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Technical Guideline

Safely Managed On-Site Sanitation: Technological Solutions for City Dwellers and Authority 'Dhaka North City Corporation'

unicef

GWSC Global Water & Sanitation Center

UPM

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Technological Solutions for City Dwellers
and Authority 'Dhaka North City Corporation'

Prepared for:

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Abbreviations

%	Percentage
ABR	Anaerobic Baffled Reactor
AIT	Asian Institute of Technology
Al	Aluminum
AS	Activated Sludge
app.	approximately
BD	Bangladesh
BDT	Bangladesh Taka
BNBC	Bangladesh National Building Code
BOD	Biochemical Oxygen Demand
CAPEX	Capital Expenditures
CH_4	Methane
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
dB	Decibel
DNCC	Dhaka North City Corporation
EC	Electro-Coagulation
ECR	Electrochemical Reactor
Fe	Iron
FRP	Fiber-Reinforced Plastic
GHG	Greenhouse Gas
H_2	Hydrogen
H_2S	Hydrogen Sulfide
HDPE	High-Density Poly-Ethylene
incl.	including
ISO	International Organization for Standardization
kW	Kilowatt
kWh	Kilowatt-Hour
m^3	Cubic Meter
mg/L	Milligram per liter
MBBR	Moving Bed Biofilm Reactor
MBR	Membrane Bio-Reactor
NH_3	Ammonia
O&M	Operation & Maintenance
OPEX	Operational Expenditures
PM	Particulate Matter
PPE	Personal Protective Equipment
SBR	Sequencing Batch Reactor
SMOSS	Safely Managed On-Site Sanitation
TSS	Total Suspended Solids
UNICEF	United Nations Children's Fund
UPM	UPM Umwelt-Projekt-Management GmbH
UV	Ultraviolet
VOC	Volatile Organic Compounds
WHO	World Health Organization
WW	Wastewater

Rationale of the Guideline

The rapid growth of the population in Dhaka poses a significant challenge for the city authorities in ensuring the livability and quality of life for its residents. The United Nations predicts that by 2030, Dhaka will have 28 million residents, requiring the city to have a timely provision of urban facilities and services, including wastewater treatment facilities. The high concentration of people living in slum areas only adds to the challenge of providing adequate services and facilities to improve the quality of life for all residents.

Dhaka City Corporation must strategically manage the city to ensure its residents have a livable and high-quality living environment. With the rapid population growth, timely provision of urban facilities and services, including wastewater treatment facilities, is crucial for Dhaka's livability and quality of life. Combining centralized and decentralized approaches may strengthen service delivery and allows the government and private sectors to consent on solutions and investment approaches.

A safely managed on-site sanitation (SMOSS) compliance assessment was carried out between June and December 2022 specifically for the areas of Gulshan-Banani-Baridhara-Nekaton (Cluster 1) in the Dhaka North City Corporation (DNCC). In total, 3,830 holdings were visited and reviewed regarding the on-site containment and the sewer system's connection to the sewer system. The results showed that 838 holdings rely on on-site containment, of which only 41 complied with the requirements for considerable safe on-site sanitation practices. Furthermore, it is to be considered that of the 1,241 holdings that are connected to the sewerage network, the majority are not connected to an actual treatment plant. This means that a large percentage of blackwater ends up in the environment posing a threat to public health.

Common practices for on-site containment systems are latrine pits and septic tanks. The Bangladesh National Building Code (BNBC) provides technical guidance on the construction of septic tanks, but the results of the SMOSS indicate that construction did not follow the requirements that would guarantee safely managed systems.

While latrine pits and septic tanks may currently be the most common on-site containment systems in Dhaka, various alternatives exist and are offered locally. These alternatives come in different treatment capacities, technology principles and treatment efficiencies. A guideline is necessary to raise awareness of the other options that citizens have and to promote understanding of these different technologies.

INTRODUCTION

Objective

UNICEF Bangladesh has commissioned the Asian Institute of Technology (AIT) in Thailand, partnering with Umwelt-Projekt-Management GmbH (UPM), to perform the "Safely Managed On-site Sanitation (SMOSS): Technological Solutions for City Dwellers and Authority 'Dhaka North City Corporation (DNCC)'" study. The overall objective of the assignment is to have a feasible on-site sanitation technological solution to guide citizens and city authorities to adopt the appropriate solution to improve safely managed sanitation at the DNCC area by 2023.

Part of this solution and an important assignment result is a technical guideline that will guide citizens to manage on-site sanitation at source / containment. This guideline will facilitate an easy overview of available, reliable, and suitable on-site containment systems besides the common latrine pits and septic tanks. It allows citizens and authorities to understand the different technologies, make essential comparisons, and decide which system is suitable for their holding.

INTRODUCTION

Intended Users

In general, this technical guideline is informative for any citizen in Dhaka, as sanitation is an important topic and a current challenge impacting everyone. More specifically, this guideline is relevant for holding owners or persons who need or intend to select an on-site containment system for a holding. In this sense, it is suitable for new holdings that have no containment system yet and where a direct connection to the sewer system is not possible, as well as for holdings that have a containment system, but where this system is not working properly or where an improved solution is desired or required to provide safe containment and treatment to a certain extent.

The guideline is further intended as a basis for authorities that provide building permits for onsite sanitation systems. It enables these authorities to assess the different onsite sanitation options and deduce requirements for applicants.

INTRODUCTION

Content of the Guideline

The technical guideline focuses on on-site containment systems available in DNCC and can be considered reliable technologies. While the guideline presents an overview of the 12 different on-site containment options, it is by no means a basis for the construction or replication of the systems by companies, nor an operation manual for operators responsible for the system's maintenance.

Furthermore, the document can be considered an evolving list with more on-site containment/ treatment systems to be added once available on the Dhaka market. The list contains systems identified during the market study. Further systems may be available on the market and should be added to the list once identified.

The guideline does not favor a system but intends to provide an objective overview. The 12 on-site sanitation systems included in the guideline are divided into two major categories: 1) Partial Solutions, and 2) Single Integrated Systems. For sustainable on-site sanitation practices, single integrated systems are recommended and should be the choice of holding owners that cannot connect to the sewerage network.

The main contents of the guideline are:

- Rapid assessment table with all available on-site solutions and their essential characteristics,
- Containment factsheet for each on-site solution with an explanation for different characteristics.

Recommendations for the Promotion of the Guideline

The effective promotion of this guideline involves a strategic approach to ensure that the intended users are aware of, understand and adopt the guideline. The following measures are recommended for an effective promotion:

- Certification of On-Site Sanitation Systems: A standard certification process should be implemented to certify products that are manufactured or/and offered in Dhaka. Ideally, the certification is done by relevant building authorities. Manufacturers and service providers could approach the authority and allow their system to be certified. It is also an option for all manufacturers and service providers to certify their systems according to ISO 31800:2020 (Faecal Sludge Treatment Units). In a future version of this guideline, only certified systems should be included.

- Guideline Application for New Holdings: Building permissions should be granted only if a reliable on-site sanitation concept is provided for new holdings that cannot be connected to the sewerage network. Especially for partial on-site containment/treatment solutions, adequate effluent post-treatment measures need to be proposed. The guideline should be shared with the builder to provide an overview of available —and ideally certified— solutions.

- Guideline Application for Existing Holdings: For existing holdings that are not connected to the sewerage network and have an inadequate on-site sanitation system (e.g. inaccessible septic tank, septic tank connected to drainage, etc.), a deadline should be set by the relevant authorities to improve or renew their system. The guideline should be shared with the holding owner to provide an overview of available —and ideally certified— solutions.

- Training for Building/Permitting Authorities: The authorities should be trained on the contents of the guideline. The training will raise awareness and develop an understanding of the different available on-site containment / treatment solutions.

In addition to the guideline that guides implementation, it is important that implemented on-site sanitation systems are officially validated and accepted. Holding owners should receive certificates from the manufacturer / contractor / service provider confirming successful initial testing and reliable functioning.

It is also important to update the Bangladesh National Building Code (BNBC) to create a more sustainable sanitation sector. Firstly, it should be extended to not only focus on septic tanks but promote more sustainable on-site sanitation practices suitable for the urban environment, such as single integrated systems.

The rationale of the Table

The rapid assessment table presents 12 on-site sanitation containment and treatment systems identified throughout a market study during which companies that offer their services and products on the Dhaka market were interviewed. The table provides fast and simple insights into the different systems that facilitate a rapid assessment and comparison of suitability based on the citizen's preferences.

The different systems have a reference number (C1 to C12) referring to the factsheets.

Categorization

The 12 on-site containment systems are divided into two categories according to the output/ effluent quality:

1. Partial Solutions: Containment / treatment systems that realize the partial treatment of black- and greywater. Effluent will require post-treatment before safe release into the environment or needs to be discharged into the sewerage network.

2. Single Integrated Systems: Containment / treatment systems incorporating multiple treatment processes within a single unit or system. Black- and greywater is effectively and efficiently treated, resulting in recycled water that can be reused on-site or safely discharged into the environment.

All the criteria listed used to compare the systems are in the left column. These criteria reappear in the factsheets with explanations and justifications.

Overview

The first criterium is an overview providing essential information on input, output, output quality, and capacities for each containment / treatment tech- nology. Input is wastewater that can be divided into blackwater and greywater:

● Blackwater refers to wastewater that originates from toilets, kitchen sinks, and dishwashers. It contains human waste, toilet paper, and organic matter from food waste. Blackwater is highly contaminated and can carry pathogens, harmful bacteria, and other potential health hazards.

● Greywater refers to wastewater from sources other than toilets, such as showers, bathtubs, bathroom sinks, and washing machines. It does not include human waste and is typically less contaminated than blackwater. Greywater may contain some traces of soap, detergents, and minor organic matter.

The output is for all systems effluent and sludge:

● Effluent refers to the treated or untreated wastewater discharged from a wastewater treatment plant or on-site treatment system. The quality of effluent varies depending on the treatment processes applied, and it needs to meet specific environmental standards before being discharged into receiving bodies of water or reused for specific purposes.

● Sludge refers to the semi-solid or solid byproduct that results from the treatment of wastewater during various treatment processes. It contains the solid materials that settle out or are removed during wastewater treatment, including suspended solids, organic matter, and microorganisms. Sludge may also include the excess biomass accumulating in biological treatment systems like activated sludge or moving bed biofilm reactor (MBBR). Sludge can be generated in primary treatment processes (e.g., sedimentation) and secondary treatment processes (e.g., biological treatment).

The rapid assessment table focuses especially on effluent quality. The effluent quality refers to the characteristics and pollution level of the effluent. In this sense, it is an indicator for the effectiveness of the system and the safe release of effluent into the environment. The rapid assessment table only provides information on the pathogen level in the effluent. In addition, the factsheets include information on Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS):

Pathogens are microorganisms, such as bacteria, viruses, protozoa, and parasites, that can cause human, animal, or plant diseases. In the context of wastewater, pathogens are often present in untreated or partially treated wastewater and can pose significant health risks if discharged into the environment

or used for irrigation or other purposes without proper treatment.

BOD is a measure of the amount of dissolved oxygen consumed by microorganisms while breaking down organic matter in wastewater. It provides an indication of the level of biodegradable organic compounds present in the water. BOD is commonly used to assess the organic pollution strength of wastewater and the potential impact it can have on receiving water bodies.

COD is a measure of the total quantity of organic compounds in wastewater that a potent chemical oxidizing agent can oxidize. It is used to estimate the amount of organic pollutants present in the water. High COD levels in wastewater indicate a higher concentration of biodegradable and non-biodegradable organic compounds, which require oxygen during degradation.

TSS refers to the total concentration of solid particles suspended in wastewater that do not settle under quiescent conditions. It includes both organic and inorganic particles. TSS is an important parameter in wastewater analysis, as it can affect water clarity and light penetration and can carry adsorbed pollutants, nutrients, and pathogens.

Suitability

The second criterium is suitability which shall indicate to the guideline user to what extent the system is appropriate in each context. It includes the suitability for different holding types, classifies space requirements and technical complexity, and indicates if the system can be installed underground or aboveground.

The six holding types are based on the Bangladesh Building Code: residential, educational, institutional, healthcare, business, and industrial. Regarding sanitation, the wastewater of these holdings can be classified as domestic or industrial. Domestic sewage is black- and greywater discharged from various household activities, such as toilet flushing, bathing, washing dishes, laundry, and general cleaning. In comparison, industrial wastewater can contain a broader range of pollutants, such as heavy metals, toxic chemicals, and higher concentrations of specific contaminants. In this sense, especially healthcare and industrial holdings generate industrial wastewater.

Space requirements and technical complexity are classified as low, medium and high. For space requirement, the following definitions are used for these relative descriptors:

Low space requirement: The system can be accommodated within a relatively small footprint. The system is compact and takes up minimal land area, making it suitable for installations where space is limited.

Medium space requirement: The system requires a moderate amount of physical space. It has a slightly larger footprint compared to low space requirement systems.

High space requirement: The system is usually larger and more extensive.

The space requirement is a rough indication. The companies offer different solutions and are in many cases able to provide customized systems considering given space availability.

For technical complexity, the following definitions are used for the relative descriptors:

Low technical complexity: The system, such as the septic tank, is simple, easy to understand, and implement. It requires minimal expertise and specialized knowledge to operate and maintain. The system does not require any mechanical components and no electricity.

Medium technical complexity: The system may require more expertise and specialized knowledge. It can involve multiple components, interconnections, and interactions that require careful design and coordination. The system may include mechanical parts and require electricity.

High technical complexity: The system is highly intricate and requires specialized knowledge for design, implementation, operation,

and maintenance. The system may have several process steps and mechan- ical components, require electricity, and demand regular and trained operation and maintenance.

Planning

The third criterium is planning. These criteria review water tightness or the risk of water leakage in the system. Furthermore, it determines if electricity is required to operate the system.

Operation & Maintenance

The fourth criterium is Operation and Maintenance (O&M) requirements. Relative descriptors are used to determine the needs and are defined as follows:

Low requirements: The system is relatively simple and requires minimal effort to operate and maintain. It has minimal intervention, usually limited to desludging. The routine maintenance tasks are infrequent and do not demand specialized expertise.

Medium requirements: The system requires periodic inspections, routine maintenance, and possibly occasional adjustments to ensure proper functioning. The procedures are reasonably manageable but may demand personnel with specific technical skills or knowledge.

High requirements: The system is complex and demands expertise for its operation and maintenance. It may require frequent monitoring and regular maintenance. A variety of tasks may need to be carried out. A high risk of failure, if not adequately managed, exists.

Investment Cost

The fifth criterium is investment costs: Relative descriptors are used to determine the costs. The factsheets include more specific cost indications based on the feedback from companies.

Certification for Bangladesh

The last and sixth criterium is the certification for Bangladesh. An official and standardized certification for on-site sanitation systems needs to be present in Bangladesh. In the case of the three systems indicating certification, the basis is a recommendation letter that certifies the operation of the system by the Department of Environment. This criterium becomes relevant if a standardized certification procedure for on-site sanitation systems is implemented in Bangladesh.

ON-SITE SANITATION SYSTEMS RAPID ASSESSMENT TABLE

Available On-Site Containment Systems

			Partial Solutions							Single Integrated Systems				
			Conventional Septic Tank	Prefabricated Septic Tank	Anaerobic Baffled Reactor (ABR)	Sequencing Batch Reactor (SBR)	Membrane Bio-Reactor (MBR)	Moving Bed Biofilm Reactor (MBBR)	Electrochemical Reactor (ECR)	Biopipe System	Johkasou Tank	NEWgenerator	Aquonic	R3H20
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Overview	Input	Blackwater	●	●	●	●	●	●	●	●	●	●	●	●
		Greywater	○	○	○	○	○	○	○	○	○	○	○	○
	Output	Effluent	⁂	⁂	⁂	**	**	**	⁂	*	*	*	*	*
	Capacity m^3/day	Minimum	2	1	2	2	1	5	0.5	1	5	1	0.6	0.5
		Maximum	75	10	200	300	6,000	300	200	1,000	100	20	1	50
Suitability	Holding Type	Residential	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
		Educational	🕮	🕮	🕮	🕮	🕮	🕮	🕮	🕮	🕮	🕮	🕮	🕮
		Institutional	🏛	🏛	🏛	🏛	🏛	🏛	🏛	🏛	🏛	🏛	🏛	🏛
		Healthcare				⊕	⊕	⊕	⊕					⊕
		Business	💼	💼	💼	💼	💼	💼	💼	💼	💼	💼	💼	💼
		Industrial				🏭	🏭	🏭	🏭					🏭
	Space Requirement		═	─	≡	═	≡	═	═	─	═	═	─	─
	Tech Complexity		─	─	═	═	≡	═	≡	═	≡	≡	≡	≡
	Cons-truction	Aboveground		▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬
		Underground	▬	▬	▬	▬	▬	▬			▬			▬
Planning	Watertightness			💧	💧	💧	💧	💧	💧	💧	💧	💧	💧	💧
	Electricity					⚡	⚡	⚡	⚡	⚡	⚡	⚡	⚡	⚡
O&M Requirements			─	─	─	═	≡	≡	≡	─	═	≡	═	≡
Investment Costs			─	─	─	═	≡	≡	≡	═	═	≡	≡	≡
Certified for Bangladesh							▭	▭	▭					

LEGEND:

- ● Blackwater
- ○ Greywater
- ● Effluent
- * Free of Pathogens
- ** Low % of Pathogens
- ⁂ High % of Pathogens
- ⌂ Residential
- 🕮 Educational
- 🏛 Institutional
- ⊕ Healthcare
- 💼 Business
- 🏭 Industrial
- ─ Low
- ═ Medium
- ≡ High
- ▬ Aboveground
- ▬ Underground
- 💧 Watertight
- ⚡ Uses Electricity
- ▭ Certified for BD

Partial Solutions

Conventional Septic Tank

C1

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge ● Biogas	
Capacities (m^3/day)	**Min** 2	**Max** 75
Output Quality	⁂ **High % of Pathogens**	
	Effluent quality (mg/L) 100 – 300 BOD 200 – 600 COD 100 – 300 TSS	
	Removal efficiencies (%) 50 – 70 BOD 25 – 50 COD 50 – 70 TSS	
Important Requirements	• Accessibility for desludging services. • Post-treatment for effluent.	

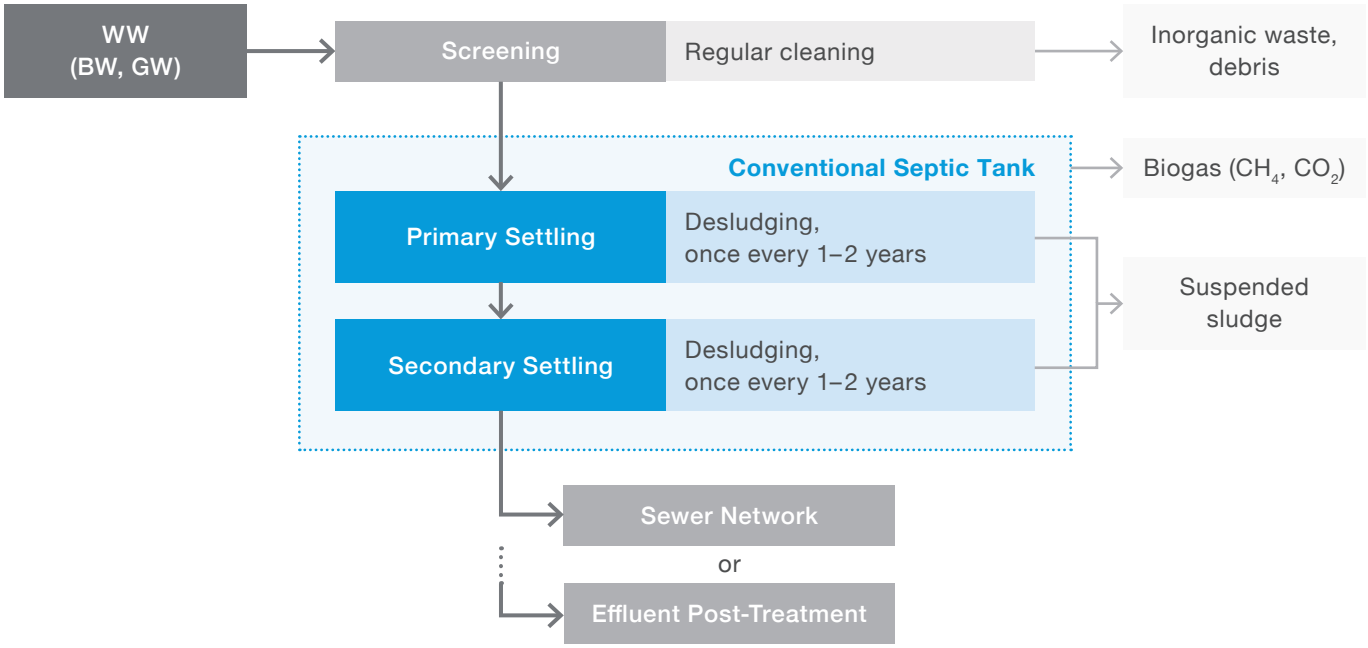
Visualization

FIGURE 01: Two-chamber septic tank during construction.
Source: Healthabitat.

Technical Description

- A conventional septic tank is an on-site system to contain and treat wastewater.
- It consists of an underground tank, typically made of concrete, with two chambers. In Bangladesh, the Bangladesh National Building Code (BNBC) should be followed for construction.
- The purpose of the septic tank is to separate solid waste from liquid waste and break down organic matter over time. Wastewater is either introduced into the tank through gravity or with the help of a pump, depending on its location.
- The treatment steps can be described as follows:
  - Primary settling: The first chamber acts as the primary settling chamber. Heavier solids settle to the bottom, while lighter materials like grease and oils float to the top, forming a layer of scum. This chamber retains the settled solids and scum, preventing them from moving into the next stage.
  - Secondary settling: The partially clarified wastewater flows into the second chamber through a baffle or a tee arrangement. The second chamber serves as a secondary settling chamber allowing further settling of any remaining solids.
  - Post-treatment: The clarified liquid, known as effluent, exits the septic tank through an outlet pipe which directs it to an appropriate post-treatment system (e.g. soak pit or systems proposed in the following factsheets).

Flowchart



Suitability

Holding Type

- The system is suitable for residential, educational, institutional, and business holdings. However, it cannot handle wastewater containing hazardous chemicals (e.g. paints, waste oils, pesticides, antibiotic drugs) that can harm the beneficial bacteria involved in the biological digestion process.
- The system is not suitable for holdings that experience frequent inflow variations (caused e.g. by excessive water consumption practices, gatherings and parties) and high-strength wastewater (e.g. from industrial processes, improper disposal of chemicals or non-biodegradable substances).

Space Requirement

- The space required for the system depends on factors like holding size, number of occupants or users, system design and local regulations (specifically the Bangladesh National Building Code (BNBC)).
- Overall, septic tanks are considered medium-sized systems.

Technical Complexity

- Septic tanks are relatively low in terms of technical complexity. They have no moving parts, mixing, consumables, etc.
- They provide basic treatment for wastewater with relatively low O&M requirements. However, the treatment efficiency is limited, and the effluent of septic tanks is still contaminated. Therefore, additional post-treatment or connection to a sewer system is necessary.

Construction

- The conventional septic tank is typically installed underground. It is important not to permanently place heavy objects on top of the septic tank and keep maintenance holes accessible.
- The system should be located at an appropriate distance from water sources.
- The system needs to be kept accessible to carry out desludging services.

Planning, Design and Implementation Considerations

General Considerations

- Some important design considerations according to the BNBC are:
  - A one-chamber septic tank is possible for small-sized tanks (≤3,000 liters or 3m³).
  - The minimum capacity of the septic tank is 2,000 liters (8 to 9 users)[1].
  - Dimensions: minimum width 1m, minimum liquid depth 1m, minimum length should be at least thrice its width (maximum 4 times its width).
  - Maximum capacity for septic tanks as residential holdings: app. 75,000 liters (300 users).
- The instructions in the BNBC should be followed by any selected civil engineering or construction company.
- The conventional septic tank is made of concrete and bricks with a set of pipes, including an inlet sanitary 'T' fitting used as an opening for the waste to enter the tank and one outlet 'T'.
- The walls, built with bricks or reinforced concrete, should be 23cm thick. The foundation floor made of cement concrete should have a thickness of 15cm. Both outer and inner wall faces, and the floor top are plastered with 12mm thick cement mortar 1:3 mix.
- Since the system may produce a certain amount of gases, venting systems are essential to allow a safe release from the tank. Ideally, the GHG is captured and either burnt or used to prevent release into the atmosphere.

Effluent Post-treatment

- The effluent of septic tanks is still contaminated and the. It therefore requires a proper connection to the sewer system or post-treatment of the effluent before releasing it into the environment.
- A variety of options for post-treatment exist. Septic tanks can be combined with other containment/treatment systems presented in the following factsheets.
- Post-treatment method needs to be chosen according to site specific factors, including soil conditions, space availability and groundwater protection considerations.

Watertightness

- Conventional septic tanks have a higher risk of not being completely watertight. They are designed to be watertight, but poor construction practices or design flaws can lead to issues with leakage or seepage. Common mistakes include inadequate sealing of joints, cracks or damage of the structure, and improper installation or backfilling around the tank.

Electricity

- Septic tanks do typically not require electricity. Electricity may be required in relation to septic tanks, e.g. if wastewater is pumped into the system.

Operation & Maintenance Requirements

- O&M requirements for septic tanks generally can be considered to be relatively low. The simplicity of the design contributes to ease of operation and maintenance.
- To maintain smooth operation, it is important to avoid disposing of any waste that may cause clogging or build-up in the tank. In such cases, the tank will need to be pumped out.
- Regular inspections are necessary to ensure the proper functioning of the tank and to detect any leaks or contamination. It is also important to inspect and validate the ventilation system for proper operation.
- The scum layer in the tank should be removed every 3 or 4 months to prevent it from taking up valuable tank volume.
- Regular desludging of the tank is required, ideally at least once every 2 years, to remove accumulated solids and maintain its effectiveness.

[1] Assuming 1 day retention time, 0.162 m³/person wastewater inflow per day, desludging every 2 years.

- When opening the tank for desludging or cleaning, caution must be exercised due to the gases produced. Open flames or fire should be strictly avoided.

Health Aspects

- When designed and operated properly, conventional septic tanks pose minimal health risks. Nonetheless, potential risks are:
  - Contamination of water sources: Improperly designed, installed or maintained, there could be a leak causing contamination of the groundwater. Commonly, effluent does not receive proper post-treatment causing contamination.
  - Exposure to pathogens: Effluent, sludge and scum contain pathogens and need therefore handled with care. During desludging or any maintenance, workers need to be equipped with personal protective equipment.
  - Inhalation of sewer gas: The biological process produces noxious and flammable gases including methane and hydrogen sulfide, that get released when the tank is opened. The system needs to be opened with care and any fire source (incl. cigarettes) needs to be forbidden around the system. Also, prolonged exposure to high levels of sewer gas due to improper ventilation or malfunction, can cause respiratory problems, dizziness and nausea.

Costs

- Investment costs for septic tanks can be considered — low compared to other onsite containment and treatment systems.
- Investment costs depend on site specific conditions and capacities of the system. CAPEX can be assumed with app. 10,000 – 50,000 BDT / m^3 treatment capacity.
- Main O&M costs arise for desludging services that should take place every second year.

Sustainability

- Septic tanks may be considered partially sustainable, also depending on design, maintenance and the overall context of their use. They provide basic primary treatment for domestic wastewater that prevents the direct release of untreated wastewater into the environment.
- Effluent cannot directly be discharged into waterbodies or soil but requires further treatment or adequate discharge into the sewer system.
- The system creates an anaerobic environment that results in the production of biogas (methane and carbon dioxide). These GHG contribute to climate change. The amount of emissions generated will depend on the retention time, tank design and wastewater characteristics.

Benefits and Limitations

Benefits

+ Low investment costs.
+ Low O&M costs.
+ Low O&M requirements.
+ Low technical complexity.

Limitations

– Very limited treatment of effluent. Post-treatment for effluent is essential.
– Produced biogas is usually not captured and released into atmosphere. Contribution to GHG emissions.
– Increased risk of groundwater contamination. Regular leakage checks are necessary.
– Regular desludging required.
– Limited resistance to shock loads.

Manufacturer / Service Provider

Conventional septic tanks can be implemented by experienced civil engineering companies focusing on wastewater treatment or on-site faecal sludge treatment. BNBC instructions should be followed.

Partial Solutions

Prefabricated Septic Tank

C2

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge ● Biogas	
Capacities (m^3/day)	**Min** 1	**Max** 10
	Single module	
Output Quality	⁂ **High % of Pathogens**	
	Effluent quality (mg/L) 100 – 300 BOD 200 – 600 COD 100 – 300 TSS	
	Removal efficiencies (%) 50 – 70 BOD 25 – 50 COD 50 – 70 TSS	
Important Requirements	• Accessibility for desludging services. • Post-treatment for effluent.	

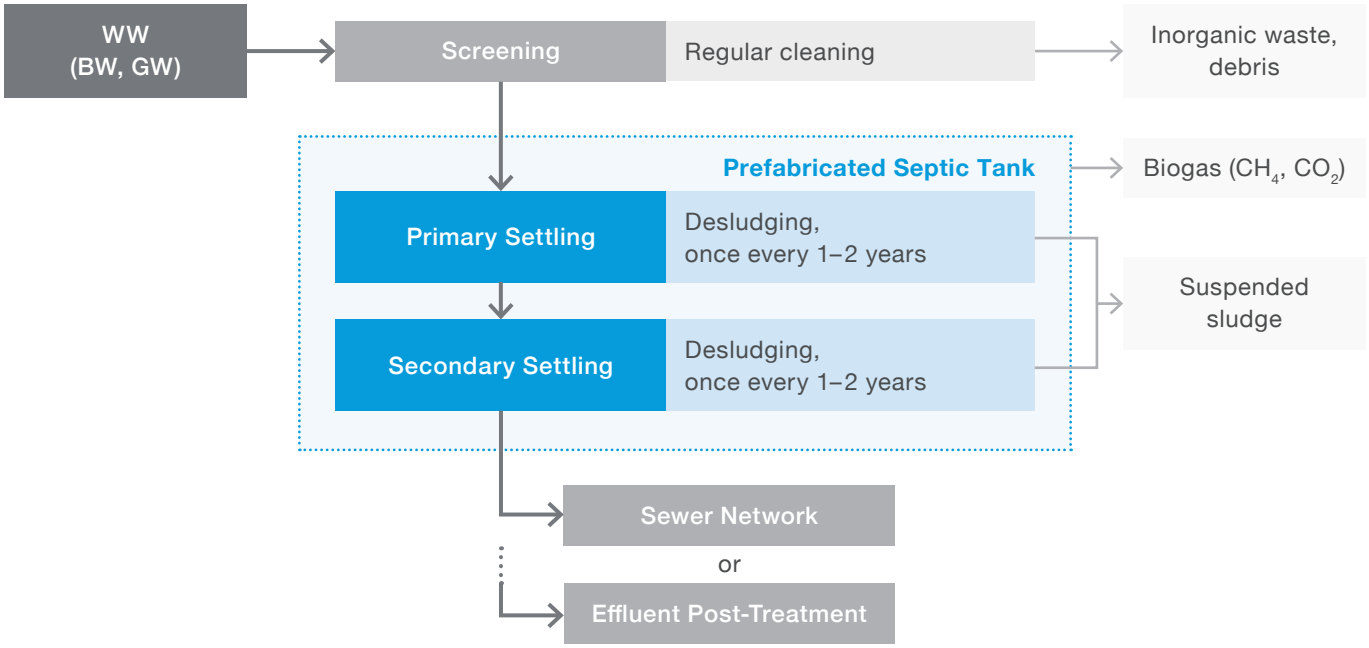
Visualization

FIGURE 02: Prefabricated septic tank during underground installation.
Source: Bowen's Septic Tank.

Technical Description

- Prefabricated septic tanks are watertight chambers made of precast concrete, fiberglass, PVC or plastic. The tank provides primary treatment for blackwater and greywater, similar to conventional septic tanks.
- The wastewater flows into a tank where a baffle or T-shaped pipe slows and directs the water downwards. The wastewater is retained in the tank for a day or more, enabling the formation of three distinct layers: scum, liquid and sludge.
  - The scum or floating layer is the top layer consisting of greases, oils, fats that are lighter than water.
  - The liquid layer is the middle layer consisting of water, dissolved materials and small amounts of suspended solids.
  - The sludge or sedimentation layer is the bottom layer consisting of solids that are heavier than water.
- The liquid leaves the tank as effluent, while scum and sludge remain. Naturally occurring bacteria in the wastewater break down the layers. Organic matter is broken down anaerobically, producing gases.
- Prefabricated septic tanks are well-established and available products, offered by many companies in Bangladesh.

Flowchart



Suitability

Holding Type

- The system is suitable for residential, educational, institutional, and business holdings. It is not suitable for wastewater containing hazardous chemicals (e.g. paints, waste oils, pesticides, antibiotic drugs) that can destroy bacteria needed for the biological digestion process taking place.
- The system is not suitable for holdings that produce regular shock loads, including inflow variations (caused e.g. by excessive water consumption practices, gatherings and parties) and high-strength wastewater (e.g. from industrial processes, improper disposal of chemicals or non-biodegradable substances).

Space Requirement

- The system is suitable in locations where space is limited, uniform septic tanks may be required in large numbers and where labor is more expensive. Single prefabricated septic tanks can be considered low-sized systems.

Technical Complexity

- Septic tanks are relatively simple in terms of technical complexity. They have no moving parts, mixing, consumables, etc.
- They provide basic treatment for wastewater with relatively low O&M requirements. However, the treatment efficiency is limited, and the effluent of septic tanks is still contaminated. Therefore, additional post-treatment or connection to a sewer system is necessary.

Construction

- Prefabricated septic tanks can be installed aboveground or underground.
- The system, although leak proof, is not suitable for areas with high groundwater level or flood-prone areas. High water level can cause floating of the system and can destroy the plumbing system as well as the tank itself.
- The system should be located at an appropriate distance from water sources.
- The system needs to be kept accessible to carry out desludging services.

Planning, Design and Implementation Considerations

General Considerations

- Plastic tanks are not sturdy as cement and can be crushed by the weight of heavy soil or vehicles driving over the places where they are installed. In case the system is installed underground, the area above the system should be kept free and accessible.
- For the installation in loose or water-logged soil, or flood-prone areas, a foundation and installation shell are required to prevent the moving and floating of the system. Alternatively, the placement aboveground may be more suitable.
- In case the system is installed aboveground, a solid foundation needs to be provided.
- The system produces gases that should ideally be captured. If not captured, the tank requires a ventilation pipe from the tank to above the roof level of the surrounding building(s) to guarantee safe release.

Effluent Post-treatment

- The effluent of septic tanks is still contaminated and therefore requires either a proper connection to the sewer system or post-treatment of the effluent prior to discharge into the environment.
- A variety of options for post-treatment exist. Septic tanks can be combined with other containment/treatment systems presented in the following factsheets.
- Post-treatment method needs to be chosen according to site specific factors, including soil conditions, space availability and groundwater protection considerations.

Watertightness

- Prefabricated septic tanks are typically made of materials such as fiberglass, plastic or concrete, which are designed to be watertight. The tanks are constructed using molds or precast techniques, allowing precise manufacturing and minimizing the chances of structural defects or weak joints that could lead to leakage. Overall, these systems are characterized by reliable and consistent quality, contributing to better water tightness and reduced risk of leakage compared to conventional septic tanks.

Electricity

- Prefabricated septic tanks do typically not require electricity. Electricity may be required in relation to septic tanks, e.g. if wastewater is pumped into the system.

Operation & Maintenance Requirements

- O&M requirements for septic tanks generally can be considered to be relatively low. The simplicity of the design contributes to ease of operation and maintenance.
- To maintain smooth operation, it is important to avoid disposing of any waste that may cause clogging or build-up in the tank. In such cases, the tank will need to be pumped out.
- Regular inspections are necessary to ensure the proper functioning of the tank and to detect any leaks or contamination. It is also important to inspect and validate the ventilation system for proper operation.
- The scum layer in the tank should be removed every 3 or 4 months to prevent it from taking up valuable tank volume.
- Regular desludging of the tank is required, ideally at least once every 2 years, to remove accumulated solids and maintain its effectiveness.
- When opening the tank for desludging or cleaning, caution must be exercised due to the gases produced. Open flames or fire should be strictly avoided.

Health Aspects

- When designed and operated properly, prefabricated septic tanks pose minimal health risks. Nonetheless, potential risks are:
  - Exposure to pathogens: Effluent, sludge and scum contain pathogens and need therefore handled with care. During desludging, workers need to be equipped with personal protective equipment.
  - Inhalation of sewer gas: The biological process taking place inside the system produces noxious and flammable gases including methane and hydrogen sulfide, that get released when the tank is opened. The system needs to be opened with care and any fire source (incl. cigarettes) needs to be avoided around the system. Also, prolonged exposure to high levels of sewer gas due to improper ventilation or malfunction, can cause respiratory problems, dizziness and nausea.

Costs

- Investment costs for prefabricated septic tanks can be considered — low, but usually higher than conventional septic tanks due to durable material choices such as HDPE or fiberglass.
- The investment costs vary depending on the system design, capacity, material and site-specific conditions. It can be estimated with costs between 15,000 and 30,000 BDT/ m^3 containment volume.
- The O&M costs for the system are relatively low since the containment system does not require electricity or additives for functioning. Costs for regular desludging need to be considered.

Sustainability

- Septic tanks may be considered partially sustainable, also depending on design, maintenance and the overall context of their use. They provide basic primary treatment for domestic wastewater that prevents the direct release of untreated wastewater into the environment.
- Effluent cannot directly be discharged into waterbodies or soil but requires further treatment or adequate discharge into the sewer system.
- The system creates an anaerobic environment that results in the production of biogas (methane and carbon dioxide). These GHG contribute to climate change. The amount of emissions generated will depend on the retention time, tank design and wastewater characteristics.

Benefits and Limitations

Benefits

+ Low investment costs.
+ Low O&M costs.
+ Low O&M requirements.
+ Low technical complexity.
+ Fast and standardized installation.
+ Leak proof as single shell design.

Limitations

– Relatively high sensitivity to coarse solids.
– Limited resistance to shock loads.
– Requires additional foundation and installation shell for loose soils and flood-prone areas.
– Requires regular desludging.
– Very limited treatment of effluent. Post-treatment for effluent is essential.
– Produced biogas is usually not captured and released into atmosphere. Contribution to GHG emissions.

Manufacturer / Service Provider

Prefabricated septic tanks can be implemented by experienced civil engineering companies focusing on wastewater treatment or on-site faecal sludge treatment.

Partial Solutions

Anaerobic Baffled Reactor (ABR)

C3

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge ● Biogas	
Capacities (m^3/day)	**Min** 2	**Max** 200
Output Quality	⁂ **High % of Pathogens**	
	Effluent quality (mg/L) 10 – 50 BOD 50 – 100 COD 20 – 50 TSS	
	Removal efficiencies (%) 70 – 95 BOD 65 – 90 COD 80 – 90 TSS	
Important Requirements	• Accessibility for desludging services. • Post-treatment for effluent.	

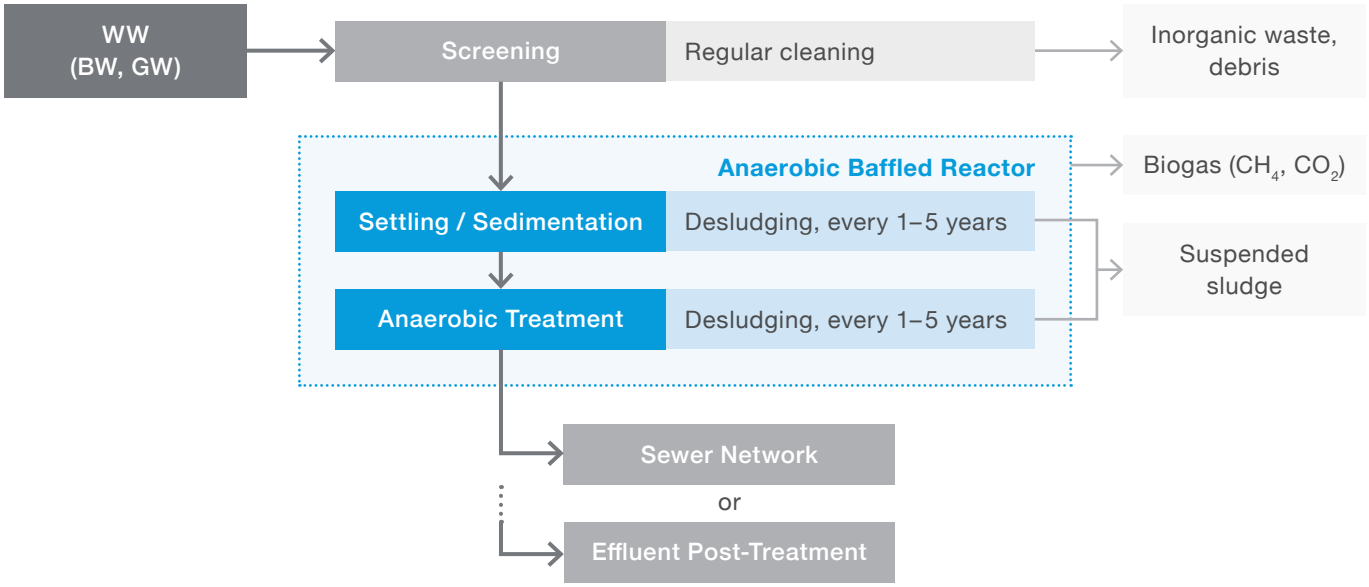
Visualization

FIGURE 03: Installed ABR with manholes for each of the 6 chambers.
Source: Gates Open Research, UPM, Anaerobic Baffled Reactor (ABR) Design Considerations for Faecal Sludge.

Technical Description

- Anaerobic Baffled Reactors are improved versions of septic tanks due to the addition of baffles/physical barriers which create a series of compartments within the system.
- The system can be constructed on-site or installed with prefabricated modules made of fiber-reinforced plastic. ABR systems are available on the market in Bangladesh for several years. Usually, the system is not prefabricated, but requires civil construction on site.
- The main treatment steps are:
  - Screening: Before entering the system, the wastewater should undergo screening to remove coarse material such as debris and inorganics that could damage the system and equipment.
  - Sedimentation: The wastewater will flow into a settler or sedimentation chamber. A septic tank or biogas system may also be used as a settler. During hydraulic retention times (HRT) of less than 3 hours, suspensible solids will settle at the bottom of the chamber.
  - Anaerobic Treatment: The wastewater continues to flow through the baffles, passing 4 to 6 chambers, alternating in upward and downward flows, which increases the contact time between the wastewater and the residual sludge, which builds up with time and contains microorganisms that anaerobically digest organic pollutants.

Flowchart



Suitability

Holding Type

- The system is suitable for residential, educational, institutional, and business holdings. It is not suitable for wastewater containing hazardous chemicals that can destroy bacteria needed for the biological digestion process taking place.
- The system is not suitable for holdings that produce shock loads including inflow variations (caused e.g. by excessive water consumption practices, gatherings and parties) and high-strength wastewater (e.g. from industrial processes, improper disposal of chemicals or non-biodegradable substances). It does not effectively work with batch feeding but requires a more constant and smooth inflow.

Space Requirement

- Due to a more complex system design compared to septic tanks, ABRs require more space. They can therefore be considered larger-sized systems.

Technical Complexity

- ABRs are moderately complex from a technical standpoint. While normally not requiring electricity for operation or including any mechanical parts, ABRs require expertise in designing for optimal flow patterns, hydraulic retention time and compartment configurations.

Construction

- ABRs are commonly installed underground. In case of prefabricated units, an installation aboveground may be possible as well.
- Heavy objects should not be permanently placed on top of ABRs. Manholes should be kept accessible.
- ABRs are not recommended for flood-prone areas or areas with high groundwater. Prefabricated versions may be installed aboveground or underground with consideration of foundation and installation shell.
- The system should be located at an appropriate distance from water sources.
- The system needs to be kept accessible to carry out desludging services.

Planning, Design and Implementation Considerations

General Considerations

- Anaerobic Baffled Reactors include a sedimentation chamber. While in smaller systems, this compartment may be integrated, larger systems can also consider a separate settler.
- Each compartment needs to have an opening for maintenance.
- ABRs have 4 to 6 chambers with consideration of max. 6kg BOD/m^3/day and optimal retention times between 16 and 20 hours. The length of a compartment should be less than 50 – 60% of the height.
- ABRs have a start-up period of several months (3 to 6 months) to reach full treatment capacity. The start-up period can be reduced by adding anaerobic bacteria / inoculum (e.g. cow manure or sludge from a septic tank).
- For the installation in loose or water-logged soil, or flood-prone areas, a foundation and installation shell is required to prevent moving and floating of the system. Alternatively, the placement aboveground may be more suitable.
- In case the system is installed aboveground, a solid foundation needs to be provided.
- The system produces gases that should ideally be captured. If not captured, the tank requires a ventilation pipe from the tank to above the roof level of the surrounding building(s) to guarantee safe release.

Effluent Post-treatment

- Although better treatment efficiencies than septic tanks, the effluent of ABRs is still contaminated and therefore requires either a proper connection to the sewer system or post-treatment of the effluent prior discharge into the environment.
- A variety of options for post-treatment exist. ABRs can be combined with other containment/treatment systems presented in the following factsheets.
- Post-treatment method needs to be chosen according to site specific factors, including soil conditions, space availability and groundwater protection considerations.

Watertightness

- ABRs have a low risk of water leakage as they are usually constructed using reinforced concrete or other sturdy materials. Therefore, they can be considered as watertight.
- ABRs are designed to be more durable and suitable for anaerobic treatment. They follow stricter engineering and construction standards as septic tanks.
- To minimize the risk of leakage, it is important to have ABRs designed and constructed by professional and experienced companies.

Electricity

- ABRs usually do not require electrical energy. Only more advanced ABRs may include pumps, blowers or control systems that require electricity for operation.

Operation & Maintenance Requirements

- O&M requirements for ABR systems can be considered to be relatively low due to passive operation and limited mechanical components.
- For a smooth operation, users should be instructed to avoid disposal of waste or harsh chemicals into the system.
- If screening is in place for the inflow, the screen should be regularly cleaned. Due to contamination, cleaning should only take place with adequate personal protective equipment (PPE) such as gloves, mask, googles.
- Regular desludging is required, although less frequent compared to septic tanks. Depending on the dimensions of the system and the daily inflow, desludging may be required every 1 to 5 years. The sludge level should be monitored. Too much accumulation of sludge reduces the effectiveness of the baffles and the HRT of the wastewater.

- During desludging, it should be ensured that some sludge remains in the system, so that the bacteria environment remains intact, and no re-start-up period needs to be considered.
- If gas collection and utilization is foreseen, regular maintenance and monitoring of the gas collection infrastructure is important.
- If the system includes pumps, blowers, valves or other control systems, these need to be regularly inspected and cleaned according to manufacturer recommendations.
- If the system includes pumps, blowers, valves or other control systems, these need to be regularly inspected and cleaned according to manufacturer recommendations.

Health Aspects

- When designed and operated properly, ABRs pose minimal health risks. Nonetheless, potential risks are:
  - Contamination of water sources: Improperly designed, installed or maintained, there could be a leak causing contamination of the groundwater. Systems implemented by conventional on-site construction have an increased risk for leakage. Furthermore, if effluent does not receive proper post-treatment, it will cause contamination.
  - Exposure to pathogens: Effluent, sludge and scum contain pathogens and need therefore handled with care. During desludging or any maintenance, workers need to be equipped with personal protective equipment.
  - Inhalation of sewer gas: The biological process produces noxious and flammable gases including methane and hydrogen sulfide, that get released when the tank is opened. The system needs to be opened with care and any fire source (incl. cigarettes) need to be forbidden around the system. Also, prolonged exposure to high levels of sewer gas due to improper ventilation or malfunction, can cause respiratory problems, dizziness and nausea.

Costs

- The investment costs of ABR systems can be considered — low compared to other onsite treatment systems, although more expensive than septic tanks.
- The investment costs vary depending on system capacity, design specifications and site conditions. Between 34,000 – 35,000 BDT/m^3/day[1] treatment capacity can be assumed.
  - 10 m^3/day treatment capacity → 340,000 – 350,000 BDT.
- The O&M costs for the system are relatively low since the system does not require electricity or additives for functioning. Costs for desludging need to be considered.

Sustainability

- ABRs may be considered partially sustainable, assuming proper system design, operation and maintenance. They provide basic primary treatment for domestic wastewater that prevents the direct release of untreated wastewater into the environment.
- Although better treatment efficiencies than septic tanks, effluent cannot directly be discharged into waterbodies or soil, but requires further treatment or adequate discharge into the sewer system.
- The system creates an anaerobic environment that results in the production of biogas (methane and carbon dioxide). These GHG contribute to climate change. The amount of emissions generated will depend on the retention time, system design and wastewater characteristics.
- Opportunities of ABRs are:
  - Energy efficiency: ABR does not require electricity and produces biogas as a byproduct that can be captured and used as a renewable energy source.
  - Sludge reduction: The anaerobic process leads to reduced amounts of sludge since organic matter is converted into biogas and stabilized sludge.

[1] Based on https://octopus.solidarites.org/2019-06-anaerobic-baffled-reactor

Benefits and Limitations

Benefits

+ Low technical complexity.
+ No electricity required.
+ Low operating costs.
+ Compared to septic tanks, lower sludge production; lower desludging frequency.
+ Relatively low investment costs.

Limitations

– Long start-up period.
– Limited treatment of effluent. Post-treatment for effluent is essential.
– Produced biogas is usually not captured and released into atmosphere. Contribution to GHG emissions.
– Not suitable for inflow variations/batch feeding.
– No clear design guideline in Bangladesh available.

Manufacturer / Service Provider

• ABR systems can be implemented by experienced civil engineering companies focusing on wastewater treatment or on-site faecal sludge treatment.

Partial Solutions

Sequencing Batch Reactor (SBR)

C4

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge	
Capacities (m^3/day)	**Min** 2	**Max** 300
Output Quality	** **Low % of Pathogens**	
	Effluent quality (mg/L) 10 – 50 BOD 10 – 50 COD 10 – 50 TSS	
	Removal efficiencies (%) 90 – 98 BOD 80 – 95 COD 90 – 98 TSS	
Important Requirements	• Electricity supply. • Wastewater holding tank (e.g. adjusted septic tank) prior SBR, if no holding chamber is integrated. • Accessibility for desludging services. • Post-treatment for effluent.	

Visualization

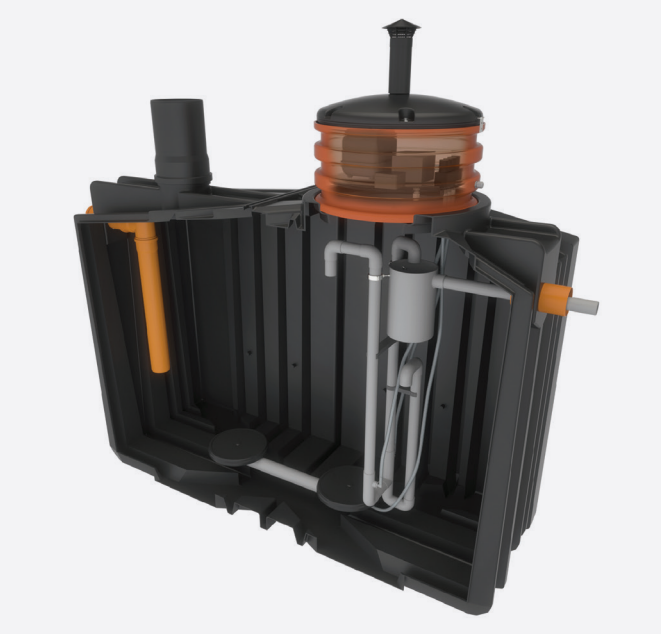
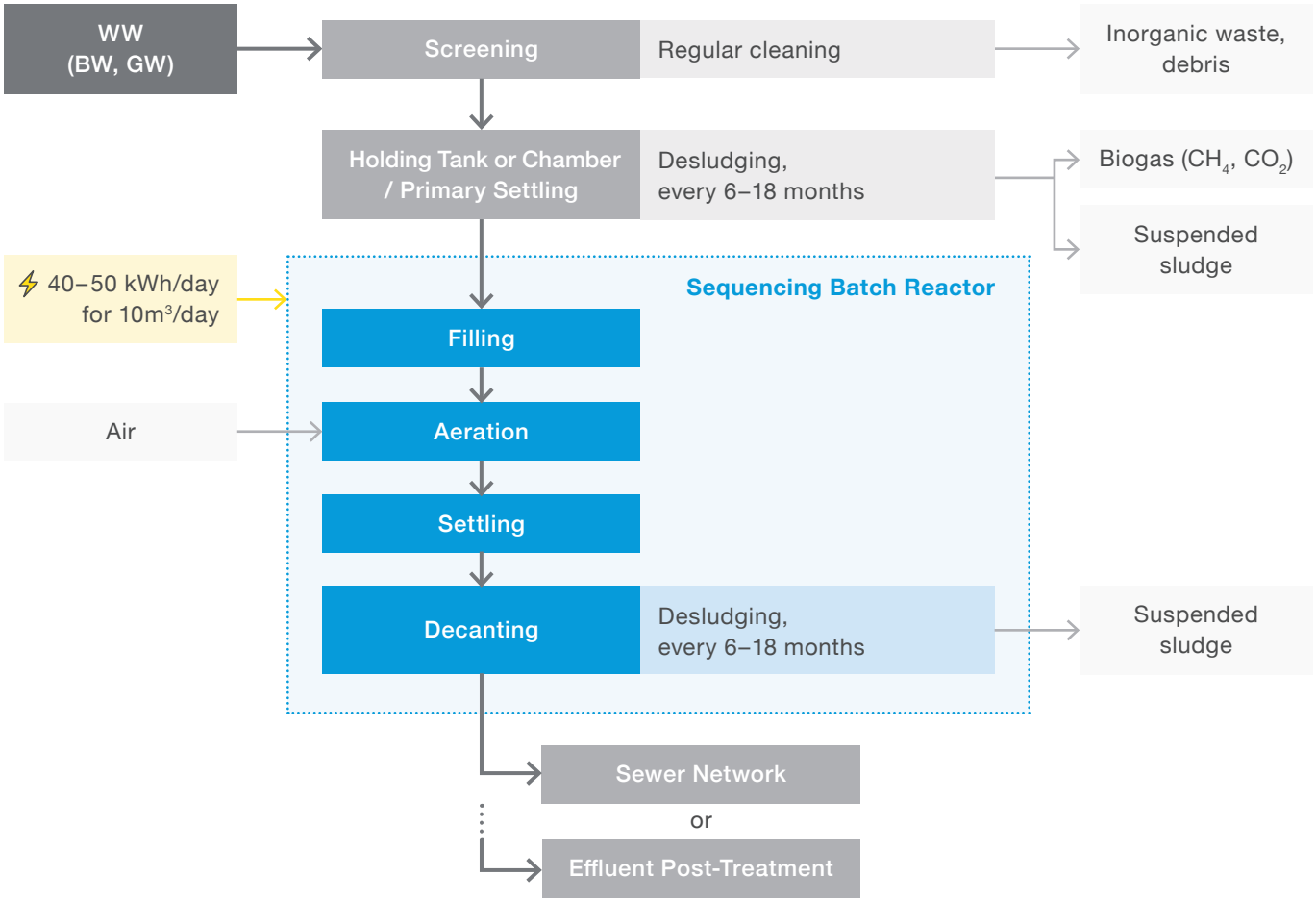


FIGURE 04: Prefabricated One-Chamber SBR system.
Source: Catalog of Technical Options for FSM in Bangladesh, IWMI.

Technical Description

- The Sequencing Batch Reactor (SBR) is a wastewater treatment system that operates in batch mode and carries different treatment stages out sequentially in a single reactor tank.
- While the conventional SBR system operates in batch mode, there are also continuous-flow SBR systems available. This requires reactors with several compartments or zones. Continuous-flow SBR are technically more complex and require advanced control strategies.
- The main treatment steps for a conventional batch-mode SBR are:
  - Screening and Storing: The wastewater (WW) are screened to remove debris, inorganics, excessive oil and grease, and flows into the WW holding tank, either for settling or equalization.
  - Filling: The reactor will be filled with WW until it reaches its operational maximum.
  - Aeration: Air will be injected through a blower enabling biological degradation of organic matter by microorganisms, nitrification and denitrification.
  - Settling: After the air injection is stopped, the WW can rest. Solids and biomass will settle to the bottom of the tank due to gravity. This allows the separation between treated effluent from biomass.
  - Decanting: Once settling is completed, the clarified effluent is withdrawn from the tank, leaving the settled solids behind.
  - Sludge Removal: The settled sludge is maintained in the reactor to keep an adequate population of microorganisms. Sludge will build up. Therefore, the system will require periodical desludging.

Flowchart



Suitability

Holding Type

- Generally, SBR systems are suitable for residential, educational, institutional, healthcare, business and industrial holdings. Nonetheless, wastewater characteristics need to be analyzed in detail, especially in regard to industrial wastewater, to confirm effective treatment.
- SBR systems are relatively good at handling shock loads including inflow variations and variations in wastewater characteristics. This is due to the batch-mode design that allows the adjustment of treatment cycles, e.g. extended aeration phase and increased biomass retention time. These variations will also demand more monitoring and involvement of the operator. If frequent shock loads are expected, additional design considerations may be advised.

Space Requirement

- SBRs can be considered medium-sized systems. Due to a modular design and sequential operation, SBR systems have usually a compact footprint. They have a larger footprint than septic tanks but require less space than ABRs.
- The WW holding tank adds to the overall space requirements of the system.
- Compact one-chamber SBR systems may be available but require very careful operation. Entry of debris or trash needs to be avoided, as well as as shock loads. Therefore, the combination with WW holding tank is recommended.

Technical Complexity

- SBRs are moderately complex from a technical standpoint. SBRs require specialized components such as an aeration system with a precise control system for sequencing and coordination of various treatment phases.
- Compared to more advanced treatment technologies, SBRs are simpler.

Construction

- Aboveground and underground installations are possible. Underground may be suitable in case of limited space or due to aesthetics considerations. Aboveground is recommended in case of high-water table or poor soil conditions.
- Since desludging is required, the access for desludging services needs to be ensured.

Planning, Design and Implementation Considerations

General Considerations

- SBR systems are available in two forms: custom-built systems and prefabricated versions. Prefabricated SBR systems are suitable for small- or medium-sized applications, while custom-built systems can be done for small-, medium- and large-scale installations.
- Preliminary treatment, such as screening to remove grit, debris, plastics, excessive oil or grease, and scum is necessary.
- A wastewater holding tank is required as part of the pretreatment. The tank either serves as a settling tank or/and as equalization tank. The choice depends on WW characteristics, design considerations, etc.
- Compact prefabricated SBR systems, if available, may integrate a holding chamber.
- Appropriate pumps and aerators should be selected, and it is advisable to have spare pumps and aerators on-site for quick repairs if needed.
- SBR systems can produce odorous compounds (H_2S, NH_3, VOCs), especially during the aeration phase. Proper ventilation and odor control technologies like biofilters or activated carbon filters can be installed to mitigate odors and minimize their impact.

Effluent Post-treatment

- Although relatively good treatment efficiencies, the effluent of SBRs is still contaminated and therefore requires either a proper connection to the sewer system or post-treatment of the effluent prior discharge into the environment.
- A variety of options for post-treatment exist. Common post-treatment options for SBR systems include disinfection, such as chlorination or UV disinfection, or filtration.
- Post-treatment method needs to be chosen according to site specific factors, including soil conditions, space availability and groundwater protection considerations.

Watertightness

- SBRs have a low risk of water leakage as they are usually constructed using reinforced concrete or other sturdy materials. Therefore, they can be considered as watertight.
- SBRs operate usually in a sequenced batch mode, where the various treatment phases are carefully controlled. The controlled operation helps maintain the integrity of the system.
- To keep a minimal risk of leakage, it is important to have SBRs designed and implemented by professional and experienced companies.

Electricity

- The SBR system requires electricity for the aeration system, mixing and control systems. E.g., for a SBR system with 10 m^3 volume, the treatment of one batch (10 m^3) may require 9 kWh to 11 kWh. Several batches can be realized in one day. E.g., for 4 batches in one day, the electricity consumption varies between 40 kWh to 44 kWh.

Operation & Maintenance Requirements

- O&M requirements for SBR systems can be considered to be moderate with a few mechanical components that require regular inspection, maintenance and occasional replacement.
- On a regular basis (e.g. daily, weekly, bi-weekly), the screening unit needs to be inspected. Debris needs to be removed and properly disposed, and the unit needs to be cleaned. The frequency will depend on WW characteristics (e.g. lots of oil and grease contents) and user habits (e.g. disposal of trash).
- Regular desludging of the system needs to take place. Desludging frequencies vary between 6 to 18 months.
- A control system is in place to monitor inflow, cycle time, aeration rate and hydraulic retention time. Treatment parameters can be adjusted to make the system effective for different types of wastewater or in case the characteristics of wastewater change. These parameter adjustments are done by trained personnel.
- After-sales service vary between manufacturers/service providers. One year warranty may be provided for equipment related aspects, while technical service is provided for unlimited time[1].

Health Aspects

- When designed and operated properly, SBRs pose minimal health risks. Potential risks are:
  - Exposure to pathogens: Effluent and sludge contain pathogens and need therefore handled with care. During desludging or any maintenance, workers need to be equipped with personal protective equipment (PPE).
  - Electrical hazards: SBR system require electrical equipment for pumps, aerators and control systems. Appropriate electrical safety measures should be followed.
  - Odors and air quality: SBRs can produce odorous compounds, particularly during the aeration phase. While the odors are generally unpleasant, they can pose a health risk if exposure levels are high or prolonged.

Costs

- The investment costs for SBR systems can be considered to be in the medium range.
- The investment costs will vary on the capacity of system and site-specific factors. An estimate is:
  - 10 m^3/day treatment capacity (suitable for app. 100 users) → 1,600,000 – 2,000,000 BDT.
- The O&M costs are mainly caused by the electricity demand of the system and the regular desludging that is required.

Sustainability

- SBR system can be considered sustainable, assuming proper system design, operation and maintenance. They provide basic primary treatment for domestic wastewater that prevents the direct release of untreated wastewater into the environment.
- The system generates less methane or carbon dioxide as anaerobic treatment system, but there is a risk that greenhouse gases may be generated. Also, fine particulate matter (PM) can be generated through processes like aeration and mixing. The tank should be covered and settling processes need to be effective to avoid the release of PM.

[1] Clean Water Engineering Services.

Benefits and Limitations

Benefits

+ Efficient and compact treatment option.
+ With WW holding tank, resistant to shock-loads and inflow variations.
+ Usually fully automatized.

Limitations

– Continuous electricity supply required.
– WW holding tank required.
– Complex control system / mechanised equipment.
– Batch mode can result in variability of effluent quality.
– Effluent requires post-treatment.
– Increased desludging frequency (every 6–18 months).
– Maintenance requires trained personnel.

Manufacturer / Service Provider

- Clean Water Engineering Services: House-723, Road-11, Avenue-4, Mirpur DOHS, Dhaka, Bangladesh. Email: spaul92@gmail.com, Phone: +880 1973186153.
- Acumen Engineering Limited: Suite B2, 2nd floor, House-133, Road-4, Block-A, Banani, Dhaka, Bangladesh. Email: yousuf@acumenengineeringltd.com, Phone: 01713467422.
- Priora Water Solutions PVT Limited: Office-39&40, 5th Floor, C Wing, KK Market, Dhankwadi, Pune MH 411037, India. Email: priorawater@gmail.com, Phone: +919881593335.

Partial Solutions

Membrane Bio-Reactor (MBR)

C5

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge	
Capacities (m^3/day)	**Min** 1	**Max** 1,000
Output Quality	** **Low % of Pathogens**	
	Effluent quality (mg/L) 1 – 10 BOD 5 – 30 COD 1 – 5 TSS	
	Removal efficiencies (%) 90 – 99 BOD 90 – 99 COD 95 – 99 TSS	
Important Requirements	• Electricity supply. • Wastewater holding tank (e.g. adjusted septic tank) prior MBR, if no holding chamber is integrated. • Accessibility for desludging services. • Post-treatment for effluent.	

Visualization

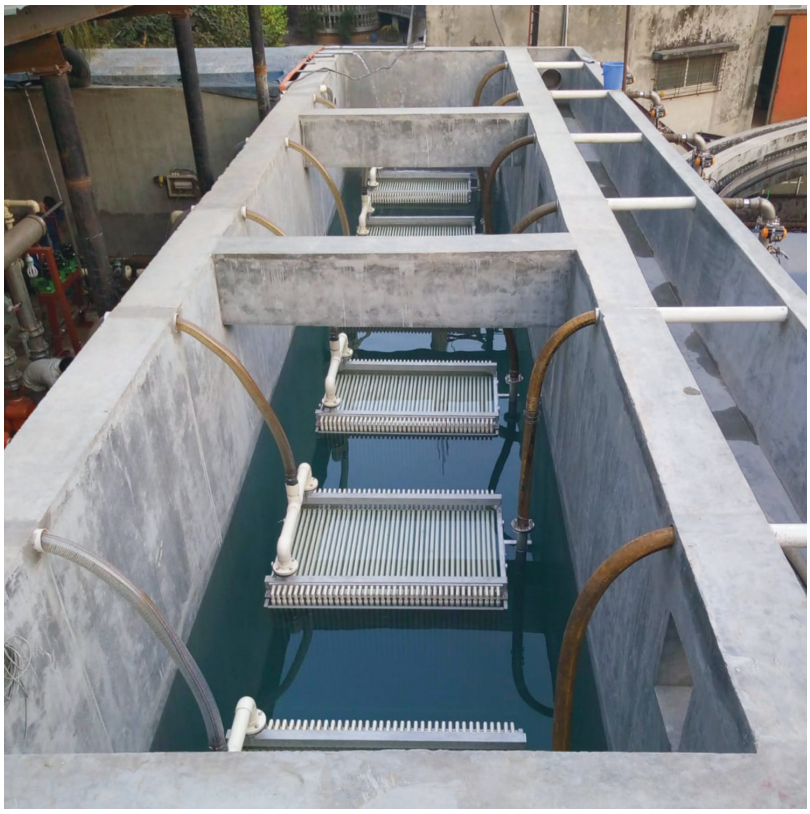
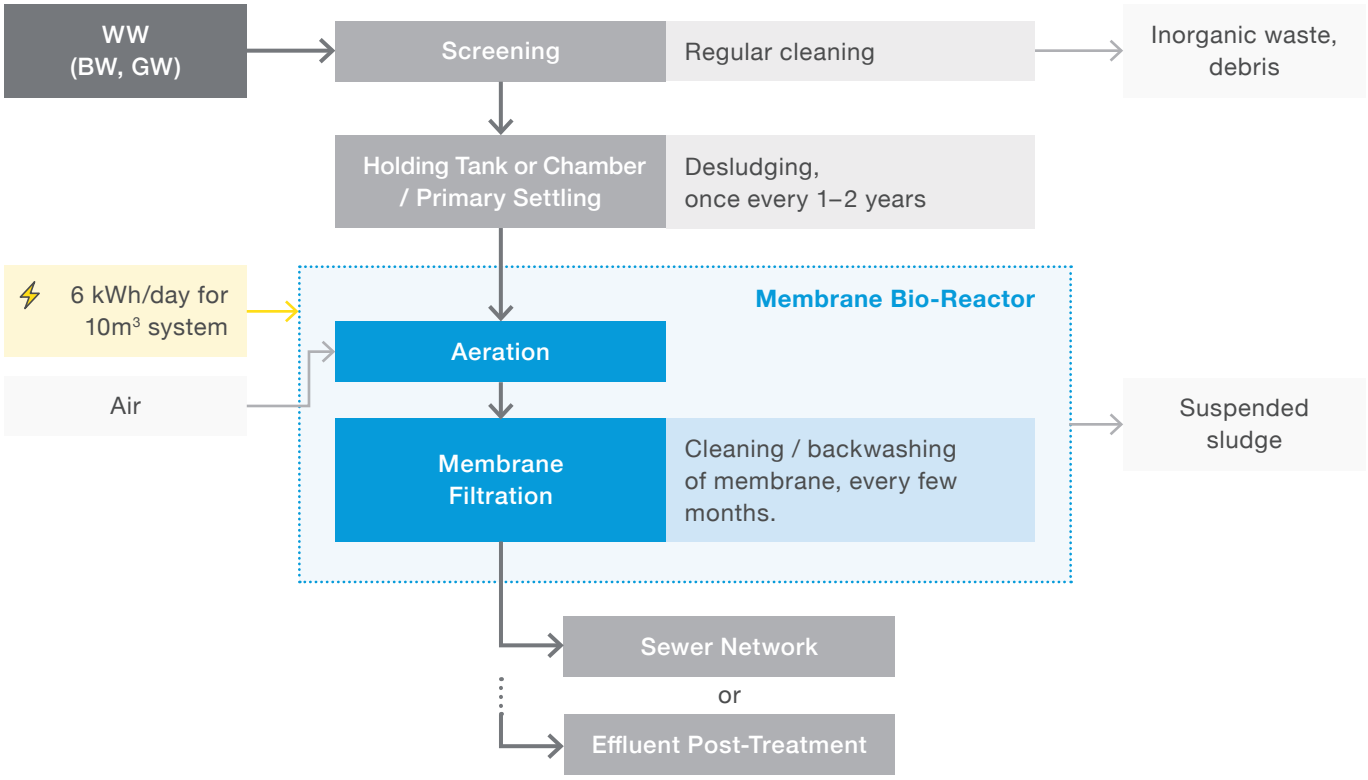


FIGURE 05: View into MBR system with membrane modules.
Source: Charm Limited.

Technical Description

- The Membrane Bioreactor (MBR) is an advanced wastewater treatment system that combines biological treatment using an activated sludge process with membrane filtration.
- Comparing all partial solutions, MBR systems can reach the highest effluent quality.
- Several companies are offering MBR systems in Dhaka, with differing features.
- The main treatment steps are:
  - Screening and storing: The wastewater (WW) are screened to remove debris, inorganics, excessive oil and grease, and flows into the WW holding tank or chamber, either for settling or equalization.
  - Aeration with activated sludge (AS): WW enters the aeration tank, where it is mixed with a microbial culture (AS) that biologically degrades organic pollutants. Microorganisms in the AS consume organic matter, transforming it into microbial biomass, carbon dioxide, and water.
  - Membrane filtration: Following aeration, the WW passes membrane modules consisting of microfiltration or ultrafiltration membranes with small pore sizes (typically between 0.1 to 0.4 microns). The membranes act as physical barriers allowing treated water to permeate while retaining suspended solids, bacteria, and other contaminants.

Flowchart



Suitability

Holding Type

- MBR systems are suitable for residential, educational, institutional, health-care, business and industrial holdings. While high treatment efficiencies can be reached, it is important in regard to industrial wastewater to characterize the wastewater and possibly add pre- or post-treatment processes to address specific contaminants.
- MBR systems are good at handling shock loads including inflow variations and variations in wastewater characteristics. The WW holding tank or chamber prior the aeration step acts as a hydraulic surge control preventing hydraulic shock or overload.

Space Requirement

- Overall, MBR systems can be considered to be large-sized systems due to space requirement for membrane modules, aeration system and associated equipment. Nonetheless, they can be designed to optimize space utilization and can be suitable for moderate space availability.

Technical Complexity

- MBRs can be considered complex from a technical standpoint. MBR systems involve complex engineering design considerations including membrane configuration, module arrangement, air sourcing mechanisms, and hydraulic optimization.

Construction

- The system can be installed aboveground or underground. For underground installation, additional engineering considerations are required, and soil conditions and groundwater levels need to be assessed to ensure stability and prevent water ingress. Further access for maintenance needs to be ensured.

Planning, Design and Implementation Considerations

General Considerations

- Pre-treatment such as screening, grit removal, equalization or advanced pre-treatment depending on the specific wastewater should be considered to prevent impacts on system performance.
- Membrane selection is essential. It will impact performance and longevity. Factors such as membrane material, pore size, fouling propensity, compatibility with wastewater characteristics are to be considered by the manufacturer.
- MBR systems are used within specific pressures, temperature and pH ranges. These aspects need to be considered by the configuration and control systems.

Effluent Post-treatment

- Although producing high-quality effluent, the effluent of MBRs may still be slightly contaminated.
- For final effluent treatment, options for MBR systems include disinfection, such as chlorination or UV disinfection, or filtration.

Watertightness

- MBR systems have generally a low risk of water leakage as they are typically designed with a focus on sealing and containment. Therefore, they can be considered as watertight.
- The membrane modules used for the MBR systems are typically enclosed within modules, preventing direct contact with the surrounding environment. This design further minimizes the risk of leakage.
- To keep a minimal risk of leakage, it is important to have MBR systems designed and implemented by professional and experienced companies.

Electricity

- MBR systems require electricity for the aeration system and the operation of membrane modules including backwashing and periodic cleaning. As reference, a MBR system with a 10 m^3 treatment capacity consumes about 6 kWh/day[1].

Operation & Maintenance Requirements

- O&M requirements for MBR systems can be considered to be high due to the membrane that requires careful maintenance.
- Regular cleaning of the membrane modules is crucial to maintain their filtration efficiency and prevent membrane fouling. Cleaning protocols may include physical cleaning (e.g. backwashing, air scouring) and chemical cleaning (e.g. use of specialized cleaning agents). The frequency and method of cleaning depend amongst other on the membrane type, fouling tendency, and operational conditions. The frequency varies between a few weeks to a few months depending on site specific conditions.
- Regular desludging or removal of excess sludge from the system is crucial to maintain system performance and minimize the potential for membrane fouling. Desludging intervals can range from a few months to a few years. Manufacturer specifications should be followed.
- Key parameters such as influent and effluent quality, membrane permeability, aeration rates, and dissolved oxygen levels need to be monitored. It may be necessary to adjust aeration rates or biomass retention time.
- Routine inspections of equipment, lubrication, calibration and replacement and repair of faulty equipment should be established.
- The operator should receive adequate training in O&M by the manufacturer/service provider or a service agreement should be established. These after-sales services are offered by the different companies.
- Companies offer up to two years of warranty as well as on-demand maintenance.

[1] Green Genesis.

Health Aspects

- There are several health-related advantages that can be reached by using MBR systems:
  - Improved water quality: The effluent poses minimal health risks when discharged into the environment and can be reused for non-potable water applications.
  - Enhanced pathogen removal: The high-quality effluent will avoid the transmission of waterborne diseases and improves public health protection.
  - Elimination of odor: no odor is produced what is beneficial for the health and well-being of workers and nearby communities.
  - Reduced public exposure: MBR systems are usually enclosed or covered, avoiding public exposure and potentially harmful substances.
- Sludge may contain pathogens and needs therefore to be handled with care. During desludging, workers need to be equipped with personal protective equipment.

Costs

- Investment costs for MBR systems can be considered relatively high due to more advanced and complex technology principles.
- Investment costs vary between companies and capacities of the system. For orientation:
  - 10 m^3/day treatment capacity → 2,000,000 BDT – 2,500,000 BDT.[1] [2]
- General O&M costs include desludging services and electricity for the operation of the system.
  - 10 m^3/day treatment capacity → up to 86,400 BDT/year.[1] [2]

Sustainability

- MBR systems offer several sustainability advantages including:
  - Higher treatment efficiency: MBR achieves high treatment efficiency in terms of organic pollutant, suspended solids and nutrient removal. The effluent will have a higher quality, beneficial for environmental protection and potential reuse applications.
  - Reduced footprint: MBRs have a compact design and eliminate the need for separate clarifiers or sedimentation tanks, resulting in a smaller overall footprint.
  - Reuse potential: The high-quality effluent can be suitable for various non-potable water reuse applications such as irrigation, industrial processes and toilet flushing. MBRs thereby contribute to water conservation and reduce the demand for freshwater resources.
  - Potential for energy recovery: MBR systems can incorporate energy recovery mechanisms such as membrane cleaning with reclaimed wastewater or the utilization of biogas generated during sludge digestion. This can help to offset energy consumption and enhance the overall energy efficiency of the system.
  - Odor control: MBR systems usually have a closed-tank design and have no odor-producing processes what will avoid causing any odor usually associated with wastewater treatment.
- As mentioned, MBR systems can generate greenhouse gas emissions, volatile organic compounds (VOCs) and odorous compounds. Properly designed, methane can be captured and used. Further, proper ventilation and odor control measures will minimize any risks and impacts.

Benefits and Limitations

Benefits

+ High treatment efficiencies.
+ With WW holding tank, resistant to shock-loads and inflow variations.
+ Usually fully automatized.
+ Flexibility in system design.

Limitations

– Increased O&M requirements (regular desludging and membrane cleaning).
– Continuous electricity supply.
– High technical complexity.
– Higher investment and O&M costs.

[1] RR Fluid and Energy / D-WaterTech.

[2] Green Genesis.

Manufacturer / Service Provider

- Charm Limited (Certified according to ISO 4500): House #587, (2nd Floor), Road #09, Avenue #04, DOHS Mirpur, Dhaka, Bangladesh. Email: info@charmbd.com, Phone: +8801716-237917.
- Green Genesis: House B/113, Mosque Road, New DO HS Mohakhali, Dhaka-1206, Bangladesh. Email: gm-tech@greengenesisbd.com, Phone: 01810033413.
- Priora Water Solutions PVT Limited: Office-39&40, 5th Floor, C Wing, KK Market, Dhankwadi, Pune MH 411037, India. Email: priorawater@gmail.com, Phone: +919881593335.
- RR Fluid and Energy / D-WaterTech: House-328, Lane-5, Baridhara DOHS, Dhaka, Bangladesh. Email: rrfluid88@gmail.com / dwatertech88@gmail.com, Phone: 01817610026.
- WTB Water Technology BD Limited: House-1248, Road-09, Level-04, Dhaka, Mirpur 1216, Bangladesh. Email: hkfservice.inn@gmail.com / info@wtbl.com.bd, Phone: +8801713565696.

Reference Projects

- Charm Limited:
  - Rooppur Nuclear Power Plant R/A Green City (Capacity: 1,500 m^3/day).
  - Knit Concern Group in Godnail, Narayanganj (Capacity: 6,000 m^3/day).
  - Next Accessories Limited. In Rupganj, Narayanganj (Capacity: 250 m^3/day).
- Green Genesis:
  - MJL Bangladesh Limited.
  - Matarbari Coal power plant.
  - Ali Haider Battleship.

Partial Solutions

Moving Bed Biofilm Reactor (MBBR)

C6

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge	
Capacities (m^3/day)	Min 5	Max 300
Output Quality	** Low % of Pathogens	
	Effluent quality (mg/L) 8 – 10[1] / <50[2] BOD 20 – 25[1] / <200[2] COD 5 – 20 TSS	
	Removal efficiencies (%) 80 – 95 BOD 70 – 90 COD 70 – 95 TSS	
Important Requirements	• Electricity supply. • Accessibility for desludging services. • Post-treatment for effluent.	

Visualization

FIGURE 06: Containerized MBBR (top). Biofilm carrier "Mutag Biochips 30TM" used by WTB (bottom). Source: Wastewater Solutions, WTB.

Technical Description

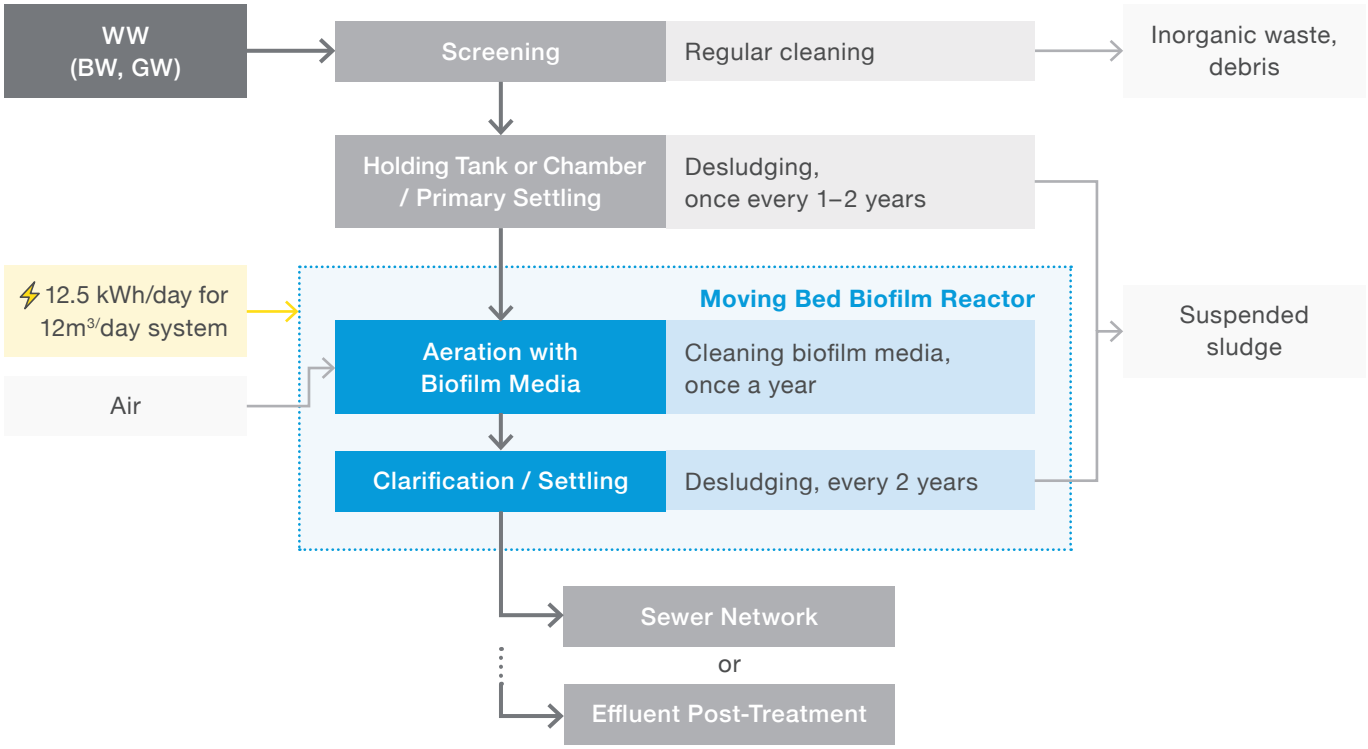
- The Moving Bed Biofilm Reactor (MBBR) is a biofilm-based biological process that takes advantage of natural cellular processes to decompose the organic matter in wastewater.
- The technology is applied as on-site solution as well as large-scale centralized solution.
- The MBBR process takes place in a reactor or aeration tank made of concrete, steel or plastic.
- The tank is equipped with support material that provides the surface for the growth of biofilm. The support material, also called media or carrier are usually small plastic chips or pellets. Their design intends to maximize the surface area they provide for biofilm and microorganisms to grow on.
- The tank should further be equipped with an aeration grid that helps the media to move and ensure contact with the components that shall be decomposed. It further ensures that oxygen is introduced continuously or intermittently into the tank.
- The main treatment steps are:
  - Aeration with Biofilm Media: As wastewater flows into the reactor, the microorganisms in the biofilm metabolized and degrade organic pollutants. The aeration promotes the contact between microorganisms and biofilm, and pollutant removal is reached. Biofilm will grow and accumulate, and eventually detach from the biofilm carrier. The detached biomass, as well as any suspended solids form a sludge in the reactor.
  - Clarification / Settling: The effluent undergoes further clarification that enables it to be either used as irrigation or discharged into drainage.

[1] WTB Water Technology Bangladesh; effluent values are based on laboratory test.

[2] RR Fluid and Energy / D-WaterTech.

- MBBR technology was invented in the late 1980s and can therefore be considered a proven solution that has been applied worldwide for municipal and industrial wastewater treatment. A variety of companies in Bangladesh are offering MBBR systems with different features (pre- and post-treatment steps).
- The system is partially available certified, e.g., by the Department of Environment for D-WaterTech.

Flowchart



Suitability

Holding Type

- MBBR systems are suitable for residential, educational, institutional, healthcare, business and industrial holdings. In regard to industries, it has proven applications in pulp and paper industry, coke oven plants, steel industry, petrochemical, chemical effluent treatment, textile industry, food and beverage industry and slaughterhouses.

Space Requirement

- Overall, MBBR systems can be considered to be moderate-sized systems. MBBR systems utilize biofilm carriers with a large surface area to support microbial growth. This high surface area allows for a significant concentration of microorganisms in a relatively small reactor volume, leading to efficient treatment and a smaller footprint.
- The space requirement varies between the different capacities and systems offered by different manufacturers/service providers. E.g., for a 10m³ system, about 50m² are required.

Technical Complexity

- MBBR systems can be considered moderately complex from a technical standpoint. MBBR systems generally do not require highly specialized equipment or complex mechanisms. The carrier media used in MBBR, while specific to the application, are readily available and not overly complex.

Construction

- MBBR systems can be installed aboveground or underground.

Planning, Design and Implementation Considerations

General Considerations

- For installation in flood-prone areas, they system should be installed at higher elevation or protected through appropriate measures such as building embankments or flood barriers. Special attention should be given to electrical components, control panels and any vulnerable parts of the system.
- If installed underground, the structural integrity to withstand load and pressure caused by surrounding soil needs to be ensured. Access via manholes or other entry points need to be considered. Proper ventilation is essential to prevent buildup of potentially harmful gases or odors. Waterproofing to prevent groundwater infiltration is important.
- Accessibility for desludging services should be guaranteed.

Effluent Post-treatment

- Effluent of the system can be used for irrigation for agricultural purposes. It may undergo hypo-chlorination prior discharge into a waterbody.

Watertightness

- MBBR systems have generally a low risk of water leakage as they are typically designed with a focus on sealing and containment. Therefore, they can be considered as watertight.

Electricity

- The MBBR requires electricity to operate a variety of components such as the aeration system, mixing system and pumps. The average consumption for a 12 m^3 system is 12.5 kWh/day[1].

Operation & Maintenance Requirements

- O&M requirements for MBBR systems can be considered to be high due to the required monitoring and adjustment of aeration to guarantee effectiveness of the treatment.
- The MBBR system requires monitoring of influent and effluent characteristics. It also requires the proper operation and maintenance of the aeration system that is vital for supplying sufficient oxygen to support the growth of microorganisms on the biofilm media. Blowers, diffusers or other equipment used by the manufacturers need to be regularly inspected, cleaned and maintained to ensure functioning and prevent clogging or damage.
- The system requires the cleaning of biofilm carriers. The frequency will depend on wastewater characteristics, general system design and carrier specifics that vary between the companies (some may have self-cleaning mechanisms). It requires to monitor biofilm thickness. Depending on site-specific conditions, it may be necessary once a year.
- The system requires desludging of accumulated solids. It requires monitoring of the sludge level. The frequency depends on the system and may be from 1 – 2 times per year to every three years.
- The companies usually provide 1 year warranty for their MBBR system.

Health Aspects

- MBBR systems are generally considered safe and suitable for wastewater treatment assuming proper design and operation. Attention should be paid to:
  - Pathogen removal: To ensure that pathogen removal is consistent and reliable, the system needs to be monitored.
  - Occupational health and safety: Anyone involved in maintenance or desludging should wear personal protective equipment (PPE) such as gloves, goggles, and masks to avoid exposure.
  - Chemical handling: Some MBBR system may require the addition of chemicals. These chemicals need to be handled safely, following recommended procedures.

[1] RR Fluid and Energy / D-WaterTech.

Costs

- Investment costs for MBBR systems can be considered relatively high depending on the specific design of the system.
- The investment costs vary depending on the capacity of the system. As orientation, the following figures can be referred to:
  - 12 m^3 capacity → 6,000,000 BDT
  - 10 m^3 capacity → 1,200,000 BDT
- General O&M costs include desludging services and electricity for the operation of the system. Furthermore, costs for exchanging of carrier material need to be considered. Some systems may require additives. Service fees may be as high as 350,000 BDT per year.

Sustainability

- MBBR systems can be considered sustainable in case of proper design, O&M and consideration of local conditions and requirements.
- The MBBR does not directly cause any emissions, but operation and management practices surrounding the system can have emissions implications:
  - Energy consumption: The system requires electricity which can be from renewable energy source. In case of fossil fuel-based sources, a contribution to carbon dioxide emissions needs to be considered.
  - Sludge management: MBBR systems generate sludge as a by-product. Improper handling of the sludge can result in emissions.
  - Chemical additions: Some MBBR systems may require the addition of chemicals for treatment enhancement. The lifecycle of these additives can contribute to emissions.
  - Aeration: Off-gas can be generated during aeration containing volatile organic compounds (VOCs) or odorous gases. These gases should be treated using air pollution control systems, such as activated carbon adsorption, biofilters or chemical scrubbers.

Benefits and Limitations

Benefits

+ High treatment efficiencies.
+ Process stability.
+ Flexibility and upgradeability.
+ Reduced sludge production (low desludging frequency).

Limitations

– Higher initial investment costs.
– Biofilm carrier maintenance.
– Additional clarification of filtration steps necessary for fine solids or suspended solids in effluent.
– Desludging is required.
– Footprint larger than other available systems.

Manufacturer / Service Provider

- WTB Water Technology Bangladesh: House-1248, Road-09, Mirpur DOHS, Dhaka-1216, Email: hkfservice.inn@gmail.com / info@wtbl.com.bd, Phone: +8801713565696.
- RR Fluid and Energy / D-WaterTech (Certified) : House-328, Road-05, Baridhara DOHS, Dhaka. Email: rrfluid88@gmail.com / dwatertech88@gmail.com, Phone: 01817610026.
- Priora Water Solutions PVT Limited: Office-39&40, Floor-5, C Wing, KK Market, Dhankwadi, Pune MH 411037, Email: priorawater@gmail.com, Phone: +919881593335.

Partial Solutions

Electrochemical Reactor (ECR)

C7

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent ● Sludge	
Capacities (m^3/day)	**Min** 0.5	**Max** 200
Output Quality	⁂ **High % of Pathogens**	
	Effluent quality (mg/L) 10 – 50 BOD 20 – 150 COD 10 – 100 TSS	
	Removal efficiencies (%) Up to 80 BOD Up to 80 COD Up to 97 TSS Up to 80 E-Coli	
Important Requirements	• Electricity supply. • Accessibility for desludging services. • Post-treatment for effluent.	

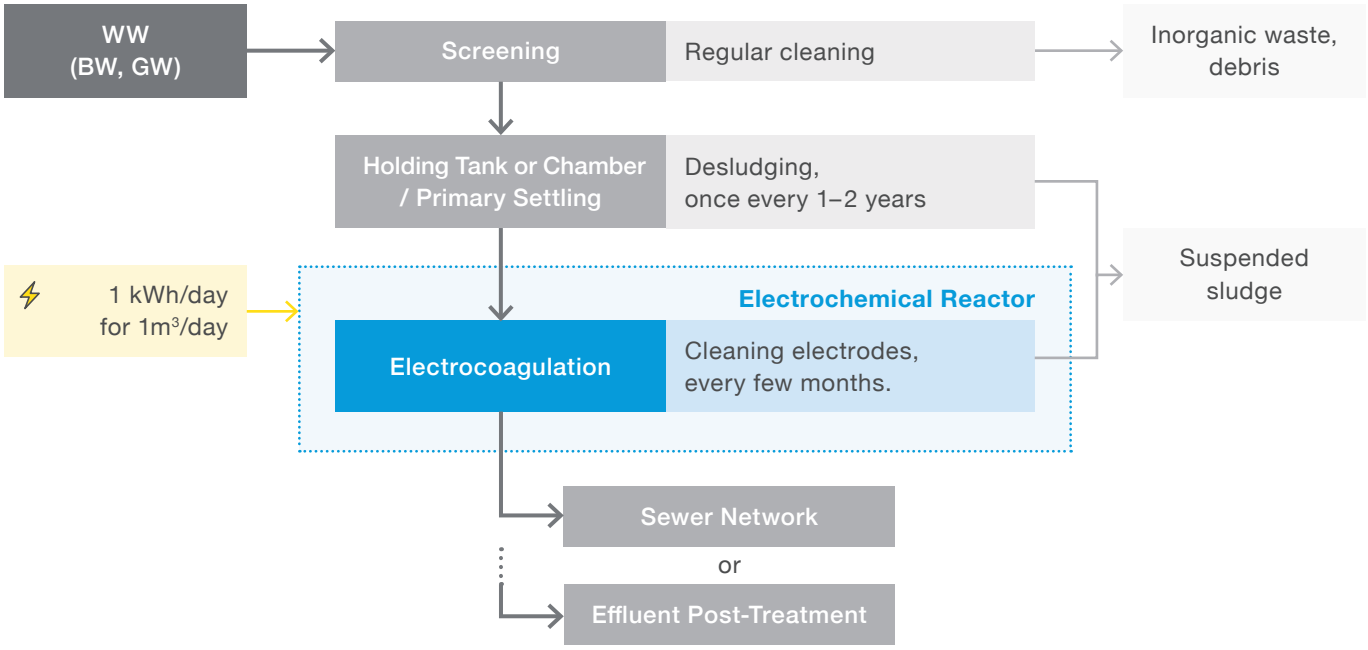
Visualization

FIGURE 07: Electrochemical Reactor.
Source: RAN Corporation.

Technical Description

- Various electrochemical wastewater treatment processes exist including electrocoagulation, electroflotation, electrodeposition and electrooxidation. In Bangladesh, only electrocoagulation (EC) is currently offered for on-site wastewater treatment.
- The EC process is an electrochemical method to remove suspended solids, chemicals, and other contaminants in wastewater by applying direct current to a pair of electrodes.
- The basic principle is a reduction and oxidation reaction.
- The EC process can be explained as follows:
  - The wastewater flows into a tank which is equipped with two electrode plates, acting as an anode and a cathode. The direct electric current will cause an electrochemical process in which anions move towards the anode to release oxidized electrons. The cations move towards the cathode to accept electrons, which causes the formation of flocs that bind contaminants in the wastewater and settle in the tank. At the same time, gas forms causing turbulence and pushing flocs to the surface.
  - During the EC process, the wastewater separates into a floating layer, flocculated sediment and treated water. The floating layer is removed via overflow weir, while sediment settles at the bottom of the tank.
- The electrodes for wastewater treatment are made of iron (Fe), aluminum (Al) or an inert material. The electrode material and quality impact the treatment efficiency.
- Further post-treatment such as filtration is possible for the effluent prior discharge.
- RANCo Electro-Coagulation System (see RAN Corporation) as available product on the Bangladesh market is tested and certified by the Department of Environment.

Flowchart



Suitability

Holding Type

- Electrocoagulation systems are suitable for residential, educational, institutional, healthcare, business and industrial holdings.Due to its capability to remove contaminants that are generally difficult to remove, it is especially suitable for industrial holdings (e.g. metal, textile and car wash industries).

Space Requirement

- ECR systems can be considered to be moderate-sized systems.
- Depending on the capacity of the system, it can require about 3 – 200 m^2.

Technical Complexity

- ECR systems can be considered highly complex from a technical standpoint.

Construction

- The system should be installed aboveground, containerized or in basements, to ensure easy access to equipment for O&M. There should also be enough access for desludging services.

Planning, Design and Implementation Considerations

- The system requires a flat concrete foundation.
- The overall effectiveness of the EC process is affected by the material and design of the electrode, the gap between the two electrodes, the electrodes polarity, the density of the current, the conductivity of the wastewater, the pH of the wastewater, the size of particles in the wastewater, etc. The manufacturer needs to have good knowledge on the characteristics of the wastewater, to adjust the system accordingly. Each system should be customized.

Effluent Post-treatment

- RANCo Electro-Coagulation System can be supplemented by ultrafiltration as pre- or post-treatment and a dissolved air flotation (DAF) filter as post-treatment to further separate and remove suspended solids (SS), fats, oils, greases (FOG) and other fine particles. Higher removal efficiencies will be achieved. Also, ozonation or chlorination is an option for disinfection as pre- or post-treatment.

Watertightness

- ECR systems have generally a low risk of water leakage as they are typically designed with a focus on sealing and containment. Therefore, they can be considered as watertight.
- Since the system is not flood-proof, mitigating measures should be applied if chosen for flood-prone area including selection of an elevated location or site, an elevated platform or foundation, flood barriers around the system as well as monitoring and early warning systems.

Electricity

- The operation of the system requires electricity. For an EC system with 1 – 3 m^3/hour of wastewater treatment capacity, the RANCo system requires 3 – 5 kWh. For large capacities, the system requires in average 1 kWh for the treatment of 1 m^3 wastewater (1,000 liters).

Operation & Maintenance Requirements

- O&M requirements for EC systems can be considered to be high due to required monitoring of the system by a skilled and trained operator.
- EC provides fast start-up to normal operation.
- Although the system can be fully automated, it requires skilled operation and maintenance. Due to the inconsistency in wastewater characteristics, the EC system requires fine-tuning of the equipment in order to achieve good treatment results.
- A main responsible should be properly trained by the manufacturer / service provider in the operation of the system. Alternatively, external services need to be arranged. RAN Corporation as available manufacturer and service provider offers 1 year warranty and free services.
- EC requires electrodes to feed the current into the wastewater. The process puts strain on the electrodes, resulting in wear and tear. Therefore, electrodes require regular cleaning and maintenance that will also prolong their lifespan. Fouling and buildup of deposits on the electrode surface should be removed by mechanical brushing, water jetting or acid cleaning according to manufacturer's specifications.
- Depending on the quality, thickness and operating conditions of the EC system, the lifespan of Fe and Al electrodes can vary from several months to several years. High quality electrodes and proper maintenance extends the lifespan.
- Regular desludging of the system is required. The frequency will depend on the sludge accumulation rate, system design and sludge storage capacity. For a system treating domestic wastewater with 10m^3 treatment capacity, desludging may be required once a year assuming low sludge production.

Health Aspects

- Since the system is watertight, it produces no odors.
- Although treatment efficiencies are better than septic tanks, the sludge and effluent can still contain pathogens and therefore need to be handled with care. During desludging, workers need to be equipped with personal protective equipment.
- EC produces hydrogen (H_2), which is non-toxic and dissipates rapidly when it is released. Nonetheless, it has a wide range of flammable concentrations in air and can easily ignite. Therefore fire sources around the system need to be avoided. Furthermore, ventilation and leak detection are important and to be considered by the manufacturers.

Costs

- Investment costs for ECR systems can be considered relatively high due to more advanced and complex technology principles.
- Investment costs depend on the capacity of the system:
  - 1 – 3 m^3/day capacity → 1,500,000 – 1,800,000 BDT
  - 10 m^3/day capacity → 2,800,000 BDT
- General O&M costs include desludging services and electricity for the operation of the system. Furthermore, prices for exchanging of electrodes need to be considered. A continuous service fee for regular fine tuning of the system to receive good treatment results may be necessary.

Sustainability

- Overall, EC can be considered sustainable assuming proper system design and regular maintenance. Sustainable characteristics are:
  - Chemical reduction: No need for chemical coagulants.
  - Energy efficiency: The system has relatively low energy consumption. Energy could be provided through renewable energy.
  - Versatility: The system can effectively treat a variety of wastewater with diverse pollutant loads and complex wastewater compositions.
  - Removal of multiple contaminants: Multiple contaminants can be removed in one treatment step.
  - Sludge minimization: Compared to other systems, the system produces less sludge.
  - Scalability and modularity: The system can easily be expanded or adjusted.
- Hydrogen which is produced during EC may not be harmful for human health, but it contributes to climate change when emitted into the atmosphere by increasing the amounts of other greenhouse gases such as methane, ozone and water vapor, resulting in indirect warming.

Benefits and Limitations

Benefits

+ Suitable for industrial wastewater. Good at elimination contaminants.
+ Quick treatment with short retention times.
+ Requires low levels of electricity that could also be generated by green energy sources such as PV.

Limitations

– High technical complexity.
– Limited elimination of pathogens.
– Requires electricity for operation.
– Electrodes are consumed and have to be replaced regularly.
– No standard solution; each system needs to be customized.
– Has to be aboveground or in accessible subsurface enclosure (e.g. building basement).

Manufacturer / Service Provider

- RAN Corporation: (Certified as wastewater treatment company by the Department of Environment). Salimullah Road-7/5, Mohammadpur, Dhaka-1207. Email: aktar2972@yahoo.com, Phone: +8801714081430.

Reference Projects

- RAN Corporation
  - Bangladesh ENT Hospital
  - Universal Medical College & Hospital
  - Comilla Trauma Center
  - Hotel Sea Crown, Cox's Bazar
  - Hotel Ocean Paradise Cox's Bazar

Single Integrated Systems

Biopipe System

C8

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent/Treated water	
Capacities (m^3/day)	**Min** 1	**Max** 1,000
Output Quality	* **Free of Pathogens**	
	Effluent quality (mg/L)[1] 8 BOD 25 COD 5 TSS	
	Removal efficiencies (%) Up to 97 BOD Up to 95 COD Up to 99 TSS	
Important Requirements	• Electricity supply. • Pre-storage tank for wastewater.	

Visualization

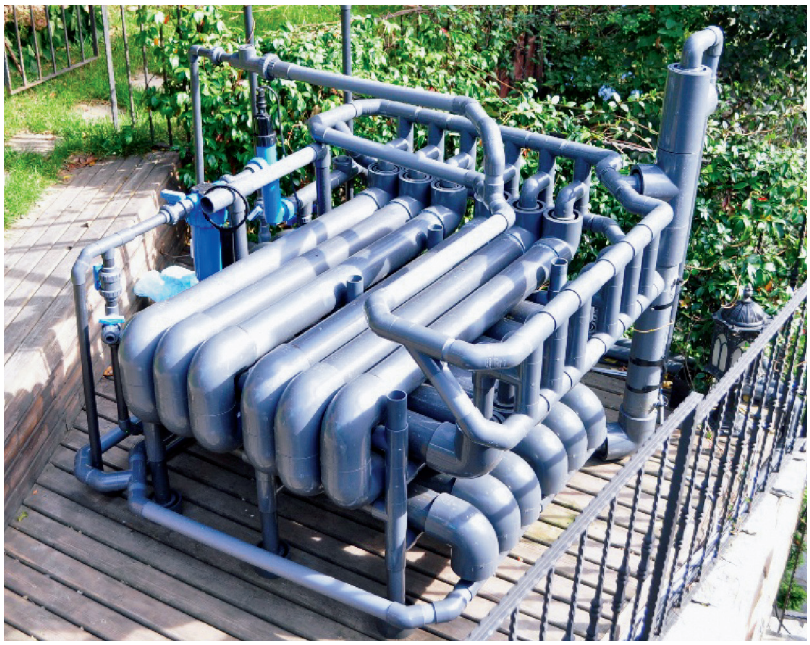


FIGURE 08: Micro-Scale Biopipe System. Source: Biotech Innovation Limited.

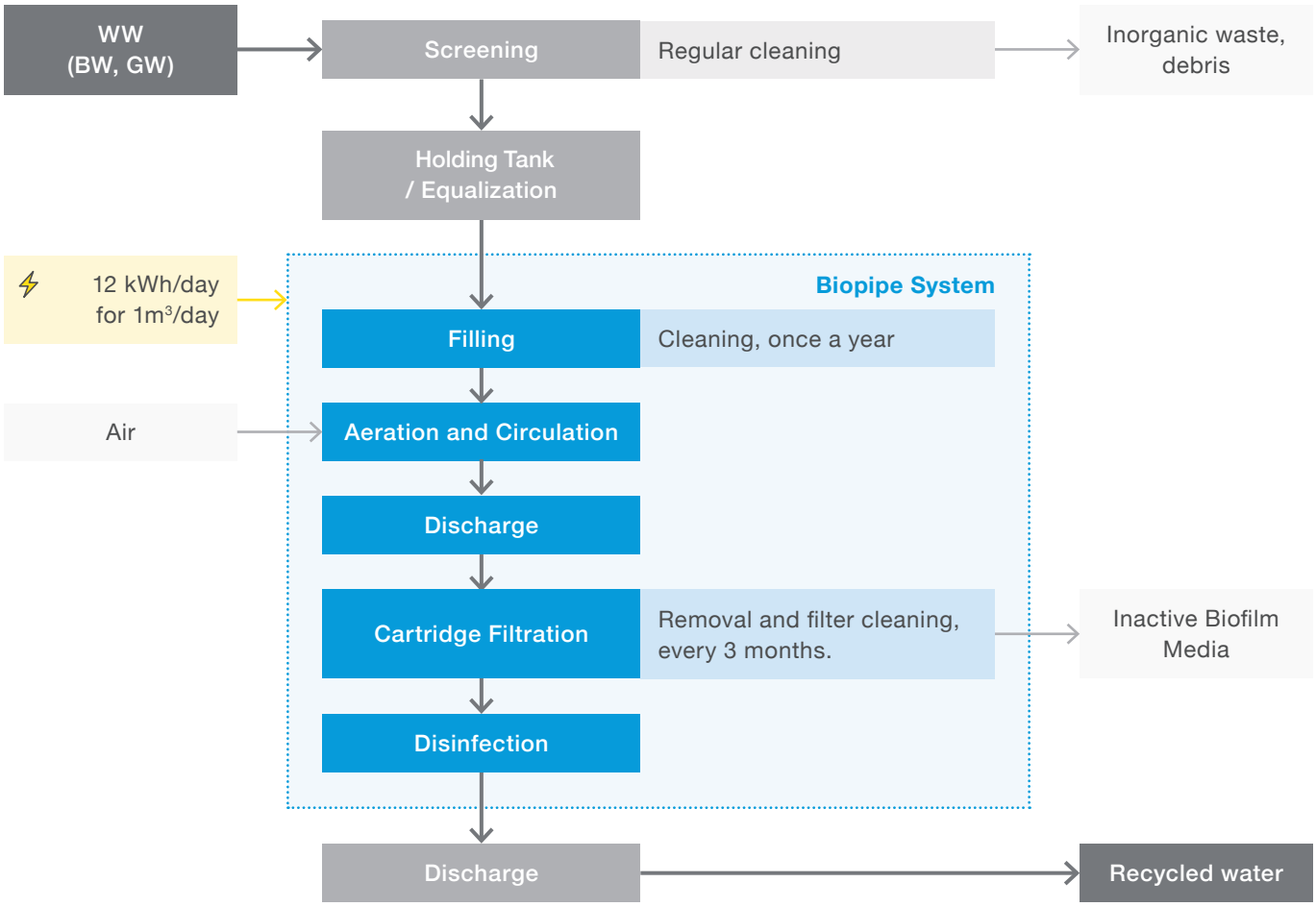
Technical Description

- Biopipe is a patented biofilm-based biological treatment system that is comprised of at least one treatment pipe (with specific carrier medium inside) and a drive to recirculate the wastewater within the pipe system.
- The system is capable to treat wastewater for reuse in irrigation and secondary use applications. The system is comprised of a tank, pipe modules, circulation and water pumps, and a UV filter. Microbiological pathogens are removed by bacteria that line the inside of the pipe. It is a batch process.
- The main treatment steps are as follows:
  - Pretreatment: After coarse and fine screening, the wastewater flows into a holding tank where homogenization and equalization take place. The tank is equipped with mixers for this purpose.
  - Filling: It is a batch process. The Biopipe will be filled with WW until it reaches its operational maximum.
  - Aeration and Circulation: A circulation pump facilitates that biopipe bacteria engage with wastewater and consume organics. Circulation periods are determined based on the effluent quality that wants to be reached. The air is injected via a venturi valve into the system to facilitate the biological process. The Biopipe has an integrated biofilm carrier. The treatment is therefore a mix of aerobic and anaerobic treatment plus biofilm.
  - Discharge: After circulation, which is done for about 180 minutes, the Biopipe system is discharged.
  - Cartridge Filtration: The wastewater passes a filter to catch inactive biofilm media that gets flushed out of the system.
  - Disinfection: Either UV filtration or chlorination is applied to disinfect the effluent and reach recycled water quality.

[1] Laboratory tested values by Biotech Innovation Limited.

- Technology has been present in Bangladesh for 7 to 8 years and has a variety of operating reference projects. The system has a lifetime of 30 years.
- The available biopipe system holds certification in USA and EU. It treats wastewater according to environmental guidelines (ECR 1995). All tests are conducted by the International Centre for Diarrheal Disease Research, Bangladesh (ICDDR, B).

Flowchart



Suitability

Holding Type

- The Biopipe system is suitable for residential, educational, institutional and business holdings. It is suitable for all holdings with domestic wastewater with max. 800 mg/ltBOD and 1,000 mg/l COD. Not suitable for industrial wastewater.
- The system is flexible to input quantities. Since it is a batch process, the system runs only when necessary input quantity in the preceding wastewater storage tank is reached.

Space Requirement

- The space requirement varies between 1m² for a 1 m³/day capacity system and 186 m² for 1,000 m³/day capacity system, which can be considered as low:
  - 5 m³/day capacity system requires 4 m².
  - 10 m³/day capacity system requires 8 m².

Technical Complexity

- The system is moderately complex from a technical standpoint.

Construction

- Needs to be kept free standing above ground, accessible for owners and maintenance workers.
- No special considerations for accessibility since desludging is not required.

Planning, Design and Implementation Considerations

General Considerations

- Biopipe Innovation as available service provider for biofilm technology uses PVC pipes, tanks and pumps for their so-called Biopipe system. It is a flexible and modular design that allows scaling and design according to customer needs. The system can be installed on rooftops, elevated structures, basements or containerized.
- A wastewater holding tank is required prior the biopipe system for storage. Existing septic tanks or pits can be adapted to holding units. This holding unit will be equipped with mixer(s) to realize equalization of the wastewater.
- Connection to canalizations or possibility for proper discharge is required for effluent/ treated water.
- A solid and flat underground is needed for the placing of the system.

Effluent Post-treatment

- The effluent does not require post-treatment if all steps including filtration and disinfection are considered. It can be used for irrigation, reused or discharged into the environment.

Watertightness

- The Biopipe system has a low risk of water leakage as it is designed with a focus on sealing and containment. Therefore, it can be considered as watertight.
- An increased risk of water leakage may exist with the WW holding tank as part of the pre-treatment. Water leakage tests should be done, especially if an existing septic tank is used.

Electricity

- The operation of the system requires electricity. Consumption varies from 12 kWh/day for 1 m^3/day capacity system to 600 kWh/day for 1,000 m^3/day capacity system.

Operation & Maintenance Requirements

- O&M requirements for Biopipe systems can be considered to be low. According to the service provider, no desludging is required, and the system works fully automated.
- Requires professional maintenance once a year for cleaning of the system. After purchase, 2 years of free service are provided.
- Operation can be monitored remotely from the mobile phone thanks to an automated system. The only regular maintenance is the cleaning of the cartridge filter with clean water every 3 months.

Health Aspects

- Closed system that in normal operation is silent and does not cause any odors.
- Produces treated water that can be used (e.g. irrigation, toilet flushing) or be discharged in canalization / water body / underground aquifer.
- No drinking water, but option of chlorination and upgrading is possible to achieve drinking water quality.

Costs

- Investment costs for Biopipe systems can be considered to be moderate.
- Investment costs vary on capacity of the system:
  - 10 m^3 capacity → 1,700,000 BDT
  - 100 m^3 capacity → 9,000,000 BDT
- O&M costs are mainly electricity costs. Simple preventive maintenance works need to be carried out on a regular basis. It can be done by the service provider for a yearly service fee or a designated responsible.

Sustainability

- Overall, Biopipe can be considered sustainable assuming proper system design and regular maintenance. Sustainable characteristics are:
  - Chemical reduction: No need for chemical coagulants.
  - Energy efficiency: The system has relatively low energy consumption. Energy could be provided through renewable energy.
  - Sludge elimination: The system does not produce sludge.
  - Scalability and modularity: The system can easily be expanded or adjusted and is flexible toward input quantities.
- Closed system that causes no emissions in normal operation and is waterproof and flood resistant.

Benefits and Limitations

Benefits

+ Produces zero sludge, but treated water (respecting Bangladesh effluent standards), harmless for the environment.
+ Closed, watertight system that does not produce any odors or significant sounds in normal operation.
+ Relatively low footprint.
+ Relatively low O&M requirements.

Limitations

– Financially viable only with treatment capacities of 3 m^3 or larger.
– Requires electricity for operation.
– Has to be aboveground or in accessible subsurface enclosure (e.g. building basement).

Manufacturer / Service Provider

- Biotech Innovation Limited: (Certified according to ISO 9001:2015 & ISO 14001:2015) House-50, Road-3, Gulshan Avenue-7, Gulshan 1, Dhaka-1212. Phone: 01769011019, Email: biotechinnovations.bd@gmail.com

Reference Projects

- Biotech Innovation Limited:
  - Biopipe STP in Justice complex, Kakrial, Dhaka (100 m^3/day capacity)
  - Uttara Apt. Dhaka (242 m^3/day)
  - NSI head quarter (100 m^3/day)
  - Bangladesh Secretariate Complex (100 m^3/day)
  - Motijheel GPO colony (200 m^3/day)

Single Integrated Systems

Johkasou Tank

C9

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent/Treated water ● Sludge	
Capacities (m^3/day)	**Min** 5	**Max** 100
	Modules can be put in series for larger capacities	
Output Quality	* **Free of Pathogens**	
	Effluent quality (mg/L)[1] <30 BOD <50 COD <80 TSS	
	Removal efficiencies (%) 80 – 95 BOD 70 – 90 COD 70 – 90 TSS	
Important Requirements	• Electricity supply. • Accessibility for desludging services.	

Visualization

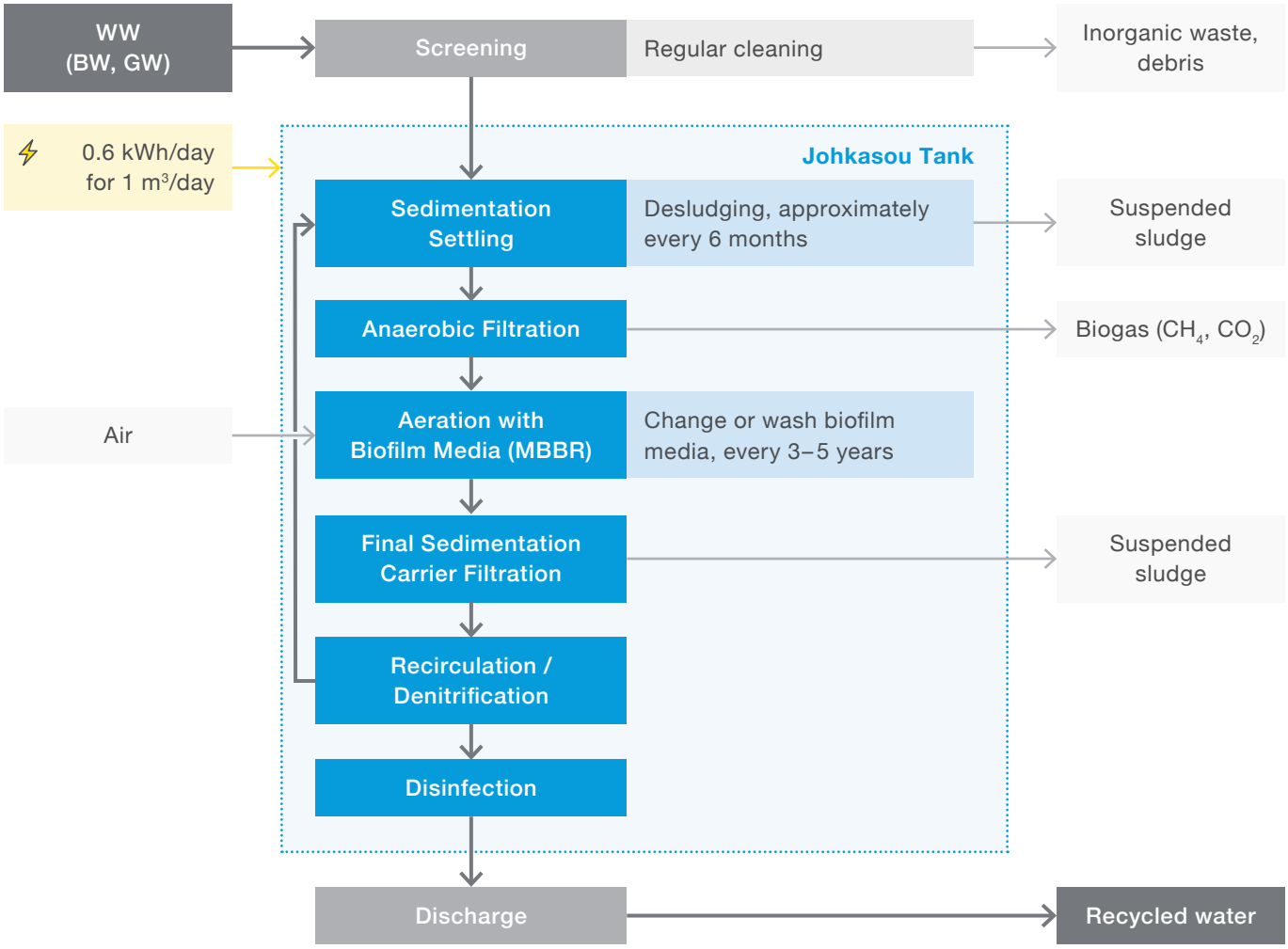
FIGURE 09: Johkasou Tank during installation.
Source: Charm Limited.

Technical Description

- Johkasou tanks are wastewater treatment tanks based on the design of the Japanese company Kubota. Six different models exist.
- In four chambers, the wastewater undergoes five major treatment steps:
  - Solid-liquid Separation / Sedimentation: The wastewater flows into the first chamber, where solid wastes settle based on their gravity. The solids or sludge remain in this chamber.
  - Anaerobic Filtration: The wastewater flows into the anaerobic contact media chamber, where organic matter contained in the wastewater is decomposed by anaerobic microorganisms.
  - Aeration with Biofilm Media: The wastewater continues into the aeration chamber or Moving Bed Biofilm Reactor (MBBR). This chamber contains support media or carriers that provide surface for biofilm or microorganisms to grow on. Aeration enabled through the blower promotes the contact between microorganisms and biofilm carriers, which enables pollutant removal and decomposing by aerobic microorganisms.
  - Final Sedimentation: The final sedimentation chamber provides place for sludge to settle resulting from the biological process that took a place in the aeration chamber.
  - Disinfection: The disinfectant chamber adds chlorine or disinfectants as a sterilization agent to eliminate pathogenic microorganisms before the effluent can be discharged into the environment.
  - Recirculation: Recirculation from the final sedimentation chamber to the initial sedimentation / separation chamber is realized via an air lift mechanism. This ensures denitrification and enables multiple times of treatment.

[1] Charm Limited; values are laboratory and real case tested.

Flowchart



Suitability

Holding Type

- Johkasou tanks are suitable for any holdings that produce domestic wastewater including residential, educational, institutional and business holdings. It is not suitable for holdings that produce wastewater containing hazardous chemicals.
- The system has a long life according to the National Building Authority of Japan with several installations being in operation for 40 to 50 years.

Space Requirement

- The space requirement for Johkasou Tank can be considered as medium. For a 10 m^3 treatment system, app. 8 m^2 are required.

Technical Complexity

- The Johkasou Tank can be considered as highly complex from a technical standpoint. The system is highly intricate with several process steps, mechanical components, requires electricity and demand regular operation and maintenance. Nonetheless, in daily operation, it does not require a skilled operator.

Construction

- Johkasou tanks can be installed aboveground or underground including in basements, under driveways, car parking, or green areas.

Planning, Design and Implementation Considerations

General Considerations

- A flat concrete platform should be provided for the system to be installed on.
- The system is prefabricated of fiber-reinforced plastic (FRP).
- Accessibility to the manholes for desludging and maintenance needs to be ensured. No heavy weights should be placed permanently on the system. No placement close to combustible or hazardous sources.
- A power source is needed for the blower that needs to be continuously running to ensure treated wastewater and to avoid bad odor.

Effluent Post-treatment

- The effluent does not require post-treatment if all steps including filtration and disinfection are considered. It can be used for irrigation, reused or discharged into the environment.

Watertightness

- The Johkasou Tank has a low risk of water leakage as it is designed with a focus on sealing and containment. Therefore, it can be considered as watertight.

Electricity

- The system requires electricity for operation. A system with 10 m^3 treatment capacity requires app. 4.8 kWh/day.

Operation & Maintenance Requirements

- O&M requirements for Johkasou Tank can be considered to be moderate.
- Users need to respect to not dispose foreign objects into the system (incl. rubber, absorbent cotton, food, cooking oil, etc.) to avoid clogging.
- Users need to respect to not add chemicals to the system (incl. hydrochloric acid, insecticide, deodorant, chlorine agent, etc.) to ensure the functionality of the system.
- Manhole covers need to be well closed / locked according to the locking mechanism. The manhole(s) need to remain accessible. No heavy weights should be placed on the system. No objects should be placed on the blower or power cable.
- Combustible and hazardous things need to be kept away from the system.
- Desludging of the system should take place every 6 months.

Health Aspects

- When operated and maintained properly, the Johkasou tank poses none too little health risks. Important aspects are:
  - Exposure to pathogens: Sludge contains pathogens and needs therefore to be handled with care. During desludging, workers need to be equipped with PPE (personal protective equipment).
  - Inhalation of sewer gases: While in operation, the system is airtight and does not emit any smell or emissions. The risk for inhaling sewer gases arises during maintenance works. The opening of manholes should be done with care. Any fire sources need to be avoided around the system. Inhalation needs to be avoided since it can cause respiratory problems, dizziness and nausea.
- The system is making some noise due to the continuously working blower. The sound is lower than 50 dB (comparable to phone vibrations).

Costs

- Investment costs for the Johkasou Tank can be considered to be 〓 moderate.
- The investment costs vary depending on the treatment capacity of the system and site-specific conditions and requirements:
  - 10 m^3 capacity → 1,200,000 BDT [1]
- General O&M costs include regular desludging services and electricity for the operation of the system. Furthermore, costs for the sterilization agent need to be considered.

Sustainability

- The Johkasou tank is a sustainable on-site containment and treatment solution. Important sustainability aspects are:
  - Effluent quality: The Johkasou tank generates effluent that meets the Bangladesh effluent norms and can be used for irrigation or other purposes.
  - Modularity and scalability: Several tanks can be installed in parallel or more tanks can be added depending on the needs.
  - Emission control: In operation, the system is airtight and doesn't cause any emissions. Only during maintenance, release of sewer gases (methane, carbon dioxide) into the atmosphere may take place.

Benefits and Limitations

Benefits

+ All-in-one compact treatment solution.
+ High effluent quality respecting Bangladesh effluent norms.
+ Low O&M requirements.
+ Modularity and scalability.
+ Prefabricated system with fast installation and start-up.

Limitations

– Regular desludging required.
– Continuous power-supply to be ensured.

Manufacturer / Service Provider

- Charm Limited: House-587, Floor-02, Road-09, Avenue-04, DOHS Mirpur, Dhaka, Phone: +8801716237917, Email: info@charmbd.com
- NewVision Solutions Limited: House-85, Floor-91, Road-03, Block-F, Banani, Dhaka-1213. Phone: +8801713079617, Email: ifwteam@newvision-bd.com

Reference Projects

- Charm Limited:
  - Mayor's House (DNCC) (10 m^3/day)
  - Dhaka Cantonment (20 m^3/day, 2 modules with 10 m^3)
  - Mohakhali Public Toilet (5 m^3/day)
  - Splash Works Office (50 m^3/day)
  - Splash Works Water Park (200 m^3/day, 4 modules with 50 m^3)

[1] Charm Limited.

Single Integrated Systems

NEWgenerator

C10

Overview

Input	● Blackwater ● Greywater	
Output	● Effluent/Treated water ● Sludge ● Biogas/Methane	
Capacities (m^3/day)	**Min** 1	**Max** 20
	Capacities can be increased by increasing the number of containers.	
Output Quality	* **Free of Pathogens**	
	Effluent quality (mg/L) <10 BOD <50 COD <20 TTS	
	Removal efficiencies (%) up to 95 COD	
Important Requirements	• Pre-treatment by solid/liquid separation (septic tank, settler). • Electricity supply. • Point of discharge or water storage for irrigation.	

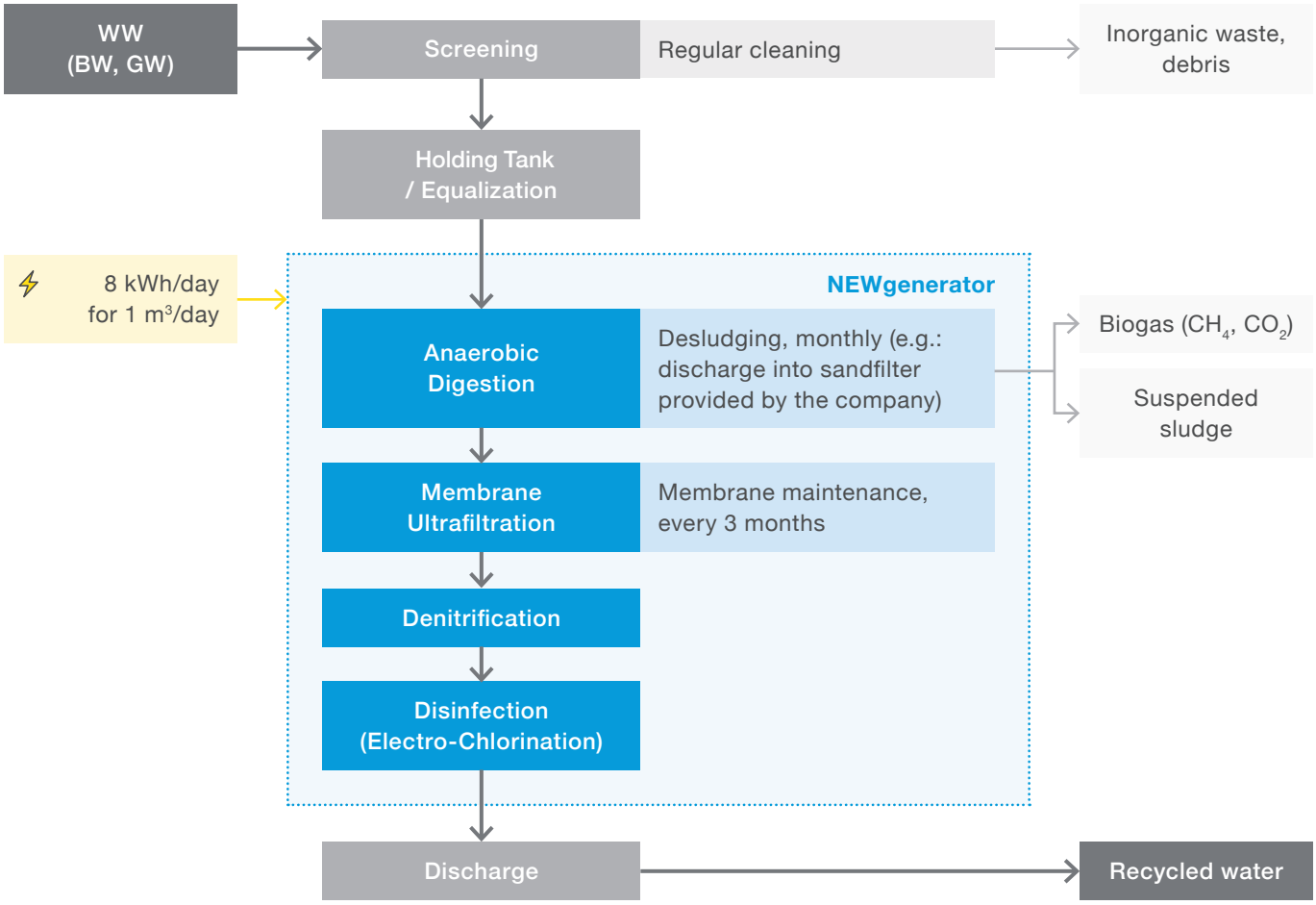
Visualization

FIGURE 10: Containerized NEWgenerator system.
Source: Documentation by UPM GmbH team during a visit to Elefo, 2022.

Technical Description

- The main treatment steps of the NEWgenerator are:
  - Pre-treatment: The wastewater into an equalization tank for a day. A pump moves the WW from the tank through a screen chamber (12mm) to the anaerobic digester.
  - Anaerobic Digestion: The high-rate anaerobic digester is specifically designed to separate solid from liquid. Inside the digester specialized microorganisms break down the organic pollutants in an oxygen-free environment converting organic matter into methane and carbon dioxide. Effluent from the final chamber is directed to a membrane for further treatment.
  - Membrane Ultrafiltration: The membrane used in this system is an ultra-filtration membrane that selectively allows only water to pass through, effectively blocking solid particles from crossing. The membrane pores are too small for pathogens and solids to pass through, resulting in pathogen-free and solid-free effluent. While the rejected particles are fed back to the anaerobic digester
  - Denitrification: The NCS (Nutrient Capture System) tank consists of multiple chambers. One chamber contains a special zeolite type, efficiently removing nutrients from the system. Another chamber utilizes activated carbon to further enhance water quality.
  - Disinfection: During the final step, the effluent is disinfected by using Electro-chlorination before it is reused or released into the environment.
  - The settled solids from AD are periodically removed and retained in a sand filter.

Flowchart



Suitability

Holding Type

- NEWgenerator is suitable for any holdings that produce domestic wastewater including residential, educational, institutional and business holdings. It is not suitable for holdings that produce wastewater containing hazardous chemicals.
- The system is flexible to input quantities variations. Since it is a batch process, the system runs in specific time intervals extracting wastewater on-demand basis from the pre-treatment unit.
- Wastewater treatment according to ISO30500, but not certified.

Space Requirement

- The space requirement can be considered as medium.
- Depending on the unit, 6–15 m^2 /unit with concrete and flat ground and a bearing capacity of 1.5 – 20 tons is needed for placing the system. The treatment container is placed above the subsurface. Additional space is required for the sand filter.

Technical Complexity

- The system can be considered to be highly complex from a technical standpoint.

Construction

- The system is installed aboveground. Containerised, free-standing system and need to be accessible for owners and maintenance workers.
- The WW holding tank as part of the pre-treatment can be installed underground.

Planning, Design and Implementation Considerations

General Considerations

- Underground equalization tank (buffer tank) or existing septic tank with one-day storage capacity.
- Sludge management of dried sludge (ca 0.2kg/year for 1m³/day) from the sand filter (provided by the company) or can also be discharged into a septic tank /holding tank. Therefore, the sludge management option (disposal, treatment or application) needs to be in place.
- Accessibility for desludging septic/holding tank services is still required but less frequent.
- Road Access (width > 2,700 mm) for truck to deliver the container.
- The system is controlled and monitored remotely.

Effluent Post-treatment

- The effluent does not require post-treatment if all steps including filtration and disinfection are considered. It can be used for irrigation, reused or discharged into the environment.

Watertightness

- The NEWgenerator has a low risk of water leakage as it is designed with a focus on sealing and containment. Therefore, it can be considered as watertight.
- An increased risk of water leakage may exist with the WW holding tank as part of the pre-treatment. Especially if an existing septic tank is used, water leakage tests should be done.

Electricity

- The system requires electricity. NEWgen100 consumes app. 8 kWh/day and NEWgen1000 app. 25 kWh/day.

Operation & Maintenance Requirements

- O&M requirements for NEWgen can be considered to be high. In addition to de-sludging, the system requires maintenance for its membrane, ion exchange system, etc.
- Monthly desludging of system into a sand filter (provided by the company). This can be made automatic if so desired.
- Membrane maintenance once in 3 months.
- Ion exchange system regeneration once in 6 months.
- Removal of dried sludge from the sand filter once in 12 months.
- Change of activated carbon in the system once in 12–18 months.
- Change of membrane once in 4–5 years.
- Change of electro chlorination cell (if used) once in 3 years.

Health Aspects

- Closed system with no odor.
- Produces pathogen free effluent.
- Handling of the dried sludge form sand filter need to be done with personal protective equipment, as it is likely to contain pathogens.

Costs

- Investment costs for the NEWgen can be considered to be high.
- Investment costs depend on the capacity of the system:
  - NEWgen100 → 1,400,000 BDT
  - NEWgen500 → 2,050,000 BDT
  - NEWgen1000 → 2,700,000 BDT
- General O&M costs include regular desludging services and electricity for the operation of the system. The costs are estimated to be app. 10% of the investment costs.

Sustainability

- No chemicals for the treatment process, except for washing of membrane and zeolite with sodium hypochlorite (NaOCl) – a chemical compound that is commonly used as a disinfectant and bleach.
- The system produces low quantities of sludge.
- The required energy can be provided through renewable energy sources.
- Anaerobic digestion is producing methane, that can be captured or need to be flared.
- System is modular and scalable, and the capacity can be easily expanded or adjusted and is flexible towards variation in input quantities.
- Water saving if effluent is recirculated for flushing.
- Effluent is saved for irrigation and will fulfill the national discharging standards in Bangladesh.
- Reduced desludging frequency of septic / holding tanks.
- Retrofitting of existing septic / holding tanks.
- Closed system that causes no emissions in normal operation.

Benefits and Limitations

Benefits

+ Small footprint.
+ WW treatment according to ISO30500.
+ Portable system that is easy to install.
+ Automated treatment system.
+ Remote monitoring.
+ Robust system; can treat variety of wastewater quality.
+ Can be stopped and started without affecting performance of the system.
+ Pathogen free effluent.

Limitations

– Regular maintenance is required.
– System will require inoculation if stopped for over 6 months.
– Electronic and electrical system needs protection against water.
– The system is installed aboveground enclosed in a container.

Manufacturer / Service Provider

- Elefo Cleantech Private Limited / Elefo Biotech Private Limited.

(Certified according to ISO 9001:2015).

Reference Projects

- Elefo Cleantech Private Limited / Elefo Biotech Private Limited.
  - 3 projects in India.

Single Integrated Systems

Aquonic

C11

Overview

Input	● Blackwater ● Greywater	
Output	● Treated Effluent ● Sludge	
Capacities (m^3/day)	**Min** 0.6	**Max** 1
	Multiple units can operate in parallel	
Output Quality	* **Free of Pathogens**	
	Effluent quality (mg/L) <20 BOD <125 COD <20 TSS	
	Removal efficiencies (%) 95 BOD 93 COD 98 TSS	
Important Requirements	• Pre-treatment by solid-liquid separation (septic tank, settler). • Electricity supply. • Point of discharge or water storage for irrigation.	

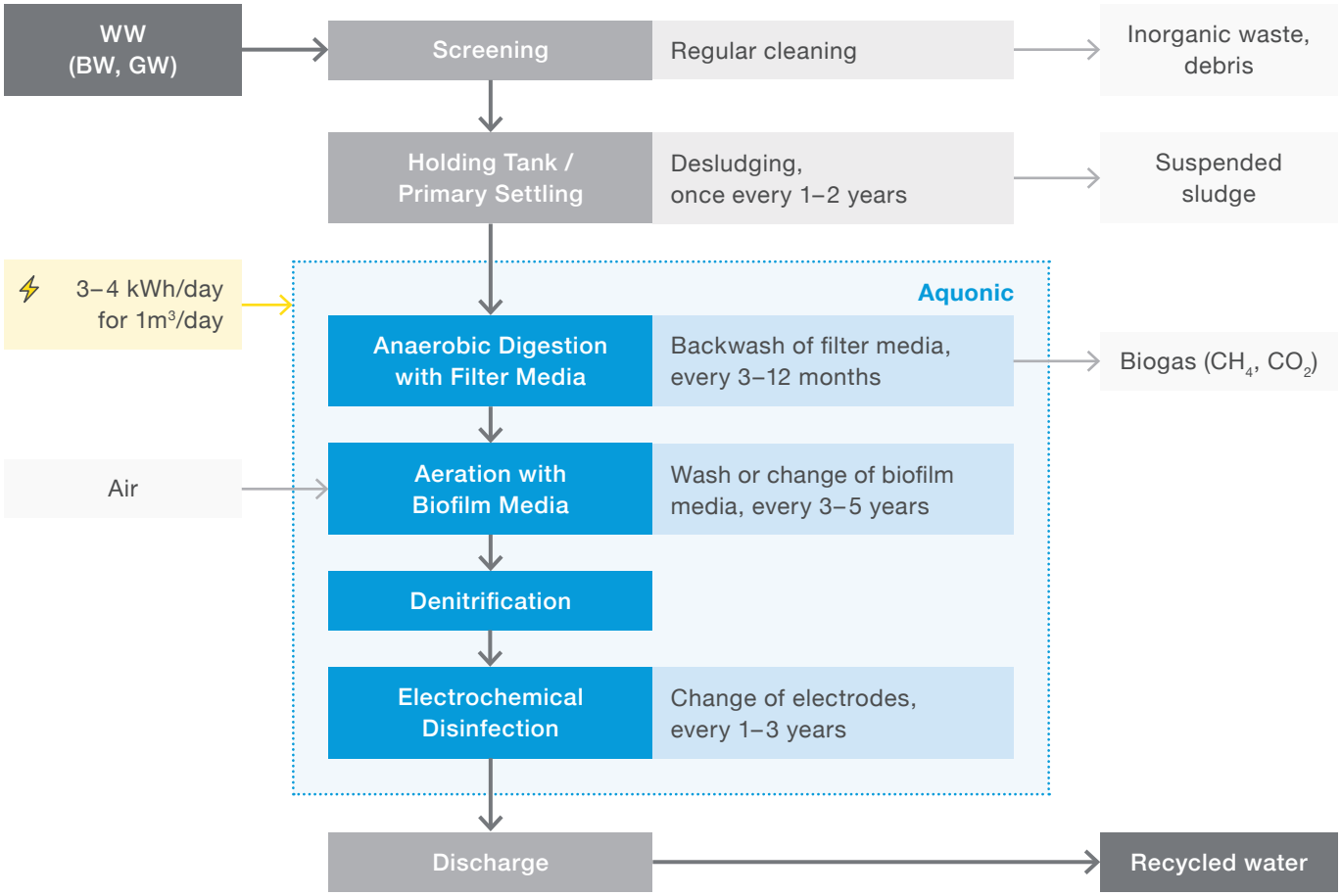
Visualization

FIGURE 11: Top view from interior of Aquonic module without lid.
Source: Documentation by UPM GmbH team during a visit to SCG, 2022.

Technical Description

- Aquonic is a patented treatment unit by SCGc, that combines different biological treatment steps, including anaerobic, aerobic and anoxic treatment principles followed by electrochemical disinfection.
- The wastewater undergoes the following treatment steps inside the Aquonic:
  - Anaerobic Digestion with Filter Media: Specialized microorganisms attached to the patented filter media remove organic pollutants and reduce overall load. In the absence of air, it is converted into methane and carbon dioxide.
  - Aeration with Biofilm Media: takes place in the presence of supplied oxygen. It involves using aerobic microorganisms attached to filter media that utilize oxygen to further degrade organic compounds. These bacteria consume the remaining organic matter and convert it into carbon dioxide, water, and biomass.
  - Denitrification: occurs in an oxygen-depleted environment. It involves the use of facultative microorganisms that can function both in the presence and absence of oxygen. This environment promotes the growth of specific microorganisms that are capable of denitrification, a process where nitrates and nitrites are converted into nitrogen gas. Anoxic treatment in Aquonic helps to eliminate excess nitrogen from the wastewater, preventing environmental issues such as eutrophication in receiving water bodies.
  - Electrochemical Disinfection: This final step utilizes electrochemical reactions to effectively kill or inactivate microorganisms, including bacteria, viruses, and other pathogens.

Flowchart



Suitability

Holding Type

- Suitable for all holdings with domestic wastewater including residential, educational, institutional and business holdings. Not suitable for wastewater with high loads of hazardous chemicals.
- The system is flexible to input quantities variations. Since it is a batch process, the system runs in specific time intervals extracting wastewater on-demand basis from the pre-treatment unit.

Space Requirement

- The Aquonic has a relatively low space requirement. The system requires about 2m²/unit.

Technical Complexity

- The system can be considered to be highly complex from a technical standpoint.

Construction

- The Aquonic requires a flat concrete foundation aboveground to be placed on. Bearing capacity should be app. 1.5 tons. Underground installation is possible with concrete foundation and brick frame. Needs to be kept free standing and accessible for owners and maintenance workers.

Planning, Design and Implementation Considerations

General Considerations

- The Aquonic is a prefabricated system that is installed in short-time. The start-up process until normal operation can require between 15 to 30 days due to initial growth of biofilm on filter media.
- Accessibility for desludging services of the septic/holding tank is required. The desludging frequency will depend on the wastewater but is usually less frequent than with conventional septic tanks.
- Solid-liquid separation as part of a pre-treatment is required prior the Aquonic tank. This means a holding or septic tank needs to be installed. Alternatively, existing septic tanks or holding tanks can be easily retrofitted.
- A ventilation system for the holding/septic tank is required as sewer gases may be generated. Ideally, the sewer gases are captured and used.

Effluent Post-treatment

- The effluent does not require post-treatment if all steps including filtration and disinfection are considered. It can be used for irrigation, reused or discharged into the environment.

Watertightness

- The Aquonic has a low risk of water leakage as it is designed with a focus on sealing and containment. Therefore, it can be considered as watertight.
- An increased risk of water leakage may exist with the WW holding tank as part of the pre-treatment. Water leakage tests should be done, especially if an existing septic tank is used.

Electricity

- The system requires electricity for operation. The electricity consumption is around 3–4 kWh/d for one unit.

Operation & Maintenance Requirements

- O&M requirements for the Aquonic can be considered to be moderate.
- A trained technician is necessary for the maintenance of the system.
- Depending on the treatment requirements and strength of the wastewater:
  - Every 3–12 months, backwash of filter media.
  - Every 1–3 years, change of the electrodes.
  - Every 3–5 years, wash or change of the filter bio-media.
- The connected toilets can remain in operation during the maintenance, because of the buffer capacity provided by septic/holding tank.

Health Aspects

- Closed system that in normal operation is silent and does not cause any odors.
- In normal operation and und if properly maintained as well as in combination with the holding/septic tank, Aquonic produces treated effluent that can be used (e.g. irrigation, toilet flushing) or be discharged to any waterbody. It can be considered pathogen free.
- During maintenance works, exposure to pathogen.

Costs

- Investment costs for the Aquonic can be considered to be high.
- The investment costs depend on the capacity of the system:
  - Aquonic 0.6m^3 → 702,000 BDT
  - Aquonic 1m^3 → 972,000 BDT
- The operation and maintenance cost are estimated to be 10–15% of the investment costs (97,200 – 145,800 BDT/year for Aquonic 1 m^3). Furthermore, expenses for desludging services need to be considered.

Sustainability

- The Aquonic tank can be considered sustainable:
  - No chemicals: No chemicals are used for the operation of the system.
  - Modularity and scalability: Several Aquonic tanks can be installed and operated in parallel. It is a prefabricated system that can be installed easily. The system can also easily be adjusted to changing input quantities.
  - Effluent management: The effluent is pathogen-free and respects Bangladesh effluent standards. It can be used for irrigation, etc. For water saving purposes, it can be recirculated and used for toilet flushing. It has no drinking water quality.
- The Aquonic is a closed system causes no emissions in normal operation and is waterproof. The holding/septic tank that is required can cause emissions as sludge is settling in the tank and an anaerobic environment may be created.

Benefits and Limitations

Benefits

+ Small footprint.
+ Suitable for retrofitting of existing systems.
+ Closed, watertight system that does not produce any odors or sounds in normal operation.
+ Moveable and easy to install
+ Automated treatment.
+ Can treat low and high strength wastewater.
+ Can be stopped and started without affecting performance of the system.
+ Pathogen-free effluent.

Limitations

– Regular maintenance is required.
– System will require start-up phase if stopped for over 6 months.
– Electronic and electrical system needs protection against water.
– Requires electricity for operation.
– Has to be aboveground or in accessible subsurface enclosure (e.g. building basement).

Manufacturer / Service Provider

- SCG Chemicals Public Company Limited: 1 Siam Cement Road, Bangsue, Bangkok 10800 Thailand. Phone: +6625861111.
- Green Genesis Limited: (Currently establishing partnership with SCG) House B/113, Mosque Road, New DO HS Mohakhali, Dhaka-1206. Phone: 01810033413, Email: gm-tech@greengenesisbd.com

Single Integrated Systems

R3H2O

C12

Overview

Input	Blackwater Greywater	
Output	Effluent/Recycled Water Sludge	
Capacities (m^3/day)	**Min** 0.5	**Max** 50
	in the automatic portable machine	
	Min 50	**Max** 1,000
	in civil structure	
Output Quality	* **Free of Pathogens**	
	Effluent quality (mg/L) <5 BOD <30 COD	
	Removal efficiencies (%) 95 BOD 85 – 90 COD 85 TSS	
Important Requirements	• Electricity supply. • Wastewater holding tank (e.g. adapted septic tank). • Accessibility for desludging services.	

Visualization

FIGURE 12: R3H2O on-site system installed in open space.
Source: Tellus Habitat.

Technical Description

- The R3H2O is provided by an Indian service provider.
- SS-304 & PP-FRP variants are available with customizable outer bodies (square and cylindrical).
- A holding tank for collection and as solid separator chamber.
- The main treatment steps are: Anaerobic Digestion, Anoxic Treatment, Aeration, Filtration and Disinfection.

Suitability

Holding Type

- Suitable for all holdings with domestic and industrial wastewater including residential, educational, institutional, healthcare, business and industrial holdings.
- There is specifically proven experience with wastewater from F&B industry and laundromat industry.

Space Requirement

- The space requirement of the system can be considered to be relatively low. Depending on the capacity it varies between:
  - 0.5 m^3/day → 1 m^2 (1 family or 5 users).
  - 50 m^3/day → 24 m^2 (100 families, 500 users).

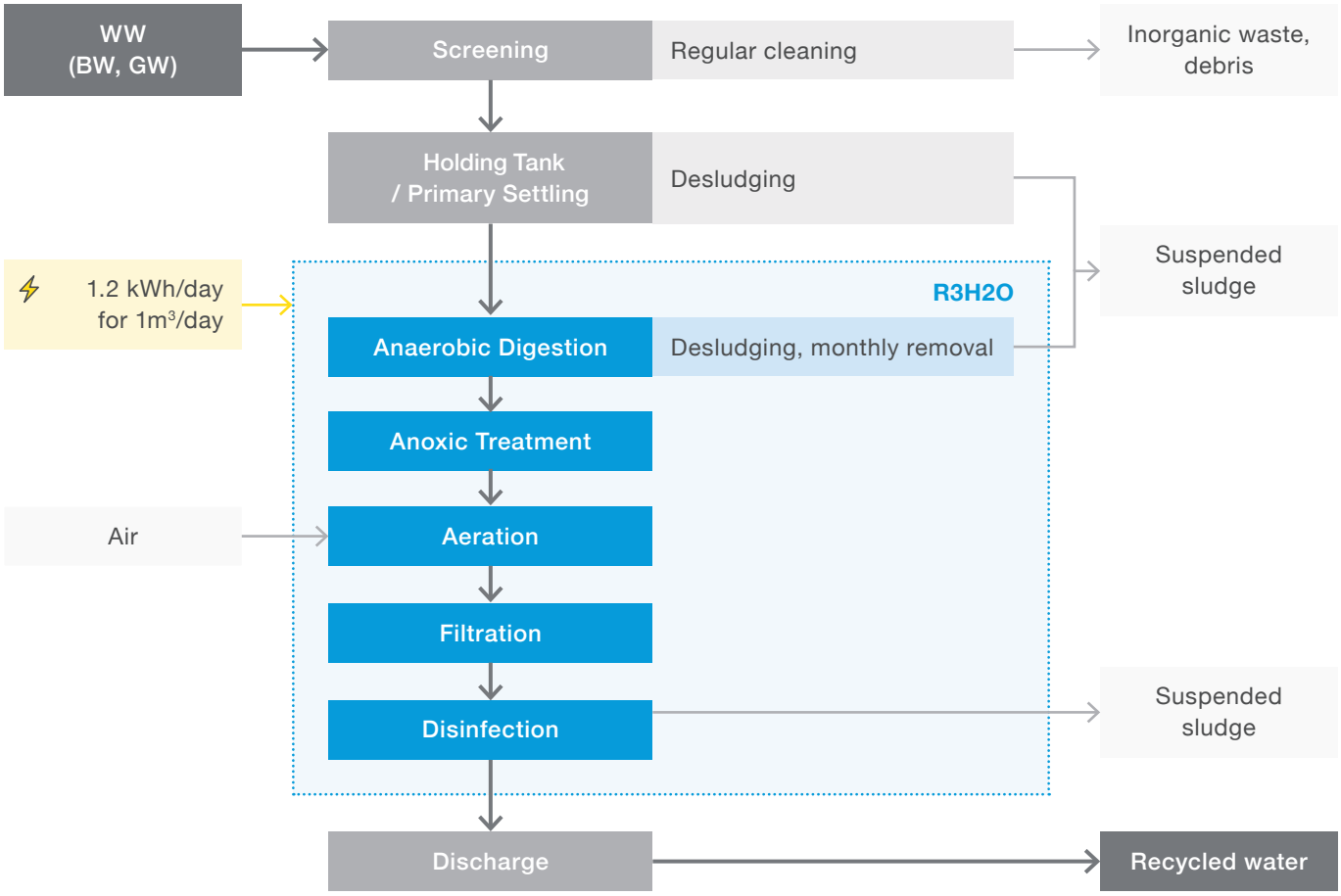
Technical Complexity

- The system can be considered to be highly complex from a technical standpoint.

Construction

- The R3H2O can be installed at any level: underground, aboveground, or even rooftop for smaller scales.

Flowchart



Planning, Design and Implementation Considerations

General Considerations

- During flooding or drought, the system can handle 30% of wastewater intake fluctuations (on both ends of the spectrum). The system will also act as a purifier for existing available water.
- Ventilation is designed to ensure that there is no odor in the near vicinity. Additionally, a disinfection system takes care of odoriferous compounds.
- The whole process from order, manufacturing, installation and commissioning takes about 6 weeks with Tellus Habitat.
- Accessibility for desludging services is required. The desludging frequency will depend on the wastewater but is usually less frequent than with conventional septic tanks.
- A wastewater holding tank is required. Either an existing septic tank can be used, or a new tank can be installed according to design requirements.

Effluent Post-treatment

- The effluent does not require post-treatment if all steps including filtration and disinfection are considered. It can be used for irrigation, reused or discharged into the environment. For disinfection, ozonation with activated carbon filter is offered.
- The units are designed considering on-site water recovery, thus producing recyclable water which meets WHO guidelines for non-potable applications around the house.
- These will include floor cleaning, flushing, gardening, irrigation, car washing, or any other usage in residential or industrial contexts which does not involve drinking/cooking.

Watertightness

- The system has low risk of water leakage. The R3H2O are high-density, double-welded polypropylene tanks with insulation cladding. Therefore, they can be considered as watertight.

Electricity

- The system ⚡ requires electricity. The average consumption is 1–1.2kWh/day for the smallest and 12–15 kWh/day for the largest systems.

Operation & Maintenance Requirements

- O&M requirements for the R3H2O can be considered to be high requiring maintenance on a monthly basis. The operation itself is fully automated.
- General maintenance include:
  - Oiling the pumps (quarterly).
  - Removing the biological sludge (monthly).
  - AMC and maintenance services are offered by Tellus Habitat.
- Consumables:
  - Biofilter change once in 5 years.
  - Activated carbon change once a year.
- The service provider gives a general warranty of 5 years for the structure and 1 year for electro-mechanical components.

Health Aspects

- During electrical fluctuations, treatment efficiency might reduce.
- Do not use treated water for drinking or cooking, even after boiling.
- The sludge removal valves are placed at the bottom ensuring minimal contact with operators while clean-up. During clean-up, Personal Protective Equipment (PPE) should be worn to avoid any direct contact with sludge.
- Only trained individuals should be allowed to do any internal maintenance.

Costs

- Investment costs for the R3H2O can be considered to be high.
- The investment costs depend on the capacity of the system:
  - 0,5 m^3/day treatment capacity → app. 275,000 BDT.
  - 50 m^3/day treatment capacity → app. 3,800,000 – 4,400,000 BDT.
- The indicated investment costs to not include taxes & transportation.
- O&M costs include mainly desludging services and electricity costs.

Sustainability

- This is the state of art on-site sanitation system that provides recycled water.
- The system generates some air emissions (in the form of CH_4 and CO_2), but significantly less than septic tanks.

Benefits and Limitations

Benefits

+ Recycled water.
+ Closed system with low risk of exposure to microbes.
+ Easy to install, transport, and maintain.

Limitations

– Electricity is required.
– Phenolic compounds (over 200 mg/L) cannot be treated.

Manufacturer / Service Provider

- Tellus Habitat: (Currently seeking for partner company in Bangladesh) #16, 14th Cross, Krishnananda Nagar, Malgala, Nagarbhavi, Bangalore 560091, India. Phone: +918527812869 / +919591019546.

Reference Projects

- Tellus Habitat:
  - 25 KLD system in Prestige Tech Vista, Bangalore.
  - 13 KLD system in Vaishnodevi builders.
  - 50 KLD system in a village in Gujarat (ACT client).
  - 10 KLD system for Glass making industry (Glassio).

Notes

Technical Guideline

Safely Managed On-Site Sanitation: Technological Solutions for City Dwellers and Authority ‘Dhaka North City Corporation’