastewater from waste into a resource is reducing the amount of wastewater produced and improving the collection and treatment of wastewater with the goal of increasing reuse.

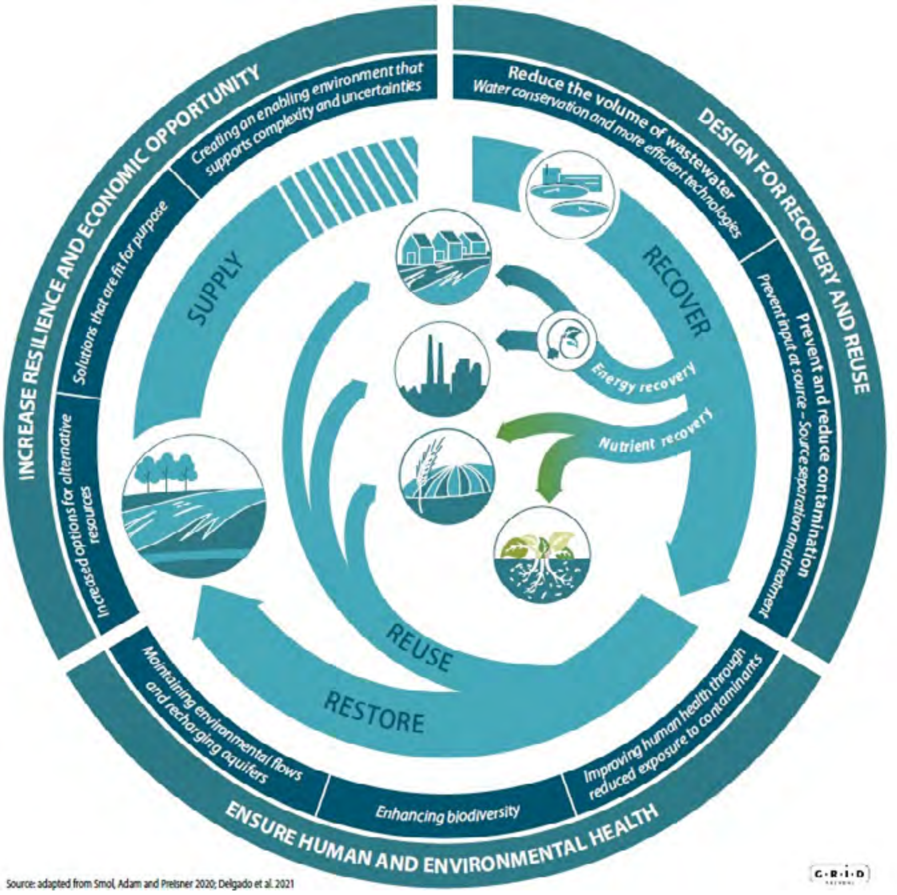

Figure 38. Circularity in wastewater management
Source: (UNEP, 2023)

Increased water stress, the cost of water and environmental protection and long-standing examples of reuse—not only in arid and semi-arid nations but also in nations thought to have abundant water resources—are the driving forces behind the circularity movement in water and wastewater management. For instance, water reuse began in Japan in the 1980s in response to a severe drought and rising demand brought on by urbanisation and economic growth. Adopting circularity promotes a comprehensive strategy for managing water resources that prevents and/or reduces the production of wastewater by optimising reuse, recycling and cascading water; recovering contaminants to minimise waste and pollution; and, storing and recovering water for the preservation and regeneration of waterbodies. Recovering nutrients (such phosphorus and nitrogen) and lowering the amount of wastewater discharged into the environment can prevent the growth of dead zones and lessen eutrophication.

In certain instances wherein advanced wastewater treatment is applied, treatment facilities recover nutrients and energy in addition to eliminating pollutants. Reusing and recovering water can ease the strain on the water resource, which is susceptible to seasonal fluctuations and sporadic dry spells. Hence, it is a means of increasing environmental resources, creating revenue and ensuring resource stability over the long run. For example, the co-location of FSTPs and wastewater treatment plants in Dakar, Senegal, is contributing to the development of circularity (UNEP, 2023). This has made it possible to recover resources for horticultural uses around Dakar, such as the sale and reuse of treated wastewater for irrigation; the production of electricity from biogas, which reduces energy prices by 25%; and, the sale of dried and treated sludge to farmers and green spaces (UNEP, 2023). By generating income, all of these improve the sustainability, dependability and resilience of services. **Six steps, or approaches, that are beneficial for putting circular economy principles into practice in the water and wastewater industry** (Smol, Adam, & Preisner, 2020) **are described below:**

- Reduction: Reducing water use and pollution at the source to avoid the creation of wastewater to the maximum possible extent.
- Reclamation (removal): The use of efficient technology to remove contaminants from sewage and water.
- Recovery: Recovering resources such as nutrients and energy from water-based waste.
- Reuse: Reusing treated wastewater as an alternate source of water supply for non-potable usage.
- Recycling: Recovering water from wastewater for potable usage;
- Rethinking: Rethinking how to use resources to create a sustainable economy that is free of waste and emissions.

9.5. Exercises

(1) In your opinion, what comes to mind when you hear 'climate-smart WASH technology'?

(2) What considerations have been made in your country in terms of sanitation infrastructure and its impact on climate change?

(3) Explore and briefly explain climate-smart technology adoption and its financial consequences.

(4) In your opinion, as an important component of a circular economy, resource recovery generates opportunities; how will this impact DWM as a whole?


EC CONTROL PANEL

Module 10. Cost and benefit analysis (CBA) of DWM

The purpose of the CBA is to evaluate the financial viability of implementing various ideas. CBA is associated with the idea that a project should only be put into action if its total benefits outweigh its total costs. The selection of technology is significantly influenced by economic factors. The available funds must be distributed in a way that meets the requisite treatment efficiency and is both economical and effective in treating the intended volume of wastewater. Elevated investments are typically needed for centralised sewage treatment systems, not only for the treatment unit but also for the sewerage infrastructure. Therefore, decentralised solutions frequently outperform conventional systems, particularly when they service dispersed pollution sources or are situated in dispersed settlements.

To improve decision-making, CBA is used to calculate the costs and benefits of several solutions and subsequently compare the derived values. The options available to us comprise many types of sanitation systems. The ratio between the action's benefits and implementation costs is shown by the Benefit-Cost Ratio (BCR). A ratio greater than 1 indicates that the return exceeded the investment; that is, for every dollar invested, there was a greater return than 1 USD. It is critical to comprehend the true meaning of the BCR. The government does not guarantee a 4 USD return on every dollar invested in a wastewater TP system with a BCR of 4. Instead, the 4 USD from the investment will benefit the entire society. It is possible to state that for every 1 USD invested, the GDP will grow by 4 USD overall.

10.1. Categories for the wastewater treatment CBA

- Among the health benefits of wastewater treatment plants is the decline in infections caused due to better cleanliness. The avoided medical costs are the first economic savings used to calculate the following: 1) The financial burden of time lost to illness; 2) the cost of averting premature deaths; and 3) both.

- The benefits of wastewater treatment also include financial savings, such as lowering water bills, or requiring less walking to get to clean water. It also considers the lower cost of water treatment because of safety and aesthetic concerns.
- The time saved by having access to better sanitation, such as using a private lavatory instead of looking for a spot to defecate outside, is known as access time. The same principles that underpin time savings linked to health also underpin the economic worth of time.
- Comfort, seclusion, convenience, safety, status and prestige are examples of intangibles. These are hard to quantify in monetary terms, but they frequently have a significant impact on people's desire and willingness to pay for better sanitation.
- Reuse includes the advantages of recycling commodities such as biogas and compost fertilisers. Hence, reuse is particularly useful in rural locations where households can acquire animal excrement.
- The tourism sector is vulnerable to unsanitary conditions. Travelers are less inclined to return if they contract food sickness or cannot locate a clean toilet.

10.2. Examples of the benefit-cost ratio

Governments can assess the cost-effectiveness of their actions in relation to others by comparing the BCRs of other nations. Example comparisons of BCRs from urban and rural locations in six countries— Vietnam, Philippines, Indonesia, Cambodia, Lao People's Democratic Republic and China (Yunnan)— are displayed in Figure 36. Wet and dry pits typically yield the highest returns on investment. Centralised wastewater treatment systems show a positive return in all countries except for Cambodia, indicating that they need to review their current strategy. It is also important to understand that the payback period of an investment can be more than 1 year. If a wastewater TP system has a lifespan of 20 years, the BCR will reflect the benefits (and the costs) over this entire period. Typically, the payback period for a pit latrine in rural areas (moving up from open defecation) is approximately 1 year. This period is significantly longer when a centralised system is employed. For instance, someone who used to defecate in the open but now has access to a latrine will probably become sick less often and have more time for productive work. The improved health and more free time will allow the individual to engage in more productive activities, which can result in a higher income that will be factored into the return on investment. The BCR can change depending on the configuration. For instance, a given solution's BCR might be higher in a rural area than in an urban area, or vice versa, depending on the location. For example, in rural Laos, the BCR for establishing wet pit latrines is 7.8, whereas in urban areas it is 6.2.

Table 2. Benefit-cost ratio comparison

Country	Rural			Urban		
	Dry pit	Wet pit	Septic tank	Wet pit	Sewerage with treatment	Septic tank with treatment
Vietnam	8.0	N/A	4.0	8.1	3.0	3.8
Philippines	5.0	8.0	2.5	4.8	4.5	4.5
Indonesia	8.1	7.0	4.0	3.3	1.8	1.9
Cambodia	2.0	3.0	N/A	1.7	0.1	N/A
Lao People's Democratic Republic	8.3	10.0	3.8	6.0	N/A	N/A
China, Yunnan Province	5.8	N/A	3.8	5.0	2.0	2.8

(Source: UN & AIT, 2015)

In the sanitation ladder, the more expensive and sophisticated the sanitation system, the further up it is in the ladder. Open defecation without access to sanitation is at the bottom of the ladder, whereas flush toilets connected to sewage are at the top. In the lowest reaches of the ladder, the BCR is usually greater. This is because there are fewer marginal advantages when groups employing improved sanitation move up the ladder because they already have experienced some benefits. The financial benefits of better sanitation and wastewater treatment are estimated in Figure 38. Intangible advantages that have no monetary equivalent are also available; These include better quality of life, increased gender inclusivity, ease, comfort, privacy, status, security and so on. It is important not to undervalue these factors. Although time savings and better health are the biggest advantages for homes, a study suggested that dignity, comfort and privacy may be the main drivers of family behaviour. On the other hand, not much research has been conducted on how these advantages may be made profitable or how they might be turned into money for people or governments. Wider-ranging external benefits that come from better national cleanliness are among the other significant advantages of improved sanitation. These advantages may include higher water productivity, which will enhance fishing conditions, a rise in tourism and a greater allure for foreign direct investment for the nation.

BENEFIT CATEGORY	POPULATION WITH UNIMPROVED SANITATION	POPULATION WITH IMPROVED SANITATION	BENEFIT ESTIMATED
HEALTH	Data on health risk per person, by age category and socioeconomic status	Generic risk reduction, using international literature	Averted health care cost, reduced productivity loss, reduced deaths
WATER	Data on water source and treatment practices	Observe changes in practices in populations with improved sanitation	Reduced water sourcing and water treatment cost
ACCESS TIME	Data on water source and treatment practices	Observe reductions in time to access toilet	Opportunity cost of time applied to time gains
INTANGIBLES	Attitudes and preferences of householders to sanitation	Benefits cited of improved sanitation	Strength of preferences for different sanitation aspects and willingness to pay
REUSE		Practices related to excreta reuse	Value gained, based on sales or own use

Figure 39. Methods for estimating improved sanitation.
(Source: UN & AIT, 2015)

It is imperative that political decision-makers conduct a CBA to evaluate and assess the many DWM situations. Using cost curve analysis, it is possible to identify strategies to improve sanitation coverage with DWM services while also bringing about adequate and suitable public, commercial and social sector solutions. By identifying efficient, scalable and sustainable sanitation solutions together with the appropriate funding requirements and economically viable conditions, this study offers a thorough framework for investments as well as a framework for prioritising the distribution of funds. It divides situations into business categories that various institutions can follow based on their areas of interest and skill. BCA findings significantly improve policymakers' capacity to decide wisely and establish appropriate policies. However, it is important to remember that favourable BCRs for DWM in one nation may not always correspond to the same circumstances in another. Every country has a unique local environment which can produce varying outcomes.

10.3. Exercises

(1) In your opinion, what measures are being implemented to ensure cost-effectiveness in terms of the local context and/or in the context of your community?

Module 11. Advocacy, communication and knowledge management

Social and behaviour change communication employs communication to shift behaviour by positively influencing social and personal determinants to act as effective advocacy strategies. These may include factors within the family or the individual, such as knowledge, attitudes, self-efficacy (the confidence that people have in their ability to perform a behaviour) and discussion. Social norms (what is deemed acceptable by society), access, affordability and quality of services, as well as socio-economic factors, all of which originate outside the family, are also significant. Involvement of the community in decisions regarding infrastructure, capital contribution, labour and material provision and regulation through consumer representatives and tariff consultations will be crucial. For improved service delivery, the community should be consulted from the beginning and throughout the implementation phase. The management of provided infrastructures can be delegated to local communities whenever possible to ensure ownership, comprehension and adoption. It has been determined that the consultation process is effective, particularly when the affected community has a clear understanding of the proposed products/services, and that it is helpful during the implementation phase, particularly in tariff setting. Sensitive awareness campaigns, behavioural change strategies and focus group discussions will help to fully engage the concerned community and achieve results that reflect their requirements.

This will:

- Encourage the formation of community-based organisations for service delivery participation;
- Establish champions in the community for advocacy;
- Engage women's organisations for inclusive services;
- Ensure the inclusion of low-income communities in pro-poor and vulnerable initiatives.

11.1. Communication and awareness raising techniques

Before installing sanitation facilities, cultural behaviour must be thoroughly examined to ensure its success. Important criteria to evaluate capture versus culture facilities include the following:

- Women's behaviour during the menstruation period (use of pads, showering, etc.);
- Men's perception of women during the menstruation period;
- Education about menstrual hygiene;
- Open defecation practices and myths surrounding it;
- Willingness to pay for sanitation facilities.

For the reuse of end products (treated manure, co-composting), if necessary, special consideration should be given to the perception of the local community, and a clear understanding of its reuse should be provided, since some cultures cannot directly reuse manure from faeces unless it is mixed with other organic materials.

The primary objectives of communications is as following:

- Knowledge that irresponsible disposal of faeces will contaminate water and spread disease;
- Awareness of the need for properly designed and constructed septic tanks;
- Corrective knowledge of the construction mechanisms;
- Motivation to desludge septic tanks regularly before their overflow.

For example, the success of the social media campaign conducted in Warangal, India, with the image of the (the demon of defecation) as shown below (Government of India, 2020), demonstrates that content should be simplified and information should not be layered. Each city is unique, with varying degrees of supply-side preparedness and cultural diversity. Each city has diverse media touchpoints; hence, media plans tailored to each city need to be implemented. In turn, this has increased the public's risk perception of untreated FS through its association with water contamination, resulting in increased motivation and intent to act among the exposed population.

11.2. Stakeholder engagement and public-private partnerships

Planners and facilitators

- Tool development for stakeholder involvement: tools for assessing stakeholder needs and perceptions.
- Principles of DWM as an integral part of urban environmental sanitation planning.

Decision-makers/politicians

- Basic strategy solutions for improving DWM systems.
- Documentation on awareness building regarding health hazards and the cost of not improving the current system, impacts, environmental consequences, etc.
- Economic aspect of improving the DWM system and recycling.
- Standards for water quality, biosolids and treated FS: objectives, needs and values.
- Developing an incentive structure and procedure to facilitate the DWM system.
- Roles of municipal authorities and private entrepreneurs: franchising, licensing, controlling and enforcement and entrepreneurship.

Private sector

- Marketing of end-product usage/application
- Management of finances by small- and medium-sized businesses
- Technical direction for wastewater TP operators
- Complementary roles of public and private partners in DWM system.
- Create an environment conducive to private investment and profit.
- Ensure tariff implementation with O&M requirements and provide private sector incentives to prevent economic spill over.

11.3 Knowledge management and information sharing within ASEAN

Sanitation practitioners require reliable, up-to-date and well-organized information for learning and making decisions. There are a growing number of sources of information, such as field-based manuals, websites and data presented in graphs, charts and maps. The problem is that this information is not always widely known or is not read or used as evidence in decision making. Knowledge management is the conscious and deliberate effort to structure and facilitate the production, capture, processing, packaging, use and storage of information and knowledge. Consequently, it is essential to initiate a programme aimed at establishing ASEAN resource centres at the regional level with the goals of knowledge management and capacity building for communities and stakeholders. ASEAN must allocate sufficient resources to the initiative and scale it up across all member states so that all stakeholders (including communities) have access to them. This can be accomplished via websites, newsletters (for instance, in Malawi, newsletters are published for learning and sharing on Community Led Total Sanitation) and/or creative writing (similar to the case presented above of Warangal, India).

11.4 Dissemination

Focusing on technical aspects alone is insufficient for sustainable sanitation; therefore, long-term dissemination of appropriate wastewater knowledge and infrastructure is required. Not only does the strategy for implementing DWM projects involve constructing hardware but also an extensive array of integrated measures, such as:

- **Informational seminars and workshops to introduce key stakeholders to the decentralised approach:** Early communication with key stakeholders is essential for sustaining macrolevel programme support.
- **Co-financing of demonstration projects:** Financial support during the start-up phase of a project enhances the achievement of desired results and impacts.

- **Sector specific information-seminars:** An early focus on specific priority can support the exchange of ideas between experts and potential clients who have similar professional experiences.
- **Technical training:** Long-term experts facilitate comprehensive training programmes for sanitation practitioners and play a supervisory role during initial technical implementations.
- **Project planning:** Project planning includes technical feasibility studies, detailed engineering designs and cost estimation.
- **Project implementation:** Depending on the needs of clients and network partners, service delivery may include construction supervision, contractor services, etc. To ensure quality standards, major tasks must always be performed by qualified professionals.
- **Technical support and monitoring:** During the first year of operation, the personnel responsible for O&M must be adequately trained by technical specialists.
- **Quality control:** The designed and constructed treatment technologies must meet discharge standards. At regular intervals, effluent testing must be performed.
- **Research and development:** The community, stakeholders and partners must engage in ongoing efforts to enhance the efficiency and effectiveness of decentralised approaches and technologies.

11.5. Exercises

(1) Based on your experience in your country, what is the general population's willingness towards sanitation infrastructure and overall perspective? How effective is community participation (especially rural population) towards achieving sanitation goals?

(2) How can demand-based designs reduce unimproved sanitation facilities/devices and improve innovation to meet customers/users' needs and expectations and appropriately service the market? How can this be achieved?


EXIT

APPENDIX

Descriptions of commonly monitored parameters at domestic wastewater treatment plants

Parameters	Characteristics of Parameters
Potential hydrogen (pH)	• Here, pH stands for potential hydrogen. • The concentration range suitable for the existence of most biological life is quite narrow and critical (typically 6–9). • Wastewater and FS with extreme concentrations of hydrogen ions are difficult to treat biologically.
Total solids (TS) **Suspended solids (SS)** **Volatile solids (VS)**	• TS refers to the material remaining when the water sample is evaporated and dried (105°C–110°C, 2hrs). TS refers to the total amount of solid and soluble material precipitated in water. • SS refers to solids greater than 1 µm ~ less than 2 mm suspended in the water sample. • VS represents substances that volatilize when evaporated residues and suspended substances are ashed by intense heat (500°C ± 50°C, 30 min). There are two types of VS: loss against TS (VS) and loss against volatile suspended solids (VSS). Because the substances remaining after intense heat are generally inorganic, VS and VSS can be considered as indicators of the organic concentration of solids in the sample.
Dissolved oxygen (DO)	• Gaseous oxygen that has been dissolved in water and is available to aquatic organisms. • The concentration is affected by the water temperature, pressure and salinity. It is consumed by the decomposition of organic matter and oxidation of ammonia in wastewater

Parameters	Characteristics of Parameters
Biochemical Oxygen Demand (BOD)	• It is one of the organic pollution indicators. • It represents the amount of oxygen consumed when organic matter is oxidised by microbial action under aerobic conditions. It is usually expressed in terms of the oxygen concentration (mg/L) reduced by incubation • Sample water at 20°C for 5 days.
Chemical Oxygen Demand (COD)	• It is an organic pollution indicator. • The amount of oxidant consumed in the chemical oxidation of an organic substance, expressed as the equivalent amount of oxygen. The oxidant used is potassium permanganate or potassium dichromate
BOD/COD (Ratio of BOD and COD)	• Typical BOD/COD ratios in untreated municipal wastewater lie within the range of 0.3–0.8. • If the BOD/COD ratio for untreated wastewater is 0.5 or greater, the waste can be easily treated by biological processes. • If the ratio is below approximately 0.3, either the waste may have some toxic components or acclimatised microorganisms may be required for its stabilisation.
Total Organic Carbon (TOC)	• It is a indicator of organic pollution and is the amount of carbon in organic substances in water, expressed in mg/L. • Typically, the total organic carbon content of a sample is determined by burning organic materials at high temperatures (900°C–950°C) and measuring the amount of carbon dioxide produced.
Mixed Liquor Suspended Solids (MLSS)	MLSS refers to suspended solids in the reaction tank mixture in the activated sludge process. It is an indicator that refers to the number of microorganisms in the reaction tank.

Parameters	Characteristics of Parameters
Nitrogen (N)	• In wastewater and in the wastewater treatment process, nitrogen is present in various forms, such as ammonia and protein, and these forms change during the treatment process. • Nitrogen is a nutrient that cause eutrophication. • Ammonia nitrogen (NH4-N), nitrite nitrogen (NO2-N) and nitrate nitrogen (NO3-N) are collectively referred to as inorganic nitrogen. • Organic nitrogen (Org-N) is determined by oxidising organic matter using the Kjeldahl method and measuring free ammonia.
Coliform Bacteria	• Coliforms are a group of bacteria found in high concentrations in the human intestinal tract and discharged into the environment with faecal matter. • Although non-intestinal bacteria are also present in the coliform group, the presence of coliforms in environmental water indicates that the water may have been contaminated with human faeces.
Heavy metals	• Heavy metals are usually found in commercial and industrial wastewater and may have to be source - controlled if the wastewater is to be reused. • For example, cadmium, chromates, lead and mercury are often present in industrial wastewater.
Residual Chlorine	It is the effective chlorine remaining in the water. There are two types of residual chlorine: free, such as hypochlorous acid and bound, such as monochloramine. It is extremely unstable and decreases rapidly over time.
Hexane extracts, normal hexane extracts	• Hexane extracts are indicators of fats and oils; they are extracted and measured using the organic solvent hexane. • Wastewater from restaurants and other establishments often contains high concentrations of fats and oils. When these fats and oils adhere to the influent pipes, they can clog the pipes and cause foul odours. When they enter the biological reaction tank, they also interfere with the biological treatment function.

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In collaboration with

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