Training Modules
for Proper Operation and Maintenance
of Domestic Decentralised Wastewater
Treatment Facilities in Lao PDR

WEPA Action Program in Lao PDR
March 2024

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Water Environmental Partnership in Asia (WEPA)

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The drafting team responsible for developing the "Training Modules for Proper Operation and Maintenance of Domestic Decentralized Wastewater Treatment Facilities in Lao PDR" comprises the following members:

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Acknowledgement

This document is the output from the WEPA Action Plan (AP) in Lao PDR, "Development of An Appropriate Domestic Wastewater Management System in Lao PDR," implemented between 2021 and 2023. The AP was supported by funding from the Ministry of the Environment, Japan, through WEPA. The training modules were completed thanks to the strong support and dedicated efforts of all involved. We express our gratitude to our collaborators, including Ms. Anousone Norlorkham, and all participants in the consulting meeting for this training module. We are also grateful to Dr. Kumokawa Shinhi from the Japan Education Center of Environmental Sanitation, Mr. Sato Ryoma and Dr. Hoang Thi Mai from the Office for Promotion of Johkasou, MOEJ, and WEPA advisor, Dr. Ebie Yoshitaka from the National Institute for Environmental Studies (NIES), for reviewing and providing insightful feedback on this document.

Table of contents

INTRODUCTION

Background on water and sanitation situation in Lao PDR

In recent years, the Lao People's Democratic Republic (Lao PDR) has experienced a relative improvement in its economy. Growing urban population movements have sparked commercial and industrial growth, placing more strain on the environment. Although the nation's economic, health, and social development indices have increased, it has made steady progress towards national development. However, there are still many obstacles to expanding access to and use of sanitation and hygiene services. Before reaching rivers and streams, wastewater is dumped directly into the environment, such as ponds, paddy fields, and roadside areas in the Lao PDR, leading to water contamination, a serious problem. Poor treatment facilities and improper onsite sanitation systems are the root causes of this problem. In Laos, almost every family uses on-site systems, particularly in metropolitan areas. Most urban residents in large towns do not have access to sewage systems. In most homes, a soak pit or septic tank, which can be emptied or replaced when full, is attached to the pour-flush toilet. Hence, coliforms and faeces from septic tanks and latrines frequently contaminate water in drainage systems. Numerous pilot projects have been conducted to enhance urban sanitation and wastewater management. This entails creating stabilisation ponds and enhancing drainage systems. These initiatives have failed because of insufficient financial or technical resources to run and maintain the facilities.

According to the 2015 UN Country Analysis Report, Lao PDR has achieved safe water and sanitation targets under the Millennium Development Goals (MDGs) (ADB, 2021). However, the nation must i) increase investments in infrastructure and sanitation facilities, ii) promote good hygiene, and iii) safeguard and restore water-related ecosystems to achieve the goal of Agenda 2030 of providing everyone with access to clean and affordable drinking water. Even if a plan is set up to accomplish these aims, the main obstacles include high open defecation rates, particularly in rural regions, differences in sanitation services between rural and urban areas, and water safety and quality standards. Both the domestic and industrial sectors emit pollutants. Domestic wastewater is the leading source of surface water contamination because it contains high levels of chemical oxygen demand (COD), nutrients, and faecal coliforms. Agricultural runoff contains nutrients from excessive fertiliser and pesticide use, resulting in a distributed source of pollution. Industrial wastewater contains a wide range of pollutants depending on the nature of the raw materials utilised, processing units, and final production outputs. They frequently contain heavy metals, greases, oils, and other contaminants.

To deal with the rising levels of domestic pollution, the Laotian government is promoting decentralised wastewater treatment (DEWAT) systems. The country's DEWAT system capacity has increased significantly due to the transition to DEWAT system development. However, organic pollutant levels in public canals are quite high (BOD5 19–32 mg/L, COD-Cr 38–101 mg/L, all exceeding the national surface water category four environmental requirements (Deevanhxay, 2022). A few DEWATS plants performed well and met effluent standards (Deevanhxay, 2022). The BOD5 levels of the two DEWATS (35 and 120 mg/L) and the septic tank (45 mg/L) did not meet the effluent limit. The DEWATS maintenance manuals are available (Deevanhxay, 2022). However, regular monitoring and maintenance are absent in certain facilities, particularly in the sedimentation chambers of certain DEWATS facilities (**Figure 0.1-1**), which have thick scum coatings and large amounts of debris. A few operators were unfamiliar with the technical operation of DEWATS. The frame and holders of the manhole cover are eroded, making it difficult to access the chambers; therefore, a user-friendly design may be required. No technical guidelines or Standard Operating Procedures exist for managing septic tanks and faecal sludge. Most facilities lack a specified budget or budget strategy for facility operations and maintenance.

Figure 0.1-1 DEWATS filled with sludge due to lack of proper O&M

The country's access to and usage of poor sanitation indicates poverty. In contrast, the wealthiest households in the country do not practice open defecation, and 65.5% of the poorest households do (ADB, 2021). According to a national survey conducted in 2017, only 23.5% of rural households dispose of baby and child waste safely. Therefore, surface water is now at risk of untreated wastewater contaminating urban and rural water supplies. Investments in water, sanitation, and hygiene are insufficient. More focus, funding, and assistance from the government and foreign partner organisations are needed for water treatment and sanitation. Laos is a predominantly hilly country with many isolated and secluded regions. The nation is vulnerable to climate-related issues, which impact the security of its water and sanitation infrastructure due to its frequent exposure to extreme weather conditions and natural catastrophes such as floods. Floods significantly impact people, businesses, and the government, with losses estimated to be between 2.8% and 3.6% of GDP (Gross domestic product). Notwithstanding these obstacles, Bolikhamxay proclaimed the nation's first province free of open defecation in 2020. According to the report from the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), shown in **Figure 0.1-2**, 70% of the nation's households have access to a basic level of sanitation (from 57% in 2012 to 71% in 2017).

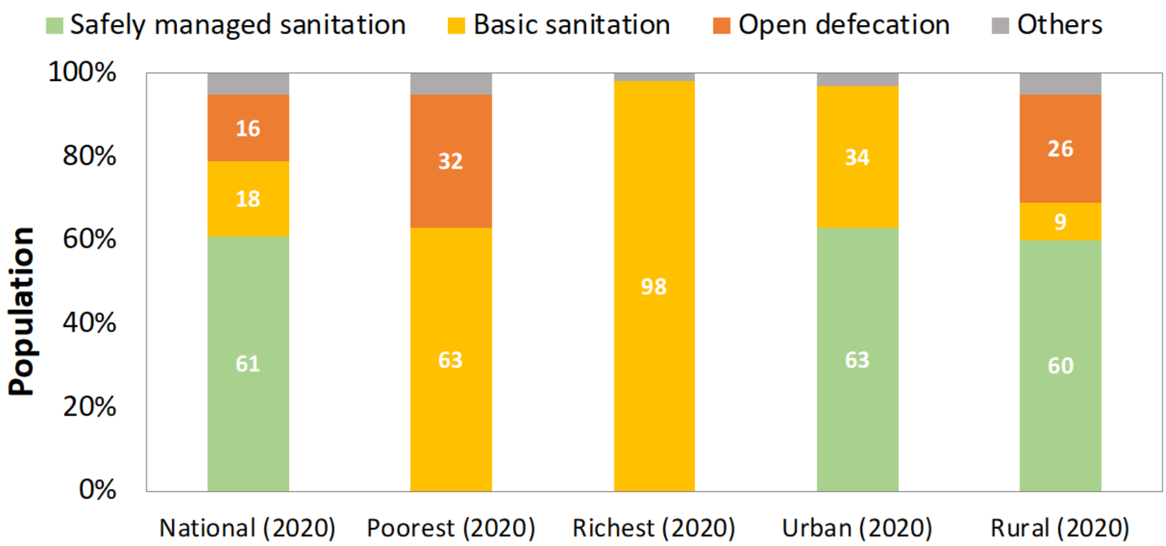

Figure 0.1-2 Lao PDR Sanitation Outlook (Sustainable Development Report 2022)

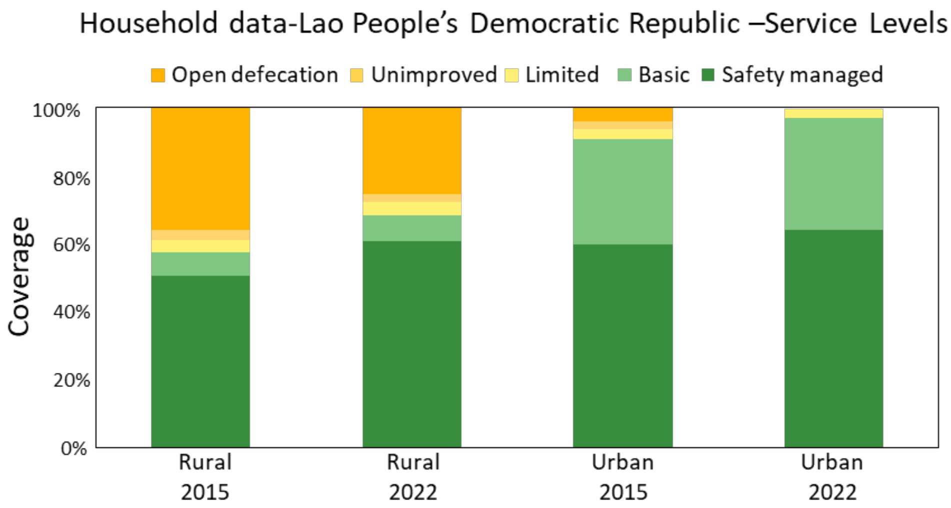

Figure 0.1-3 Rural and urban sanitation service levels (WHO/UNICEF, 2023)

Defaecation in the open decreased from 38% in 2011–12 to 24% in 2017. The primary impediments to effectively tackling wastewater treatment concerns in Laos are as follows:

(i) Insufficient legal framework

(ii) Absence of specific wastewater discharge standards.

(iii) Insufficient financial and technical resources are available for the appropriate setup, management, and maintenance of wastewater treatment facilities.

0.1 Objectives of WEPA Action program in Lao PDR

The objective of this project was to improve the water and sanitation environment in Lao PDR by enabling the proper operation and management (O&M) of decentralised wastewater treatment facilities, which are widely used in Laos. To achieve this goal, the project aims to transfer appropriate and specific maintenance knowledge to public officials responsible for the water environment and, through this training, to develop the capacity of these officials to provide training on proper O&M to managers and operators of decentralised wastewater treatment facilities.

This document compiles information on practical maintenance and management in Laos. Moreover, it is hoped that Laos will eventually optimise its maintenance and management methods, considering the desired water environment, economy, and efficiency. The training was conducted in Laos using this document, and the MONRE plans to develop guidelines for the O&M of decentralised wastewater treatment facilities in Laos.

0.2 Target audiences

The training content described in these modules can benefit various target audiences involved in operating and managing decentralised wastewater treatment facilities in Laos. The target audience included the following:

- Public officials and technical staff in charge of domestic wastewater management and planning
- Private contractors involved in the operation and maintenance of decentralised wastewater treatment systems
- Owners, facility managers, and operators of decentralised wastewater treatment systems

0.3 Scope of this training material

The training materials cover a comprehensive range of topics and aspects but are not limited to the following:

- Overview of domestic wastewater and faecal sludge management in Lao PDR (including characteristics of domestic wastewater/faecal sludge; hazards and associated health impacts; generated volume/amount; existing national policies, regulations, and requirements for treatment, applied effluent standards, and requirements for regular monitoring/reporting; current technical/technological approaches, business models for collection and treatment of domestic wastewater and faecal sludge management, including its advantages & disadvantages)
- Introduction to septic tanks and decentralised wastewater treatment systems, and existing challenges and opportunities for the effective utilisation of these systems to address long-standing water pollution issues in Lao PDR
- Step-by-step approach for proper operation and maintenance of septic tank standard operating procedures (SOPs) and decentralised wastewater treatment systems
- Technical guidance for proper sludge collection, treatment, and management in the Lao PDR.

TERMS AND DEFINITIONS

ABR	Anaerobic Baffled Reactor
ADB	Asian Development Bank
AIT	Asian Institute of Technology
ASEAN	Association of Southeast Asian Nations
BMGF	Bill and Melinda Gates Foundation
BOD	Biochemical Oxygen Demand
BORDA	Bremen Overseas Research and Development
DWS	Department of Water Supply
DHHP	Department of Hygiene and Health Promotion
DHUP	Department of Housing and Urban Planning
CBS	Community-Based Sanitation
CSDA	City Service Delivery Assessment
CWIS	The Citywide Inclusive Sanitation Services
CWIS SAP	The Citywide Inclusive Sanitation Services Assessment and Planning
EEM	Environmental Engineering and Management
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
HoSan	Hospital Sanitation
JICA	Japan International Cooperation Agency
LIRE	Lao Institute for Renewable Energy
MAF	Ministry of Agriculture and Forestry

MOH	Ministry of Health
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MPWT	Ministry of Public Works and Transportation
Nam Saat	National Center for Environmental Health and Water Supply National Environmental Quality Standard
NEQS	National Environmental Quality Standards
NPCS	National Pollution Control Standards
NGGS	National Green Growth Strategy
NRESV	Natural Resources and Environment Sector Vision
RESan	Real Estate Sanitation
O&M	Operation and Maintenance
SBS-Lite	School-Based Sanitation-Lite
SDG	Sustainable Development Goals
SFD	Shit Flow Diagram
SME	Small and Medium Enterprise
TP	Treatment Plant
TSS	Total Suspended Solid
WB	World Bank
WHO	World Health Organisation
WWRL	Water and Water Resource Law
UDD	The Urban Development Division
UN	United Nations
UNICEF	United Nations Children's Fund
WASH	Water, sanitation, and hygiene

TRAINING MODULES

MODULE 1.
Basics of wastewater Treatments

1.1 Purpose of this module

The purpose of this chapter is to first learn the basic science and legal regimes related to the water environment and water treatment, which are necessary for training in the maintenance and management of decentralised wastewater treatment systems. This chapter summarises the types of wastewater, water quality indicators, basic principles of water treatment, and legal regimes in Laos.

1.2 Classification of wastewater type

Several definitions of wastewater exist. Here, wastewater is defined as "a combination of one or more of domestic effluent consisting of blackwater (excreta, urine, and faecal sludge) and greywater (kitchen and bathing wastewater); water from commercial establishments and institutions, including hospitals; industrial effluent, stormwater, and another urban run-off; agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter" (UNESCAP, UN-Habitat & AIT, 2015). The number of people living in a household, their behaviour, way of life, and standard of living, and the legal and technical framework that governs the area, all impact the type and quantity of wastewater households produce.

The different sanitation systems generate the following products:

- **Blackwater** is a mixture of urine, faeces, and flushing water, along with anal cleansing water (if anal cleansing is practised) or cleaning materials (toilet paper).
- **Greywater** is generated by bathing, hand washing, cooking, and laundry. They are sometimes mixed or treated with water.
- **Urine** is liquid human waste that does not mix with faeces or water.
- **Brown water** is blackwater without urine.
- **Domestic wastewater** comprises all sources of liquid household waste, including blackwater and greywater. Moreover, it did not include stormwater.
- **Excreta** is a mixture of urine and faeces that do not mix with any flushing water (although small amounts of anal cleansing water may be included).
- **Faecal sludge (FS)** is raw or partially digested in a slurry or semisolid form, and it is the collection, storage, or treatment of combinations of excreta and black water, with or without grey water, and it is the solid or settled content of the pit latrines and septic tanks.
- **Effluent** is a liquid that leaves a technology, typically after blackwater or sludge has undergone solid separation or a few other types of treatment.
- **Septage**: The material pumped out of a septic tank, cesspool, or other on-site treatment facility after collection over time is known as septage. The mixture of liquid, sludge, and scum that accumulates in septic tanks is known as septage. Septic tank wastewater can be collected in drains and/or sewers and processed in a suitable treatment facility.

1.3 Basic monitoring parameters

The basic indicators of water quality are as follows: For more information on the environmental standards in Laos, see the **Annex 1**.

(1) pH

- Because **chemical reactions in water are affected by pH**, it is an important factor in **determining water quality changes** and **treatment efficiency**.
- Neutrality is defined as a pH of 7, whereas a higher hydrogen ion concentration is called acidity, resulting in a pH value lower than 7. pH range denomination:
  - Ultra acidic <3.5
  - Extremely acidic 3.5–4.4
  - Very strongly acidic 4.5–5.0
  - Strongly acidic 5.1–5.5
  - Moderately acidic 5.6–6.0
  - Slightly acidic 6.1–6.5
  - Neutral 6.6–7.3
  - Slightly alkaline 7.4–7.8
  - Moderately alkaline 7.9–8.4
  - Strongly alkaline 8.5–9.0
  - Very strongly alkaline 9.0–10.5
  - Hyper alkaline >10.5
- If nitrification occurs during wastewater treatment, the pH decreases. However, if denitrification proceeded, the pH increased.

(2) DO (Dissolved oxygen)

- DO is gaseous oxygen that is dissolved in water and is available to aquatic organisms. **Aquatic organisms use dissolved oxygen to breathe and DO must be maintained at appropriate levels to sustain the water body's ecosystem.** The concentration should be greater than 5 mg/L for healthy water.
- The water temperature, pressure, and salinity affect the concentration, and it is consumed by decomposing organic matter and oxidation of ammonia in wastewater. In aerobic wastewater treatment, DO is consumed more rapidly because of the higher microbial concentrations and must be replenished by aeration.
- Dissolved oxygen must be considered and maintained, even in wastewater treatment plants. Levels of approximately 2 mg/L are adequate for biological processes (albeit low compared to natural healthy waters that support aquatic life). Furthermore, having dissolved oxygen in the process facilitates effluent discharge; therefore, "dead" water or water deficient in dissolved oxygen does not damage nature.

(3) BOD (Biochemical Oxygen Demand)

- BOD is one of the organic pollution indicators[1].
- BOD represents the amount of oxygen consumed when organic matter is oxidised by microbial action under aerobic conditions, and **it is usually expressed in terms of the oxygen concentration (mg/L) reduced by incubating sample water at 20°C for five days.**

(4) COD (Chemical Oxygen Demand)

- COD is one of the organic pollution indicators.
- This is the amount of oxidant consumed in the chemical oxidation of an organic substance and is expressed as an equivalent amount of oxygen. Potassium permanganate or potassium dichromate was used as an oxidant[2].

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[1] Organic matter is one of the indicators of water quality, but the direct negative effects of organic matter in the aquatic environment are small. Organic matter is used as a water quality indicator because when it enters rivers, lakes, swamps, and oceans, it is decomposed by aerobic microorganisms that consume dissolved oxygen and degrade the habitat of aquatic organisms.

[2] Since the oxidation reaction methods for BOD and COD are different, the oxidation characteristics for the target organic substance are also different, and the values for BOD and COD do not match.

(5) BOD/COD (Ratio of BOD and COD)

- Typical BOD/COD ratios in the untreated municipal wastewater were within the 0.3–0.8 range.
- If the BOD/COD ratio for untreated wastewater is 0.5 or greater, the waste is easily treatable by biological processes.
- If the ratio is below 0.3, the waste may contain toxic components or acclimatised microorganisms may be required for stabilisation.
- COD and BOD were run on numerous wastewater samples to obtain the COD:BOD ratio. Divide each sample's COD concentration by its BOD concentration, and the findings were averaged.

(6) TOC (Total Organic Carbon)

- TOC is an indicator of organic pollution and is the amount of carbon in organic substances in water, expressed in mg/L.
- Typically, a sample's total organic carbon content is determined by burning organic materials at high temperatures (900–950°C) and measuring the amount of carbon dioxide produced.

(7) TS (Total solids), SS (Suspended solids), VS (Volatile solids)

- TS refers to the material remaining when the water sample is evaporated and dried (105–110°C, 2 hrs). TS refers to the total amount of solid and soluble materials precipitated in water.
- SS refers to solids greater than 1 µm–less than 2 mm suspended in the water sample.
- VS represents substances that volatilise when evaporated residues and suspended substances are ashed by intense heat (500 ± 50°C, 30 min). Two types of VS are available: loss against TS (VS) and loss against SS (volatile suspended solids [VSS]). Because the substances remaining after intense heating are generally inorganic, VS and VSS can be considered indicators of the organic concentration of solids in the sample.

(8) MLSS (Mixture of suspended solids)

- The MLSS refers to the suspended solids in the reaction tank mixture during the activated sludge process. This indicates the number of microorganisms in the reaction tank[3].

(9) N (Nitrogen)

- In wastewater and wastewater treatment processes, nitrogen is present in various forms, such as ammonia and proteins, which change during treatment.
- Ammonia nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N) are collectively referred to as inorganic nitrogen.
- Organic nitrogen (Org-N) was determined by oxidising organic matter using the Kjeldahl method and measuring free ammonia. Because the ammonia in the sample was measured then, Org-N could be obtained by subtracting NH_4-N from the nitrogen determined. In wastewater treatment, approximately 60–70% of the influent Kj-N is NH_4-N, and the rest is Org-N:
  Org-N = (Kj-N) – (NH_4^+-N)
- A sample's total nitrogen (TN) is the sum of organic and inorganic nitrogen:
  TN = (Org-N) + (NH_4^+-N) + (NO_2-N) + (NO_3-N)
- **Nitrogen is one of the nutrients that cause eutrophication.**

(10) P (Phosphorus)

- Phosphorus is present in water as inorganic phosphate (phosphate) or organic phosphorus (orthophosphate). The most important phosphates in aquatic environments are orthophosphates (PO_4^{3-}) and polyphosphates ($P_2O_7^{4-}$ and $P_3O_{10}^{5-}$), gradually hydrolysed to PO_4^{3-} in water.
- **P is a nutrient and one of the limiting factors of eutrophication.**

[3] In Johkasou system where the activated sludge method is used, the MLSS concentration should be maintained at around 1000–3000 mg/L and that of the nitrification and denitrification tanks at around 3000–6000 mg/L. Johkasou may maintain good functionality without meeting these numbers; therefore, daily data should be collected and managed.

(11) Coliform bacteria

- **Coliforms are a group of bacteria observed in high concentrations in the human intestinal tract** that are discharged into the environment with faecal matter.
- Although non-intestinal bacteria are present in the coliform group, the presence of coliforms in environmental water indicates that the water may have been contaminated with human faeces, indicating the potential for contamination.

(12) Heavy metals

- **Heavy metals are metals with a specific gravity of 4–5 or greater, including iron, chromium, copper, gold, lead, zinc, cadmium, and mercury.** Certain substances, such as iron and copper, are essential for living organisms, but their requirements are negligible. Heavy metals are generally toxic to more than a certain amount because they accumulate in the body and are not easily excreted.
- Heavy metals are usually observed in commercial and industrial wastewater and may have to be source-controlled if the wastewater is to be reused.

(13) Residual chlorine

- This is the **effective chlorine remaining in the water.** Two types of residual chlorine exist: free chlorine (hypochlorous acid) and bound chlorine (monochloroamine), and it is extremely unstable and decreases rapidly over time.

(14) Fat, Oil and Grease (FOG)

- **FOG includes lipids comprising fatty acids, triacylglycerols, and fat-soluble hydrocarbons. In households, this can come from plant and animal fat in food matter, oils, salad dressings, cheeses, sauces, butter, and fried food, and it can come from liquids from synthetic matter, such as detergents and soaps.**

1.4 Basic wastewater treatment methods

Water pollutants can be classified into three main categories: suspended, sinking, and dissolved. Wastewater treatment separates pollutants from water or converts them into harmless and stable substances. Treatment methods can be broadly categorised into physical, chemical, physicochemical, and biological. The table below lists the major treatment methods, techniques, and prominent removal technologies.

1. Physical, chemical, biological, and physicochemical methods remove contaminants (pollutants) from wastewater and are typically categorised as physical, chemical, and biological unit processes or operations.
2. Physical unit operations are treatment modalities that rely heavily on applying physical force.
3. Common physical-unit operations include Screening, mixing, flocculation, sedimentation, flotation, filtration, and membrane filter operations.
4. Chemical unit procedures are treatments in which pollutants are removed or converted by adding chemicals or other chemical reactions.
5. The most frequently utilised processes in wastewater treatment are ion exchange, gas transfer, oxidation, reduction, precipitation, adsorption, and neutralisation.
6. The primary processes involved in physicochemical processes include filtration, reverse osmosis, flocculation, coagulation, and electrocoagulation. The primary wastewater treatment processes are flocculation and coagulation.
7. Unit processes are treatments in which pollutants are eliminated through biological activities.
8. The main purpose of biological treatment is to remove biodegradable organic materials, whether dissolved or colloidal, from wastewater.

Table 1.4-1 Basic wastewater treatment methods

Treatment methods	Removal methods	Technologies
Physical treatment	Screening	Sieves
	Filtration	Filters
	Difference in specific gravity	Sedimentation/ flotation separation
	Heat energy	Evaporation/ drying
	Electric energy	Electrolysation
	Aerobic decomposition	Activated sludge method
Chemical treatment	Oxidation reaction	Oxidation
	Reduction reaction	Reduction
	Metathesis reaction	Neutralization/flocculation
Physio- chemical treatment	Interface potential	Coagulating sedimentation/ Coagulating flotation
	Adsorption	Activated carbon adsorption
	Exchange of ion	Ion-exchange resin
	Electronic-chemical 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 method Biochemical oxidation or sludge digestion

The type of treatment technology units used depended on the community. For example, slum communities use simple grease traps and vegetative systems as wastewater treatment systems, whereas other households use commercial septic tanks and decentralised domestic wastewater treatment such as activated sludge. As described earlier, DEWAT technology has a comparative advantage over centralised wastewater treatment plants in terms of cost. The cost of DEWATs may differ from the choice of technology combination where the land availability and price play significant roles in the DEWATs technology combination. For example, in the core urban area, where the population density is high and constrained by land availability and price, compact underground anaerobic digesters will be a natural choice, but not a pond or filter. In peri-urban areas where land is available, and prices are relatively low, simple technology, such as a pond or filter system, would be a natural choice and could enhance urban space on the verge of urbanisation.

1.5 Basic principles of wastewater treatment

1) Sedimentation and separation

Sedimentation is the process of separating solids from liquids in water depending on differences in gravity. In decentralised wastewater treatment systems, sedimentation and separation tanks are always installed before biological reaction tanks to separate sand, stones, and raw settleable matter from the influent wastewater and to reduce the load on the subsequent biological treatment. Baffles and other devices were installed to extend sedimentation time and ensure effective sedimentation and separation in the tanks. In addition, in systems that use activated sludge processes, sedimentation separation separates the activated sludge from clean water in the reaction tank.

The SS removal efficiency in a settler is proportional to the pond surface area and settling velocity of the particles and inversely proportional to the influent volume. Therefore, water surface load, the influent volume divided by the tank surface area, is an important design factor. Other factors affecting the sedimentation efficiency include the water temperature, sedimentation time, and effective depth of the settler. The longer the time spent in the clarifier, the more effective the sedimentation and separation of suspended solids. However, the longer the time, the less effective the treatment. If the settling tank has a large capacity and the retention time is long, the sedimented sludge may decompose, and the water quality may deteriorate. The degradation process may hamper sludge settling because gases create bubbles and re-suspend solids. Suppose the settling sludge is the opposite and the settling time is short. In that case, the settling separation effect of the sludge will be poor, increasing the load on the biological reaction tank and worsening the water treatment performance.

2) Anaerobic digestion

Anaerobic biological treatment involves decomposing organic and inorganic matter without molecular oxygen. The main applications are stabilising concentrated sludge from wastewater treatment and treating concentrated organic industrial waste.

The biological conversion of organic matter under anaerobic conditions typically occurs in three steps:

1. In the first step, a group of organisms hydrolyses organic polymers and lipids into basic structural building blocks such as monosaccharides, amino acids, and related compounds that are suitable energy sources and cellular carbon.
2. The second group of non-methanogenic microorganisms comprises facultative and obligate anaerobic bacteria. These microorganisms are often referred to in the literature as acidogens or acidifiers.
3. A third group of microorganisms converts hydrogen and acetic acid produced by acidogens into methane gas and carbon dioxide. The bacteria responsible for this conversion are strict anaerobes called methanogens. The excess sludge that must be disposed of is minimal because of the low synthesis rate of anaerobic microorganisms.

Typical anaerobic treatment technology:

- Upflow anaerobic sludge blanket (UASB) reactors
- Anaerobic baffled reactors (ABRs)
- Anaerobic filters (AFs)
- Covered Lagoons

3) Anaerobic filtration

This method can treat carbonaceous organic waste to overcome the limitations of several anaerobically attached microorganism growth processes. An anaerobic filter is a column filled with various solid media used for bacterial attachment. The waste flowed upwards through the column, contacting the medium on which the anaerobic bacteria flowed and were retained. Because the bacteria are retained in the medium and not washed off in the effluent, mean cell residence times can be obtained on the order of 100 days.

4) Activated sludge method

When air is blown into a wastewater tank, microorganisms, such as bacteria, protozoa, and metazoans, use the organic matter in the wastewater to multiply and form cohesive gelatinous flocs. This is activated sludge. After the settling process, when air is introduced into a mixture of sewage and activated sludge, the organic matter in the sewage is adsorbed by the activated sludge, oxidised, and decomposed by the microbes in the activated sludge. A few of the organic matter is converted into activated sludge. The removal of organic matter during the activated sludge process can be summarised as follows:

i. When colloidal organic matter in wastewater encounters activated sludge, it is adsorbed on the surface of the activated sludge within a short period.

ii. Adsorbed organic matter is absorbed into the bodies of microorganisms, and oxidation and assimilation of organic matter by microorganisms occurs.

   <Oxidation>

   Organic matter + O_2 → CO_2 + H_2O + Energy (for microorganisms to maintain living organisms and cellular synthesis)

   <Assimilation>

   Organic matters + O_2 + Energy → Microorganism (growth) + CO_2 + H_2O

In this process only approximately 30% of the BOD removed by oxidation of organic matter is oxidised to gas, and the rest is concentrated in sludge (activated sludge and excess sludge) by the assimilation of organic matter. In this activated sludge method, the activated sludge can be separated from the treated water at the settling area after the reaction tank by gravity sedimentation without additional energy. This viable treatment method emphasises properly treating sludge with concentrated organic matter.

5) Disinfection

Disinfection refers to the selective destruction of disease-causing organisms instead of sterilisation, which involves the destruction of all organisms. The disinfection of treated wastewater is fundamental for the management of this resource.

Major infectious agents in wastewater can be classified into three broad groups: bacteria, eukaryotic parasites (primarily protozoans and helminths), and viruses. Diseases caused by waterborne bacteria include typhoid fever, cholera, parathypoid, and bacillary dysentery. Disinfection is commonly accomplished using (1) chemical agents, (2) physical agents, (3) mechanical agents, and (4) radiation.

The principal mechanisms of disinfection are as follows: (1) damage to the cell wall, (2) alteration of cell permeability, (3) alteration of the colloidal nature of the protoplasm, (4) inhibition of enzyme activity, and (5) damage to cellular DNA and RNA. The damage to or destruction of the cell wall results in cell lysis and death. A change in the selective permeability of the cell membrane allows vital nutrients such as nitrogen and phosphorus to enter the cell. If the cellular DNA and RNA are damaged, the organism cannot reproduce and eventually dies.

1.6 Water and sanitation related regulations in Lao PDR

1) National policy on water supply, sanitation, and hygiene (2019)

The 2019 National Policy on Water Supply, Sanitation, and Hygiene outlines all actors' principles, guidelines, and roles. Moreover, it sets out 16 policy statements and clarifies institutional roles and responsibilities. The Policy emphasises that the capabilities of local stakeholders are vital in decision-making and implementation. This follows the Sam Sang framework of the three buildings, and national policies and strategies are being disseminated widely across all levels.

(1) Promote and protect the rights of all people living in Lao PDR to access safe and sufficient water services for use and consumption equally at affordable and fair tariffs and to ensure safe sanitation and hygiene facilities that meet defined standards.

(2) Protects water resources from contamination, negatively impacting water resources.

(3) Support decentralisation for local planning using bottom-up approaches. Increase implementation at local levels to achieve tangible results as per “3 Builds”.

(4) Identify priority targets, focusing on locations and sectors as follows:

- **Rural settings**: Those who live in mountainous areas, rural, remote areas, poor and ethnic groups, and those affected by development projects and natural disasters.
- **Urban settings:** Those who live in the suburbs (countryside) and earn minimum wages and those who resettle from mountainous areas to the lowlands, including poor communities in densely populated areas.
- **Health:** Ensure that healthcare facilities have a safe and sufficient water supply, sanitation facilities, and appropriate garbage and wastewater management measures.
- **Education and sports**: Ensuring all educational institutions have sufficient water and sanitation facilities. Special attention has been paid to early childhood and primary school education in rural areas.

(5) Build capacity for development and overall management of water supply, sanitation, and hygiene services through scheduling regular training at all levels and institutions, including the private sector, focusing on increasing women's involvement in the water supply, sanitation, and hygiene sectors.

(6) Ensure that water for both use and consumption is fully managed, mobilised, and sustainable with community ownership and civil society engagement.

(7) Raise hygiene and sanitation awareness, focusing on behavioural change. Coordinate relevant sectors and local authorities to increase community ownership and engagement of civil society in these areas.

(8) Implement water safety plans and focus on water quality surveillance to ensure that MoH water standards are met, including establishing water quality laboratories.

(9) Regulate and collect tariffs on drinking water and water supply to ensure that consumers receive fair and reasonable prices. This includes the wastewater service charges.

(10) Establish effective and sustainable mechanisms for monitoring and evaluation by involving relevant sectors in monitoring WASH implementation.

(11) Water use for production should be promoted if it is of sufficient quality and quantity.

(12) Management of faecal sludge disposal from septic tanks and safe disposal of related waste products.

(13) Manages and controls all pollutants that affect rivers, streams, lakes, ponds, groundwater, and other sources.

(14) Promote the use of renewable energy and reuse resources as much as possible.

(15) Enhance water security and climate change resilience to sustainably protect water resources, prevent environmental accumulations and droughts, promote clean environments, and prevent pollutants and adverse effects on humans, flora and fauna, and water resources. Sufficient water is provided in terms of both quality and quantity.

(16) Provide sufficient budgets to implement policies, strategies, and the five-year program of each related sector, with contributions and engagement from the government, international partners, the private sector, and communities.

2) Existing National Policies and Guidelines

The legal framework of Lao PDR has evolved rapidly since the adoption of the first legal instrument for environmental management in the 1990s. Article 10 of the Lao PDR Constitution of 1991 (amended in 2013) states that all organisations and citizens must protect the environment and natural resources, such as land, underground [resources], forests, animals, water sources, and the atmosphere. The first legal instruments from this constitutional provision included the Regulation on Industrial Waste Discharge (1994) and the Law on Water and Water Resources (1996). The 1999 Environmental Protection Law (EPL), with its most recent amendment in 2012, constitutes the backbone of the country's legal framework for environmental management (JICA 2013).

The Environmental Protection Law includes several provisions focused on environmental health risks. The law aims to balance social and natural environments, sustain and protect natural resources and public health, and contribute to mitigating socio-economic development and climate change. The revised version in 2012 introduced the concept of environmental health and its impact on the social environment, **recognising the importance of protecting humans from the potential impacts of environmental degradation**. Other provisions in the law explicitly refer to protecting human health as a key goal of environmental protection and pollution control. The Environmental Protection Law recognises four main types of pollution: air, soil, water, and disturbances (noise, light, odour, vibration, and heat). **These pollution types are controlled by National Environmental Quality Standards (NEQS) and National Pollution Control Standards (NPCS).** The NEQS establishes the concentrations of key pollutants as environmental quality parameters for air, water, and soil.

In contrast, the NPCS sets limits for pollutant emissions from those holding a permit from the authority**.** The Environmental Protection Law **establishes workers' rights to operate in an environment free of toxic chemicals at their workplace and its surroundings**. **In February 2017, the Lao government updated its NEQS** for national air and water quality and the NPCS for vehicle emissions through Decree No. 81/PM and Ministerial Decision No 0485/MoNRE.

Under the MoNRE's leadership, Laos's government has taken steps to monitor and enforce compliance with environmental standards. Ministerial Instructions No. 5688/MoNRE and No. 6439/MoNRE, adopted in late 2018, regulate the standard procedures and parameters for sampling and analysing important key air and water pollutants.

The Law on Water and Water Resources (2017) includes several provisions addressing the linkages between environment, health, and development. This includes the obligation to maintain a minimum water flow in watercourses to ensure that communities and ecosystems can meet their needs and to establish reserved areas to protect water for drinking and consumption. The law creates a system of underground and superficial water rights to manage the allocation of water for small-, medium-, and large-scale uses, including electricity generation, irrigation, mining, and industry. **Medium and large-scale users must pay charges that are funnelled into the Environmental Protection Fund**, **along with charges for wastewater discharges and fees for the restoration of water resources from investment projects and other activities.** The law assigns rights and duties to health sector authorities in areas such as inspection and surveillance of the quality of water used for drinking and consumption and the supply of clean water to people living in rural areas. The provisions of the law give responsibility to line ministries to manage water use in the sectors they lead, including agriculture and forestry, energy and mines, public works and transportation, industry and commerce, tourism, education, and sports.

The Law on Water and Water Resources is a cornerstone of the country's green growth program, with implications for environmental fiscal instruments, water pollution and waste, energy, agriculture, forests, watersheds, wetlands, flood and drought risk, climate change, groundwater, information and data management, nutrition, and tourism. Additionally, i**t has implications for managing trade-offs and harnessing mutual opportunities among these themes and sectors.** This new legal framework is based on international best practices and assigns implementation responsibilities to the (MoNRE) while recognising cross-sectoral imperatives.

3) Water Quality Regulations and Requirements for Domestic Wastewater Management and FSM

(1) Water and Water Resources Law (2017)

The Lao PDR National Assembly approved the updated **water and water resources law in 2017,** which aims to improve the sustainability of Lao's water resources. The Law determines the principles, regulations, and measures regarding the management, administration, protection, development, and use of water and water resources; **prevention of harmful effects on water; and restoration and rehabilitation of adversely affected areas**. The Ministry of Natural Resources and Environment oversees the wastewater discharge regulations in collaboration with other relevant ministries and local administrations. Wastewater discharged into water sources by any individual, legal entity, or organisation shall be treated and comply with wastewater discharge standards and subject to payment of fees and service charges. **Three categories are identified based on the volume of wastewater and concentration of chemical substances**: **small, medium, and large wastewater discharge**. Wastewater discharge permits have a duration of two years and may be renewable based on the conditions and standards of wastewater discharge. The objective of the "Decree on the Implementation of the Water and Water Resources Law" (No. 204/PM of 09/10/2001) was to support several articles provided in the Water and Water Resources Law and to establish the responsibilities of different ministries, agencies, and local authorities for the management, exploitation, development, and use of water and water resources.

(2) Environment Impact Assessment Decree (2022)

The Lao government issued Environmental Impact Assessment Decree No. 389/GL on Environmental and Social Impact Assessment (ESIA) and Initial Environmental Examination (IEE) of Investment Projects (2023), implementing and extending the provisions prescribed under Article 21 of the Law on Environmental Protection. This instruction aims to ensure uniformity in the Initial Environmental Examination (IEE) conducted for every investment project and activity of public and private enterprises, both domestic and foreign that operate businesses in Lao PDR that cause or are likely to have environmental and social impacts. Investment projects and activities must conduct efficient initial environmental examinations to contribute to sustainable socioeconomic development. The ESIA regulation assigns the Department of Environment and Social Impact Assessment (DESIA) responsibility for reviewing the ESIA regulation, including recommendations for issuing the Environmental Compliance Certificate (ECC) and undertaking compliance monitoring, and it assigns the

Provincial Department of Natural Resources and Environment (PoNRE) responsibility for reviewing, issuing ECC, and monitoring projects requiring an IEE. Ministerial Agreement No. 8056/MoNRE on the Endorsement and **Promulgation of List of Investment Projects and Activities Requiring for Conducting the Initial Environmental Examination or Environmental and Social Impact Assessment** (Vientiane Capital, 2013) categorises projects and activities into two groups: Group 1 shall prepare the IEE, and Group 2 shall prepare the ESIA. All water-supply processing factories are in Group 1; therefore, an IEE is required. Municipal wastewater treatment plants with a capacity of less than or equal to 5000 persons must prepare an IEE, whereas an ESIA is required for operations over that capacity. **IEE is required for the construction of sewage drainage.** Regardless of size, all industrial wastewater treatment plants should prepare an ESIA. In 2019, the government issued a decree on environmental impact assessment No21/GOL, which defines IEE and comprehensive environmental impact assessment. The decree was amended in 2022 by decree 389/GOL dated 20 October 2022. Article 13, No. 6 states that the environmental management and monitoring plan (EMMP) must be prepared separately from the IEE report.

4) Effluent Standards (National Environmental Standard 2017)

National environmental standards were adopted based on the Environmental Protection Law, the Decree on National Environment Standard No. 81/GL, dated 21st February 2017, and the Agreement on National Environmental Standard No. 0832/MoNRE, dated 3 March 2017. The agreement is applied to any relevant person, entity, or organisation to implement the control of pollution discharged into the environment in Lao PDR. The standard defines the indicators of chemicals and contaminant concentrations in air, soil, and water. The main national water standards in the agreement for water quality are indicated in Article 10 of the Surface Water Quality Standards, which establishes surface water quality classifications (category 1–5) and specifies the maximum concentration that will not harm human health and the environment. Article 14 describes water pollution control standards that indicate the highest concentration level allowed in treated wastewater and dilution discharged into public canals or natural water resources. These standards are **specified for general factories, major buildings, housing estates, toilets, and discharge into public canals, pig farms, car washes, and gas stations.**

5) Monitoring and Reporting Requirements

Environment Inspection The) Ministry of Natural Resources and Environment was reformed in September 2021, which reduced the number of its organisations (offices/departments/institutes) from 14 to 12 and renamed the Department of Pollution Control and Monitoring the Department of Natural Resources and Environment Inspection. The Department of Environment **is responsible for the implementation and derivation of policy, strategy, law and regulation on management work and environmental protection**, including work on environment protection, pollution control, toxic chemical control, disposal of solid waste, **including hazardous waste**, approval of environmental certification, and promotion of community participants.

The Department of Natural Resources and Environment Inspection is **responsible for management inspection of the management and utilisation of natural resources**, implementation of environmental duty (tariffs) of investment projects and businesses according to environmental management and monitoring plans, including concession contracts and various contracts related to projects, and inspection of urgent environmental incidents. The implementation of technical work is the responsibility of local authorities according to laws and regulations.

The Department of Water Resources is responsible for the establishment and implementation of strategies for water management and water resources, basin, and reservoir management plans, permits for water utilisation and services on water and water resources, certification of technical aspects related to water utilisation and water resources, review and certification of hydrological studies, defining the minimum water quantity and water utilisation management plan for investment projects, and setting policies on integrated water and water resource management according to the law.

1.7 Current situation of sanitation in Lao PDR

1) Achievement in urban and rural areas

Since 2015, the share of the population using properly managed drinking water has climbed slightly from 16% to 18% by 2022, while open defecation has decreased from 25% to 16% of the population during the same period (UN, 2023)**. Despite a rise in securely managed sanitation services, reaching 61% of the population by 2022, Lao PDR falls considerably below the regional averages for these two measures** (UN, 2023)**.** Urban infrastructure projects, starting with secondary towns, small towns, LPPE projects, and Pakse urban environmental improvement projects, have problems in terms of use and maintenance, which can be divided into the following important points:

1) The operation, use, and maintenance of urban environment infrastructure in the past depended mainly on drivers and garbage collection workers, making sewage pouring from toilets in the garbage disposal field unsystematic.
2) This is caused by the definition of tasks, units, and responsible personnel not according to the tasks suitable for the infrastructure invested and the employees' basic skills.
3) A lack of a specific unit responsible for the operation and management of the use and maintenance of urban environmental infrastructure (which includes employees with the knowledge to be responsible), and coordination with service providers to use the created environmental infrastructure is still limited.
4) The organisation considers its position as a macro-level unit, which is the technical and implementation unit of the province.
5) The allocation of priority budgets to support managing the use and maintenance of urban environmental infrastructure and waste management within the organisation to serve such tasks is still limited.
6) Implementation unit of the province (The Urban Development Division (UDD), DPWT, etc.) in the operation of dealing with garbage, dirty water, and urban cleaning, which is a priority task of the province considers urban cleanliness as important in solving urban environmental problems.
7) According to the law of the local government, the UDAA can determine the activities to make the urban environmental priority tasks (urban cleanliness) that the city is growing more and more formally managed, and make a budget and staff plan to make these activities run well.

8) Currently, the UDAA can improve its work by focusing specifically on managing the use and maintenance of urban environmental infrastructure to be more responsible, especially in collecting data on the use of drainage services (the number of households that need to use drainage services, drainage service units)

Furthermore, Lao PDR has made significant efforts nationwide to increase rural access to adequate sanitation. The Lao government has challenged villages nationwide to become open defect-free (ODF). To help villages accomplish this, the National Centre for Environmental Health and Water Supply (Nam Saat), Department of Hygiene and Health Promotion, and Centre for Information and Health Education (CIEH), under the Ministry of Health, with technical and financial support from the Water Sanitation Program (WSP), developed a national behaviour change communication (BCC) campaign and toolkits aimed at encouraging the construction and purchase of latrines among rural households. Nam Saat worked with the WSP and Population Services International (PSI) to make latrines available in the country's southern provinces to fulfil the generated demand.

In Vientiane, black water from toilets is discharged through septic tanks. According to the "Standards of Septic Tanks for Households" (Ministry of Public Works and Transport), single-treatment septic tanks (which accept black water from toilets) or combined treatment septic tanks (which accept black water from toilets and grey water from kitchens) must be used before discharging water into public water bodies. As stated in the standards, the volumetric size of septic tanks should be based on hydraulic retention times of 24 h and 200 L/d. This volume excluded the filter media and sludge volume for two years.

A 2011 JICA study revealed that more than 95% of households and buildings in the survey areas had sanitary facilities consisting of septic tanks or soak pits. **The results show that the maintenance work (desludging of septic tanks) is not properly and regularly carried out.** Furthermore, **the facilities received only black water; therefore, other domestic wastewaters are discharged without any treatment**, constituting a major source of water contamination in the canals. **Grey water from kitchens, bathrooms, and washing other than toilets is discharged into drainage canals without any treatment**.

2) Installation of pit Latrines

Most households have a pour flush latrine or dry pit latrine to eliminate black water and **a soak pit to eliminate grey water**. The 2011 population census showed that 13% of urban residents still require wastewater services (87% of urban citizens already had access to wastewater services). To end the practice of scattered faecal dropping, soak-pit systems were installed. However, a few new/small districts must install dry-pit systems as stopgap measures to ensure basic services for the poor until adequate funds are available for soak-pit systems. The different types of latrines include the following:

- Pour-flush toilet: three concrete rings, one concrete slab (no tiles), one ceramic pour-flush pan, and one plastic emptying hole cover.
- Dry-pit toilets with slabs
- Dry-pit toilets with PVC pipes for vents
- Toilets that turn faeces into fertiliser for farms (composting latrine)

Figure 1-5.1 Pour-flush Toilet [Water and Sanitation Program, 2016]

3) Faecal Sludge and Septage Management Information

The coverage ratio of household wastewater treatment facilities was obtained from the Lao Statistical Bureau (LSB) in the 4th Population and Housing Census (2015 PHC). According to the 2015 PHC, at the national level, 73.2% of households used “improved” sanitation facilities (such as flush or pour-flush toilets, ventilated pit latrines, and composting toilets). **Among urban[4] households, this proportion was as high as 94%**. This proportion was highest in **Vientiane, the Capital of Laos,** where nearly all households had access to an improved sanitation facility. In Borikhamxay, Vientiane Province, and Xayabury, this proportion was greater than the 90% mark. Laos's most common sanitation facility is a **flush or pour-flush toilet** used by 842,830 households (71% of total households).

The most recent survey on the status of sanitation facilities in Laos is the Lao Social Indicator Survey conducted by the Lao Statistics Bureau in 2017 (2017 LSI). The survey used the 2015 PHC village register as the sampling frame and classified toilet facilities in more detail than in the 2015 PHC. Compared to the results of the 2015 PHC, the proportion of households using improved sanitation facilities increased in rural areas, **from 65.0% to 67.0% in rural areas with roads and from 41.3% to 52.2% in rural areas without roads.** The 2017 LSI defines an improved sanitation facility as a facility that hygienically separates excreta from human contact. Improved sanitation facilities include flush or pour flushes connected to piped sewer systems, septic tanks, pit latrines, ventilated improved pit latrines, pit latrines with slabs, and composting toilets.

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[4] The 2015 PHC classifies a village as “urban” if it meets three or more of the following criteria:

- Village is situated in a district or provincial center.
- More than 70% of total households in the village use electricity.
- More than 70% of total households in the village use piped water.
- Village is accessible by road in two seasons.
- Village has a permanent market operating throughout the day.

Otherwise, it is considered rural. Rural villages are further classified into two categories: those with roads accessible all year-round by four-wheeled motor vehicles and those that are not.

MODULE 2. Decentralised wastewater treatment systems

2.1 Purpose of this module

This module provides fundamental information on decentralised wastewater treatment systems and an overview of their structures and characteristics. Additionally, it includes a summary of decentralised wastewater treatment facilities, guidance on determining their scale, and an exploration of the structures commonly used in Lao PDR, including septic tanks, DEWATS, KIDS (Kind Integrated Digestion Strand), Johkasou, and FSM (lagoon, anaerobic digestion tank, and grease traps). These facilities represent the country's most common form of decentralised wastewater treatment.

2.2 What are decentralised wastewater treatment systems?

1) General information

Decentralised wastewater treatment systems depend on onsite sanitation technologies. Most times, wastewater, scum, and sludge are mixed at the generation point, and both are emptied together in the treatment system, or any 'containment' method is used. **Various technologies are adopted for the treatment.** This wastewater treatment system is for single-family homes and small apartment buildings.

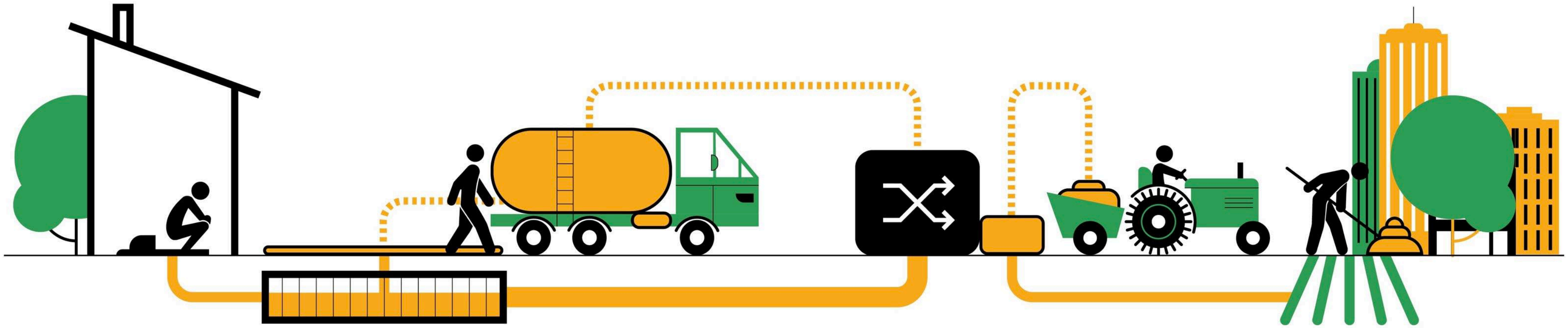

Figure 2.2-1 Example of the system of decentralised wastewater treatment & management, Source: UNICEF, 2022

Decentralised wastewater management consists of various approaches for collecting, treating, and reusing wastewater for individuals or clusters of homes, businesses**, and communities**. **An evaluation of site-specific conditions is performed to determine the appropriate type of treatment system for each location.** These systems are part of a permanent infrastructure and can be managed as stand-alone facilities or **integrated with centralised sewage treatment systems**. **They provide a range of treatment options, from simple, passive treatment with soil dispersal, commonly called 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 the agriculture fields/soil. They are **typically installed at or near the point where the wastewater is generated.**

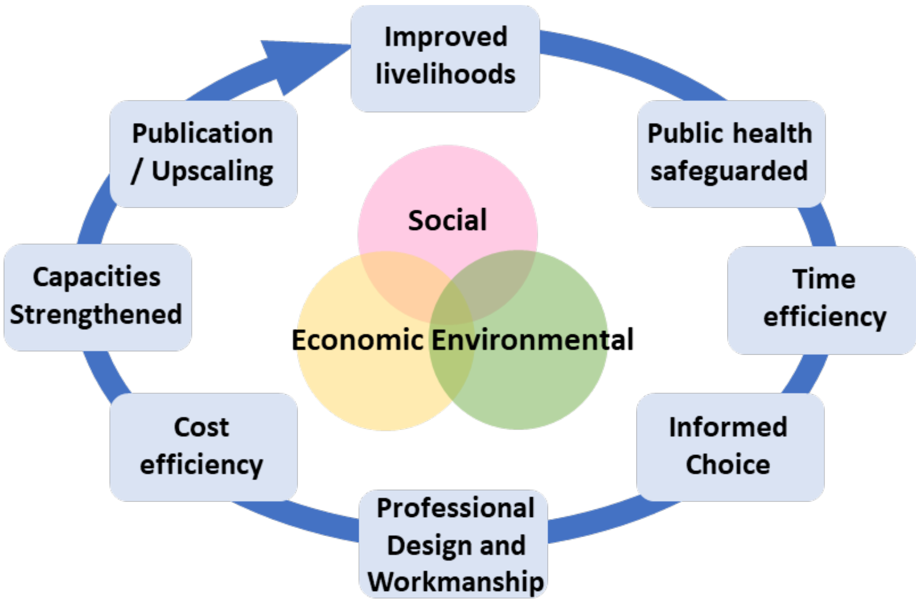

Figure 2.2-2 Visual Presentation of Benefits of Decentralised Wastewater Treatment System. (UNESCAP, UN-Habitat & AIT, 2015)

2) Application of decentralised wastewater treatment systems

- The system does not require **much land compared to a centralised treatment plant.** The installation space is relatively small and can be underground in private parking lots.
- No large-scale treatment facility or sewer pipe work was required, resulting in low initial investment costs.
- The system encompasses an approach considering technical and engineering aspects and the specific local economic and social situation.
- Treatment for wastewater flows with COD/BOD ratios from **1 m³ to 1000 m³ per day** and unit.
- Treat wastewater from domestic or industrial sources and **provide primary, secondary, and tertiary treatment for wastewater from housing, communities, hospitals, or businesses.**
- An integral part of comprehensive wastewater strategies, where systems can complement other centralised and decentralised wastewater treatment options.
- Depending on the technical layout, **biogas supplies energy**.
- Reliability, longevity, tolerance to inflow fluctuations, and **cost efficiency**. Periodic **management and maintenance are required**, but with low control and maintenance frequency compared to centralised wastewater treatment facilities that require daily adjustment and maintenance.
- Functions without technical energy inputs for certain systems. Independence from external energy sources provides more reliable operation and fewer fluctuations in effluent quality. **Depending on the systems, pumping for water lifting and/or air blowers for aeration may be necessary**.
- **Appropriate combinations of treatment modules are selected** depending on the required treatment efficiency, costs, and land availability.
- Although these can be constructed using locally available materials and implemented by the local workforce, high-quality planning and construction standards must be met.
- **Few operation and maintenance skills are required**. **While the users can carry out most operational tasks, some maintenance services might require a local service provider.** In certain cases, a service provider can deliver both operation and maintenance**.**

- **Reduce pollution load to meet legal requirements**. **Generated sludge must be handled, treated, and disposed of following international and/or national standards** (Ulrich, et al., 2009).

2.3 Design Principles and Guidelines

1) General aspects

The primary goal of wastewater treatment is to remove or reduce pollutants to levels that prevent harm to the environment and humans. Before determining the necessary treatment methods and unit sizes, planners and designers must consider the following factors: the quality and quantity of raw wastewater, local conditions affecting treatment processes, and compliance standards for final discharge or reuse. Laboratory analysis is essential for assessing pollution levels, treatment feasibility, environmental impacts under local conditions, and the suitability of biogas production. Wastewater quality can vary throughout the day and seasons, making data analysis inherently approximate. Moreover, it is crucial for designers to understand the significance of each parameter and its typical range rather than precise figures. In practice, an accuracy level of ±10% is usually more than adequate.

2) Determining the scale of decentralised wastewater treatment systems

When installing a decentralised wastewater treatment system, the basic size of the system cannot be determined without fully considering the quantity and quality of incoming wastewater. As shown below, the quantity and variability of the wastewater and the amount of pollutants in the wastewater must be fully considered.

(1) Wastewater volume and variation

The amount and variation of wastewater vary significantly depending on the building use and must be carefully considered in the design and maintenance of decentralised wastewater treatment facilities.

- Generally, it is fundamental to set the number of users when designing a decentralised wastewater treatment facility (NUD) after thoroughly investigating the amount and quality of wastewater, **O&M capacity (i.e., possible frequency of the O&M), and so on in the specific building.**
- For new buildings, studying the actual flow characteristics is impossible. In this case, the NUD should be determined by referring to the inflow situations in buildings with similar uses.

For example, **Figure 2.3-1** shows the results of a study on the hourly drainage characteristics of detached houses, apartment buildings, hospitals, and offices in Japan.

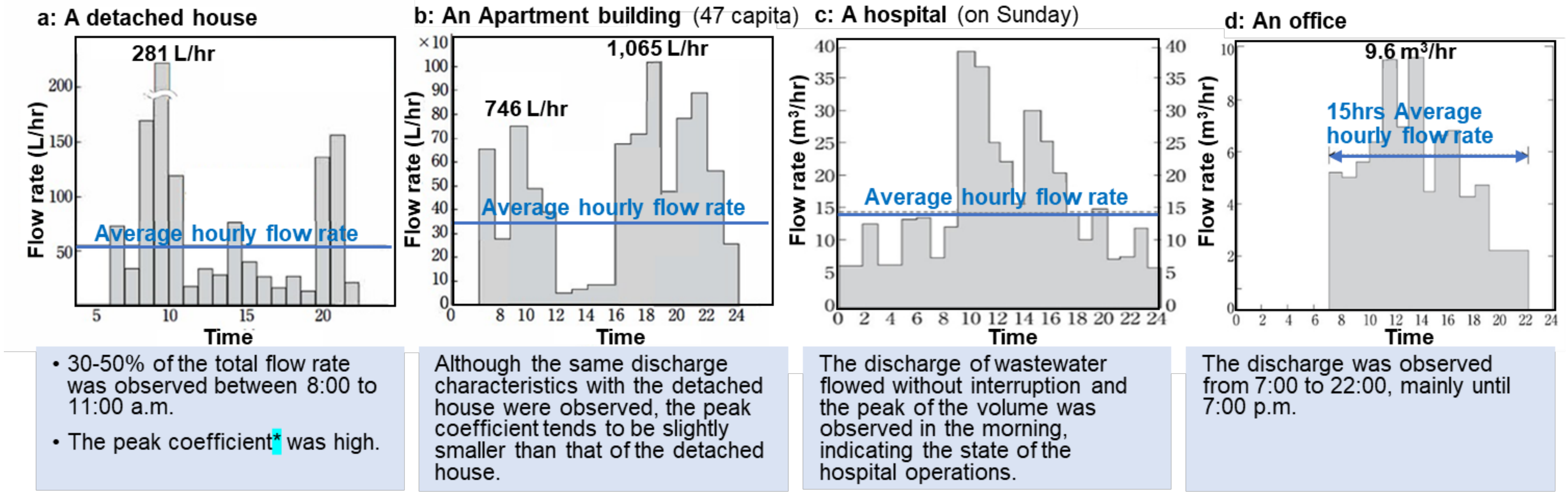

Figure 2.3-1 Examples of characteristics of discharge in Japan (Kawamura, 2013)

a: a detached house (Total flow rate: 1,312 L/day, average hourly flow rate: 54.7 L/hr),

b: an apartment building (Average hourly flow rate: 344 L/hr)

c: a hospital. d: an office (Total flow rate: 356m3/day. average hourly flow rate: 14.8 m3/hr)

d: an office (Total flow rate: 86.0m3/day, average hourly flow rate: 5.8m3/hr)

* Ratio of maximum hourly flow rate to average hourly flow rate; it indicates the magnitude of the hourly fluctuation of inflow.

(2) Person load of wastewater

The person load differs from country to country and should be developed in each country. The average daily personnel load for domestic wastewater in Japan is as follows:

Table 2.3-1 Average person load of domestic wastewater per day in Japan

Water volume and Pollutants	Amount (unit)
Wastewater volume	200–250 (L/person/day)
BOD	40–50 (g/person/day)
Nitrogen	8–10 (g/person/day)
Phosphorus	1–1.5 (g/person/day)

Grey water accounts for 70–80% of the total flow rate in domestic wastewater and 60–70% as BOD. The **proportions of nitrogen and phosphorus are derived from black water**. Considering these factors, the values below were used as the basic population equivalent (PE) in Johkasou's design.

The basic amount of PE:

- **Wastewater volume: 200 L/person/day**
- **BOD loading: 40 g/person/day**
- **BOD concentration: 200 mg/L**

(3) Determining the scale of the facility

The scale of the facility should be determined based on the NOD[5]. As explained in the previous section, NUD is not simply based on the number of people living in the building because the amount and variability of wastewater varies depending on the use of the building. The design of the Johkasou system is presented as an example.

In Johkasou's design, this standard, the NUD of Johkasou, was obtained from the Standard for Estimation of Population for Johkasou of Buildings (JIS A 3302: 2000)[6] (See **Annex 2**). **This NUD is converted from the amount of wastewater (L/day) or BOD (kg/day) discharged from the building**. Moreover, it can be obtained by (1) dividing the volume of wastewater (L/day) or BOD load (kg/day) by PE and (2) using larger values.

[5] Although the NUD unit is "per capita", it represents the number of persons for Johkasou design, and it does not indicate the number of living and/or working persons in the building.

[6] This standard was developed based on the Japanese lifestyle.

3) Selection of Appropriate Technologies

Appropriate technology is defined as technology that is designed with consideration for the environmental, ethical, cultural, social, and economic aspects of a community. Technologies that require **fewer resources are easier to maintain, have lower overall costs, and have less environmental impact**. **Basic Guideline when Constructing DEWATS**

- Accessibility (women, girls, elderly, disabled and sick)
- Affordability (low-income communities)
- Land availability
- Functionality
- Quality
- Sustainability over the long term
- Manageability
- Operation and maintenance (O&M) requirements
- Compliance with environmental protection regulations (with the least possible ecological impact)
- Improvements to health.

Before selecting a technology, evaluating and analysing all options available for the sanitation value chain is important. A rounded point of view for the entire sanitation chain whenever is necessary; **for instance, if a utility needs to check on which containment to adopt in a certain area**, it will need to check on the collection and transport system available and to which type of treatment at the end, to maximise outputs for all segments.

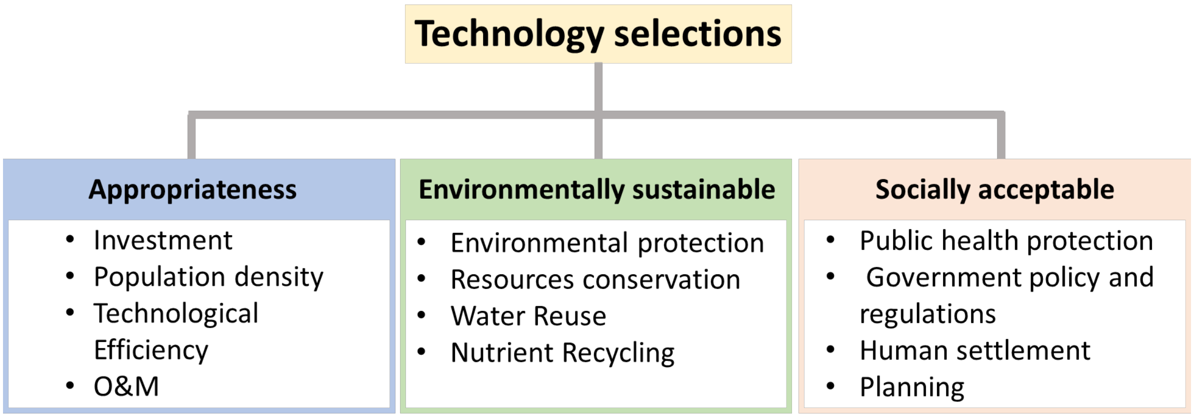

Figure 2.3-2 Selection of Appropriate Technology

Types of technologies:

- Simple without any energy input, based on natural processes such as filtration, settling, and evaporation, such as sludge drying beds and settling thickening tanks.
- Complex mechanised versions, such as screw presses, activated sludge, and aerated ponds, require electrical energy.
- Reinvented Toilet Technology: Innovation for sustainable sanitation through disinfecting waste, solid-liquid separation with total efficiency, safe disposal, preventing harmful pathogens and reducing hazards.

Simple technologies are effective and efficient considering the capital investment and **operational requirements.** Additionally, it is easy to construct with locally available materials and is mostly used and widely adopted. **However, it requires a larger area**. Mechanised systems are reliable and fast but require huge energy consumption and capital investment. **Spare parts are not easily available, and operation and maintenance require skilled labour**. **Treatment technologies are combined to achieve the desired effluent and solid standards.** Technology combinations may be devised- effluent standards, resource recovery priority such as soil amendment, fuel, reclaimed water, priority from regulation, financial funding mechanisms, institutional availability, and capacity.

2.4 Existing decentralised wastewater treatment systems in Laos

1) List of Decentralised Wastewater Treatment Systems

Several trial and pilot projects have utilised decentralised wastewater treatment in communities and commercial buildings. From 2009 to 2021, approximately 29 decentralised wastewater treatment facilities with a 1–200 m^3/day will be installed in nine provinces, with a total treatment capacity above 743 m^3/day, as shown in **Table 2.4-1**. These systems utilised the design and technology from the Lao Institute for Renewable Energy (LIRE), the Bremen Overseas Research and Development Association (BORDA), and Johkasou from Japan.

Four collective small-scale "decentralised wastewater treatment systems" or "community-based sanitation" (CBS) devices in Vientiane Capital ranging from 7 to 26 m^3/day in capacity, which were constructed in 2010 and 2012 funded by JICA, Lao Institute for Renewable Energy (LIRE), and Bremen Overseas Research and Development Association (BORDA). Two units at Khoualuang Primary School and the Faculty of Engineering Dormitory, National University of Laos, are running and maintained properly. The other two units stopped operating only three to five years after construction. **The main reasons for functional disruption are collection pipe damage and poor maintenance.** As these existing decentralised wastewater treatment systems have only anaerobic processes, the discharge quality is insufficient and does not meet the existing standards, with a BOD_5 concentration of 100 mg/L or more. The influent BOD_5 of the two pilot decentralised wastewater treatment systems in **Vientiane, the Capital of Laos,** was 226 mg/L for the community (Thongkhankham) and 87 mg/L for the school (Khoualuang), with effluent BOD5 values of 162 and 21 mg/L, respectively. **The JICA technical cooperation project estimated the effluent BOD from septic tanks (black water only) to be approximately 50–100 mg/L.** These values indicate that **it is difficult for conventional septic tanks to achieve new effluent standards that define more stringent pollution emissions** (e.g. toilet effluent and effluent to public canals **with BODs of less than 30 mg/L**).

In addition to the above-decentralised wastewater treatment systems, several projects have studied the feasibility of other treatment systems in Lao PDR. The JICA project **is testing the Kind Integrated Digestion Strand (KIDS) treatment system** at the National University of Laos Food Court. A feasibility **study is being carried out for centralised wastewater treatment** in **Vientiane, the capital of Laos, supported by a Hungarian government loan from 2018 to** 2024. The Wastewater and Solid Waste Treatment Capacity Building project, supported by KOICA, includes an activity for the construction of wastewater management facilities and developing and further fine-tuning **O&M guidelines for decentralised wastewater treatment systems and FSM plants (lagoon in mostly landfill, faecal sludge treatment plant (FSTP) constructed wetland in Nahai-Vientiane, anaerobic digest tank and crease traps (in landfill of GMS.2-GMS.4))**

Table 2.4-1 List of existing decentralised wastewater treatment systems in Lao PDR

No.	Location	Type of Technology	Commercial name	Treatment capacity (m^3/day)	Number of users	Operation year	Province
1	Dormitory Resident, Faculty of Engineering, NUOL	Anaerobic treatment	Community-based sanitation (CBS)	10	125 persons	2009	Vientiane Capital
2	Thongkhankham Village, Unit 11, 12, 13	Anaerobic treatment	CBS	11.2	146 persons	2010	Vientiane Capital
3	Khoualuang Primary School (SBS 1.0)	Anaerobic treatment	School-based sanitation (SBS)	7	87 students, 4 Teachers, 25 monks	2010	Vientiane Capital
4	Student Dormitory, Northern Agricultural and Forestry Collage	Anaerobic treatment	Small and Medium Enterprise (SME)	15	128 persons and Canteen for 80 people	2011	Luang Pra Bang Province
5	Operation Camp of THPC	Anaerobic treatment	SME	70	700 staffs	2011	Khammouan province
6	Expansion Camp of THXP	Anaerobic treatment	SME	30	300 staffs	2011	Khammouan province

Table 2.4-1 List of existing decentralised wastewater treatment systems in Lao PDR (continued)

No.	Location	Type of Technology	Commercial name	Treatment capacity (m^3/day)	Number of users	Operation year	Province
7	Khoualuang Temple/school and Khoualuang village	Anaerobic treatment	CBS	26	455 persons	2012	Vientiane Capital
8	Hin Heup district, Department of Water Resources (DWR), MONRE	Anaerobic treatment	CBS	3	66	2013	Vientiane Province
9	Nam Papa State Enterprise Attapeu (NPSE)	Anaerobic treatment	CBS	14	163	2014	Attapeu province
10	Nam Papa State Enterprise Attapeu (NPSE)	Anaerobic treatment	CBS	14	235	2014	Attapeu province
11	National Academy for Politics and Public Administration (NAPPA)	Anaerobic treatment	Real Estate Sanitation (RESan)	2 × 80	1600	2014	Vientiane capital
12	Xe-Pian Xe-Namnoy Hydroelectric Power Plant Project	Anaerobic treatment and gravel filter	RESan	-	-	-	Attapeu province

Table 2.4-1 List of existing decentralised wastewater treatment systems in Lao PDR (continued)

No.	Location	Type of Technology	Commercial name	Treatment capacity (m^3/day)	Number of users	Operation year	Province
13	Navieng village	Anaerobic treatment	CBS	14	161	2015	Houaphan province
14	Health and Science college	Anaerobic treatment	RESan	10	500 (90 students stay in dormitory)	2015	Luanphrabang province
15	Xe-Pian Xe-Namnoy Hydroelectric Power Plant Project	Anaerobic treatment	RESan	8	150	2015	Attapeu province
16	Lao Disabled Women Development Centre (LDWDC)	Anaerobic treatment	RESan	6.4	80	2015	Vientiane Capital
17	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); Lao PDR, Vientiane (Lao-German House)	Anaerobic treatment	RESan	1.5	50	2015	Vientiane Capital
18	World Bank	Anaerobic treatment	RESan	10.2		2015	Vientiane capital

Table 2.4-1 List of existing decentralised wastewater treatment systems in Lao PDR (continued)

No.	Location	Type of Technology	Commercia l name	Treatment capacity (m^3/day)	Number of users	Operation year	Province
19	Hospital, Xekong, Provincial	Anaerobic treatment	HoSan	35	50 beds	2016	Xekong Province
20	Pakhoatai Primary School	Anaerobic treatment	SBS-Lite	1	220	2016	Bokeo Province
21	Night market in luangprabang	Anaerobic treatment	ReSan	5	-	2017	Luanphrabang province
22	Huaydin Village Primary School	Anaerobic treatment	SBS-Lite	-	-	2017	-
23	Kuay Village Primary School	Anaerobic treatment	SBS-Lite	-	-	2018	-
24	Angnoi Village Primary School	Anaerobic treatment	SBS-Lite	-	-	2018	-
25	Luangnamtha district,	NA	-	-	-	2018	Luangnamtha province
26	Huaysay District,	NA	-	-	-		Borkeo province

Table 2.4-1 List of existing decentralised wastewater treatment systems in Lao PDR (continued)

No.	Location	Type of Technology	Commercial name	Treatment capacity (m^3/day)	Number of users	Operation year	Province
27	Wattay International Airport, International Terminal	Anaerobic and aerobic treatment	Johkasou	200	-	-	Vientiane capital
28	Wattay International Airport, Domestic Terminal	Anaerobic and aerobic treatment	Johkasou	50	-	-	Vientiane capital
29	Sethathirath Hospital	Anaerobic and aerobic treatment	Johkasou	40 + 2	-	-	Vientiane capital

Figure 2.4-1 Johkasou system at Wattay International Airport (Kubota, 2022)

The application of decentralised wastewater treatment systems **is based on the principle of low maintenance since the most important parts of the system work without (or low) technical energy inputs and cannot be switched off intentionally**. State-of-the-art technology is offered at affordable prices because all construction materials are locally sourced. Most decentralised wastewater treatment systems in Laos differ only in their treatment capacities and are almost identical in their structural features and maintenance requirements. The following modules summarise the details (**see 2.5 and Module 3**).

2) Sludge Treatment facilities

Vientiane's first faecal sludge treatment plant opened in December 2017 with financial support from French metropolitan agencies. According to information from plant operators, the quantity of sludge carried into the plant is **approximately 50 m^3/day in the dry season and approximately 100 m^3/day in the rainy season**. The processing fee that a desludging operator pays to the sludge treatment plant depends on the tank size and is 30,000 kip/6 m^2. **The desludging fee households pay to a desludging operator ranges from 60 US$ (500,000 kips)/6 $m^3$to 200 US$ (1,70,000 kip)/ 10 m^3, which applies to hotels, factories, restaurants, schools, etc.** Building owners and desludging businesses **negotiate the fee based on the actual size of the septic tank**. According to the Global Green Growth Institute (GGGI, 2018), solid waste, including faecal sludge, was deposited in landfills by the **Vientiane City Office for Management and Service** (VCOMS) **in Vientiane**. However, **faecal sludge is no longer deposited at the KM 32 landfill** site as these activities **were shifted to the new faecal sludge treatment plant.**

In addition to the above facilities, a faecal sludge treatment plant (FSTP) in Nahai Xaysettha District was **launched in 2017** with French financial support. Sludge gathered from septic tanks is delivered by vacuum trucks to the FSTP, where the liquid and solid phases are separated via reed beds, enabling the elimination of pollution through an anaerobic biological process. The accumulated layer of humus created on the surface of the reed beds was removed, dried every eight years, and used to improve soil quality for gardening and agriculture. **FSM have been applied in GMS.2 and GMS.4 at the landfill implemented (lagoon in mostly landfill,** anaerobic **digest tank, and grease traps (in the landfill of GMS.2-GMS.4))**

2.5 Characteristics of decentralised wastewater treatment systems

1) Comparison among commonly introduced decentralised wastewater treatment technologies in Lao PDR

A comparison of the three main decentralised wastewater treatment technologies in Lao PDR, septic tanks, anaerobic buffered reactors, and Johkasou systems, is shown in **Table 2.5-1**.

Table 2.5-1 Comparison of decentralised wastewater treatment technologies

	Septic tank	Anaerobic baffled reactor (ABR)	Anaerobic Filter	Horizontal Subsurface Flow Constructed Wetland	Waste Stabilisation Ponds (WSPs)	Johkasou
Capacity (m^3/day)	Small	Small–middle	Small–middle	High	High	Small–middle
Target	Blackwater	Blackwater	Black water+grey water	Black water+grey water	Black water+grey water	Black water+grey water
Method	Anaerobic only	Anaerobic only	Anaerobic only	Anaerobic+Gravel filter	Anaerobic+Aerobic	Anaerobic+Aerobic
Treated water quality	Low • 50% of solids, 30–40% of BOD, and 1-log removal of *E. coli* • Moreover, it cannot remove nutrients (nitrogen and phosphorus)	Higher compared to conventional septic tank • 50% of solids, up to 90% of BOD, and 1-log removal of *E. coli* • Low reduction in pathogen and nutrients	• Suspended solids and BOD removal can be as high as 90%, typically between 50% and 80%. • Total Nitrogen removal is limited and normally does not exceed 15% • Low reduction of pathogens and nutrients	• High reduction of BOD, suspended solids, and pathogens • Little nutrient removal	• BOD reduction of up to 75% • High reduction of solids, BOD, and pathogens	High Clean discharge is discharged directly • BOD <20mg/L • Nutrients can be removed.

Table 2.5-1 Comparison of decentralised wastewater treatment technologies (continued)

	Septic tank	Anaerobic baffled reactor (ABR)	Anaerobic Filter	Horizontal Subsurface Flow Constructed Wetland	Waste Stabilisation Ponds (WSPs)	Johkasou
Discharge	• Dirty discharge penetrated the ground. • Gray water is discharged without treatment.	• The system should be checked monthly for solid waste, and the sludge level should be monitored every six months. • If the effluent is reused in agriculture or directly used for fertigation, it should be treated further. Or it can be discharged appropriately.	• Not recommended to construct them in areas with high groundwater tables. • Not suitable for high-flooding areas	The water flows below the surface, and any contact of pathogens with humans and animals is minimised.	Sludge requires proper removal and treatment	Clean discharge is discarded directly into the river, lake, and sea.
Initial Cost	Low	• High investment cost • Low operating cost	• High investment cost • Low operating cost	• High investment cost (depending on the cost of land and large land requirement) • Low operating cost	• High investment cost (depending on the cost of land and large land requirement) • Low operating cost	High

Table 2.5-1 Comparison of decentralised wastewater treatment technologies (continued)

	Septic tank	Anaerobic baffled reactor (ABR)	Anaerobic Filter	Horizontal Subsurface Flow Constructed Wetland	Waste Stabilisation Ponds (WSPs)	Johkasou
Main body	Civil structure constructed at the site	Require expert design and construction	Require expert design and construction	Require expert design and construction	Require expert design and construction	FRP is manufactured in factories.
Maintenance works	Desludging only (every 3 to 5 years)	Desludging is required every 2 to 4 years	• Scum and sludge levels need to be monitored. • Over time, solids will clog the filter's pores, and the growing bacterial mass will become solid, break off and eventually clog pores. When efficiency decreases, the filter must be cleaned.	• Regular monitoring and maintenance–to avoid water backing up caused by fallen plants, garbage, wetland outlet blockage • Regular thinning and cutting of vegetation	• Scum build-up shall be regularly monitored • Removal of macrophytes to minimise mosquito breeding • Desludging of anaerobic pond every 2 to 5 years, depending on the sludge build-up	• Desludging once a year • Cleaning, adjustment, inspection, and changing spare parts are required.

Table 2.5-1 Comparison of decentralised wastewater treatment technologies (continued)

	Septic tank	Anaerobic baffled reactor (ABR)	Anaerobic Filter	Horizontal Subsurface Flow Constructed Wetland	Waste Stabilisation Ponds (WSPs)	Johkasou
Utility	Nothing special	The main O&M costs are related to the removal of primary sludge and the cost of electricity if pumps are required for discharge.	Nothing Special	• Aesthetically pleasing and harbours animal habitat • Electric pumps are required for intermittent loading.	Mechanical equipment is necessary to dig ponds.	• Electricity (for a blower) • Water (for cleaning)

2) Characteristics of decentralised wastewater treatment systems

(1) Grease trap

Grease traps work because animal fats and vegetable oils (grease) are 10–15% less dense than water, and grease will not mix with water. Thus, fats and oils float on top of the water. When wastewater enters a grease trap, the flow rate is sufficiently reduced, giving the wastewater sufficient time to cool and separate into the three layers. The grease rose to the top of the interceptor and was trapped using a baffle system. The solids settled at the bottom, and the separated clear water escaped under an outlet baffle. Many grease traps have filters for collecting solid debris, which reduces the number of solids settling at the bottom of the trap.

Over time, solids and grease build-up, and if left to accumulate for a long enough period, they can start to escape through the outlet, and in certain circumstances, they can back up through the inlet. Therefore, the traps must be cleaned and pumped out regularly.

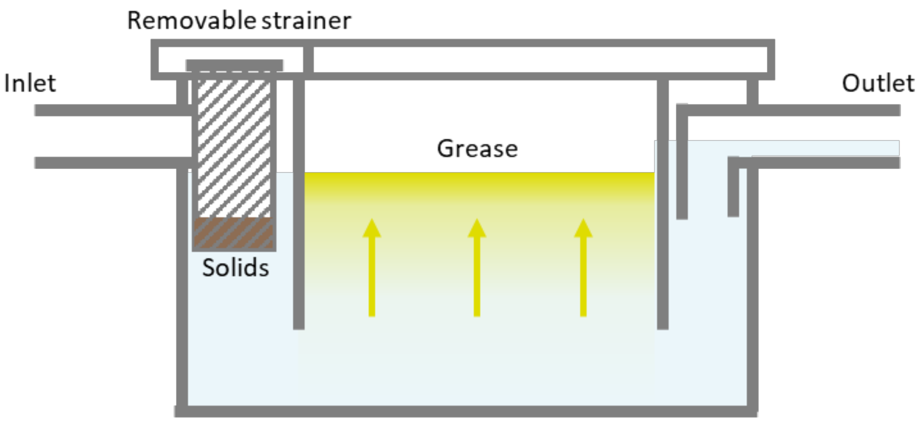

Figure 2.5-1 Outline of grease trap

(2) Screen tank

Manually cleaned screens require little or no equipment maintenance and provide a good alternative for smaller plants with fewer screenings. Mechanically cleaned screens tend to have lower labour costs than manually cleaned screens and offer the advantages of improved flow conditions and screening capture over manually cleaned screens.

(3) Septic tanks

a. General information

Blackwater and greywater go through a waterproof container called a septic tank, constructed of concrete, fibreglass, PVC, or plastic, for primary treatment. Organic matter and sediments were reduced via settling and anaerobic processes; however, the treatment was mild. As the liquid moves through the tank, scum, mostly oil and grease, floats to the top, whereas the heavy particles sink to the bottom. **The sink materials eventually undergo anaerobic degradation** (ADB Institute; ASCI, 2022). However, because build-up occurs more quickly than decomposition, the accumulated sludge and scum must be cleaned out regularly (ADB Institute; ASCI, 2022). **The septic tank's effluent must be distributed using a leach field or soak pit** or transferred to another treatment technology using a solid-free sewer (ADB Institute; ASCI, 2022). Although efficiency varies widely depending on the operation, maintenance, and climatic circumstances, in general, a properly designed and managed septic tank should remove 50% of solids, 30 to 40% of BOD, and 1 log of *E. Coli* (ADB Institute; ASCI, 2022).

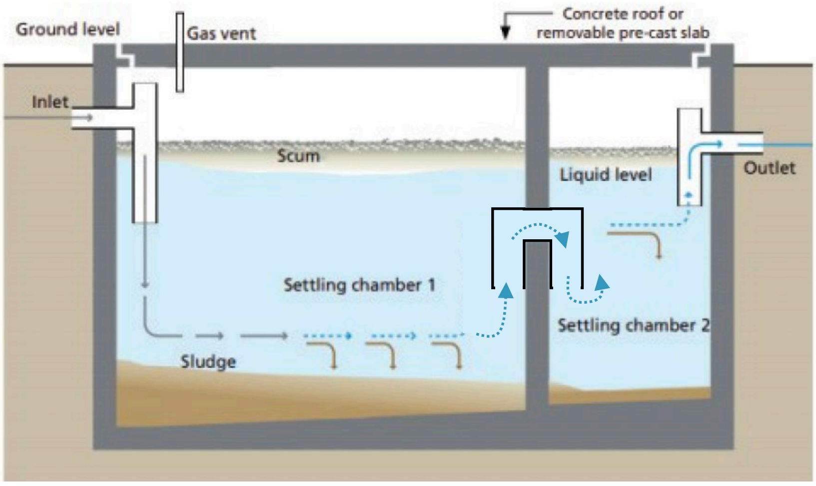

Figure 2.5-2 Example of septic tanks (Ministry of Construction-Hanoi, 2011) This figure has been modified (revised) by the author.

b. Design Requirements and consideration

A septic tank should have two chambers at the least; if there are only two chambers, the first chamber should comprise two-thirds of the overall length of the tank. **The first chamber should be at least 50% of the tank's length**. **In the first chamber, most of the solids settle. The purpose of the baffle, or the space between the chambers, is to keep particles and scum from leaving along with the wastewater.** The T-shaped exit pipe further decreased the amounts of scum and sediment released. **Maintenance requires that all chambers be accessible (via access ports). To allow for the regulated release of unpleasant and possibly dangerous gases, septic tanks should be vented.** The number of users, amount of water used per person, average annual temperature, **desludging frequency, and the wastewater's properties all affect how a septic tank is designed.** For moderate treatment, the retention period was 48 h. **An Aquaprivy is a type of septic tank modification.** The excreta fell into this straightforward storage and settling tank directly beneath the toilet. The effectiveness of Aquaprivy as a treatment option is minimal. **Designed for 1 to 2 days of sewage retention.**

Table 2.5-2 Recommended sizes of septic tanks (ADB Institute; ASCI, 2022)

Users	Length (m)	Breadth (m)	Liquid depth (cleaning interval of) (m)	
			One year	Two year
5	1.5	0.75	1	1.05
10	2.0	0.90	1	1.40
15	2.0	0.90	1.3	2.00
20	2.3	11	1.3	1.80
50	5	2	1	1.24
100	7.5	2.65	1	1.24
150	10	3	1	1.24
200	12	3.3	1	1.24
300	15	4	1	1.24

c. Types of Septic Tanks:

c-1. Single-chambered septic tanks

- Low efficiency and require high maintenance
- Low rate of digestion of solids
- **Requires frequent emptying**

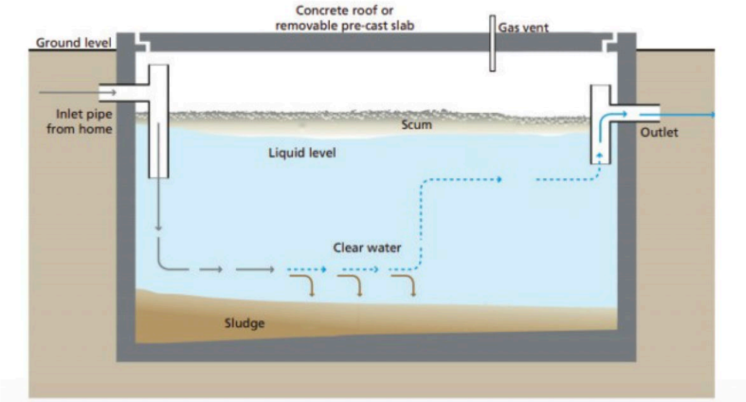

Figure 2.5-3 Example of single-chambered septic tanks (Ministry of Construction-Hanoi, 2011)

c-2. Two or three-chambered septic tanks

- The first chamber is at least twice the size of the second.
- The effluent from the first chamber passed to the second chamber, and the partitioning between them prevented scum and sludge from escaping into the second chamber.
- T-shaped outlet pipe further reduced the amount of scum and sludge discharged **Need to be desludged once in three years.**

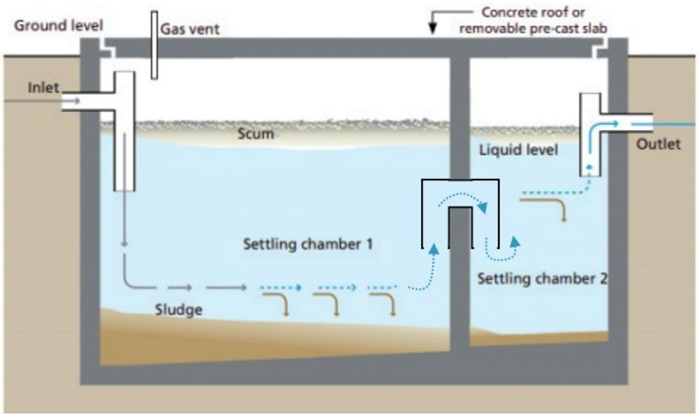

Figure 2.5-4 Example of two chambered septic tanks (Ministry of Construction-Hanoi, 2011) This figure has been modified (revised) by the author.

(4) Anaerobic Baffled Reactor (ABR)

a. General information

When ABR is used, a settler is installed at the front of the ABR. A primary treatment technology called settling removes suspended particles through sedimentation. Additionally, it is known as a clarifier, sedimentation unit, settling basin, or tank. **Lighter materials float to the top of a settler, whereas settleable particles sink to the bottom due to the low flow velocity.** Sedimentation has been employed for sludge thickening, post-chemical coagulation/precipitation, grit removal, and **secondary clarity in activated sludge treatment. Settlers can remove 50–70% of suspended particles and 20–40% of organic material (BOD).** Many different types of settlers are available, and they occasionally serve other purposes. They can be integrated into unified treatment units or function as separate tanks.

An enhanced septic tank with several baffles forcing effluent to flow underneath is called an ABR. Improved treatment results from longer contact time with active biomass (sludge). Organic matter was more effectively removed and digested in the upflow chambers. Up to 90% less BOD was produced, much less than with a traditional septic tank. **No rack or screen on the DEWATS anaerobic baffled reactor.** The larger solids were separated in a settling chamber before the wastewater was moved to a sequence of upflow chambers. **By using downspouts mounted on partition walls or baffle walls that create a down shaft, the water flow between chambers is directed to the bottom of the subsequent room.** Downpipes shorten the digester's overall length and expense, whereas downshafts distribute the flow more evenly, making them the best option. **Any type of wastewater with a BOD exceeding 150 mg/L can be treated with**

an anaerobic baffled reactor. (Ulrich, et al., 2009). Although it works better with a greater organic loading, residential wastewater can benefit from its use. **Baffled reactors are a new system, having just a tiny amount of experience with tiny units. Baffled reactors are a highly efficient version of the less effective septic tank that combines easy, low-cost construction with straightforward, efficient functioning. The range of treatment performance is 70% to 95% BOD and 65% to 90% COD elimination** (Ulrich, et al., 2009)**. However, three months are required for maturation.**

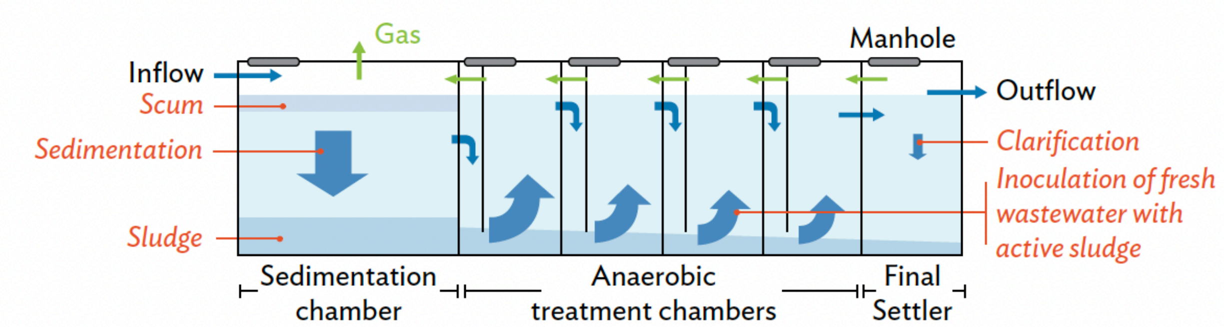

Figure 2.5-5 Anaerobic treatment without media filter sets including 2 parts settler and baffler reactor. (ADB, 2021)

b. Design Requirements and consideration

The primary function of a settler is to reduce the turbulence and velocity of wastewater, which aids in sedimentation. Settlers are rectangular or circular tanks with a 1.5–2.5 h hydraulic retention time as standard. **Less time is required if the BOD level is minimal for the biological phase**. Tank construction should guarantee optimal performance, even at maximum flow. An effective distribution and collecting system (baffles, weirs, or T-shaped pipes) combined with a well-designed inlet and outlet architecture is required to minimise whirlpool currents and short-circuiting and to keep the scum inside the basin. **Depending on the design, gravity may accomplish desludging through a bottom exit, airlift, vacuum pump, or manual pump. Mechanical collectors continuously scrape the settled solids in large primary clarifiers towards a sludge hopper at the bottom of the tank, where they are pumped to sludge treatment facilities. Sludge removal is facilitated by a tank bottom that is properly sloped.**

Additionally, scum removal can be accomplished mechanically or manually. Sludge extraction rate, retention duration, and wastewater parameters are the variables that affect the main settler's effectiveness. Temperature differentials, wind-induced circulation, thermal convection, density currents, and thermal stratification can reduce it in bitter regions. These occurrences may have resulted in short-circuiting. Various ways exist to improve the settler performance: installing tubes and inclined plates (lamellae), which expand the settling area, or using chemical coagulants are two options.

A sedimentation chamber located in front of the actual ABR is used to remove most settleable solids. Stand-alone units usually include an integrated settling compartment; **primary sedimentation can alternatively occur in a separate Settler or**

another earlier technology (such as the current Septic Tanks). Designs without a settling compartment are especially appealing for (semi) centralised treatment facilities that use prefabricated modules or combine ABR with another technology for primary settling. The daily range of the inputs was typically 2–200 m^3. Critical design factors include a hydraulic retention time (HRT) of 48 to 72 h, a wastewater upflow velocity of less than 0.6 m/h, and the number of upflow chambers of three to six. Baffles or vertical pipes may be used in the design of chamber connections. **Maintenance requires that all chambers be accessible (via access ports). The biogas generated by anaerobic digestion in an ABR is typically not collected due to its insufficient amount.** The tank must be vented to enable the regulated escape of malodourous and perhaps hazardous gases.

(5) Anaerobic Filter

a. General information

When the anaerobic filter-bed reactor is used, a settler is installed at the front of the anaerobic filter-bed reactor. An explanation of **settler is described in the previous chapter.**

An anaerobic filter is a fixed-bed biological reactor with one or more filtering chambers connected in series. **The active biomass affixed to the filter material's surface traps particles and breaks down organic matter as wastewater passes through the filter.** Stopped solid and BOD removal using this method can reach 90%. However, it usually hovers around 50% and 80%. **The amount of nitrogen removed is restricted and typically stays below 15% of total nitrogen (TN).** However, experience indicates that clogging may render 25–30% of the total filter mass inactive. **Although a cinder or rock filter might not clog entirely, lower treatment limited efficiency suggests that certain parts are clogged.** Smaller pore sizes can cause filters made of sand or gravel to be completely blocked. Clogging occurs when wastewater finds a path through several open pores. Gradually, the less-used void plugs and **the few left open experience higher flow velocities**. As a result, **the retention period is shortened, and the active microorganisms are removed.** If the microbial film is solid, it must be removed. This can be accomplished by backwashing or withdrawing the filter mass to clean the external reactor.

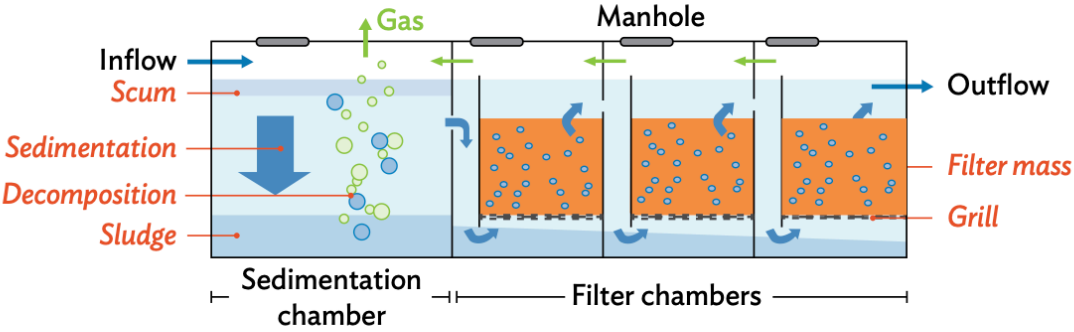

Figure 2.5-6 Anaerobic treatment without baffler reactor sets). Including 2 parts settler, and media filter (ADB, 2021)

b. Design Requirements and Consideration

Pre- and main treatments are necessary to eliminate the sediments and trash that could clog the filter. Most settleable solids were eliminated in the sedimentation chamber before the anaerobic filter. Although separate settlers or other older technologies (such as existing septic tanks) can be used for primary sedimentation, small-scale standalone systems typically feature an integrated settling chamber. Designs without a settling chamber are particularly appealing for (semi-) centralised treatment facilities that combine an anaerobic filter with additional technologies, such as an ABR. The upflow mode is typically used during operating anaerobic filters because it reduces the possibility of washed-out fixed biomass. **The water level must be 0.3 m above the filter material to ensure a consistent flow regime.** The primary design parameter affecting filter performance is the hydraulic retention time (HRT). Twelve to thirty-six hours of HRT are advised. **A broad surface area for bacteria to grow on and holes big enough to avoid clogging are characteristics of the perfect filter.** The surface area ensures the increased contact between the organic matter and the connected biomass, efficiently breaking down. **For every m^3 of occupied reactor volume, the material should ideally provide between 90 and 300 m^2 of surface area.** The typical diameter of the filter material is between 12 mm and 55 mm. Materials such as gravel, crushed rocks or bricks, cinders, pumice, and specifically moulded plastic bits are frequently employed depending on what is locally available. **Baffles or vertical pipes might be used to design the chamber connections. Maintenance requires that all chambers be accessible (via access ports).** The tank must be vented to enable the regulated escape of malodourous and perhaps hazardous gases.

c. Type of anaerobic baffled reactor

c-1 Improved multi-chamber septic tank-an anaerobic baffled reactor with a filter

- The tank consists of one or more baffles which force the sewage to flow from the bottom to the top until it flows into the next chamber.
- Upflow chambers catalyse the sedimentation of solids and digestion of organic matter.
- Filter chambers typically remove 50–80 percent BOD as sewage flows through **them.**

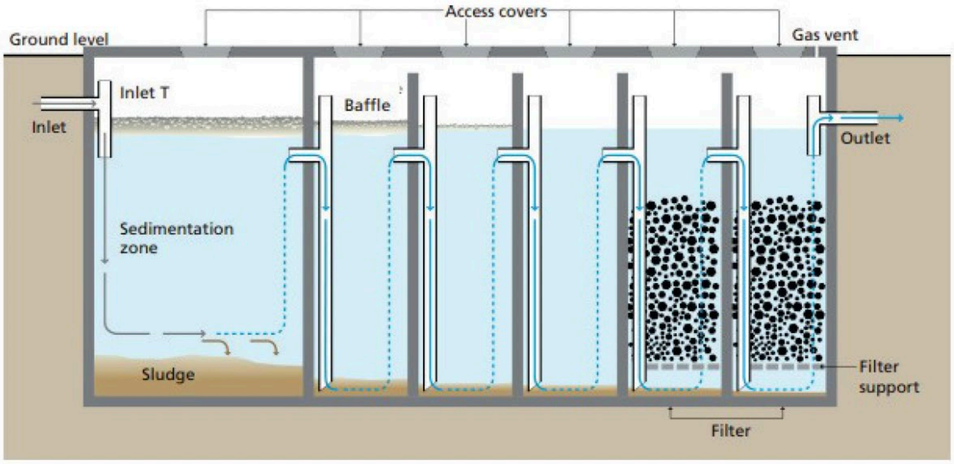

Figure 2.5-7 Anaerobic treatment sets). Including three parts: settler, baffler reactor, and media filter (Ministry of Construction-Hanoi, 2011)

(4) Horizontal Subsurface Flow Constructed Wetland (Planted Gravel Filter)

a. General information

A vast gravel-filled basin with planted wetland plants is called a horizontal subsurface flow wetland. The filter material removes particles from the wastewater as it **passes through the basin horizontally, while microorganisms break down the organics**. The filter medium serves as a plant substrate, a stable surface for bacteria to adhere to, and a filter to eliminate particles. **While facultative bacteria break down most organic materials, vegetation allows aerobic bacteria to colonise the area and break down organic materials by transferring a tiny quantity of oxygen to the root zone**. The permeability of the filter was sustained over large areas by plant roots.

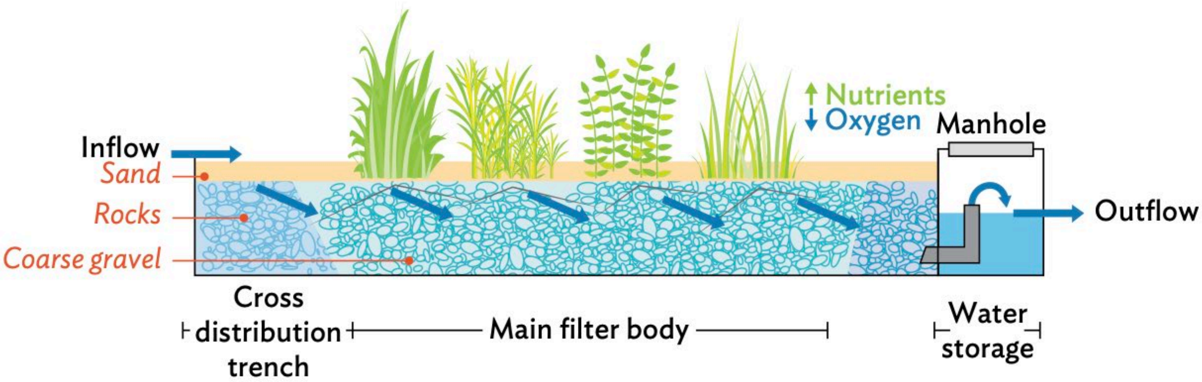

Figure 2.5-8 Planted gravel wetlands without sand media (ADB, 2021)

b. Design Requirements and consideration

A horizontal subsurface flow wetland's design is determined by the amount and quality of the influent and the treatment goal. Decisions regarding compartmentation and the number of parallel flow routes were included. The cross-sectional area (width multiplied by depth) establishes the maximum potential flow, whereas the surface area (length multiplied by width) controls wetland removal effectiveness. Generally, 5–10 m^2 of surface space is required per person equivalent. **To guarantee effective therapy and prevent blockage, pre- and main treatment are crucial. An intake cascade can aerate the influent to facilitate oxygen-dependent processes, like nitrification and BOD reduction.** The bed should be lined with an impermeable liner (such as a geotextile or clay) to stop leaching. Moreover, i**t should be shallow and wide to maximise the water flow path in touch with plant roots. To spread the flow equally, employ a wide inlet zone.** A well-designed inlet that permits a uniform distribution is essential to avoid short-circuiting. **To maximise treatment performance, the water surface should be able to be modified by a variable outlet.** Most gravel used to fill beds (up to a depth of 0.5 to 1 m is small, round, and evenly sized with a diameter of 3–32 mm. **Although more prone to clogging than gravel, sand is acceptable. Alternative filter materials, such as PET, have been effectively employed recently.** To guarantee subsurface flow, the water levels of the wetlands were maintained between 5 and 15 cm below the surface. **Using any natural plant that can thrive in a moist, nutrient-rich environment with broad, deep roots is fine. Reed, Phragmites australis, is a popular option since its horizontal rhizomes reach the bottom of the filter.**

(5) Waste Stabilisation Ponds (WSPs)

a. General information

Waste Stabilisation Ponds (WSPs) are sizable artificial bodies of water. For enhanced therapy, the ponds can be utilised singly or in combination. Three basic kinds of ponds exist: anaerobic, facultative, and aerobic (maturation). Each has unique treatment and design features. Additionally, i**t should be connected in series, with wastewater moving from the anaerobic pond to the facultative pond and ultimately to the aerobic pond for the best possible treatment.** The initial treatment step, the anaerobic pond, lowers the organic load of the wastewater. This pond was anaerobic throughout its depth. **Sedimentation and subsequent anaerobic digestion inside the sludge remove solids and BOD.** By converting organic carbon to methane, anaerobic bacteria can eliminate up to 60% of the BOD. **The anaerobic pond's effluent is transported to the facultative pond through a series of WSPs, where more BOD is eliminated.** Oxygen was supplied to the uppermost layer of the pond by wind mixing, natural diffusion, and photosynthesis by algae. **When oxygen is removed from the lower layer, it turns anoxic or anaerobic.**

Settleable solids collect and break down near the pond's bottom. The aerobic and anaerobic organisms can reduce BOD by up to 75%. Aerobic ponds are intended to remove pathogens, whilst facultative and anaerobic ponds are intended to remove BOD. **As the last in a sequence of ponds that provide the ultimate level of treatment, an aerobic pond is called a maturation, polishing, or finishing pond.** As it is the shallowest pond, photosynthesis occurs because sunlight can reach the entire depth. **Algae that are photosynthetic release oxygen into the water and absorb carbon**

dioxide that is created when bacteria respire. Since sunlight is the primary energy source for photosynthesis, the concentration of dissolved oxygen peaks during the day and decreases at night. Natural breeze mixing contributes to dissolved oxygen.

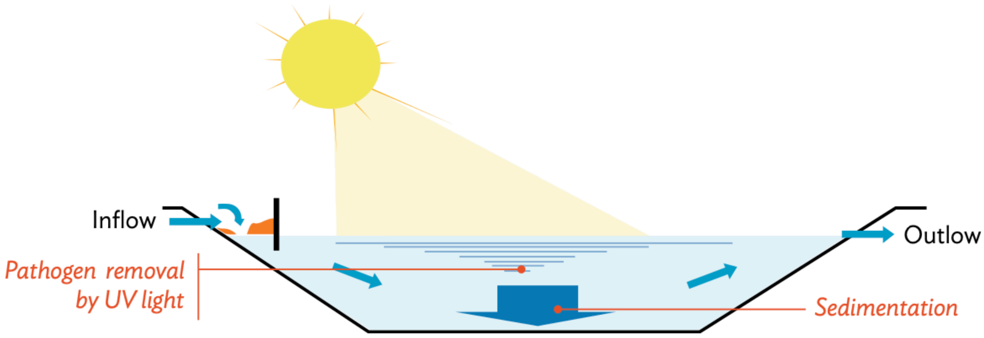

Figure 2.5-9 Sunlight disinfection (ADB, 2021)

b. Design Requirements and consideration

Built to a depth of 2-5 m, anaerobic ponds have a brief retention period of one to seven days. Facultative ponds should be constructed at a depth of 1–2.5 m, with a detention period of 5–30 days. **Typically, aerobic ponds range in depth from 0.5 to 1.5 m. This pond works well to remove most nitrogen and phosphorus from the wastewater when combined with algae and/or fish harvesting. Building multiple aerobic ponds in succession is ideal to achieve a high degree of pathogen clearance.** Pre-treatment was necessary to stop the build-up of scum and to keep extra particles and trash out of the ponds. **The ponds need liners to stop seeping into the groundwater.** Any impermeable material, such as clay, asphalt, or compacted earth, can be used to make a liner. **Using the material that was dug, a protective berm should be built around the pond to shield it from runoff and erosion.** A fence must be placed to keep people and animals out of the area and prevent trash from entering the ponds.

(6) Johkasou

a. General information

The two main steps in Johkasou's treatment are as follows (**Figure 2.5-10**):

- **Primary treatment**: The solids can be physically separated;
- **Secondary treatment**: Aerobic microorganisms break down dissolved organic contaminants and remove them. **Since the microbes multiply due to this process, the larger microorganisms are isolated and eliminated as sludge.** Disinfection significantly lowered the number of coliform bacteria.

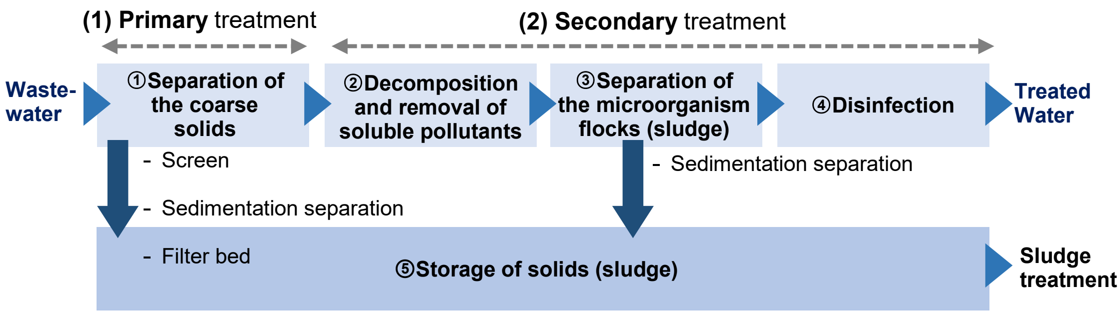

Figure 2.5-10 Basic treatment process of Johkasou

The structure of Johkasou should be either the following:

- **<u>The standard structure type</u>** was designated by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), Japan. The current structural standards are classified into Nos. 1–12 according to effluent quality, as shown in the table below.
- **<u>The certified structure type Johkasou, which introduced proprietary treatment technologies and uniquely designed the structures and capacities</u>** by the manufacturers. This type passed performance evaluation tests and was

recognised by the MLIT as having a performance equal to or better than the structural standard type.

b. Structure

Various types of Johkasou exist, but the common features that make **them structure different from other decentralised wastewater treatment facilities are:**

- The use of blowers for aeration and sludge transfer/circulation and,
- The installation of disinfection equipment

c. Type of Johkasou

c-1. BOD removal type (Anaerobic filter- contact aeration process)

Specification

- Standard structure type
- Applicable NUD: 5–50 capita
- **Treatment performance: BOD removal rate >90%, Effluent BOD <20mg/L**

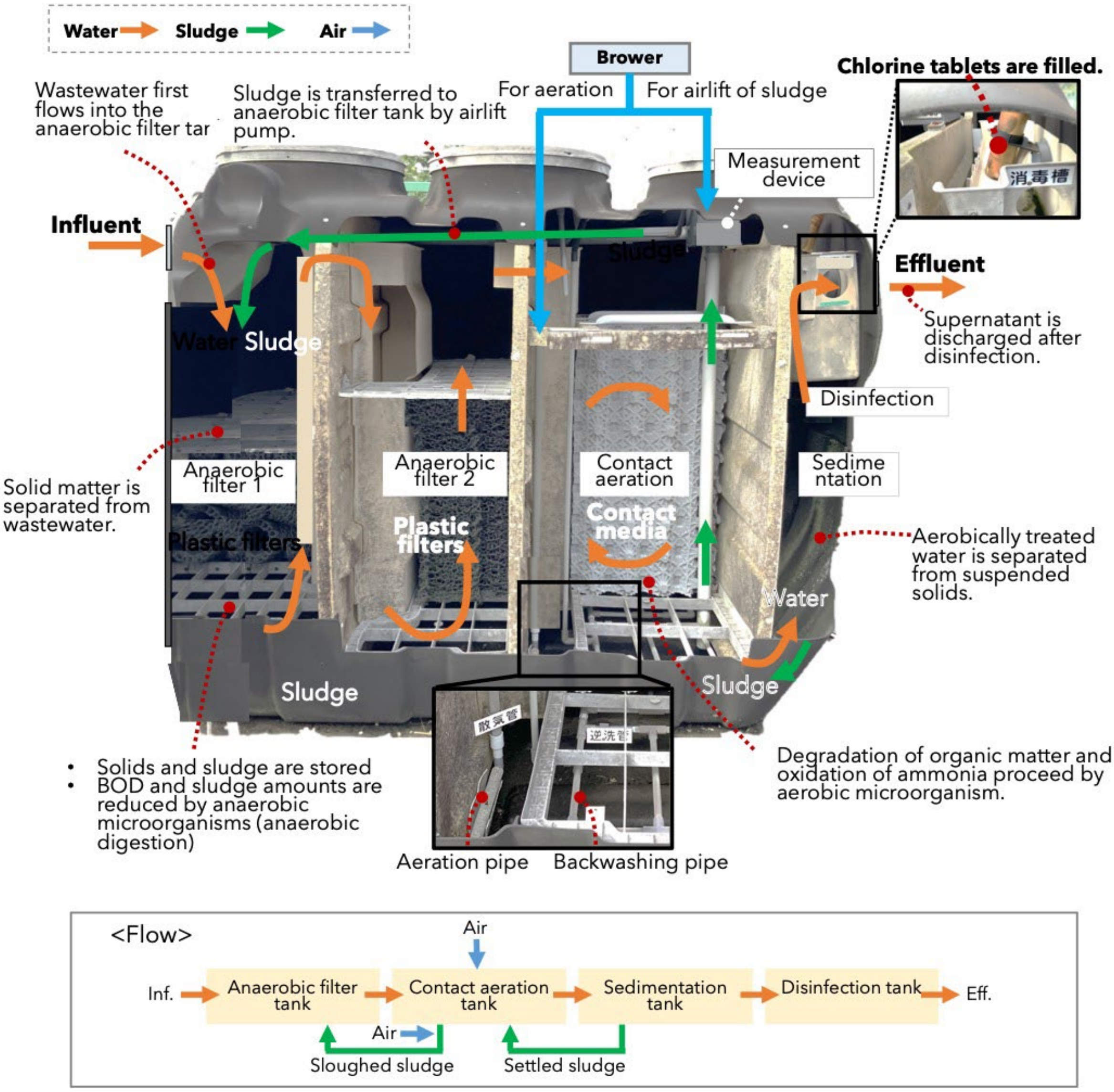

Figure 2.5-11 Example of Johkasou (BOD removal type)

c-2. Nitrogen removal type (Anaerobic filter moving bed biofilm filtration process)

Specification

- Certified structure type
- Applicable NUD: small scale (depends on the manufacturers' standard)
- **Treatment performance: effluent BOD <20mg/L and effluent TN <20mg/L**

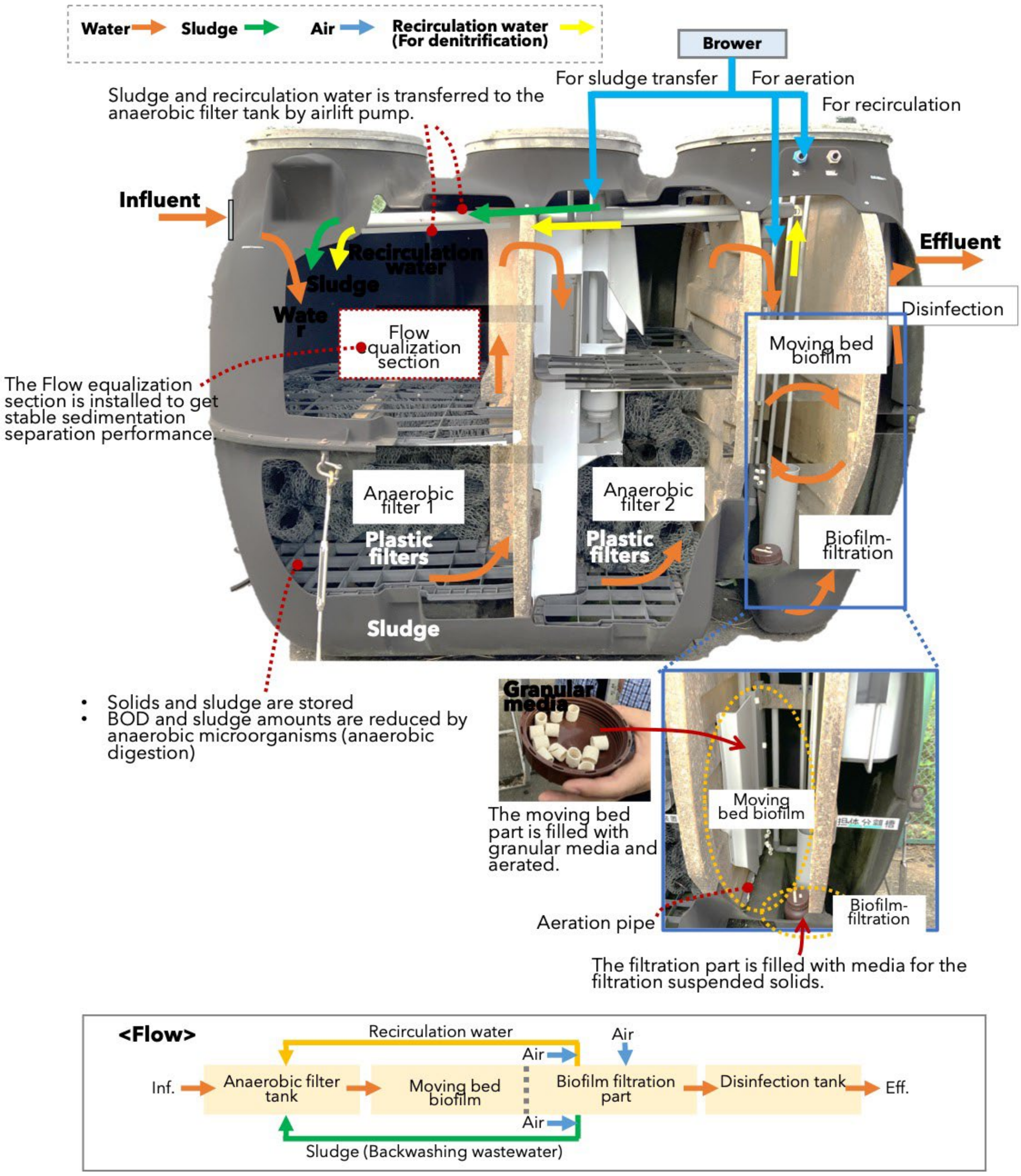

Figure 2.5-12 Example of Johkasou (Nitrogen removal type)

(7) KIDS

a. General information

The wastewater treatment system utilising recycled media, KIDS (Figure 1), uses carriers placed close together in the reaction tank, with air piping at the bottom. The wastewater passes between the carriers with repeatedly arranged "aerated areas" and "non-aerated areas". The aerobic and anaerobic microorganisms attached to the carriers (strands) in these areas digest and degrade pollutants in wastewater.

KIDS media is made from recycled carriers that are stable over the long term, specially made from used "polyethene resin" that coats electric wires. The diameter of the ``strand" is 5.5 mm, and the basic shape is 50 cm in length and width and 25 cm in height (Figure 2) by stacking them in the tank, a "KIDS reaction tank" is formed.

Bubbles generated from the aeration pipe at the bottom pass through this KIDS carrier, supplying the necessary oxygen, and the fragments of the microbial film that are generated and detached around the carrier are precipitated in the subsequent "non-aerated areas". The purification principle was that the soluble organic matter produced by anaerobic decomposition was partially decomposed and removed again in the subsequent aerobic section, and a series of repetitions were carried out. In other words, extremely low sludge generation was achieved by repeating aerobic treatment and anaerobic decomposition.

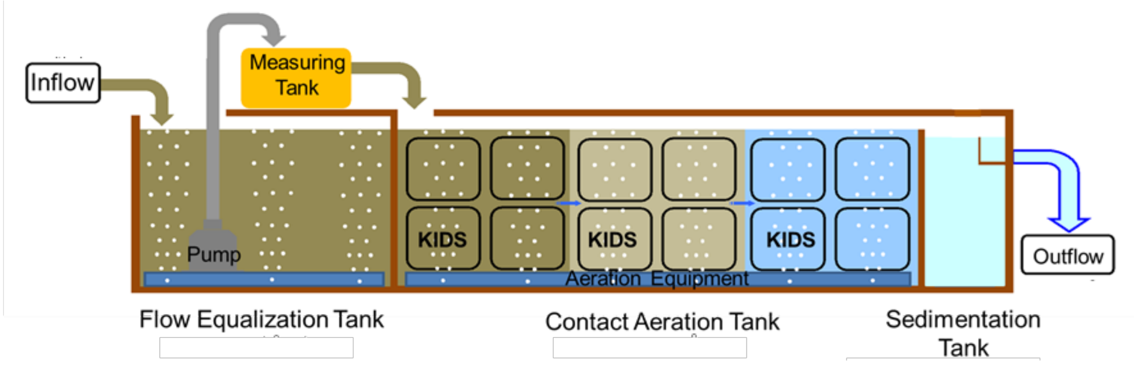

Figure 2.5-11 Outline of Wastewater Treatment System Utilizing Recycled Media KIDS (JICA and Accrete Co., Ltd, 2018)

Figure 2.5-12 Filtering Media (KIDS) (JICA and Accrete Co., Ltd, 2018)

The KIDS treatment method is suitable for treating organic and domestic wastewater from businesses and factories, and it is easy to maintain and manage and produces low sludge. The activated sludge method is suitable for large-scale sewage treatment plants; however, for commercial and household wastewater, it must be easy to maintain and manage. In addition, the fact that ``less sludge is generated" means that ``periodic sludge removal" can be done less frequently.

Another advantage is that they can be used in underground treatment facilities. No moving parts exist in the treatment facility; therefore, it was possible to create a completely underground treatment facility, except for a few inspection ports. This site could be used effectively by creating a parking lot above it. Deciding where to construct a new treatment facility is a major issue for existing businesses and hotels. Therefore, if a treatment facility is installed in an existing parking lot, the upper part can be used as a parking lot. Odour countermeasures can be taken easily, if necessary. The carrier has a long lifespan. The KIDS carrier is made by dissolving the wire coating; therefore, it is not decomposed by ultraviolet rays or microorganisms for a long period. Thus, the KIDS carriers can be manufactured in Laos.

b. Design and Requirement

A “raw water adjustment tank” should be available. In the case of business wastewater, it is necessary to alleviate fluctuations in the quantity and quality of water. A “fine screen” is necessary to prevent large garbage from entering the KIDS unit. As a "finishing section", to stabilise the quality of the treated water, a settling tank is required to settle and remove suspended solids flowing out from the KIDS unit and store the generated sludge. In addition, if human waste flows in, it will be used as a place to “disinfect” just in case. This treatment facility has no moving parts or mechanical equipment, can only be operated using a blower, and requires less frequent maintenance. In addition, for residential sewage treatment facilities, it is possible to install a "sedimentation separation tank" at the front stage, like the "septic tank method", without using a raw water adjustment tank.

The previous investigation confirmed that the sludge generation rate was 41% in the "first settling tank outlet water" and 50% in the "raw sewage". Generally, in the case of the normal activated sludge method, the sludge generation rate is said to be 100 to 75%; therefore, it can be said that it is about half of the conventional method.

c. Examples of KIDS facilities

A unit of the KIDS facility was installed and investigated at the Food Court of the National University of Laos on the Dongdok campus. The designed treatment capacity was 30 m^3/day, and the BOD was reduced from 200 mg/L to less than 30 mg/L, and it was equipped with a screen, equalisation tank, inflow measurement tank, two series of reaction tanks, a sedimentation tank, and a water discharge tank.

Figure 2.5-13 Wastewater Treatment System Utilizing Recycled Media KIDS with solar power at the Food Court of the National University of Laos

One unit of the KIDS facility was installed in a confectionery factory in Japan. The water used was 40 m^3 mL daily in two treatment tanks, 1.25 m wide × 7.9 m long × 4 m deep. A previous water quality survey showed that the inflow BOD decreased from 3500 mg/L to approximately 100 mg/L. In this case, the retention time was approximately 100 h because of the high concentration of raw water. However, in the case of industrial wastewater, the characteristics of each type of wastewater are different; therefore, if the industry is different, it may be necessary to prepare in advance.

A unit of the KIDS facility was installed in the cleaning factory. The volume of water used was 200 m^3/day. The raw water BOD was 80 mg/L, the treated water was 30 mg/L, and the residence time was approximately 20 h.

The KIDS facility is operated to treat hospital wastewater in Vietnam. The amount of water treated was 560 m^3 per day (wide 2.5 m [2 series × 23 m × 5 m]), which started operation in 2011. Sludge was not extracted until 2017, and the quality of the treated water was good.

(8) FSM: Lagoon

a. General information

In places where land availability is not a constraint, potential environmental damage and risks to human health are limited, and a low-cost solution is required, a sludge-drying lagoon can provide a dewatering and end disposal route for digested sludge. Moreover, it is comparable to a drying bed in that it requires huge land expenses and labour-intensive mechanical removal of dewatered particles; however, it is easier to build because no filtrate drainage is necessary. A lagoon is a shallow reservoir with a sealed base that prevents sludge from entering groundwater, aquifers, or other environmental water bodies. Sludge was dumped into the lagoon, and the solids were allowed to settle. Water is lost through evaporation during the drying/dewatering operational cycle, which lasts for many months.

In contrast, sediments create a thick layer at the base of the lagoon, which is stabilised by anaerobic biological activities. Over the digested sludge layer, a supernatant water layer of more than 0.5 m is maintained. This layer allows oxidising odorous substances to be created and released from the sludge layer during anaerobic digestion. The dried sludge was removed once the dewatered sludge had reached the target solid content of 25–30%. The typical operational cycle of a lagoon is more than a year, depending on the local temperature. This is much longer than a drying bed when most water is lost through drainage.

a. Design Requirements and consideration

The lagoons were massive dug constructions, and the scale of the site construction was relatively long. Precipitation, evaporation, sludge type, volume, and solid concentration influence the depth and area required for sludge-drying lagoons. A minimum of two distinct lagoons (if not three) were provided to ensure the availability of storage space for cleaning, maintenance, or emergency conditions. The type of sludge used in a lagoon can considerably impact the number and type of odours and vector problems that arise. Only anaerobically digested sludge should be used in drying lagoons. Lagoons can be of any shape; however, a rectangular design allows for quicker sludge disposal. Lagoon dikes should have a slope of 1:3, vertical to horizontal. They should be shaped and sized to allow for maintenance, mowing, transit of maintenance vehicles atop the dike, and access for trucks and front-end loaders into the lagoon. The surrounding land was graded to prevent surface water from entering the lagoon. A return to the treatment facility must exist to extract the surface liquid and pipe it out. Public access to sludge lagoons should be restricted.

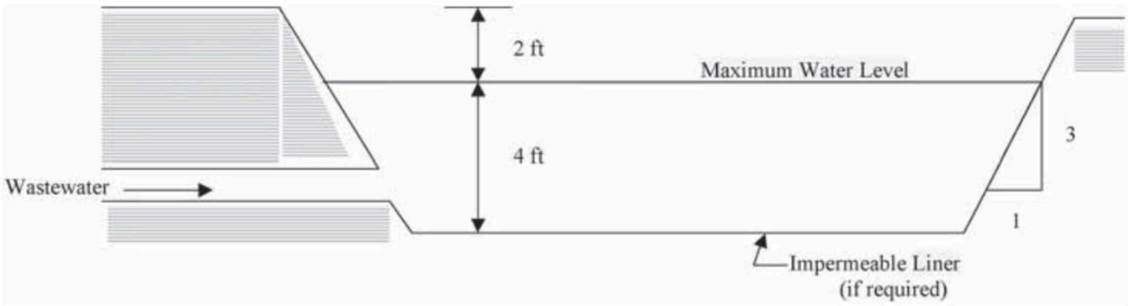

Figure 2.5-14 The Lagoon Process (Wang, Shammas, Williford, Chen, & Sakellaropoulos, 2007)

(8) FEM: Anaerobic Digestion Tank

a. General information

Anaerobic digestion is a natural biological process that uses diverse bacterial populations to disrupt organic matter. Although many different types of digesters exist, their biochemistry is essentially identical. Anaerobic digesters are purpose-built devices that utilise natural processes. These systems can reduce odours, vector attraction, pathogens, , and solid volumes. Organic carbon is digested anaerobically by naturally occurring microbes. Digestion occurs when organic compounds break down in oxygen-free environments. Certain digester systems distinguish between "wet" and "dry" digesters or low-solid and high-solid systems, and the process is sometimes referred to as fermentation. Numerous microorganisms consume organic matter, such as animal dung, sewage sludge, discarded food, and other organic matter, during digestion without oxygen. Chemistry and engineering can be used to control and improve this process. Hydrolysis and fermentation, also known as acidogenesis (the creation of soluble organic molecules and short-chain organic acids) and methanogenesis (the bacterial conversion of organic acids into methane and carbon dioxide), are chemical reactions that occur during anaerobic digestion. Methanogenesis converts acetic acid, carbon dioxide, and hydrogen into biogas during methanogenesis. Biogas, mostly composed of methane and carbon dioxide, is a sustainable energy fuel that can be used for various applications. Due to its high organic matter concentration, landfill leachate is an ideal substrate source for the system. Digesters can process a wide range of feedstocks. Certain digesters are built for a single feedstock but can be modified for different feedstocks or combinations. The co-digestion of sewage sludge with other feedstocks (e.g. fats, oils, grease [FOG], discarded food, cheese or wine waste, and manure) can boost biogas production.

b. Design Requirements and consideration

Digesters have various sizes, designs, and applications. AD systems can be house- or city-sized. These methods could be used for waste processing and energy generation. Anaerobic digester systems can be built to optimise mixing, volume reduction, biogas production, pathogen elimination, vector attraction reduction, and odour management. Systems can be constructed as batch or continuous flow systems within a sealed vessel or holding tank or as a series of vessels. Various anaerobic digestion methods are available. Low-rate anaerobic digesters are often utilised for small systems (under 1 million gallons per day), have no auxiliary mixing, and run for long sludge retention periods (SRTs) in the 30–60-day range. High-rate systems are widely utilised and are supplemented with heating, auxiliary mixing, homogeneous feeding rates, and sludge thickening before digestion. An operating temperature of about 36.6 °C is maintained in the digesters.

MODULE 3. Practical and Technical information on Operation and management

3.1 Purpose of this module

The specifics of maintenance to perform proper maintenance should be understood.

This chapter is to **learn practical and technical maintenance management content**.

3.2 Common considerations

1) Why proper O&M is necessary?

The below figure 3.2-1 is an illustration of a settler. The settler was designed and operated under the right hydraulic conditions of 1–2 h (hydraulic retention time) to separate suspended and colloidal wastewater components by **flotation (scum) and sedimentation (bottom sludge).** Additionally, owing to the **anaerobic condition takes place a partly biological degradation and mineralisation of both scum and bottom sludge.** Commonly, the accumulation rates of scum and bottom sludge are higher than the degradation and mineralisation rates, leading to accumulation. **Once the design storage capacity is exhausted, sludge and/or grease can be washed out and might affect the next treatment stage. To obtain consistently good and stable treated water quality,** it is **necessary to periodically inspect the increase in scum and accumulated sludge in the settler and changes in treated water quality** and to clean the tank when the sludge storage capacity has been reached.

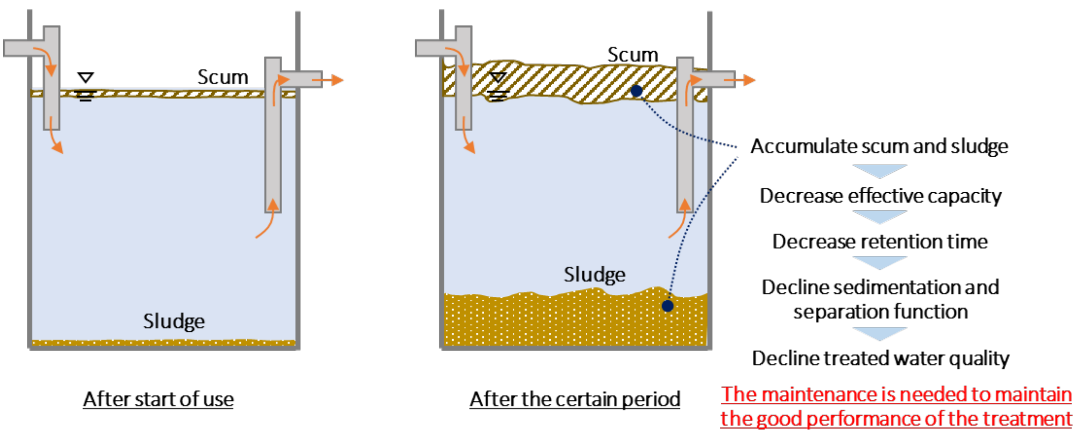

Figure 3.2-1 Effect of O&M on water treatment at settler (Reference: Guidance of Johkasou development project 2012, by JECES, written in Japanese)

2) General contents

(1) Operation

Continuous and repetitive activities involved in the operation of technical facilities, infrastructure, and businesses to create value for stakeholders (e.g., a cleaner environment, improved public health, and profits).

(2) Maintenance

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. Includes inspection, testing, maintenance, serviceability classification, repair, reconstruction, and refurbishment.

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 at **its original or designed capacity and efficiency.**

The maintenance mainly includes:

- to ensure that the plant is working
- and constantly running
- Check the function.
- **Remove sludge deposits**
- Cleaning

- Checking the settings
- Control of biological performance (analysis of parameters)
- Control of the discharge point.
- Measurement of sludge levels
- **Indication of desludging**
- Writing a maintenance report

3) Consideration of frequency

Typical O&M frequencies are shown below:

- **First inspection**: to confirm the installed system properly.
- **Weekly:** Visual check (inlets, outlets, covers, tanks, ventilation pipes)
- **Every 3 to 6 months**: Cleaning mechanical equipment
- **Every six months:**
  - Functional checks on manual and electrical devices
  - Determination of sludge level
  - Effluent sampling and analysis
- **Every 12 months and/or on-demand**: Removing sludge
- **Every 3 to 5 years**: Tightness control

The frequency of O&M 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&Ms may need to be increased**. Observing the conditions at each inspection, keeping records, and organising the information will help optimise O&M.

4) Record keeping

For maintenance and inspection, the following information must be provided and maintained for a certain period[7].

- Name of the person who conducts the work
- Date and time of work
- Maintenance and inspection work
- 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 form that satisfies the following requirements:

- Easy to complete
- Easy to read
- Easy to convert to electronic format
- Easy to tabulate

In certain cases, manufacturers may provide their format.

[7] 3 years in the case of Japan

5) Caution

- **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 within minutes.**

3.3 Common requirements of O&M

1) Additional monitoring and maintenance every 6 months

Additional maintenance is required every six months. In addition, wastewater must be sampled and analysed every six months. Additional analysis of influent water must be performed annually or every 18 months to determine treatment performance.

The table below shows the content of the additional work and how it must be performed.

Table 3.3-1 Additional activities every six month

Parameter	Sampling point	value	How to determine	Where to determine?
Sludge level	Sedimentation tank All chambers of the ABR or AF	<50% of volume <40% of volume	Using measuring pipe for sludge level	On-site
Settable solids	Outflow	<1 mL/L	Imhoff cone	On-site/Laboratory
Sludge volume	Aerobic Stage	150–600 mL/L	Graduated cylinder	On-site
pH Value	Inflow/Outflow	7.0–8.0	pH meter	On-site/Laboratory
Dissolved oxygen	Aerobic Stage	>2 mg/L	DO meter	On-site
COD	Outflow	<120 mg/L	-	Laboratory
BOD5	Outflow	<25 mg/L	-	Laboratory
TN	Outflow	<25 mg/L	-	Laboratory
P	Outflow	<5 mg/L (2 mg/L)	-	Laboratory
SS	Outflow	<35 mg/L	-	Laboratory

2) Periodical self-monitoring and maintenance activities

The following recommendations apply to the area around the septic system and general construction:

(1) Fence/Posts

Fences should be inspected periodically to ensure they are of sufficient height and conditions to keep livestock and the public off. Warning signs should be visible and posted reasonably on both sides of entry gates and fences.

(2) Landscaping/Vegetation on System Components

All trees and shrubs were kept clear. **Do not plant trees or shrubs on system components.** If a tree or shrub has a strong root system, the roots may damage the liner or berm or enter the tank. The roots in the tank can reduce the tank capacity or block the inlet or outlet.

(3) Concrete Structures

All trees and shrubs were separated from each other. **Tanks must be inspected for leakage at least every five years.** Prevent dirt from entering the manholes and cover. **During sludge removal or cleaning, do not place vacuum trucks on the tank cover plate.** Ventilation and discharge pipes/manholes should be kept out of reach of the animals.

(4) Earthwork

Keep the top of the service embankment clear of weeds to allow access to facility personnel, vehicles, and equipment. The embankment sidewalls were maintained to prevent erosion and damage. Periodically inspect the earthwork for animal burrows, remove burrowing animals, and fill holes, as necessary, to prevent catastrophic embankment failure.

(5) Synthetic Liners

Synthetic liners (e.g. HDPE and PVC) generally provide better leak resistance than clay (bentonite). When the liner is properly secured (keyed) to the berm, weed growth is reduced because there is less exposed soil surface for weeds to take root. The liner was inspected periodically to note any UV (sunlight) damage, and cracks or holes were immediately repaired.

(6) Soil or Clay Liner

If there is a soil liner, inspect it regularly to check for erosion, buried animals, and weed growth. **Clay liners must be kept moist during use to prevent surface cracking**. Clay liners may need to be reconsolidated with new clay materials to repair the holes and cracks.

3.4 Specific O&M contents

1) Grease Traps

Cleaning grease traps regularly is critical to prevent FOG from mixing with sewer water. More frequent cleaning intervals (less than 90 days) may be required to keep the grease traps running effectively. FOG can have a negative influence on facilities and the environment. FOG-blocked systems can cause sewage backup and overflow from manholes. If you notice floating oil or grease deposits in a cleanout "downstream" of the trap/interceptor, increase the cleaning frequency and implement a more regular cleaning. Grease traps should be cleaned when the amount of floating grease and sludge-like substances at the bottom of the trap is 25% of the volume of the trap. Because of the odours that may be produced, it is strongly advised that grease trap repair be scheduled during non-business hours. The opening of the grease trap always ensured that the space was well-ventilated.

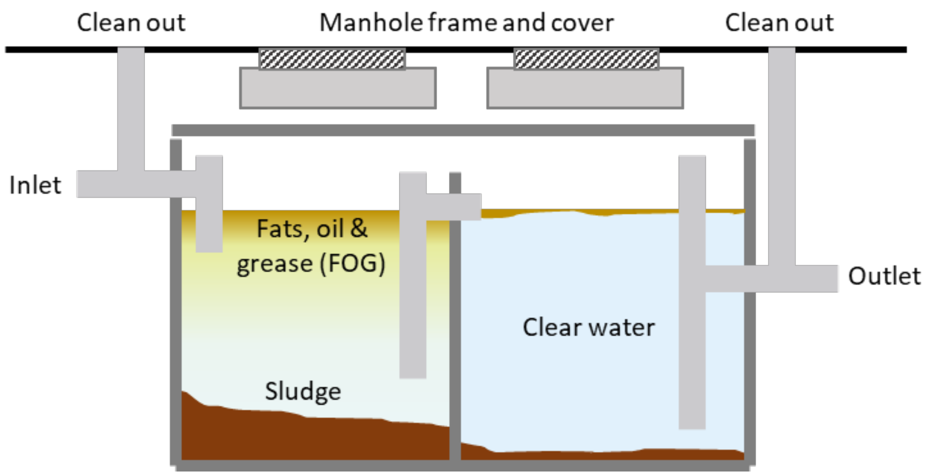

Figure 3.4-1 Schematic of a grease trap

2) Septic tanks, ABR, and anaerobic filters

(0) Common contents

The most important O&M requirement for tank systems is the periodic removal of settleable solids. The sludge level in the tank **every six months to determine if solids need to be removed.** Two methods are commonly used for measuring solids and scum in tanks.

- **Method 1: Use the sludge level gauge**. The tube was pushed to the bottom of the tank through the various layers. **After pushing the tube to the bottom of the tank and pulling it up to the bottom, take a cross-section of the inside of the tank as a sample.**
- **Method 2: Use a long stick.** The cloth was wrapped around the bottom of the stick and lowered to the bottom of the tank. The stick should be inserted through a hole in the scum layer or, if possible, through a baffle or T-piece to prevent the scum from forming on the cloth. **The depth of the scum can be estimated by the length of the scum attached to the fabric.**

When cleaning the tank, remove all contents, including scum, liquids, and solids. Use only tank access ports for cleaning. Other O&M activities required for the tanks include the following periodic inspections:

- **Are there any obstructions at the inlet and outlet, and what is the water level?**
- Are there any obstructions to the vent lines?
    - **Watertightness of the structure**

Table 3.4-1 O&M activities of septic tanks, ABR, and anaerobic filters

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
1	**Visual check of the tanks** (without opening the cover lid) Check construction, any deficiencies, and accessibility.	X	X		X	
2	**Visual check of the tanks** (open the cover lid and check without stepping inside) Check inlet and outlet chambers for any deficiencies outside and inside the construction. Check inlet and outlet pipes, check for clogging and sediment, and check for water tightness of construction and pipes. Check the ventilation pipe.		X		X	

Table 3.4-1 O&M activities of septic tanks, ABR, and anaerobic filters (Continued)

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
3	**Control of the tanks** Check construction, check inlet and outlet pipe, check ventilation pipe, check for water tightness of the construction and pipes, check all chambers of the tank, inlet and outlet, and visual check of water level in the chambers. Remove clogging in between the tank chambers if necessary. Check the bottom sludge level and thickness of the scum layer by using a sludge level measuring device. Remove scum and bottom sludge if necessary (vacuum truck). Remove garbage disposals discharged to the tank. Wash and flush, if necessary, the outlet manhole and remove sediments, if any.				X	

(1) Septic tank

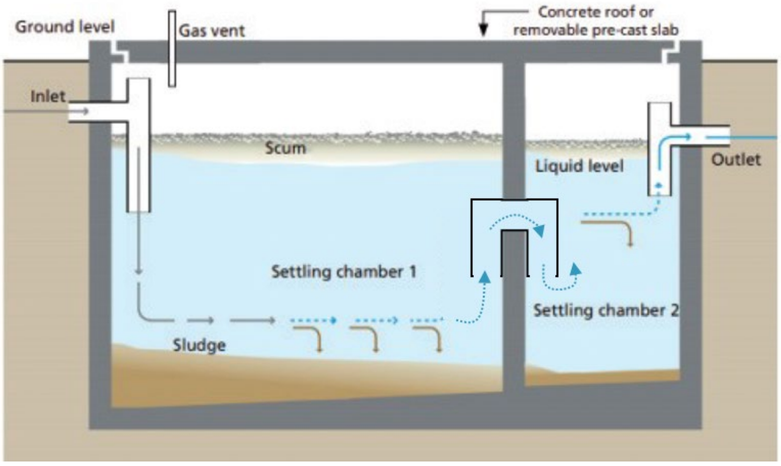

Figure 3.4-2 Schematic diagram of septic tank. (Ministry of Construction-Hanoi, 2011) This figure has been modified (revised) by the author.

Sludge removing

- Every 1 to 3 years, as needed.
- Perform desludging when the sludge reaches 50% of the tank volume.

How to be determined

- Use of Sludge Level Gauge. Moreover, it should be removed when the sludge level in the tube reaches half of the total column.

How to desludge

a. The scum layer and bottom sludge were removed from both chambers of the tank. The second chamber was completely empty.

b. The sludge–water mixture was left for 30 cm in the first chamber of the tank or returned from the truck to the first chamber after it had been completely emptied.

c. Fill both chambers with water.

(2) Anaerobic baffled reactor

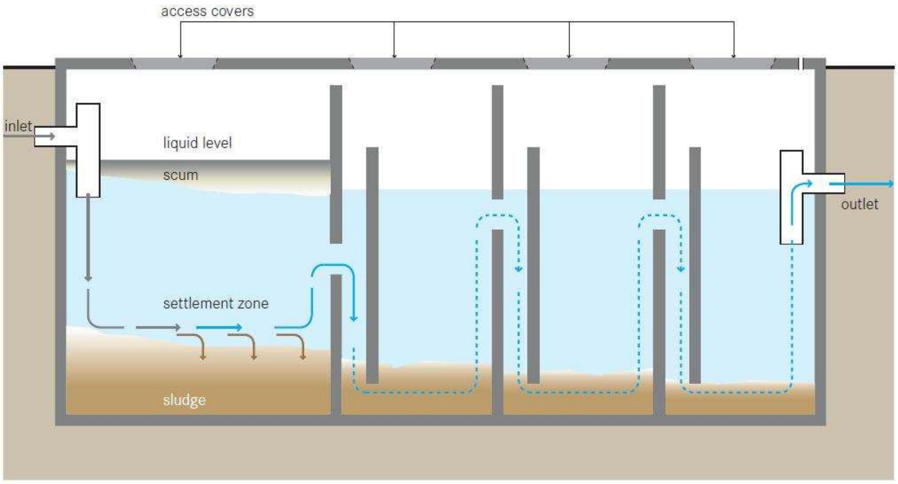

Figure 3.4-3 Schematic diagram of anaerobic baffled reactor (Ministry of Construction-Hanoi, 2011)

<u>Sludge removing</u>

- Every 1 to 3 years, as needed.
- Perform desludging when the sludge reaches 50% of the tank volume.

<u>How to be determined</u>

- Use of Sludge Level Gauge. Moreover, it should be removed when the sludge level in the tube reaches half of the total column.

<u>How to desludge</u>

a. Empty the first chamber of the ABR.

b. The sludge-water-mixture returned from the truck to a height of 30 cm in the first chamber

c. Fill with water

d. Remove sludge from other chambers of the ABR only if the sludge level is higher than 30–40% of the height. The sludge and water were not completely removed from the chamber. Leave at least 10 cm of sludge in each baffle chamber.

(3) Anaerobic filter

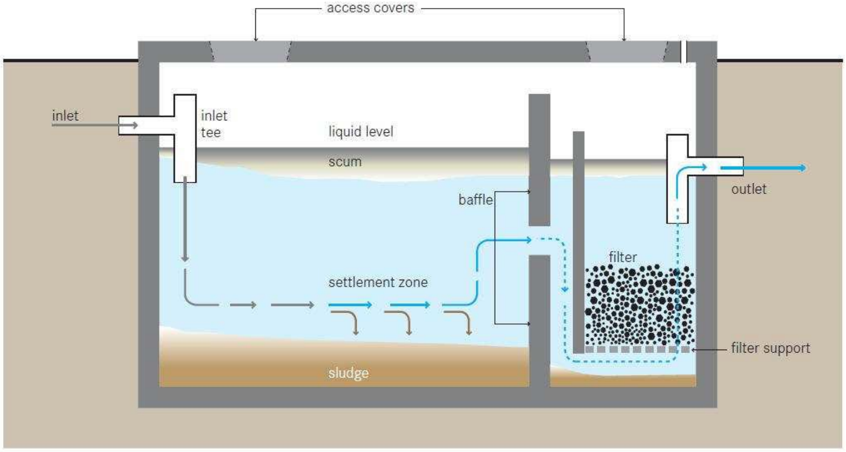

Figure 3.4-4 Schematic diagram of anaerobic filter (Ministry of Construction-Hanoi, 2011)

Sludge removing

- Every 1 to 3 years, as needed.
- Perform desludging when the sludge reaches 50% of the tank volume.

How to be determined

- Use of Sludge Level Gauge. Moreover, it should be removed when the sludge level in the tube reached half of the total column.

How to desludge

a. The first chamber of the AF was empty. The sludge-water-mixture was returned from the truck to a height of 30 cm in the first chamber. Fill with water.

b. Remove sludge from other rooms of the AF only when the sludge level is above 30–40% of the height. The sludge at the bottom of the reactor was completely removed. **Do not empty the water in the filter chamber.**

c. If the cleaning efficiency decreases or the filter medium becomes clogged, the filter medium is backwashed. If necessary, the filter medium was removed from the aquarium and cleaned.

2) Constructed wetlands

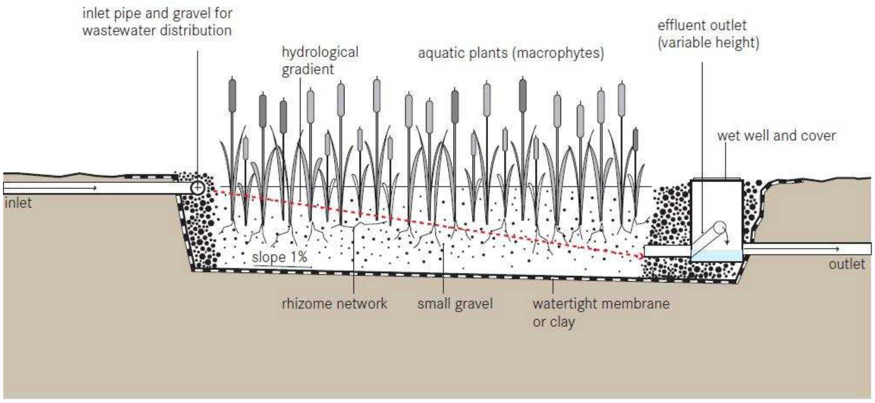

Figure 3.4-5 Schematic diagram of constructed wetlands

Constructed wetlands lose capacity when overloaded for long periods. However, the **short-term load spikes do not cause performance problems**. Overloading can occur **if the pre-treatment system fails and suspended solids, sludge, or grease enter the constructed wetlands.**

O&M of constructed wetlands should focus on keeping the pre-treatment systems functioning properly. Effluent from the pre-treatment system must be analysed for settleable solids using **an "Imhoff cone" to determine the number of solids transferred to the wetland**. **Sludge in the pre-treatment system must be removed** regularly. **Other O&M activities required for constructed wetlands include periodic inspections of**

Are there any obstructions, and what is the water level?

Outlet structure (swivel arm) versus water level.

- Hydraulic loading factor and pollutant loading are influent and effluent BOD and TSS concentrations and influent flow rate.

- Wetland vegetation includes diseases and insects (weeds and predators are removed until wetland vegetation is fully established).

Table 3.4-2 O&M activities of constructed wetlands

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
1	**Visual check water distribution chamber** (without opening the cover lid)	X	X		X	
2	**Visual check water outlet chamber** (open the cover lid and check without stepping inside) Check construction, any deficiencies, and accessibility. Check the water level in the outlet chamber, colour, odour, and turbidity. Check for sediments.	X	X		X	
3	**Control of the water distribution and outlet chamber** (open the cover lids) Check outside and inside of the construction; are there any deficiencies? Check distribution and outlet pipe, water tightness of construction and pipes. Remove sediments from the water distribution chamber and outlet. Check the water level in the wetland and adjust it if necessary. Wash and flush, if necessary, inlet and outlet chambers.				X	

Table 3.4-2 O&M activities of constructed wetlands (continued)

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
4	**Visual check of the plant bed** Check for garbage disposal, water on the surface, smell, and general bed condition.	X	X		X	
5	**Control of the plants and plant bed** For growth of the plants: check for vermin and dry plants, and if plants from the surroundings are growing into the filter, check for external plant growth in the wetland. Remove unwished plants and cut back reed plants if necessary.				X	X
6	**Control of the CW liner** Check synthetic liners if damaged by weeds, animals, or sunlight. Check for erosion, burrowing animals, and weed growth in earthen or clay liners. Re-compact if necessary.		X		X	

Table 3.4-2 O&M activities of constructed wetlands (continued.)

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
7	**Control of feeding pipes (Vertical flow CW)** Check outside and inside of the construction; are there any deficiencies? Check distribution and feed pipes. Wash and flush if necessary. Check distribution fittings, valves, check valves. Start the feed pump and check for noises and unwished spraying from the feed pipes. Check for water on the surface after feeding. Check drainage pipes and outlet, and check ventilation pipe. Wash and flush drainage if necessary.				X	

Water level

The water did not stand on the surface of the filter near the inlet.

How to?

Adjustments were made by lowering or raising the swivel arm of the spout. The water level was 5–15 cm below the surface.

Water distribution

Optimal water distribution on the inlet side must be managed occasionally (3–6 months).

Plants

Plants need to be pruned regularly.

Filter media

If treatment efficiency decreases, the gravel filter must be replaced. Estimated filter replacement time: 8–15 years.

3) Waste stabilisation ponds

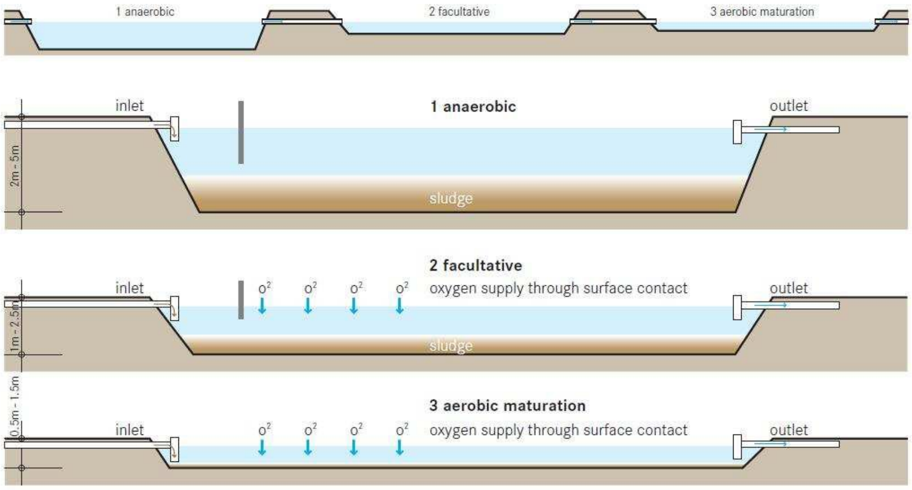

Figure 3.4-6 Schematic diagram of waste stabilisation ponds

O&M should focus on keeping the water surface of aerobic ponds clean and free from shading. Plants that overhang the water's surface or provide shade must be removed to ensure proper aeration and wind mixing (beneficial algae need sunlight to produce oxygen). Dead leaves and bushes should be removed from the water's surface. **Remove all aquatic plants from the pond by cutting or burning them annually. Additionally, check the sludge level in the pond every year.**

Other O&M activities required for WSP include regular checks of:

Is there any obstruction to the entrance structure, and what is the water level?

- Water level of the exit structure

- Hydraulic load factor and pollutant loading, that is, inflow and outflow concentrations of BOD and SS, and inflow flow rate

Table 3.4-3 O&M activities of waste stabilisation ponds

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
1	**Visual check water inlet/water outlet** Check construction, water distribution, and any deficiencies. Check the water level.	X	X		X	
2	**Visual check construction/water surface** Check pond banks, remove bushes or plants growing on the berm, check earthwork after removing weeds, repair root damage, check fencing (if any) Remove leaves, plants, or vegetation from the water surface; remove garbage from the water surface. Check the pond surface colour and odor.		X		X	

Table 3.4-3 O&M activities of waste stabilisation ponds (Continued.)

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
3	**Control of the pond liner** Check synthetic liners of the WSP if damaged by weeds, animals or sunlight. Check for erosion, burrowing animals and weed growth in earthen or clay liners. Re-compact if necessary.		X		X	
4	**Control of the WSP** Remove aquatic vegetation from ponds by cutting or burning (and/or herbicide application). Check bottom sludge level by using a sludge level measuring device.					X (yearly)

Table 3.4-3 O&M activities of waste stabilisation ponds (Continued.)

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
5	**Control aeration units (if necessary)** Check functionality. Check anchoring and placement. Maintain the aerator per the manufacturer's recommendation at least every six months.	X	X		X	

Water Distribution

The inlet and outlet structures must be maintained regularly, at least every six months.

Sludge

If the sludge level in the pond exceeds 20% of the water surface, the sludge must be removed. At least every 10–15 years.

Water Surface

Keep clean and shaded.

Vegetation

Aquatic vegetation should be removed from the pond once a year.

4) Johkasou

Similar to **other decentralised wastewater treatment systems, Johkasou requires periodic removal of sludge and scum**. **Other unique aspects of Johkasou O&M include:**

- Replenishment of disinfectants
- Blower inspections
- Adjustments of an airlift pump

The Ministry of the Environment of Japan launched a video clip on YouTube explaining how to properly maintain and dispose of sludge.

https://youtu.be/8DP4fkigSwE?feature=shared

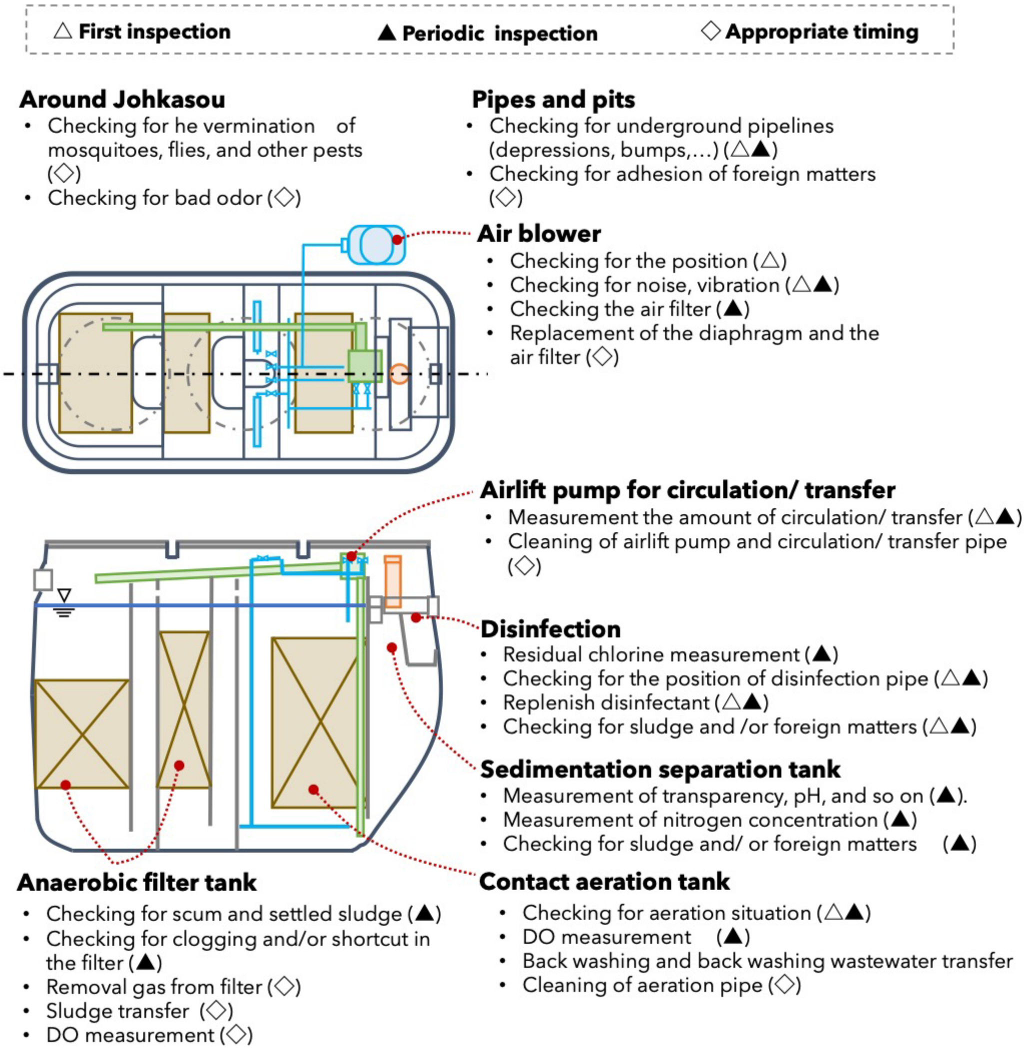

Figure 3.4-7 O&M points of Johkasou

Table 3.4-4 O&M activities of Johkasou (1. first chamber of anaerobic filter tank)

	How to check	Unusual situation	O&M contents	O&M Frequency[8]
▪ Influent section	Visual check	- Foreign matter is adhering to the surface	- Remove foreign matter	Each periodic inspection
▪ Water level ▪ Clogging anaerobic filter	Visual check or insert the transparent pipe	- Water level is higher than the water level guideline - Significant water level rise scar is observed	- Remove foreign matter - Cleaning should be conducted if it is needed	Each periodic inspection
▪ Scum	Visual check or insert the transparent pipe	- Large amounts of scum are observed - (If the accumulation is more than 10 cm above the water surface, it is considered time for cleaning)	- Consider the time for cleaning	Each periodic inspection
▪ Settled sludge	Visual check or insert the transparent pipe	- The sludge is settled to the bottom edge of the filter bed	- Consider the time for cleaning	Each periodic inspection

[8] The frequency depends on the types and capacities. For detailed information, refer to the O&M manual provided by the manufacturer.

Table 3.4-4 O&M activities of Johkasou (1. first chamber of anaerobic filter tank) (continued.)

	How to check	Unusual situation	O&M contents	O&M Frequency[9]
▪ Foreign matters	Visual check	- Diapers and hygiene products are observed	- Check with the user and explain the conventions of use	Each periodic inspection
▪ Oil	Visual check	- A large amount of oil is floating in the water	- Check with the user and explain the conventions of use	Each periodic inspection
▪ Mosquitoes, flies	Visual check	- Large numbers of Mosquitoes and/or flies are present	- Use insecticides to control them	Each periodic inspection
▪ Odour	Check for unusual smells	- Significant odour with manhole closed	- Seal the manhole - If any abnormality is observed in the treatment function, track the cause and treat	Each periodic inspection
▪ DO	DO meter	- More than 1.0 mg/L	- Adjust the recirculation water amount	Appropriate timing
▪ pH	pH meter	- pH<5.8 or 8.6<pH	- Check with the user to determine if any special substances exist in the influent	Appropriate timing

[9] The frequency depends on the types and capacities. For detailed information, refer to the O&M manual provided by the manufacturer.

Table 3.4-5 O&M activities of Johkasou (2. Second chamber of anaerobic filter tank)

	How to check	Unusual situation	O&M contents	O&M Frequency
▪ Water level ▪ Clogging anaerobic filter	Visual check or insert the transparent pipe	- The water level is higher than the water level guideline - Significant water level rise scar is observed	- Remove foreign matter - Cleaning should be conducted if it is needed	Each periodic inspection
▪ Scum	Visual check or insert the transparent pipe	- Large amounts of scum are observed - If the accumulation is more than 10 cm above the water surface, it is considered time for cleaning	- If sufficient storage capacity exists in the first chamber, transfer to the first chamber. When the first chamber has reached capacity, it will indicate it is time to clean.	Each periodic inspection
▪ Settled sludge	Visual check or insert the transparent pipe	- The sludge is settled to the bottom edge of the filter bed.	- Consider the time for cleaning	Each periodic inspection
▪ DO	DO meter	- more than 1.0 mg/L.	- Adjusting the recirculation water amount	Appropriate timing
▪ pH	pH meter	- pH<5.8 or 8.6<pH	- Check with the user to determine if any special substances exist in the influent.	Appropriate timing

Table 3.4-6 O&M activities of Johkasou (3. contact aeration tank)

	How to check	Unusual situation	O&M contents	O&M Frequency
▪ Water appearance	Visual check	- Many SS are circling	- Backwash and sludge transfer	Each periodic inspection
▪ Aeration ▪ Agitation	Visual check	- Unbalanced aeration - Aeration does not occur	- Adjust the aeration valve - Cleaning of aeration pipe - Inspection of air blower (diaphragm, air filter)	Each periodic inspection
▪ Status of biofilm adhesion on contact media	Visual check	- Biofilm is not observed - Clogging has occurred	- Consider the seeding - Backwash and sludge transfer	Each periodic inspection
▪ DO	DO meter	- More than 1.0 mg/L	- Check the circulation water amount - Check the loading	Each periodic inspection
▪ pH	pH meter	- pH<5.8 or 8.6<pH	- Inspection and cleaning of transfer pipes - Adjust the valve - Inspection of blower	Appropriate timing

Table 3.4-6 O&M activities of Johkasou (3. contact aeration tank) (continued)

	How to check	- Unusual situation	- O&M contents	O&M Frequency
▪ Water circulation amounts	Measuring cylinder Stop timer	- Circulation water is not transferred	- Backwash and sludge transfer	Each periodic inspection
▪ Foam formation	Virtual check	- Significant foaming is observed	- Addition of an anti-foaming agent - Consider the seeding - Check with the user to confirm the amount of detergent	Appropriate timing

Table 3.4-7 O&M activities of Johkasou (4. sedimentation tank)

	How to check	Unusual situation	O&M contents	O&M Frequency
▪ Scum	Visual check or insert the transparent pipe	- A large number of scum is observed	- Transfer sludge to an anaerobic filter (first chamber)	Each periodic inspection
▪ Overflow weir	Visual check	- Foreign matter is adhering to the surface	- Remove foreign matters and cleaning	Each periodic inspection
▪ Settled sludge	Visual check or insert the transparent pipe	- Large amount of sludge is observed	- Check the operational situation of the circulation adjustment system - Sludge transfer	Each periodic inspection
▪ pH	pH meter	- pH<5.8 or 8.6<pH	- Check the circulation water amount - Adjust the air volume as necessary	Appropriate timing
▪ Effluent water	Visual check	- A large amount of SS is observed in the effluent	- Backwash and sludge transfer - Clean as necessary.	Each periodic inspection

Table 3.4-8 O&M activities of Johkasou (5. Disinfection tank)

	How to check	Unusual situation	O&M contents	O&M Frequency
▪ Disinfection	Visual check	- No disinfectant - Disinfectant is depleting quickly, or disinfectant is not depleted	- Replenish disinfectant - Adjust the dissolving amount	Each periodic inspection
▪ Settled matters	Visual check	- Sediment in the tank and turbidity in the effluent	- Cleaning	Each periodic inspection
▪ Residual chlorine	Residual chlorine meter	- Not detected or significantly high	- Replenish disinfectant - Adjust the dissolving amount	Each periodic inspection

Table 3.4-9 O&M activities of Johkasou (6. Blower)

	How to check	Unusual situation	O&M contents	O&M Frequency
▪ Operational situation	Visual check	- No operation	- Check the power - Inspection of auto stop function	Each periodic inspection
▪ Noise, vibration	Visual check, listing the noise	- Unusual noise or vibration is observed	- Check the blower base	Each periodic inspection
▪ Air filter	Visual check	- Dust is adhering to the surface	- Cleaning	Each periodic inspection

5) KIDS

To ensure each piece of equipment at the facility is operating normally and exhibiting its functions, it is recommended that regular inspections be carried out as often as described in the "Inspection Operation Overview for Each Equipment". Table 1 summarises the key points and frequencies of the regular facility inspections.

Two blowers were installed to supply air to the reaction tanks, one operational. To monitor the operating status of the blower, remember the normal sound; if you notice any other unusual noises, stop the blower, switch to another stopped blower, and request repair.

The equalisation tank temporarily stores wastewater to reduce water volume and quality fluctuations. A mesh cage was installed at the inflow point to prevent large solids from entering the tank. The accumulation of large solids inside the mesh basket was observed through the opening. If a large amount of solid matter accumulates and begins to block the inflow pipe, the mesh basket is lifted upward and disposed of the solid matter.

The interior of the reaction tank was observed by pulling the middle part of the iron lid with a hook. Air was supplied to the tank using a diffuser pipe installed at the bottom, which created bubbles on the water surface. Ensure that bubbles are observed on the reaction tank surface.

The sedimentation tank was located at the bottom of the grating lid, and the interior was observed through the gap. The supernatant water flowed over the triangular partition plate. Observe dirt inside the troughs and walls and the presence of floating objects on the water surface.

The discharge tank was located at the bottom of the grating lid, and the interior was observed through the gap. The treated water (supernatant) that flows from the sedimentation tank is temporarily stored in the discharge tank before being released into the surrounding environment. The water clarity and colour were observed to confirm that the treated water was clean.

Photovoltaic solar panels were installed on top of a wastewater treatment facility. The generated electricity is transmitted to the power distribution board via the solar power generation monitoring board and used as a power source for the drainage facility. Check the power generation status on display on the monitoring panel.

Table 3.4-10 outlines operation inspection and frequency (KIDS)

Name of equipment	Outline of operation inspection	Frequency
Electrical panel	Check that the blower and pump have stopped operating and that the warning light is on or off	Once a week
Blower	Listen to the operation sound and check if there are any unusual sounds	
Discharge tank	Check the clarity and colour of the water	
Sedimentation tank	Confirm the presence of floating objects on the water surface and the water flow from the outflow plate	
Measuring tank	Observe the V-type flow and water scale plates and clean them as necessary	
Equalisation tank	Observe the inflow screen section and clean the mesh basket as necessary	Once a month
Reaction Tank	Checking the status of air bubbles on the water surface and the presence of strange odours	
Solar panel equipment	If the alarm sounds, check the display board	Everyday

6) Other O&M activities

(1) Control of effluent values and sampling

Table 3.4-11 O&M activities of control of effluent values, sampling, and analysis

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
1	**Sample effluent/Random sample** Determine pH, settable solids, colour, odour, and turbidity on site. In a laboratory, sample effluent and determine/analyse all relevant parameters (BOD, COD, TN, SS, P, pH)				X	
2	**Sample influent** Determine pH, colour, odour, and turbidity on-site					X

(2) O&M records

Table 3.4-12 O&M activities of records

No.	Control and maintain activities	Weekly	Monthly	Three Months	Six months	On-demand
1	**Self-monitoring record** **Down-writing of undertaken activities**	X	X			
2	**Maintenance and control report (O&M report)** Prepare the O&M report Down-writing of all control and maintenance activities undertaken. Down-writing of all occurrences, findings, and repair activities are undertaken Down-writing of on-site determined parameters				X	
3	**Plant operation diary** Keeping a plant operation diary where all self-monitoring records and O&M reports are included The operation diary should include all analysis reports, all desludging reports, notices of defects, repair orders, etc.	X	X		X	

8) FSM:

a) Lagoon

Minimal operator interaction is required because the system functions under gravity (from the inflow). Daily checks, including those for sludge entry, are required. An FSM site requires competent personnel, including mechanics. Construction can take six months or more because of the size of the location. FSTPs using lagoons or massive reactor tanks must have a drowning prevention system with safety equipment, signage, and training. Plants with large lagoon cells frequently have boats from which operations are performed. Workers must wear flotation devices, work in pairs, and be taught suitable procedures to reduce their risk of drowning. Moreover, to monitor visual or sensory inputs, visual observations of plant conditions, such as scum on a treatment lagoon, can be installed.

Figure 3.4-8. Faecal Sludge Lagoon System, San Fernando City, Philippines (Strande, Ronteltap, & Brdjanovic, 2014)

b) Anaerobic Digester

Anaerobic digester tank maintenance involves the routine inspection, cleaning, and repair of the system. The tank's structural integrity, including the roof, walls, and floors, was verified throughout the inspection procedure. Any structural component damage should be addressed promptly to prevent leakage or collapse. The inspection procedure should involve checking the valves, pumps, and pipes to verify they are in good working order. Cleaning the anaerobic digester tanks is necessary to prevent sludge and scum collection. Sludge and scum build-up can limit system efficiency by lowering the available volume for digestion. The cleaning process entailed removing accumulated sludge and scum from the tank. A vacuum truck or pump can be used to remove sludge, and a skimmer or scraper can be used to remove scum. Anaerobic digester tank maintenance should include checking the pH, temperature, and volatile solid content. The pH should be between 6.5 and 8.5 to ensure the digestion process runs well. To enhance the growth of anaerobic bacteria, the digester temperature should be kept between 35°C and 55°C. Volatile solid concentrations should be measured to ensure the correct amount of organic matter is digested.

The operation of anaerobic digester tanks entails feeding the system with organic waste. Organic waste should be screened to remove non-organic contaminants that may interfere with digestion. Organic waste should be shredded to increase surface area and accelerate digestion. The feeding process was repeated frequently to ensure a steady flow of organic waste materials into the system. The management of biogas produced by anaerobic digester tanks should be included in tank operation. Biogas can be collected using a gas-collecting system, stored in a biogas holder, or used directly to generate energy. To avoid leaks or explosions, the generated biogas should be carefully managed. Management of the digested material should be included in the operation of anaerobic digester tanks. This material can be utilised in agriculture or landscaping as a fertiliser; it should be filtered before being utilised as fertiliser to remove any remaining solids and microorganisms. Digested waste should be stored in a designated place to avoid contaminating the surrounding environment.

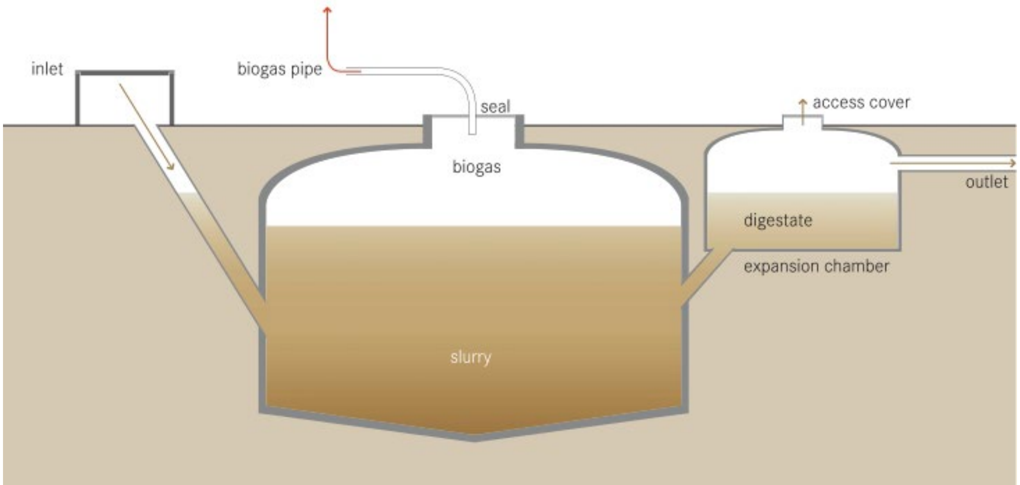

Figure 3.4-9 Schematic of an anaerobic digester (Tilley, et al., 2014)

MODULE 4: Duties and responsibilities for proper O&M of domestic wastewater treatment systems

4.1 Purpose of this module

This module addresses the duties and responsibilities for the proper operation and maintenance of domestic wastewater treatment systems within the context of Lao PDR. It highlights the roles of various government bodies and the private sector in managing water, sanitation, and wastewater treatment, emphasizing adherence to international standards and guidelines. The module also advocates for the implementation of Decentralized Wastewater Treatment Systems, emphasizing the importance of capacity building, stakeholder engagement, and public participation, with a focus on gender inclusion in decision-making processes. It includes detailed sections on technical training, tools for planning and assessment, and feasibility studies, discussing various business models to ensure long-term sustainability in wastewater management.

The content demonstrates a comprehensive approach, integrating technical, regulatory, and institutional aspects to improve wastewater treatment practices in Lao PDR.

4.2 Institutional Agreements

In Lao PDR, the Department of Water Supply within the Ministry of Public Works and Transport (MPWT) is responsible for managing water, sanitation, and wastewater treatment (Module 2 highlights the existing policies and guidelines implemented in Lao PDR). In addition to the general discharge standards set by the Ministry of Natural Resources and Environment, **there are no clear regulations on treating wastewater or heavy metals discharge.** Because of this, sanitation and wastewater treatment projects in Lao PDR, which are financed by multilateral development agencies such as the World Bank (WB) or the Asian Development Bank (ADB), must adhere to international good practices and standards, as defined in the International Finance Corporation (IFC) and WB Environment, Health, and Safety (EHS) guidelines. **Considering these constraints, the Department of Housing and Urban Planning (DHUP) within the MPWT has been involved. Moreover, it works with BORDA to apply DEWATS as an instrument for environmental improvement and an important part of wastewater treatment solutions across the country, especially in urban areas.** This move was in response to a 2011 study by the Japan International Cooperation Agency (JICA) on improving the water environment in Vientiane. The study concluded that large-scale investments in conventional sewerage would not be necessary and **recommended the gradual introduction of DEWATS.**

1) Central government and Local governments

- To divide roles among ministries, the Ministry of Planning and Investment (MPI) created an overall master plan and policy, while other ministries created guidelines and handbooks describing specific activities.
- In wastewater treatment, the MoNRE and MPWT prepare business plans and submit them to the MPI. The MoNRE formulates policy plans, and the MPWT formulates management and implementation plans.
- The MPWT oversees centralised wastewater treatment in **Vientiane, the Capital of Laos**, and the DPWT scrutinises the effectiveness of the plans. The DPWT constructs the urban sanitation infrastructure and wastewater treatment facilities, and VCOMS (official name: VUDAA) oversees operation and maintenance.
- **No clear definition or direction exists on the division of roles for decentralised wastewater treatment facilities.** As this depends on case-by-case situations, relevant organisations are compiling data from model cases and developing guidelines for overseeing decentralised wastewater treatment.

2) Owners and residents

Owners of a household and residents must use and maintain septic tanks and/or wastewater systems to keep them clean and in working order following sanitation principles. Regular desludging (more than once every two years) and cleaning of filters are necessary for maintaining good septic tank performance. Regular septic tank monitoring and maintenance are recommended to avoid affecting neighbours or the environment.

3) Private sector

Concerning O&M of wastewater systems, private businesses in Lao PDR only use sludge extraction. No records or confirmation of private entities that manage and operate wastewater treatment facilities exist. No private business market exists for managing and monitoring sewage treatment facilities. To nurture such industries, it is necessary to institutionalise the management and monitoring of wastewater treatment facilities and establish a system market. **Private sector participation in decentralised domestic wastewater management: 1) there are no manufacturers of factory-produced septic tanks in Laos; 2) local contractors carry out construction; 3) regarding operations, there are only desludging companies–types of services provided: construction, sludge extraction, and stage of decentralised domestic wastewater management. Maintenance of decentralised wastewater treatment facilities has not been established as an essential work area.** BORDA has been conducting O&M training for DEWATS users (i.e., communities and school operators at the beginning of use) but has not been able to follow up on regular maintenance.

Policy encouragement for private sector involvement: As an example of the involvement of the private sector, in Vientiane, the Capital of Laos, the collection of sludge is carried out solely by the private sector with no public-sector sludge operations.

4) Regulations for private-sector business

Regulations exist on private-sector sludge collection. No other regulations are in effect. BORDA trains and supports local officials in designing DEWATS. Instructors may be invited to train by Asian countries that have partnerships with Laos, such as the Asia Institute of Technology (AIT) in Thailand.

4.3 Role of Distribution Among Stakeholders and Administrative Management

1) Specific actions

Following are the specific actions to build capacity and raise awareness:

1. **Capacity building for decentralised sanitation needs to be reoriented the mind-set away from centralised solutions.** Moreover, it is challenging for engineers to believe that **inexpensive decentralised treatment systems are as good as the traditional costly infrastructure.** The political economy of large contracts, expensive operations, and the maintenance of centralised treatment systems pose hurdles.
2. **Establish good coordination and collaboration to develop strategies that make knowledge accessible at multiple times and in multiple ways.**
3. **Strategies may involve research papers, evidence summaries, policy briefs, media and advocacy, oral presentations, policy dialogues, and community-level engagement programs.** Key enablers must include personal contacts/relationships with policymakers, understanding the policy environment, timeliness, and relevance of evidence (including cost benefits), and summarising information with clear, implementable recommendations. PR campaigns nationwide ensure public participation, behaviour change, and sanitation promotion and its benefits to human and environmental health.
4. State-wide capacity-building interventions, including workshops and seminars, are required. **Municipal officers get transferred on short notice; hence, capacity**

building must be state-wide and, if possible, across both rural and urban administration.

5. **A major challenge in building capacity is how to improve the knowledge and skills of stakeholders to address an immediate challenge and to ensure longer-term priorities are not neglected.** Programs and projects are mostly short; however, urban/rural sanitation is linked to urban/rural planning and the long-term sustainability of systems and the environment, managing the demand for water, reducing the wastewater footprint, and addressing inequality in access to sanitation and water, systems, and governance.
6. **Training of trainers (ToT) must focus on understanding the core content of DEWATs, capacity-building training**, sequencing sessions, and developing practical exercises.
7. **The training is different from academic courses and teaching.** Training conveys specific skills and ways of thinking and doing from one skill to another. Key messages and facts were prioritised over perspectives and ideas.
8. **If sanitation is perceived as a technological challenge, not a governance and municipal challenge, people will be estranged from the problem.** The government's economy will continue to push high-cost centralised sanitation as a solution. **People's engagement is therefore critical in understanding and demanding decentralised solutions to make the population pay a substantial part of capital and operational costs as a public good.**
9. **Participation of women is low in decision-making at the administrative level, in deciding technological solutions, in urban and rural planning, and in the operation of treatment plants.** Moreover, it is impossible to promote decentralised

solutions without engaging with women. Manual cleaning of septic tanks and sewer lines takes a heavy toll and poses a risk to workers. **Both gender and inclusion need to be factored into capacity building and training modules, to alert the staff and consultants and define concrete recommendations for implementation.**

10. **Institutions mandated to deliver capacity-building programs at the state level are often poorly staffed.** They need to be supported by DEWAT training modules and trainers in the short run and linked to universities and institutes in the long run.

2) Stakeholders

On the needs for Capacity Building for various stakeholders:

(1) Technical personnel and engineers

- **Clear definition of DEWATs and FSM**, characteristics, sampling, and analysis.
- Treatment features and feasible options: Basic design, cost evaluation, operational guidance, and pre-selection measures.
- Characteristics and quantities of generated sludge from decentralised wastewater treatment system.
- Training manuals for unskilled workers.

(2) Planners and facilitators

- Tool development for stakeholder involvement – tools for assessing stakeholder needs and perceptions.
- Principles of DEWATs and FSM are integral to urban environmental sanitation planning.

(3) Decision makers/politicians

- Basic strategy solutions for improving the DEWATs and FS management systems.
- Documentation on awareness building regarding health hazards, the cost of not improving the current system, impacts, and environmental consequences.
- The economic aspect of improving DEWATs and FSM system and recycling.
- Standards for water quality, biosolids, and treated faecal sludge: objectives, needs, and values.
- Developing incentive structure and procedure to facilitate DEWATs and FSM system.
- Roles of municipal authorities and private entrepreneurs: Franchising, licencing, controlling, enforcement, and entrepreneurship.

(4) Private sector

- Marketing the use of end-products.
- Financial management of small to medium entrepreneurs.
- Technical guidance for treatment plant operators.
- Complementing roles of public and private partners in the management of DEWATS and FSM systems.

4.4 Planning Approach

1) Steps for Planning

Domestic Wastewater and Faecal Sludge Management functions along the service chain from containment to reuse/disposal. Several stakeholders are involved in this chain, each with their own needs and priorities. **For example, Authorities want to establish and maintain order in society and make it clean and healthy. To make domestic wastewater and FSM sustainable, all the needs and priorities shall be identified and addressed in the plan by involving all major actors.** Therefore, it is important to plan for this at an early stage.

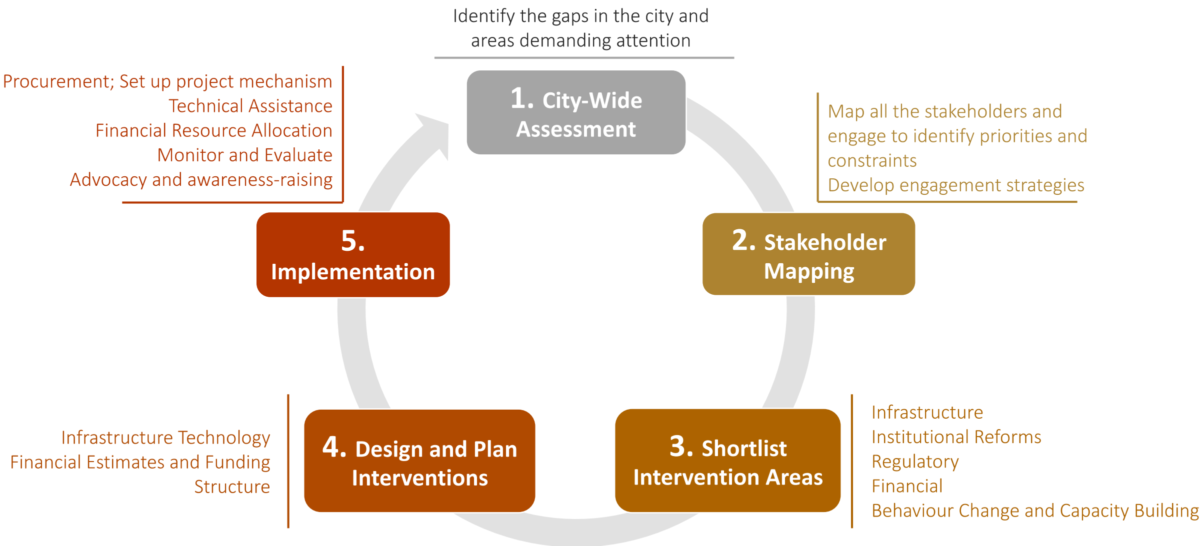

Figure 4.4-1 Steps for Planning (Source: Athena Infonomics)

2) Assessment of the Initial Situation

Assessment of the initial situation is the first step in the project cycle, provides the baseline information for decision-making, and it describes the existing service chain–how it is (shift flow diagram), and the gaps and prioritises the issues to be addressed (Situational Assessment Tool). Identifying key stakeholders and approaches to their engagement (Stakeholder Assessment Tool). **Identify regulatory and institutional framework–gaps and overlaps through City Service Delivery Assessment (CSDA). The main goals are to set the scene for the intervention, understand the context, identify key stakeholders, identify threats and other issues affecting targets, prioritise the issues to be addressed, and provide enough information.** Initial situation assessment: Different tools can be used in as many cities as possible, and planners often get stuck with where and how to start.

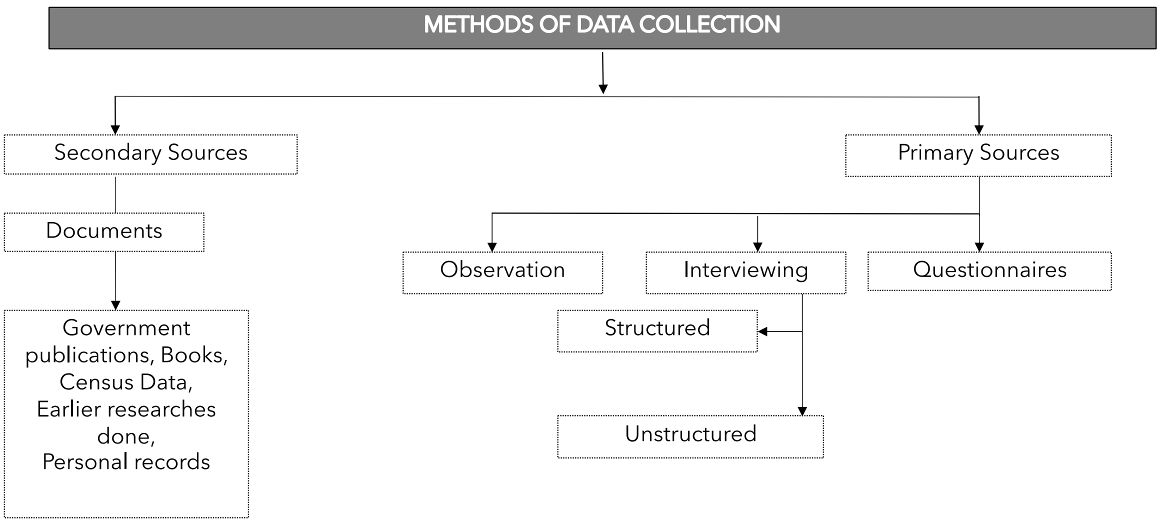

Figure 4.4-2 Assessment of the initial situation

3) Tools for Initial Situation Assessment

(1) Shit Flow Diagram (SFD)

An excreta flow diagram (or shit flow diagram, SFD) is easy to understand advocacy and decision support tool that communicates how excreta 'flows' through a city or town. The tool attempts to track down the excreta flow in a city along the sanitation service chain. Based on contributing populations, an SFD provides an indication of where their excreta go and a representation of public health hazards. The SFD provides an overview of the outcomes of existing sanitation systems, from which sanitation priorities can be identified and solutions developed. For further information, please refer to https://sfd.susana.org. **To prepare an SFD, quantitative and qualitative data from sanitation systems and governance aspects along the sanitation service chain are needed. When data is unavailable, assumptions need to be made, and how to do that is documented in the report.** An SFD can be produced at three levels (initial, intermediate, and comprehensive) depending on the purpose of the analysis, extent of data collected, extent of stakeholder engagement, and depth of data analysis.

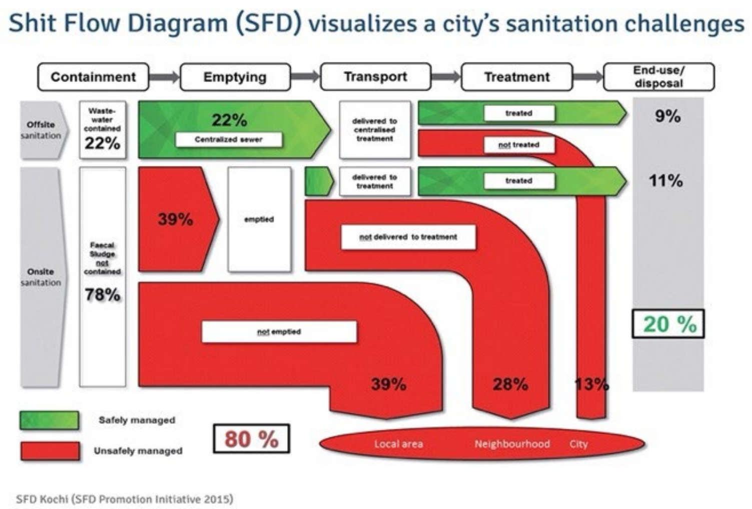

Figure 4.4-3 Example of SFD flow of Kochi, India (Roeder, 2016)

(2) Situational Assessment Tool (SAT)

A questionnaire-based tool is designed to assess the existing 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: infrastructure, regulatory, institutional, capacity, awareness, and finance and management. This tool is aimed at informed users: city planners, donors, and consultants. The tool uses radar graphs (with six aspects as their axes) and colour codes (shades of green representing good to excellent situations, shades of yellow representing below-average to above-average situations, and shades of red representing inadequate to poor situations) to present the assessment and provide users with an idea of which aspects require thorough attention/interventions **to improve the overall situation of FSM**.

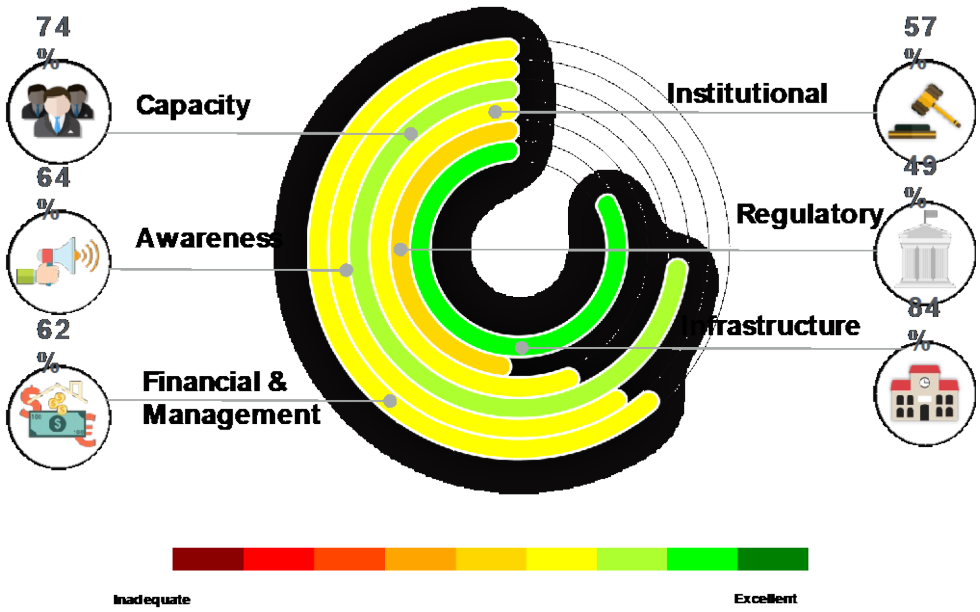

Figure 4.4-4 Example: Overall FSM Situation in Mingalar Taung Nyunt

The overall infrastructure of the township is good, with excellent coverage of containment systems and accessibility. The containment systems are frequently emptied, and the collected faecal sludge is transported to the treatment facility. The treated effluent is then used for agricultural or agro-based purposes but is limited to non-food crops only. However, 25% of unlined containment systems, an inadequate number of vehicles for transporting faecal sludge, and the unavailability of suitable and sufficient land for disposal facilities create a gap of 14% in this aspect.

4) Stakeholder Engagement and Analysis

(1) General

Stakeholder analysis identifies and characterises stakeholders, investigates their relationships, and plans for participation. This is vital for understanding a project or policy's social and institutional contexts. **The findings can provide early and essential information on who will be affected by the projects and who could influence the project (positively or negatively)–which individuals, groups, or agencies need to be involved and how and whose capacity needs to be built.**

Figure 4.4-5 Stakeholder engagement and analysis

(2) Importance of Stakeholder Engagement and Analysis

- Identify who to involve and the level of participation.
- Understand the influence and interest of stakeholders.
- Understand conflicts of interest between stakeholders.
- Identify relations between stakeholders that should be improved and strengthened.
- Understand how to deal with different people.
- Assess how to best harness the positive aspects of the informal sector and minimise its negative impacts.

(3) Tools for Stakeholder Analysis or Stakeholder Engagement Tool

Stakeholder analysis tool

Stakeholder analysis tools and a participatory stakeholder analysis approach for FSM projects can be used. This tool provides the potential lists of FSM stakeholders, the criteria, and the analytical method to categorise them based on their degree of interest and influence. Additionally, it includes a stakeholder table for documenting the stakeholders' information and the stakeholder matrix, which shows the four main categories of stakeholders based on the analysis. In addition, the tool users can get information on participation levels and communication tools for each stakeholder group. Stakeholder analysis is an iterative process that must be repeated throughout a project. **Documenting all the identified stakeholders and their information in the tool makes it easier for the project team to re-analyse and review the stakeholders' information.** The stakeholder matrix can be used as a communication tool for meetings with the project team or concerned partners. **Therefore, this tool accelerates the traditional stakeholder analysis process. For more information: https://www.fsmtoolbox.com/planning.**

Functions of Stakeholder Analysis:

- Identify the key stakeholders
- Record the lists of Stakeholders and their information
- Assessment of Stakeholder Interest and influence with multiple criteria
- Analyse the interest and influence of stakeholders
- Categorise stakeholders in the Stakeholder Matrix (based on their degree of interest and influence)
- Determining the engagement methods to get the stakeholders involved in the project

5) Regulatory and Institutional Assessment

Current situation and challenges persist indistinct FSM laws and strategies, fragmented institutional setup, focus more on Infrastructure and not on the organisational and financial aspects, institutional framework not local situation-specific, and unclear regulating and enforcing roles and responsibilities. Therefore, it is vital to have:

- **Regulatory Checklist:** Generic regulations for Household and Operators along the service chain.
- **Existing and Missing: FSM Regulations that are prevalent at present and those that are not**
- **Identify involved Organisations:** Based on the situation-specific institutional structure, prepare an Organisational Chart.
- **Delineate their roles and responsibilities:** Single out responsibilities for the identified organisations.
- **Gaps and Ov**erlaps: Analyse gaps and overlaps for recognised FSM organisations. Recommendations for further reading of singled-out gaps.
- **Suggestions of Regulations that are missing.**

Tools for Regulatory and Institutional Assessment

The City Service Delivery Assessment (CSDA) Tool

The CSDA is a complementary tool to assess why the situation is as it is, including the assessment of local-level policies, institutional readiness, and the capacity of the local government. **Moreover, it supports a systematic process for working with stakeholders to assess the enabling environment for citywide inclusive sanitation and to present the results in a simple and accessible way. Additionally, it includes an Action Checklist to help stakeholders identify and prioritise immediate and follow-up actions to improve the enabling environment for the delivery and sustained operation of inclusive sanitation services across the city.** For more information, please refer to https://incsanprac.com/tools.html.

6) The Feasibility Study

The main goal of the feasibility study is technology selection along the service chain (for example, septic tank/pit latrine/solar septic tank at the household level, manual or mechanical or combination of both for faecal sludge emptying and transport, treatment technology combination based on reuse option- either fuel or fertiliser, etc. Moreover, it helps in alternative technology selection, design, and drafting of technology, financial analysis, assessment of selected options for proposed technology and alternative technology, site selection, Geographic Information System (GIS), development of project timeframes, and operation and maintenance plans for the proposed option.

Tools for the Feasibility Study

a. Financial and Technological Assessment Tool

The Financial and Technology Assessment Tool is intended for three target user groups: City Planners/Utility Managers, Consultants, and Donors. The primary focus is collecting, transporting, and treating faecal sludge to implement the FSM project better. This tool has three main functions: baseline assessment, treatment-technology selection, and financial viability assessment. This tool lets users compare various scenarios based on technical and financial variables.

The main functions of Financial and Technology Assessment are:

- **The baseline assessment estimates the volume of faecal sludge generated from households, commercial establishments, and institutions.** This helps to determine the number of vacuum trucks required and the treatment plant's capacity.

- **The Technology assessment is based on site-specific criteria. Moreover, it provides faecal sludge treatment options, including primary, dewatering, pre-effluent, post-effluent, and sludge treatment.** The tool requires inputs from users, such as energy availability, flood-prone areas, groundwater table, limited space, the skill level of operators, capital cost, operation and maintenance cost, climate conditions, and priority for reusing treated faecal sludge. This tool offers treatment options that suit the context of an area.
- **The financial viability assessment calculates cost estimates for Capex and Opex, including cost and financing, debt, revenue, cash flow, income statement, and balance sheet.**

b. CWIS SAP Tool

The tool helps decision-makers compare the effects of different sanitation interventions or investments on sanitation services' equity, financial sustainability, and safety. The tool analyses and illustrates each possible intervention to reach low-income areas, positively impacts service providers' viability, and increases the amount of waste that can be safely disposed. This tool supports decision-making and communication regarding the interventions that should be prioritised. For more information, please refer to https://www.cwisplanning.com.

7) Integrated Planning Approach

Figure 4.4-6 Enabling Environment Source (Strande, Ronteltap, & Brdjanovic, 2014)

An enabling environment contributes to the feasibility and success of faecal sludge management. Successful sanitation projects in low-income countries are few. Failed projects are the norm rather than the exception. In most cases, this is due to a lack of integrated planning. **People often focus on the physical infrastructure, but technologies are only one part.** Common reasons for failure include implementing infrastructure without consulting key stakeholders or planning adequate operations, maintenance, and financial transfers. If an enabling environment for faecal sludge management does not exist in the first place, it must be developed as part of an integrated plan. Propose an elimination-based approach based on technology selection in the local context and interest in end-use.

4.5 Business Model Framework

1) Business Model

Various stakeholders are **involved in the DEWATS and FSM service chain** and the financial flows between them. The **stakeholder linkage and financial flow mechanism must be analysed to ensure long-term sustainability**. Possible service models are discussed in this section.

Table 4.5-1 Framework for Collection and Transportation

Issue	Description
Key Player	1. Local administrative organisations 2. Private companies (licensed and unlicensed company)
Value Proposition	1. Faecal sludge Collection service 2. Oil and grease removal/wastewater collection
Key Resources	1. Collection trucks 2. Equipment, i.e., DWM cover opening equipment 3. Human resources, i.e., municipality officers, operators (drivers, assistants, etc.)
Customer Segment	1. Households 2. Buildings 3. Industrial Estate

Table 4.5-1 Framework for Collection and Transportation (continued)

Issue	Description
Distribution Channels	1. Service area: Within the municipality/permitted areas 2. Truck parking station: Municipality or private company office 1. Daily distance: Vary by number of requests made, trip, location of the treatment plant (TP)/discharge area
Customer Relation Management	1. Find new customers: Community leader, sticker, name card, radio spot. 2. Keep current customers: Provide fast services, cleanliness, affordable prices, and regular customers with contracts. 2. Deny a few customers: 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 3. Other service fee
Revenues	4. Collection fee: Depending on the volume and faecal sludge fee rate 5. Other service fee: The service provides consideration and agreement
Core capabilities	1. Local administrative organisations: Money subsidised by the central government 2. Private company: Cost Control

Table 4.5-2 Framework for Treatment and Reuse

Issue	Treatment	Reuse
Key Player	1. Local administrative organisations 2. Private companies (licensed and unlicensed companies)	
Value Proposition	Faecal sludge Treatment	Reuse of products and by-products: Depending on the TP (dried sludge as fertiliser, liquid as plant watering, raw water for water supply production)
Key Resources	1. Treatment plants and facilities depend on the availability of land, the amount of sludge, and the budget 2. Equipment: Depends on the treatment technology 3. Human resources: Operator and labour	
Customer Segment	Collection and transportation provider (same organisation as treatment provider; different organisation from treatment provider)	Agriculture section, i.e. vegetable garden, fruit plantation, flower garden
	TP location - Within the municipality area - Nearby area - No TP/only disposal area	Reuse site - No delivery as a customer might pick up the product at TP

Table 4.5-2 Framework for Treatment and Reuse (continued)

Issue	Treatment	Reuse
Customer Relation Management	1. Find new customers: n/a (Truck and TP usually are under the same organisation. If there are available TP, collection truck will find TP on their own) 2. Keep current customers: Provide adequate capacity and low treatment fee 3. Deny a few customers: Inadequate capacity	1. Find new customers: Promote product application, quality, and safety 2. Keep current customers: Offer adequate products, cheap and good quality 3. Deny a few customers: Inadequate products/low product quality
Costs	1. Fixed costs: Investment (land and construction) 2. Variable costs: O&M costs (depending on the technology), personnel expenses, administrative costs, etc. 3. Other service fee	
Revenue	Treatment fee: In case their collection and treatment are from different organisation	1. Selling dry sludge 2. Profit from other reuse activities
Core Capabilities	Good location and appropriate treatment technology	Reuse technology and equipment

(7) The demand-based model

Households, commercial sectors, and institutions are the major drivers of this model. The service depends on user demand. The service fee is charged according to the volume of emptied faecal sludge. Because households have no uniform septic tank sizes and the government does not have any programs on FSM, the current practice of emptying is demand-based, and the fee is set in negotiations between the service provider and the household. **To make the service affordable for all and the service fee uniform, the local government shall develop the service fee to be charged by the private operators to the households.**

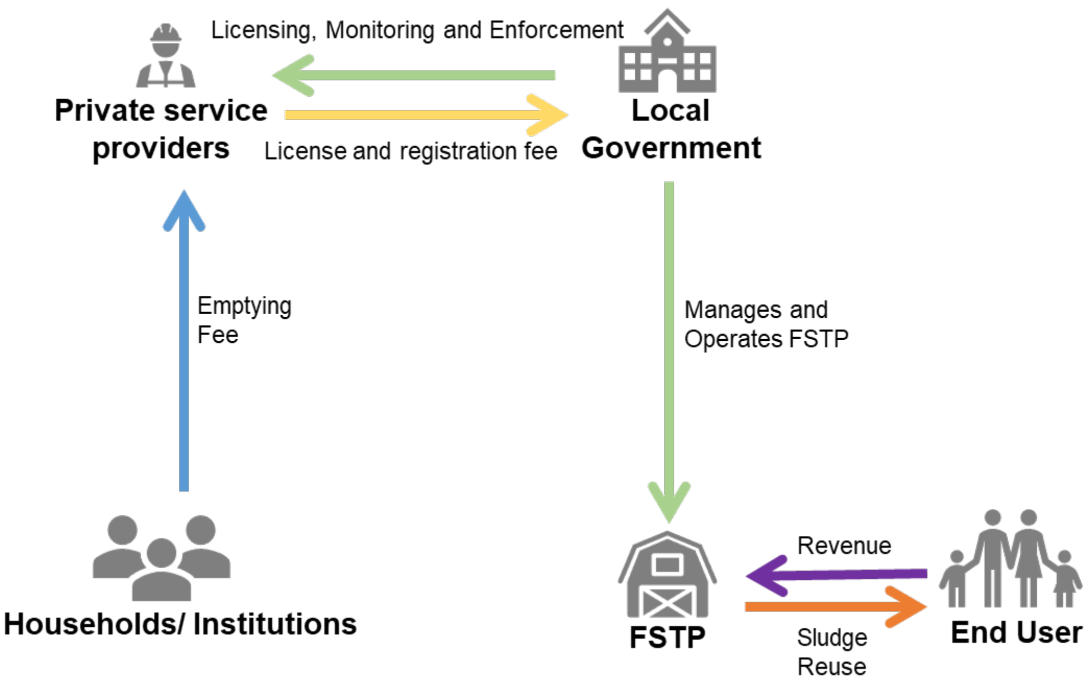

Figure 4.5-3 Financial flow through different stakeholders for demand-driven model

(8) Regularized Model

The local government drives the model, where septic tanks are regularly emptied. In this case, an additional fee, a built-in water tariff, is charged to the users, which will later be used to empty the septic rank. For example, this model was adopted in Hai Phong City in Vietnam, whereby a public Hai Phong Sewerage and Drainage Company provides scheduled desludging service. The company charges a 15% surcharge on the water bill, which will later be used to cover the expenses of emptying and transport services. The company has maintained the GIS database for households with septic tanks and plans desludging service every 5–6 years for households and 1–2 years for apartments. There should be a discussion amongst the local government to develop partnerships and financial mechanisms with the private sector. This model will only apply to households with septic tanks; separate fees will be charged to households with other containment types.

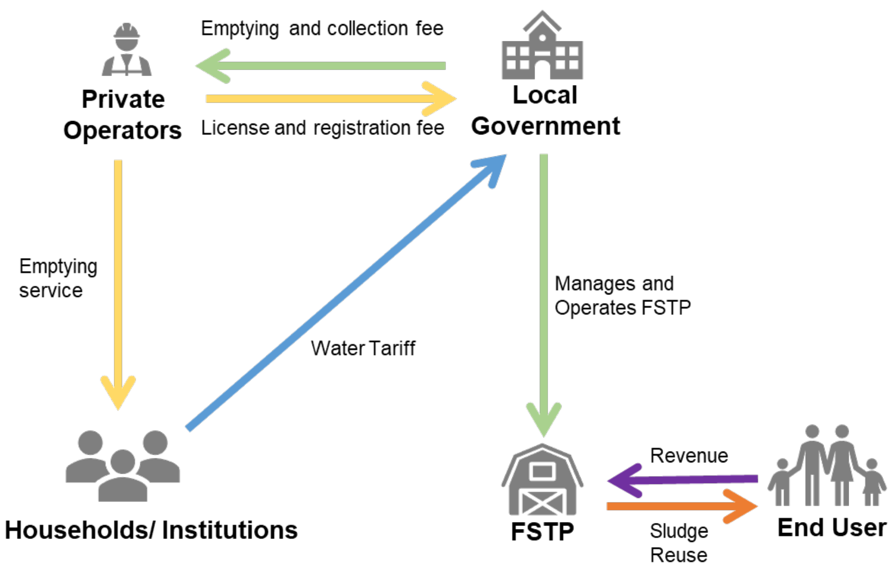

Figure 4.5-4 Financial flow through different stakeholders for regularised model

(9) Comparison of different service models for FSM

Table 4.5-3 Comparison of the service models for FSM

Service model	Pros	Cons
Regularised model - Built-in sanitation fee as a surcharge on water tariff, which can later provide the regular emptying service (e.g., every 3 years or 5 years)	- A constant source of revenue - Constant volume at the treatment facility to plan for resource recovery-based treatment (e.g., co-composting) - Avoids the overflow of the septic tank as regular emptying is carried out	- Users having a large septic tank may not be willing to participate. In 99% of the households, there is no uniform septic design and size. - Not applicable to households with soak-away tanks or cesspools
Demand-based model	- Covers different types of containment types. - The operation cost of emptying and transport are met through the service fee - The service fee is based on the volume of FS emptied at the emptying rather than the monthly surcharge on a water bill.	- Non-uniform emptying demand considering varying septic tank volumes and soak-away tanks - The treatment plant is likely to face fluctuating volumes of FS at the treatment plant considering the non-uniform demand for emptying - Irregular emptying causes the septic tanks to overflow, posing a risk to the environment and health

Combination of demand-driven and regularised model

The regularised model is only applicable to the area served by the proper septic tank. For example, adopting a regularised model to target septic tank users might produce fruitful results. **The mixed model combines demand-based and regularised models, as shown in the figure below.**

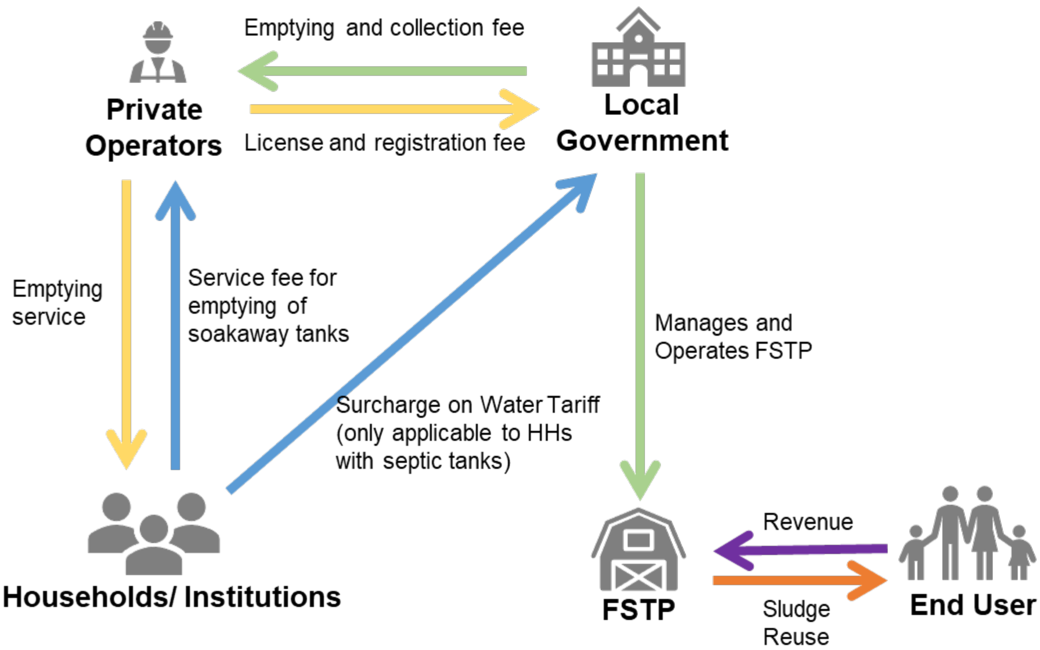

Figure 4.5-5 Financial flow through different stakeholders for regularised model

Remarks:

The analysis pointed towards adopting a demand-based model for the short-term period of five years. Regularisation and/or a combination of both can be considered when the preliminary period ends.

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ANNEX

Annex 1. Lao PDR National Environmental Standards

Table Annex 1-1 Category of Surface Water Quality

Parameter	Symbol	standard value of each category					Unit	Methodology
		1	2	3	4	5		
Color, Oder and Taste	None	n	n'	n'	n'	None	Not define	Not define
Temperature	t°C	n	n'	n'	n'	Not define	°C	Thermometer
potential of Hydrogen	pH	6-8	6-8	5-9	5-9	Not define	Not define	Electrometric pH Meter
Dissolved Oxygen	DO	>7	6.0	4.0	2.0	< 2	mg/L	Azide Modification
Electro-conductivity	Ec	< 500	≦1000	≦2000	≦4000	>4000	µS/cm	Ec meter
chemical oxygen demand	COD	<5	5-7	7-10	10-12	>12	mg/L	Potassium Dichromate Digestion; Open Reflux or Closed Reflux
Total coliform bacteria	Not define	n	5,000	20,000	Not define	Not define	MPN/ 100 ml	Multiple Tube Fermentation Technique
Fecal coliform bacteria	Not define	n	1,000	4,000	Not define	Not define	MPN/ 100 ml	Multiple Tube Fermentation Technique
Total Suspended Solid	TSS	<10	≦25	≦40	≦60	>60	mg/L	Glass Fiber Filter Disc
Phosphate	PO_4	< 0.1	0.5	1	2	>2	mg/L	Ascorbic acid
Ammonium ion	NH_4^+	< 0.5	≦1.5	≦3	≦ 4	>4	mg/L	Kjeldahl
Nitrate-Nitrogen	NO_3-N	n	5.0			Not define	mg/L	Cadmium Reduction
Ammonia-Nitrogen	NH_3–N	n	0.5			Not define	mg/L	Distillation Nesslerization
Phenol	C_6H_5OH	n	0.005			Not define	mg/L	Distillation,4-Amino antipyrene
Copper	Cu	n	1.5			Not define	mg/L	AA-Direct

Table Annex 1-1 Category of Surface Water Quality (Continued)

Nickel	Ni	n	0.1	Not define	mg/L	Aspiration
Manganese	Mn	n	1.0	Not define	mg/L	
Zinc	Zn	n	1.0	Not define	mg/L	
Cadmium	Cd	n	0.003	Not define	mg/L	
Chromium Hexavalent	Cr^{+6}	n	0.05	Not define	mg/L	
Lead	Pb	n	0.01	Not define	mg/L	
Mercury	Hg	n	0.001	Not define	mg/L	AA-Cold Vapour Technique
Asenic	As	n	0.01	Not define	mg/L	AA -Direct Aspiration, ICP
Cyanide	CN^-	n	0.07	Not define	mg/L	Pyridine-Barbituric Acid
Radioactive - alfa - beta	Radioactive -α -β	n	0.1 1.0	Not define	Becqurel/L	GC
Organochlorine pesticide		n	0.05	Not define	mg/L	
Dichlorodiphenyltrichloroethane	DDT	n	1.0	Not define	µg/L	
alpha-Benzene hexachloride	α -BHC ($C_6H_6Cl_6$)	n	0.02	Not define	µg/L	GC
Dieldrin	$C_{12}H_8Cl_6O$	n	0.1	Not define	µg/L	
Aldrin	$C_{12}H_8Cl_6$	n	0.1	Not define	µg/L	
heptachlor and heptachlor epoxide	$C_{10}H_5Cl_7$ And $C_{10}H_5Cl_7O$	n	0.2	Not define	µg/L	
Endrin	$C_{12}H_8Cl_6O$	n	Must be not found	Not define	µg/L	

Note:

Category 1 is a natural source of good quality water, does not go through any production process or chemical additives and is free from wastewater from all kinds of activities.

Category 2 is a source of water that is used and consumed but must be disinfected. This type of water is suitable for the conservation of aquatic animals, fisheries, water sports and so on.

Category 3 It is a source of water for consumption and must be sterilized, this type of water is suitable for agriculture, animal husbandry and so on.

Category 4 A source of water that is used and consumed but must be sterilized, this type of water is suitable for industry, as a place to treat wastewater from the city or community and so on.

Category 5 is a source of water that is used for transportation and be reservoir for treatment of wastewater from cities or communities, and so on.

n: Is a natural water source

n': is a natural water source but does not change ±3°C in temperature

Table Annex 1-2 Type and size of buildings that need to be controlled for water pollution

Type of building	Size				
	A	B	C	D	E
Condominium	≧500 rooms	≧100 to <500	<100 rooms	Not define	Not define
Hotel	≧ 200 rooms	≧60 to < 200 rooms	< 60 rooms	Not define	Not define
Dormitory	Not define	≧250 rooms	≧50 to <250 rooms	≧10 to <50	Not define
Massage shop (ໜor similar)	Not define	≧ 5,000 m^2	≧ 1,000 to <5,000 m^2	Not define	Not define
Hospital	≧ 30 bed	≧10 to <30	Not define	Not define	Not define
School, College, institue	≧ 25,000 m^2	5,000 to <25,000 m^2	Not define	Not define	Not define
Office	≧ 55,000 m^2	10,000 to < 55,000 m^2	≧ 5,000 to <10,000 m^2	Not define	Not define
Comercial buiilding	≧25,000 m^2	5,000 to < 25,000 m^2	Not define	Not define	Not define
Fresh market	≧2,500 m^2	1,500 to < 2,500 m^2	1,000 to < 1,500 m^2	500 to < 1,000 m^2	Not define
Resturant, food court	≧2,500 m^2	500 to < 2,500 m^2	250 to < 500 m^2	100 to < 250 m^2	ໜ້ອຍກວ່າ 100 m^2

Table Annex 1-3 Standards for control of water pollution from buildings

Parameter	Symbol	maximum value for each type					unit	Analysis method
		A	B	C	D	E		
potential of Hydrogen	pH	5.5-8.5	5.5-8.5	5.5-8.5	5.5-8.5	5.5-8.5	Not define	pH Meter
Biological Oxygen Demand 5 Days	BOD_5	20	30	40	50	60	mg/L	Azide Modification at 20 °C, 5 days
Total Suspended Solid	TSS	30	40	50	50	60	mg/L	Glass Fiber Filter Disc
Sediment Solid	SS	0.5	0.5	0.5	0.5	Not define	mg/L	Imhoff Cone 1,000 cm^3 1hour
Total Dissolved Solid	TDS	500	500	500	500	Not define	mg/L	Dry Evaporation 103-105 °C, 1hour
Sulfide	S^{2-}	1.0	1.0	3.0	4.0	Not define	mg/L	Titration
Nitrogen	TKN	35	35	40	40	Not define	mg/L	Kjeldahor colormetric
Fat, Oil and Grease	FOG	20	20	20	20	100	mg/L	Solvent Extraction by Weight

Table Annex 1-4 Standards for water pollution control from resettlement villages

Parameter	Symbol	maximum value for each type		Unit	Analysis method
		(A) 100 to 500	(B) ≧500		
potential of Hydrogen	pH	5.5-8.5	5.5-8.5	Not define	pH Meter
Biological Oxygen Demand 5 Days	BOD_5	30	20	mg/L	Azide Modification at 20 °C , 5 days
Total Suspended Solid	TSS	40	30	mg/L	Glass Fiber Filter Disc
Sediment Solid	SS	0.5	0.5	mg/L	Imhoff Cone 1,000 cm3 1hour
Total Dissolved Solid	TDS	500	500	mg/L	Dry Evaporation 103-105 °C, 1 hour
Sulfide	S^{2-}	1.0	1.0	mg/L	Titration
Nitrogen	TKN	35	35	mg/L	Kjeldahl
Fat, Oil and Grease	FOG	20	20	mg/L	Sovent Extraction by Weight

Table Annex 1-5 Standards for controlling water pollution from toilets

Parameter	symbol	standard value	Unit	Analysis method
potential of Hydrogen	pH	6-9	Not define	pH Meter
Biological Oxygen Demand 5 Days	BOD_5	30	mg/L	Azide Modification at 20 °C , 5 days
Chemical Oxygen Demand	COD	125	mg/L	Potassium Dichromate Digestion ; Open Reflux or Closed Reflux
Total Suspended Solid	TSS	50	mg/L	Glass Fiber Filter Disc
Total Nitrogen	TKN	10	mg/L	Kjeldahl
Phenol	C_6H_5OH	2	mg/L	Distillation and Aminoantipyrine Method 4
Fat, Oil and Grease	FOG	5.0	mg/L	Solvent Extraction by Weight
Total Dissolved Solid	TDS	400	MPN/ml	Dry Evaporation 103-105 °C, 1 hour

Table Annex 1-6 Standards for controlling water pollution in public canals

Parameter	symbol	standard value	Unit	Analysis method
potential of Hydrogen	pH	5.5-8.5	Not define	pH Meter
Electro-Conductivity	Ec	2,000	µS/cm	
Total Dissolved Solid	TDS	1,300	mg/L	Dry Evaporation 103-105 °C, 1 hour
Biological Oxygen Demand 5 Days	BOD_5	30	mg/L	Azide Modification at 20ºC , 5 days
Total Suspended Solid	TSS	30	mg/L	Glass Fiber Filter Disc
Per-manganese	MnO_4^-	6.0	mg/L	Titration
Hydrogen Sulfide	H_2S	1.0	mg/L	Titration
Cyanide	CN^-	0.2	mg/L	Distilation and Pyridine Barbituric Acid
Fat, Oil and Grease	FOG	5.0	mg/L	Solvent Extraction by Weight
Formaldehyde	CH_2O	1.0	mg/L	Spectrophotometry
Phenol and Cresol	C_6H_5OH	1.0	mg/L	Distillation and Aminoantipyrine Method 4
Resident Chlorine	Cl^-	1.0	mg/L	Lodometric Method
Radioactive	Not define	must not have	mg/L	General
Color and Odor	Not define	not observed	mg/L	General
Tar	Not define	must not have	mg/L	General
Heavy metal				
Zinc	Zn	5.0	mg/L	Atomic Absorption (AA)
Chromium Hexavalent	Cr^{+6}	0.3		
Arsenic	As	0.25		
Copper	Cu	1.0	mg/L	Atomic Absorption (AA)
Mercury	Hg	0.005		
Cadmium	Cd	0.03		
Barium	Ba	1.0		
Selenium	Se	0.02		
Lead	Pb	0.1		
Nickel	Ni	0.2		
Manganese	Mn	0.5		

Annex 2. Standard for estimation of population for Johkasou design

The standard for estimating the population for Johkasou design is divided into 11 categories depending on building use and clarified further in each category. **Table Annex 2** is an example of the standards. For the installation of Johkasou, the scale of the Johkasou is calculated using several factors (e.g. total floor area, number of toilets, and capacity) according to a formula selected based on the building used in the table.

Suppose the standard value based on similar types of buildings or other documents does not correspond to the actual situation owing to usage conditions. In that case, the Johkaou population can be increased or decreased based on other information.

Table Annex 2 Estimation of the population for Johkasou of buildings (JIS A 3302: 2000) (an excerpt)

Cat.		Building use	Number of users for designing (NUD) Formula	Remarks
-	Gathering place facilities			
	A	Public assembly hall, theatre, cinema, house, and entertain	n = 0.08A	n: NUD A: Total floor area (m^2)
	B	Cycling stadium, racecourse and motorboat racecourse	n = 16C	n: NUD C: Total number of toilet stools (peace)*
	C	Stand, and gymnasium	n = 0.065A	n: NUD A: Total floor area (m^2)

* Total number of toilets: total sum of the number of toilets, urinals, and multiple-use toilets.

Annex 3. Outline of structural standards for Johkasou

Table Annex 2 Outline of Structural Standards for Johkasou (MOEJ, 2019)

Class	Type of treatment	Treatment process	Number of users for design (scale: 5, 50, 100, 200, 500, 2000, 5000)	BOD removal rate	Treatment performance: Effluent quality (mg/ℓ) BOD	COD	T-N	T-P
1	Combined domestic wastewater treatment	Separation-contact aeration process	5–50	90% or more	20 or less	—	—	—
		Anaerobic filter-contact aeration process	5–50				—	—
		Denitrification type anaerobic filter-contact aeration process	5–50				20 or less	—
4	Flush toilet wastewater treatment	Septic tank process	5–500	55% or more	120 or less	—	—	—
5		Land infiltration process	5–500	SS: 55% or more	SS: 250 or less	—	—	—
6	Combined domestic wastewater treatment	Rotating biological contactor process	50–	90% or more	20 or less	30 or less	—	—
		Contact aeration process	50–					
		Trickling filter process	500–					
		Extended aeration process	100–					
		Conventional activated sludge process	5000–					
7		Contact aeration and trickling filter process	100–	—	10 or less	15 or less	—	—
		Coagulation separation process	50–					
8		Contact aeration and activated carbon absorption process	100–	—	10 or less	10 or less	—	—
		Coagulation separation and activated carbon absorption process	50–					
9		Nitrified water recirculation type activated sludge process	50–	—	10 or less	15 or less	20 or less	1 or less
		Tertiary treatment type denitrification dephosphorization process	50–					
10		Nitrified water recirculation type activated sludge process	50–		10 or less	15 or less	15 or less	1 or less
		Tertiary treatment type denitrification dephosphorization process	50–					
11		Nitrified water recirculation type activated sludge process	50–		10 or less	15 or less	10 or less	1 or less
		Tertiary treatment type denitrification dephosphorization process	50–					

12 Emission standard under the Water Pollution Control Law	Class	COD (mg/ℓ)	SS (mg/ℓ)	n-Hex (mg/ℓ)	pH	Total coliforms (N/mℓ)
	6-11	60	70	20	5.8~8.6	3,000 or less
	6-11	45	60	20	5.8~8.6	3,000 or less
	6-11	30	50	20	5.8~8.6	3,000 or less
	7-11	15	15	20	5.8~8.6	3,000 or less
	8	10	15	20	5.8~8.6	3,000 or less