TECHNICAL BRIEF

SUSTAINABLE WASTEWATER MANAGEMENT FOR WATER VILLAGES

GRID ARENDAL

A UNEP Partner


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Call to Action

Urgent and coordinated action is required at the global, regional and local levels to address the lack of sanitation and wastewater treatment affecting over 2 million people living in water villages worldwide. These communities, often excluded from formal infrastructure and services, discharge millions of litres of untreated sewage daily into the waters they rely on. The resulting public health and environmental risks are severe and escalating. Community-led sanitation and wastewater treatment solutions, such as floating toilets, biodigesters, and decentralized treatment systems, must be prioritized to safeguard health, protect ecosystems, and unlock the socio-economic potential of these unique settlements.


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Sustainable Wastewater Management for Water Villages

Technical Brief

A conservative estimate suggests that over **2 million people** worldwide live in water villages – settlements built directly over or alongside bodies of water. The homes are often constructed on stilts or floating platforms, and a defining feature of these communities is the near-total absence of formal water and sanitation services. Most sewage and other household wastes are discharged directly into surrounding waterways. **Collectively, these communities generate an estimated 4 million litres of sewage every day, contaminating nearby ecosystems and, in the case of lake and river settlements, polluting the very water used for drinking, cooking, washing and cleaning.**

This Technical Brief presents practical and context-relevant solutions for managing wastewater in water villages. It offers 8 actionable recommendations for policymakers to inform investment and regulatory decisions that improve health and environmental outcomes.

> ***4 million litres of sewage every day***

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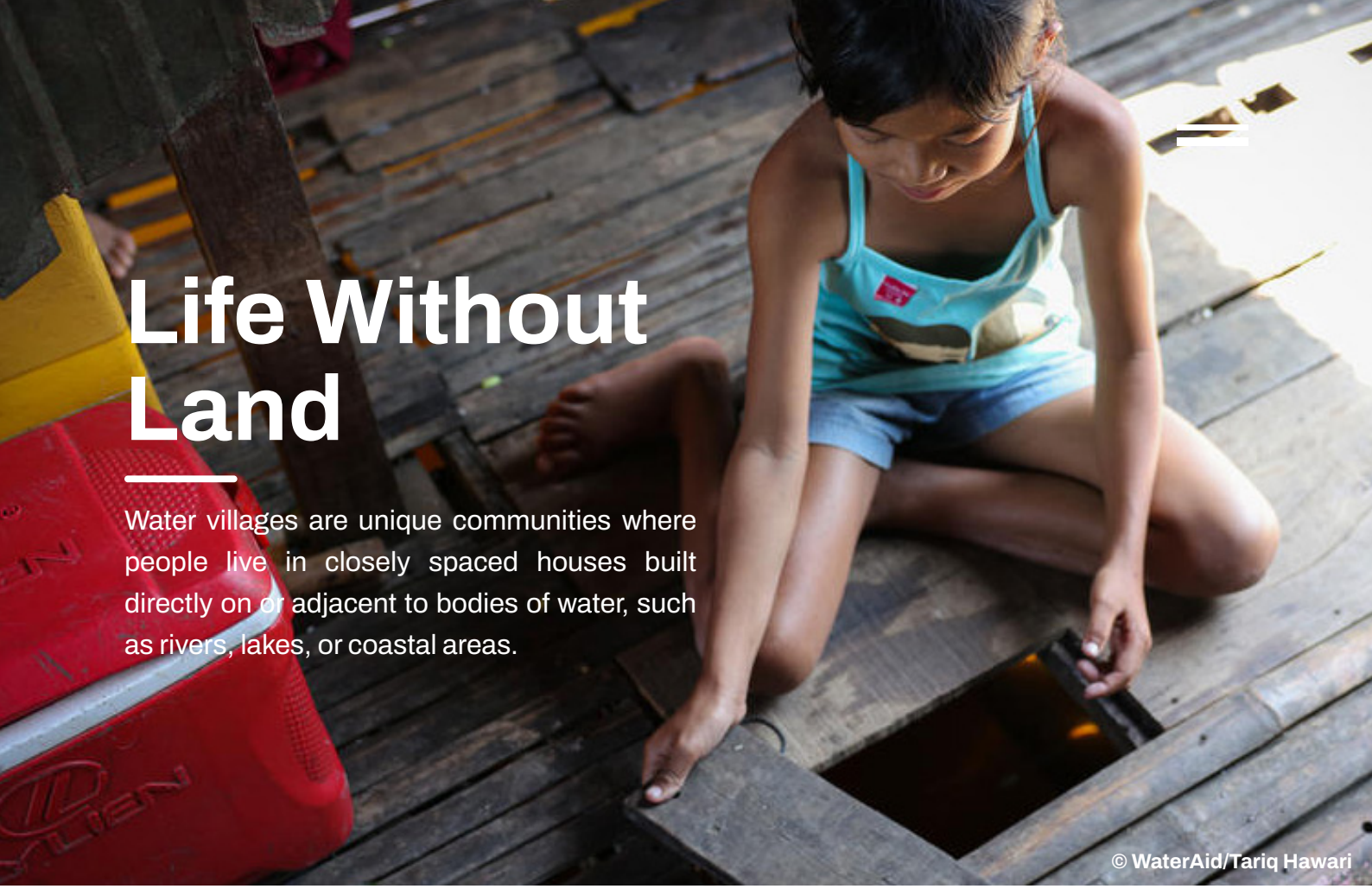

Life Without Land

Water villages are unique communities where people live in closely spaced houses built directly on or adjacent to bodies of water, such as rivers, lakes, or coastal areas.

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Historically, these settlements emerged in response to environmental, social, and economic challenges (Evers 2013). They are found around the world, with large populations concentrated in Southeast Asia, South America and West Africa. Some are ancient, such as the floating village of Cai Beo in Viet Nam where archaeological excavations suggest human habitation as far back as 7000 years (Nguyen 2022). Others are more informal, such as the Cai Rang floating market, which is home to a large number of migrants from the Mekong delta, many of whom arrived on boats in the 1990s. These boats have since become permanent homes (Cuini 2020).

Fishing and aquaculture are major sources of income in water villages, while traditional lifestyles have also created tourism opportunities. The 400-year-old Ganvié township, which houses nearly 40,000 people in elevated houses on Lake Nokoué, Benin (RGPH5 2023) is a popular destination. Nearly 100,000 visitors take a guided boat tour of the town every year, generating USD 8 million (EMC 2025). Other notable sites include the Uros floating islands in Lake Titicaca, Peru. Estimated to have been established nearly 4000 years ago, the extensive floating islands are man-made, woven from the totora reed which grows in the lake (Jeremic and Marchi 2024).

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Global distribution of water villages and their populations

Estimating the number of people living in water villages remains difficult as residents are often excluded from government registries and official service systems. A preliminary review of published estimates (Figure 1) suggests that at least 2 million people live in such communities worldwide.

Figure 1: **Preliminary review of the global distribution of water villages and their population.**

Name	Country	Population
Sausalito	United States	1000
Bayou Communities	United States	Unknown
Ciénaga's stilt towns	Colombia	2500
Santa Cruz del Islote	Colombia	816
Leticia	Colombia	100000
Uros Floating Islands	Peru	1300
Belén	Peru	60000
Pantanal Wetlands	Brazil	Unknown
Bokodi floating village	Hungary	2000
Makoko	Nigeria	250000
Ganvie	Benin	20000
Nzulezo	Ghana	550
Yawnghwe	Myanmar	80000
Moken village	Thailand	800
Koh Panyee	Thailand	1600
Champu Khangpok	India	2000
The Clan Jetties Of Penang	Malaysia	800
Kampong Phluk	Cambodia	6000
Tonlé Sap Floating Villages	Cambodia	80000
Châu Doc Floating Village	Vietnam	Unknown

Name	Country	Population
Halong Bay Floating Villages	Vietnam	1600
Tai O	Hong Kong	2000
Aberdeen Floating Village	Hong Kong	6000
Sitio Pariahan	Philippines	100
Day-asan Floating Village	Philippines	1800
La Flora	Philippines	1518
Sabang Gibong	Philippines	833
Kampong Ayer	Brunei	10250
Hanuabada stilt village	Papua New Guinea	15000
Koki stilt village	Papua New Guinea	750
Kia	Solomon Islands	1900
Lilisiana	Solomon Islands	1000
Hagalu	Solomon Islands	Unknown

Collection based on people and area	countries	Population
Bajau Peoples	Philippines, Malaysia and Indonesia	1000000
84 major water villages	Borneo (Malaysia, Brunei, Indonesia)	215000

Environmental and Health Challenges

Water villages provide affordable housing for low-income households, but this comes at a significant social and environmental cost (Ferguson 1996). These settlements are consistently identified as sources of pollution due to the historical practice of discharging waste, including sewage, directly into surrounding waters (e.g., Dollah et al. 2023).

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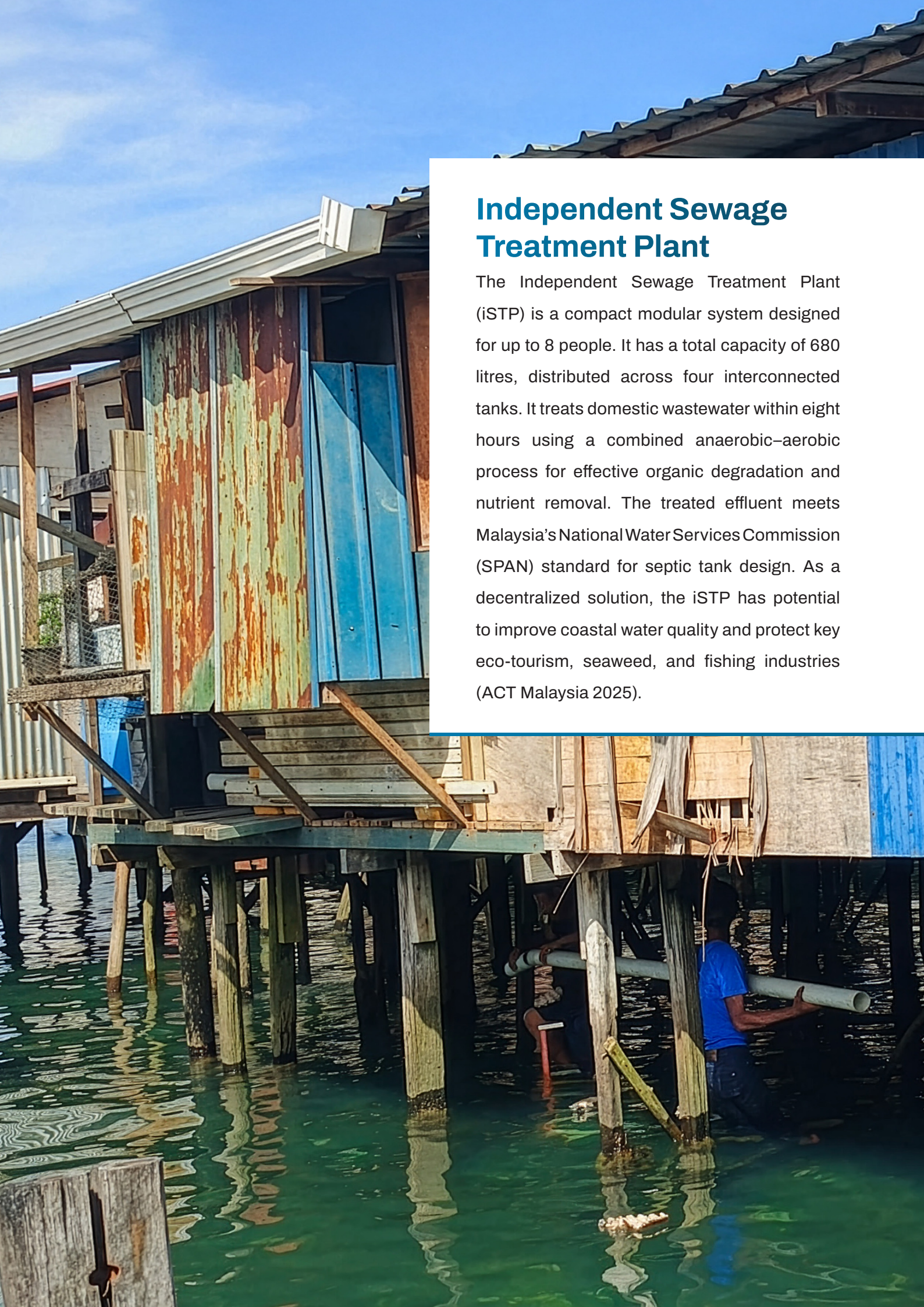
More than
1 million people

For example, more than 1 million people living on or around Tonle Sap Lake in Cambodia use the lake for waste disposal. Nearly half the water used for drinking, cooking and washing in these communities is also drawn from the lake (Watanabe et al. 2022). A recent study found concentrations of Proteobacteria (a group that includes a wide variety of human pathogens) were more than 10 times higher around water villages compared to non-point source areas of the lake (Ung et al. 2019). Similarly, elevated levels of high microbial resistant E. coli bacteria have been detected around the water villages, with a marked increase in concentration during the low-water season in June. The risk of infection is exacerbated by increasing population numbers and climate change (Yoneda et al. 2022).

Previous work in floating villages in Cambodia found high rates of diarrhoea and other waterborne diseases (Brown 2010; Table 1). Innovative solutions such as floating toilets and biodigesters have demonstrated that locally made, affordable sanitation systems can significantly reduce contamination and improve community health. However, challenges remain in scaling these solutions, ensuring maintenance, and fostering community ownership.

Health Issue	Statistic	Reference
Diarrhoea (adults)	~18.8% experience severe diarrhoea annually	Nakamura et al. 2023
Diarrhoea (children)	Up to 45 episodes per year	Watanabe et al. 2022
Toilet access	Only 58.2% of households have a toilet, most being simple floor openings discharging directly into water	Watanabe et al. 2022
Handwashing with soap	Only 40–45% of children wash hands before eating or after defecation	Watanabe et al. 2022

Table 1 **Health and sanitation information, Tonle Sap Lake (Cambodia)**



Independent Sewage Treatment Plant

The Independent Sewage Treatment Plant (iSTP) is a compact modular system designed for up to 8 people. It has a total capacity of 680 litres, distributed across four interconnected tanks. It treats domestic wastewater within eight hours using a combined anaerobic–aerobic process for effective organic degradation and nutrient removal. The treated effluent meets Malaysia's National Water Services Commission (SPAN) standard for septic tank design. As a decentralized solution, the iSTP has potential to improve coastal water quality and protect key eco-tourism, seaweed, and fishing industries (ACT Malaysia 2025).

Water Villages in Sabah

Coastal communities in Sabah, located between the South China and Sulu Seas, have a long tradition of establishing settlements on water, especially in flood- prone and low-lying coastal areas. Living on water offers access to trade and fishing, while providing some defence against hostile groups. Ten years ago, it was estimated that there were 84 major water villages on Borneo, with more than 43,000 dwellings and over 215,000 residents. About 24 per cent of these were located along the coast of Sabah (Evers 2015).

Communities such as Sembulan Tengah in Kota Kinabalu and Lok Urai on Pulau Gaya, have deep historical roots, but face significant challenges due to social disadvantage and lack of infrastructure. Communities regularly experience outbreaks of cholera (Malunda et al. 2024). However, despite the harsh conditions and lack of many modern amenities, they remain vibrant communities with schools, shops and mosques.

In Lok Urai, a pilot project supported by the United Nations Environment Programme (UNEP) and UN-Habitat has introduced Independent Sewage Treatment Plants (iSTPs) that can be installed under homes and schools. These light-weight, low-energy systems have shown early success in improving hygiene and reducing disease risks (UNEP 2021).

Options for Managing Wastewater in Water Villages

Sewage management in water villages is uniquely challenging due to the absence of land-based infrastructure. Any solution must be culturally acceptable to the users, technically possible (taking into consideration physical challenges such as tides, storms, flooding and the lightweight nature of many buildings), and financially viable to install and maintain. Figure 2 illustrates consideration for wastewater treatment in floating villages.

Several of these approaches have been developed into innovative and context-appropriate solutions, such as the iSTPs piloted in Lok Urai, Sabah (see page 11). Others include:

Floating Toilets in Cambodia

Several floating toilets designs have been installed in Tonle Sap, Cambodia to address the sanitation challenge. One notable innovation is the HandyPod treatment system developed by Wetlands Work. This system uses a series of anaerobic digestion chambers that release partially treated wastewater into a floating garden of water hyacinths or polystyrene filters. The plant roots further break down some pollutants before the treated effluent is discharged into the lake, producing effluent that exceeds Cambodian government discharge standards (Engineers Without Borders 2017).

Considerations for wastewater treatment in water villages

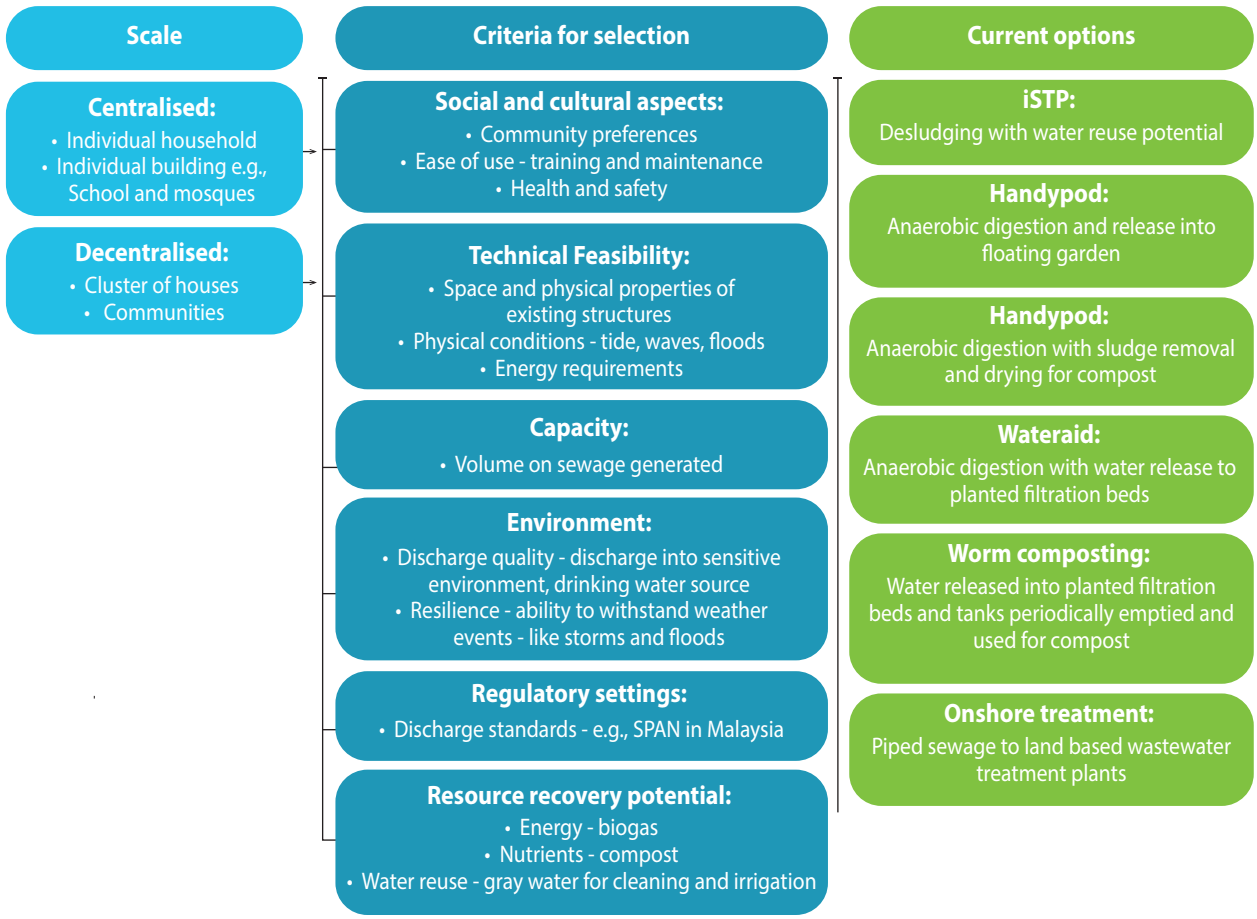


Figure 2. **Considerations for wastewater treatment in floating villages**

The HandyPods have been shown to reduce E. coli levels in surrounding water by up to 50 per cent. However, these toilets do not eliminate all bacterial contamination in the lake, as other sources, such as large volumes of pig waste from surrounding areas, also contribute to pollution (NPR 2014).

Floating toilets - with or without urine diversion - are among the Oother Handypod systems tested at Tonle Sap include. These floating toilets that are connected to a series of anaerobic digestion tanks containing biofilm that breaks down sewage and reduces pathogens. When the tanks are full, the partially digested faeces are dried and transported to on-land compost sites or used as garden fertilizer. The system is capable of Instead of water discharging into floating gardens the producing grey water produced that can be used for washing and cleaning (Straits Times 2023). A HandyPod toilet costs between 50-200 USD depending on the number of tanks employed (ADB 2009).

Floating sewage digestion tanks in Chong Prolay village on the Tonle Sap Lake in Siem Reap province Cambodia (from www.wetlandswork.com).

WaterAid has also installed public floating toilets in Cambodian river communities. These facilities use floating septic tanks filled with coconut fibre connected to planted filtration beds. Tanks require desludging approximately every two years (WaterAid 2024).

Worm composting toilets

Worm composting (vermicomposting) toilets, though not yet tested in water villages, offer a low-cost, dry sanitation option. These dry composting toilets (urine is diverted or absorbed into the composting material) have an aerobic-composting chamber that contains bedding materials such as coconut fibre and composting worms, typically the red wriggler (*Eisenia fetida*) and the Indian blue worm (*Perionyx excavatus*). The worms and associated microbes break down faecal matter, reducing the volume, odour and pathogens. The resulting vermicompost can be periodically removed for use as fertilizer (Alonso-Marroquin et al. 2023). The liquid waste can be managed with a green filter system before being discharged into the water or used as grey water.

Recommendations for Policymakers

To achieve sustainable wastewater management in water village communities, policymakers should prioritize co-designed, culturally appropriate solutions that reflect community needs and practices (see Table 2). Technologies such as floating toilets, biodigesters, and vermicomposting systems are viable but face barriers, including limited funding (the cheapest published decentralised system cost 50 USD per household to install), low technical capacity, and community reluctance to pay for services traditionally accessed for free (WaterAid 2017). Overcoming these challenges requires multi-stakeholder collaboration, including support from local governments, NGOs, and international donors (UNEP 2023).

Promising strategies include community-led maintenance models (as in Sabah), awareness campaigns, and the use of locally sourced materials to reduce costs and foster ownership. Integrating sanitation with livelihood programmes, such as compost reuse or biogas generation, can enhance sustainability and community ownership. Participatory design and local regulation, including subsidies or microfinance schemes, can accelerate adoption. Improved sanitation and water quality also support tourism and local economic growth, providing further incentives for investment.

Strategy	Description	Examples	Reference
Community consultation	Engaging residents early in planning ensures alignment with local needs, cultural practices, and economic realities. Consultation can include workshops, household surveys, and demonstrations of technologies.	iSTP in Sabah	UNEP 2025
Centralised sanitation systems	Individual aerated wastewater treatment style septic tanks attached to homes, schools etc.	Septic tanks in Sabah	UNEP 2025
Decentralized sanitation systems	Locally managed biodigesters, composting toilets, or wetlands.	Floating toilets in Lake Nokoué, Benin; biodigesters in Bangladesh slums	EMC 2025; Narone et al. 2022
Floating or modular toilets	Floating sanitation units that can be safely emptied.	WaterShed toilet boats in Cambodia; prototype floating latrines in Makoko, Nigeria	WaterAid 2024; RTF 2016
Community education and engagement	Hygiene and waste disposal awareness campaigns.	WaterAid WASH programmes in Southeast Asia; UNICEF hygiene education in Cambodia	WaterAid 2024a; UNICEF 2025
Water access innovations	Rainwater harvesting, solar filtration, portable treatment kits.	Rainwater tanks in Tonle Sap; LifeStraw filters in Kenya	Wetlands Work 2025; Life Straw 2022
Partnerships and funding	Collaborations among governments, NGOs, and donors.	Gates Foundation sanitation grants; ADB-funded floating toilet pilots	Gates Foundation 2025; ADB 2021
Monitoring and maintenance	Community-led upkeep of sanitation infrastructure.	Community toilet committees in India; village health volunteers in Cambodia	BU 2024; Oum et al. 2005

Table 2 **Strategies for improved wastewater management in floating villages**

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GLOBAL WASTEWATER INITIATIVE

Join the Global Wastewater Initiative

The Global Wastewater Initiative (GWWI) is a multi-stakeholder partnership whose Secretariat is hosted by the United Nations Environment. Launched in 2013, its purpose is to address wastewater-related issues, prompt coordinated action and encourage new investments for sustainable wastewater management. The GWWI intends to bring about a paradigm shift in the way wastewater is seen, from waste to a resource, and prevent further pollution and degradation of our environment.

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