CLIMATE-SMART WASH TECHNOLOGY CATALOGUE WITH MODELING

UNICEF x AIT

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KEY MASSAGE

"Since 2011, several innovative WASH technologies have been developed within different contexts that people in less-developed countries can access and creating a platform of global sanitation sustainability. In support of well-designed WASH technologies adopted and applied in the regional contexts, the AIT team has been assigned to provide the technical support to develop a catalogue under the project "Development of Climate-Smart WASH Technology Catalogue with Modeling" funded by the UNICEF with comprehensive reviews including specifications of associated greenhouse gas emission data, energy efficiency for household and community choices and uses. With the outcomes from this assignment, the Climate-Smart WASH catalogue is expected to assist the WASH actors with best information available and deliver best possible outcomes for children and people in the less-developed countries with knowledge and advices for their decisions and actions, all leading to future sustainability."

Prof Dr. Thammarat Koottatep
Project lead

ABBREVIATIONS:

BW	Black water
COD	Chemical oxygen demand
DFS	Dried faecal sludge
DM	Domestic wastewater
EFF	Effluent from OSS system
EC	E. coli
FC	Faecal coliform
FSM	Faecal sludge management
GDW	Groundwater
GHG	Greenhouse gas emissions
GW	Greywater
HW	Handwashing
N	Nitrogen
OSS	Onsite sanitation system
RW	Rain water
WS	Water supply
WR	Water reuse
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TC	Total coliform
SW	Surface water
SN	Sanitation
WFS	Wet faecal sludge
YW	Yellow water

LIST OF TECHNOLOGY

Water

1. Hybrid Ion Exchange system
2. Solar-Powered water supply system
3. Community well with handpump
4. Household Sand Filter
5. Household Membrane Filters
6. Complete water filtration system

Hygiene

7. Foot-operated handwashing station
8. Splash handwashing and drinking stations
9. Solar Powered Automated Hand Washer
10. Autarky handwashing station (AHWS)

Sanitation

11. Solar Septic Tank (SST)
12. Aerated septic tank
13. ECO-SAN Toilet
14. ZYCLONE CUBE
15. Vermicomposting toilet
16. Omni Processor
17. Planted Drying Bed
18. The Black Soldier fly (BSF)
19. Co-composting
20. Anaerobic Digestion

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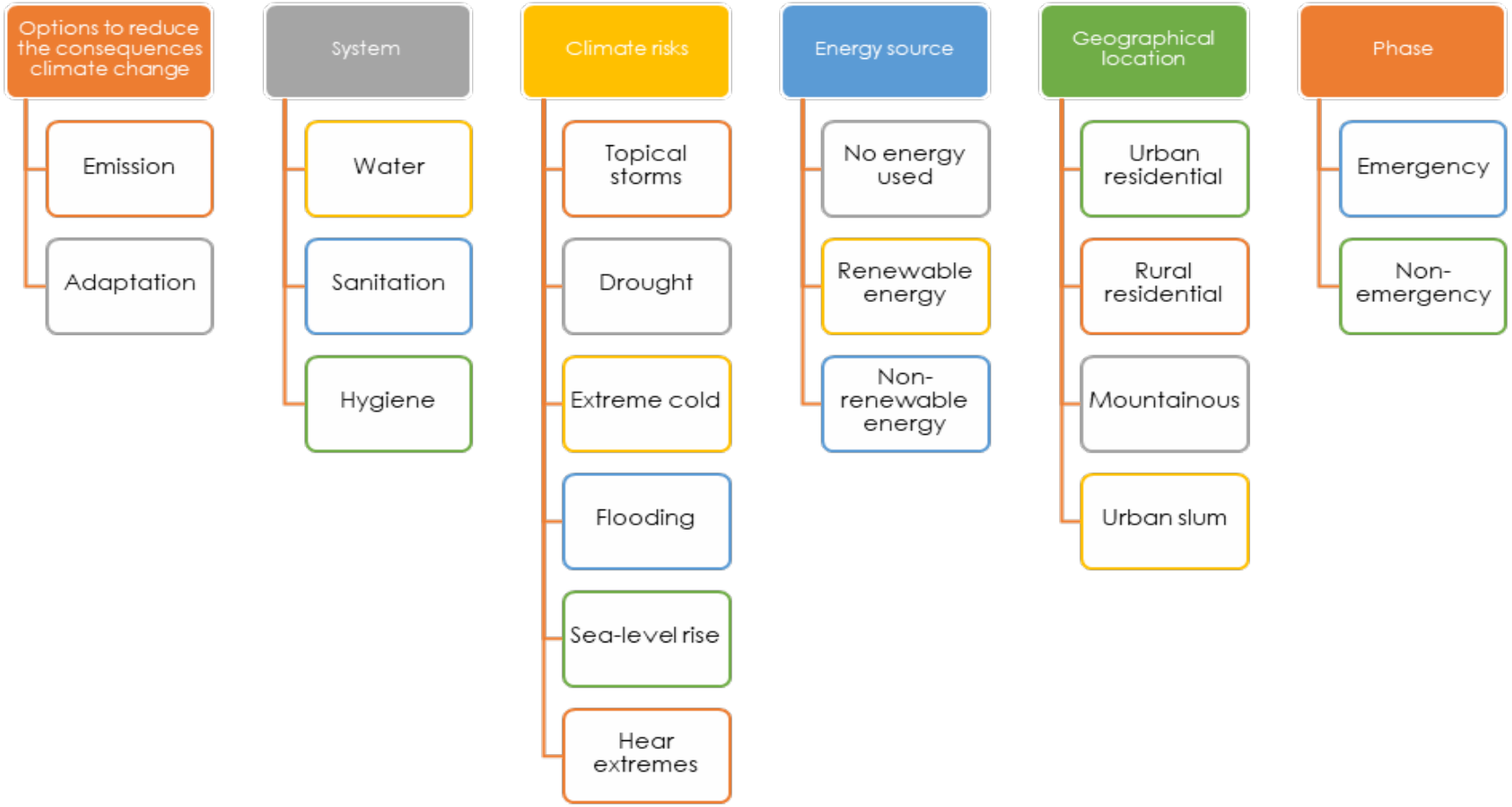
WATER 

HYGIENE 

SANITATION 

CATEGORIES AND CRITERIA IN THE CLIMATE SMART WASH INFORMATION



20 TECHNOLOGIES AND EACH CONTRIBUTION TO MITIGATION SCOPE 1&2 AND ADAPTATION

TECHNOLOGIES	SECTOR	MITIGATION Scope 1	MITIGATION Scope 2	ADAPTATION	CROSS-CUTTING
1 Title: Hybrid Ion Exchange system	Water	-	+	+	✔
2 Title: Solar-Powered water supply system	Water	-	+	-	✔
3 Title: Community well with handpump	Water	+	-	+	✘
4 Title: Household Sand Filter	Water	-	-	+	✘
5 Title: Household zMembrane Filters	Water	-	-	+	✔
6 Title: Complete water filtration system	Water	-	-	+	✔
7 Title: Foot-operated handwashing station	Hygiene	-	-	-	✔
8 Title: Splash handwashing and drinking stations	Hygiene	-	-	+	✔
9 Title: Solar Powered Automated Hand Washer	Hygiene	-	-	-	✔
10 Title: Autarky handwashing station (AHWS)	Hygiene	+	+	+	✔
11 Title: Solar Septic Tank (SST)	Sanitation	+	+	+	✔
12 Title: Aerated septic tank	Sanitation	+	+	+	✘
13 Title: ECO-SAN Toilet	Sanitation	-	-	+	✔
14 Title: ZYCLONE CUBE	Sanitation	-	+	+	✔
15 Title: Vermicomposting toilet	Sanitation	-	-	+	✔
16 Title: Omni Processor	Sanitation	+	-	+	✔
17 Title: Planted Drying Bed	Sanitation	+	-	+	✘
18 Title: The Black Soldier fly (BSF)	Sanitation	-	+	+	✔
19 Title: Co-composting	Sanitation	+	-	+	✔
20 Title: Anaerobic Digestion	Sanitation	+	-	+	✘

1. HYBRID ION EXCHANGE SYSTEM

WATER

TECHNOLOGY DESCRIPTION

The Hybrid Ion Exchange system is a mobile drinking water technology that is installed as mobile-enabled water ATMs. The purpose of this technology is to further purify the contaminated water and offer prepayment option using mobile money (pay-as-you-go cards). The technology is employed with the "HIX" (Hybrid Ion Exchange), a patented nanotechnology-based resin platform capable of consistently removing arsenic and fluoride in contaminated raw water sources, especially groundwater. The technology comes up with given benefits of scalable technology, cost-effectiveness, and safe filtration technology with an integrated water flow and quality monitoring solutions, working with mobile operators and reducing water wastage. Meanwhile, it has some limitations of requiring energy to operate the system as needs of well-trained operators and economical management to sustain the service.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Electricity**
Energy consumption (kwh/d)	**13 kwh/m³** *water produced*
GHG Emission (kg CO_2 eq./ annum)	**6.5 kgCO^2 eq/ m³** *water produced*
Remark	Annual GHG emission (kg CO_2 eq./annum) of the technology was not reported. Rather, it was estimated based on energy consumption per volume of treated water.

Total GHG emission	**N/A**	kg CO_2 eq./annum
	6.5 kgCO_2 eq/ m³ *water produced*	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Drought, Tropical storms, Dust storm** As this technology is especially designed for improved the contaminated groundwater, it can generally provide much greater resilience to drought than traditional water supplies including springs and surface water sources. In many regions, groundwater is the only perennial source of water supply. With the equipped management system through mechanical, digital, and cloud-based automation thereby reducing cash leakage, water loss, and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources as possible as detecting and preventing leakage in piped water systems can lead to large savings in the energy used to transport, treat and distribute water.
Development impact: Environmental and health benefits	The technology can provide an important source of safe drinking-water in the curtain circumstances, especially a useful source of contaminated groundwater by reducing the levels of the contaminants (i.e., arsenic and fluoride) of health concern.
Climate risks	**Yes** **Flood,** 1. Damage to infrastructure (e.g., collapse of unlined wells and physical damage to wellhead). 2. Inundation of wells and water treatment systems. 3. Inaccessibility of the water sources 4. The water resources get polluted.
Adaptability: *Remarks: the additional detail of equipment or practices (installation and SMART monitoring etc) to adapt and respond to changing conditions while maintaining functionality*	**Text (Detail):** 1. In flood-prone areas, raising the wellhead and applying protected wells need to be implemented. 2. Location consideration need to be considered prior to installing the water treatment technology. 3. Flood protection (e.g., levees, drainage ditches, artificial waterways, soil, and water conservation on adjacent land to enhance infiltration and reduce runoff, etc.)

Resources or Reference:

1. Drinkwell. (2021). Drinkwell Water ATMs improve the performance of your water system through automation. Available: https://drinkwellsystems.com/ (Accessed: 21 September 2021)
2. German, M., Seingheng, H., & SenGupta, A. K. (2014). Mitigating arsenic crisis in the developing world: Role of robust, reusable and selective hybrid anion exchanger (HAIX). Science of the total environment, 488, 547-553
3. Sarkar, S., Greenleaf, J. E., Gupta, A., Ghosh, D., Blaney, L. M., Bandyopadhyay, P., ... & SenGupta, A. K. (2010). Evolution of community-based arsenic removal systems in remote villages in West Bengal, India: assessment of decade-long operation. water research, 44(19), 5813-5822.

Remarks: N/A: not available data

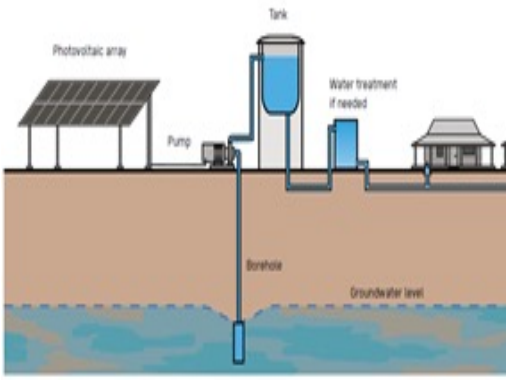
TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** The technology offers hybrid ion exchange, zirconium nanoparticles, a material that has a high affinity for arsenic and fluoride removal providing the following advantages: 1) 6x lower energy costs vs. Reverse Osmosis (RO) 2) 99% water recovery vs. 40- 50% for RO. Also, the Drinkwell is installed with the Water ATMs which simplify complex water system management through mechanical, digital, and cloud-based automation thereby reducing cash leakage, water loss, and human dependency required to operate a community-based water system.
Stage of technology	**Commercial**
Application level	Community, Institution
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	Number: 1– 6
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	• Arsenic removal: > 99%; Effluent Arsenic: <1 ppb • Iron removal: 88%; Effluent Iron:<0.24 mg/L • Fluoride removal: 88%: Effluent Fluoride: <0.47 mg/L • TDS removal: 40%
Complies with the standards	WHO drinking water quality standards (2017)
O&M Requirement	• Regular O & M tasks include the daily verification of instrument accuracy. • A media replacement is required during the operating period based on the raw water input.
Capital cost and investment cost (USD and USD/m^3)	**1,385-4,450 USD/system** The costs include products, materials, installation, construction costs
O&M cost (USD/year)	**510-2,100 USD/year** The costs include energy costs, and operational & maintenance (Water testing, media regeneration and Caretaker) costs
Durability/Lifespan (years)	5-10 years* Life span of the HIX resin
Manufacturer/Products name/ Brand	Drinkwell™
Reviewed countries of application	Laos, Cambodia, Bangladesh and India
Countries of product available	Laos, Cambodia, Bangladesh and India
After sale services	Yes

2. SOLAR-POWERED WATER SUPPLY SYSTEM

WATER

TECHNOLOGY DESCRIPTION



The solar-Powered water supply system is designed to be manufactured on-site using locally available materials following the open-source construction manual. The Solar electrical energy is produced when photovoltaic (PV) cells convert solar energy to electricity, which usually then powers a submersible or surface pump to abstract raw water from the sources. Solar-Powered pumping systems (SPPS) should be combined with an elevated water storage tank (or if unavoidable, with batteries) to store energy, ensuring a continued water supply on cloudy days and at night. The technology comes up with the advantages, namely use of renewable energy, a low-carbon energy option, no dependency on erratic or expensive fuel chain supply, and no pollution or noise produced. Also, it presents relatively low maintenance costs and therefore low overall cost to users. Nevertheless, the limitations including high capital investment, high risk of theft of panels, requiring a larger water storage capacity, dependence on solar radiation levels are still found for the technology.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**None**
Disposal	**None**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Solar energy**
Energy consumption (kwh/d)	Various depending on treatment processes applied (SPPS3–4 kW/ m^2)
GHG Emission (kg CO_2 eq./ annum)	None
Remark	-

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding,** The Solar-Powered water supply system aims to upgrade many of the traditional hand pumps. The new systems break down less frequently than hand pumps, and cost very little to maintain. The systems can support multiple communities and are helping to sustain life, in a region that is highly prone to drought and famine. As such, the solar powered water systems are helping to improve resilience. By ensuring that the water supply would not be impacted by electricity cuts during/following storms and floods, the solar-powered water supply system can be designed based on identified risks, such as building stronger foundations for water towers to ensure they could withstand the impact of a typhoon, installing water tower and pump head above the flood line, etc.
Development impact: Environmental and health benefits	The Solar-Powered water supply system are a well-accepted technology. As a renewable energy source, they reduce the need for energy derived from fossil fuels, thus reducing the system's carbon footprint, and improving air quality.
Climate risks	**No**
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**None**

Resources or Reference:

Resources or Reference:

1. Coerver, A. , Ewers, L., Fewster. E., Galbraith, D., Gensch, R., Matta, J., Peter.M. (2021). Compendium of Water Supply Technologies in Emergencies (1st Edidtion). WASH Sector - Cox's Bazar/ Bangladesh, UNICEF.
2. Engineering For Change. (2021). Pumpmakers DIY Solar Pump: Dietmar Stuck. Available from: https://www.engineeringforchange.org/solutions/product/pumpmakers-diy-solar-pump/ (Accessed: 22 Febuary 2022)
3. Sontake, V. C., & Kalamkar, V. R. (2016). Solar photovoltaic water pumping system-A comprehensive review. Renewable and Sustainable Energy Reviews, 59, 1038-1067.

Remarks: N/A: not available data

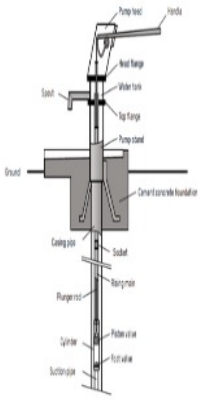
TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** The solar-Powered water supply system is a well-accepted technology. As a renewable energy source, they reduce the need for energy derived from fossil fuels, thus reducing the system's carbon footprint and improving air quality. SPPS also have a low running cost, and the operation and use are simple and reliable.
Stage of technology	**Commercial**
Application level	Community, Institution
Geographical location:	Rural residential area, Mountainous area, Urban slum
Phase	**Both emergency and non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	<18,000 L /day
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	Various depending on The treatment processes applied
Complies with the standards	WHO drinking water quality standards (2017)
O&M Requirement	• Regular checks of current, voltage and frequency are needed. • Requires only simple maintenance, batteries (if used), inverters and pumps need more frequent servicing from skilled operators. • Maintenance involves regularly cleaning the dirt and dust from the panels and protecting the panels from animal and human damage
Capital cost and investment cost (USD and USD/m^3)	**1.17 USD/m^3** water produced with the return on investment ranging generally from between 1–4 years. *Remark: Products, materials, installation, construction costs*
O&M cost (USD/year)	**N/A** **N/A**
Durability/Lifespan (years)	The solar panels warranty is up to 25 years.
Manufacturer/Products name/ Brand	-
Reviewed countries of application	Africa and Asian countries
Countries of product available	Africa and Asian countries
After sale services	Yes

3. COMMUNITY WELL WITH HANDPUMP

WATER

TECHNOLOGY DESCRIPTION



Community well with handpump is water supply with a positive displacement pump that displaces a fixed amount of water per cycle from the deep well. The ground water is lifted from depths of up to 90 meters with the aid of additional levers or gears. The pump is rarely suitable in the acute phase of an emergency and is instead better for long-term water supply in rural areas with low population densities. There are various types of pumps used for pumping ground water from the wells such as Piston-Plunger Suction Pump, Direct Action Pump and Deep Well Piston Pump.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**0.02 kg CO2 eq / m^3** *water produced*
Disposal	**None**
Remark	*Estimated by considering the GHG (CO2 CH4 and N2O) dissolved in groundwater during the water extraction process (Jahangir et al., 2012).*

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Manpower**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./ annum)	**None**
Remark	None

Total GHG emission	**N/A**	kg CO_2 eq./annum
	0.02 kg CO2 eq /m^3 *water produced*	kg CO_2 eq./m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Extreme heat** A warmer climate is highly likely to result in more frequent drought. The deep well with handpump generally have much greater resilience to drought than traditional water supplies including springs and surface water sources. In many regions, groundwater is the only perennial source of water supply. However, a more nuanced understanding of drought is needed to formulate a proper response.
Development impact: Environmental and health benefits	Groundwater is generally of a better quality than surface water, especially in terms of the microbiological risk. Regardless, it should still be checked regularly, as variations can have health impacts.
Climate risks	**Yes** **Flooding and Sea-level rise** 1. Pollution of water sources (and consequent health effects, e.g. increase in waterborne diseases) 2. Saline intrusion (affecting coastal groundwater especially during dry season in regions with high rainfall variability.
Adaptability: *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Text (Detail):** 1. Improving resilience of protected wells to flooding 2. Including treatment of drinking water by heating 3. Including Household water treatment and safe storage

Resources or Reference:

1. Coerver, A. , Ewers, L., Fewster. E., Galbraith, D., Gensch, R., Matta, J., Peter.M. (2021). Compendium of Water Supply Technologies in Emergencies (1st Edidtion). WASH Sector - Cox's Bazar/ Bangladesh, UNICEF.
2. Jahangir, M. M., Johnston, P., Khalil, M. I., Grant, J., Somers, C., & Richards, K. G. (2012). Evaluation of headspace equilibration methods for quantifying greenhouse gases in groundwater. Journal of environmental management, 111, 208-212.
3. Foster, T., Priadi, C., Kotra, K.K., Odagiri, M., Rand, E.C. and Willetts, J. (2021). Self-supplied drinking water in low-and middle-income countries in the Asia-Pacific. npj

Remarks: N/A: not available data

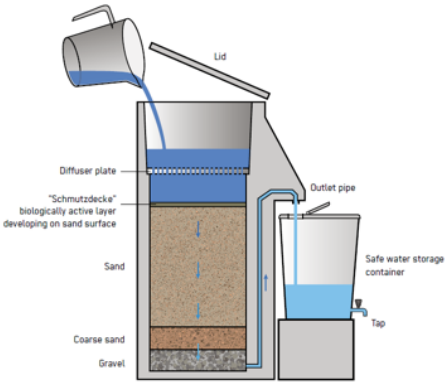
TECHNOLOGY SPECIFICATIONS

Innovative technology	**No** By comparing to the other water technologies, the community well with handpump is a conventional technology that they can take quite a long time to construct and are not typically as a novel option for water supplies.
Stage of technology	**Commercial**
Application level	Community, Institution
Geographical location:	Urban residential area, Rural residential area, Urban slum
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	600-4500 L/h ** Depending on types of an applied type of pumps*
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	The ground water may have variable chemical water quality; hence, proper treatment processes are recommended for drinking water. The ground water may have variable chemical water quality; hence, proper treatment processes are recommended for drinking water. Wells may also require disinfection following a contamination event (such as flooding).
Complies with the standards	N/A ** the water quality of the water source should be satisfactory with the WHO drinking water quality standards (2017)*
O&M Requirement	• Groundwater level monitoring should be conducted, and provisions for this must be made at the time of borehole construction. • The moving parts of the pumps, such as levers or gears, also require more regular maintenance and replacement.
Capital cost and investment cost (USD and USD/m^3)	**100 -5,000 USD/station (unit)** ** Depending on types of used pumps* *Remark: Products, materials, installation costs*
O&M cost (USD/year)	**60–150 USD/year** *Remark: operational and maintenance costs*
Durability/Lifespan (years)	>10 years
Manufacturer/Products name/ Brand	N/A
Reviewed countries of application	Asia-Pacific, Africa
Countries of product available	Asia-Pacific, Africa
After sale services	N/A

4. HOUSEHOLD SAND FILTER

WATER

TECHNOLOGY DESCRIPTION



A biosand Filters (BSF) are constructed to remove suspended solids and microbial contaminants from water with varying levels of turbidity through a combination of physical and biological processes. They can be used intermittently and well as continuously, making them suitable for household use. To ensure the required uniform flow, the outlet tube is embedded in the container wall to the outside and is free of taps, and hoses or control valves is above the sand layer. This ensures that when the filter is at rest, it maintains 5 cm of water above the sand surface, called the standing water. Two layers of gravel at the bottom of the filter ensure uniform flow through the sand and prevent sand from entering the outlet tube.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Manpower**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./ annum)	**None**
Remark	None

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding, Sea-level rise, Extreme heat** Degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply. The climate change has been projected as a cause of the potential increases in flooding, drought etc., decreasing drinkable water availability, algal blooms, coastal inundation, and sea level rise. For example. Indirect effects on drinking water quality occur when users are forced to switch to lower quality drinking water supplies, for example when groundwater tables decline, and users must switch to contaminated surface water. The Household Biosand Filter can increase resilience to water quality degradation by enabling users to improve water quality at the point of use.
Development impact: Environmental and health benefits	The Household Sand Filter is one of the Household water treatment and safe storage (HWTS) technologies that can provide and promote improved water quality for the induvial households. It hence could provide a safe water and improve health of people under hazard conditions from climate change impact.
Climate risks	**Extreme heat** Water quality problems, e.g. due to increased proliferation of pathogens in the harvested water (and consequent health effects, e.g. in waterborne diseases)
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Extreme heat** 1. Including treatment of drinking water by heating. 2. Using some HWTS technologies (e.g. chemical disinfectants).

Resources or Reference:

1. Coerver, A. , Ewers, L., Fewster. E., Galbraith, D., Gensch, R., Matta, J., Peter.M. (2021). Compendium of Water Supply Technologies in Emergencies (1st Edidtion). WASH Sector - Cox's Bazar/ Bangladesh, UNICEF.
2. Mutemi, S., Hoko, Z., & Makurira, H. (2020). Investigating feasibility of use of bio-sand filters for household water treatment in Epworth, Zimbabwe. Physics and Chemistry of the Earth, Parts A/b/c, 117, 102864.
3. United Nation University. (2016). Biosand Filter: A Household Water Treatment Option for Africa. Available: https://inra.unu.edu/publications/articles/biosand-filter-a-household-water-treatment-option-for-africa.html (Accesed 18 September 2021)

Remarks: N/A: not available data

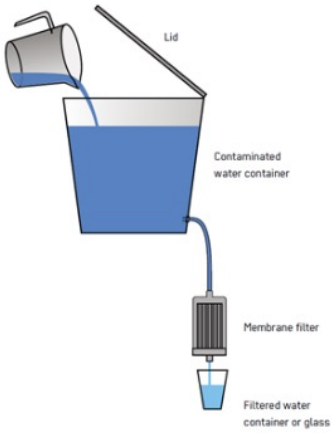
TECHNOLOGY SPECIFICATIONS

Innovative technology	**No** As a household water treatment options/technologies, the BSF is considered as a typical and basic household water treatment which employ a conventional treatment process i.e., sand filtration for treating the raw water.
Stage of technology	**Commercial**
Application level	Household
Geographical location:	Rural residential area, Mountainous area, Urban slum
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	10 L (per batch)
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	Bacteria protozoa, helminth removal: > 99%, Virus removal: 70-99%, Iron removal: 90-95%, Turbidity removal: >95%/ Turbidity: <1 NTU
Complies with the standards	WHO drinking water quality standards (2017)
O&M Requirement	• Safe storage containers may require periodic replacement. • Requires the user to pour water from the same source into the filter each day to maintain the biological layer. • The outlet tube, lid and diffuser should also be cleaned on a regular basis.
Capital cost and investment cost (USD and USD/m^3)	**10–100 USD/unit (system)** Remark: Depending on the materials used and context
O&M cost (USD/year)	**2-10 USD/year** *Remark: Operational and maintenance costs*
Durability/Lifespan (years)	5 - 10 years
Manufacturer/Products name/ Brand	N/A
Reviewed countries of application	Asia-Pacific and Africa
Countries of product available	Asia-Pacific and Africa
After sale services	N/A

5. HOUSEHOLD MEMBRANE FILTERS

WATER

TECHNOLOGY DESCRIPTION



Household Membrane Filters (HMF) generally use ultrafiltration (UF) or microfiltration (MF) membranes as flat sheet or hollow fiber modules. Water is filtered by gravity flow. Particles, colloids, protozoa, bacteria and viruses are retained on the membrane surface. The removal performance depends on the pore size of the membrane and its manufacturing quality. Membrane Filtration refers generally to MF, UF, Nanofiltration and Reverse Osmosis membrane-based systems. MF membranes usually have a pore size of 0.1–0.5 µm and remove particles, bacteria, and protozoa from water. Household Membrane Filters can be distributed in all response phases when water is generally available, but the quality is poor or unknown and there is a risk of contamination during storage or at home.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Manpower and gravitational flow**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./ annum)	None
Remark	None

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding, Extreme heat** Degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply. The climate change has been projected as a cause of the potential increases in flooding, drought etc., decreasing drinkable water availability, algal blooms, coastal inundation, and sea level rise. For example. Indirect effects on drinking water quality occur when users are forced to switch to lower quality drinking water supplies, for example when groundwater tables decline, and users must switch to contaminated surface water. The Household Membrane Filters can increase resilience to water quality degradation by enabling users to improve water quality and provide drinkable water at the point of use.
Development impact: Environmental and health benefits	Household Membrane Filters is an innovative Household water treatment and safe storage (HWTS) technologies that can improve water quality for the households. This could provide a safe water and improve health of people under hazard conditions from climate change impact.
Climate risks	**Yes** **Extreme heat** Water quality problems, e.g. due to increased proliferation of pathogens in the harvested water (and consequent health effects, e.g. in waterborne diseases)
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Extreme heat** 1. Including treatment of drinking water by heating. 2. Using some HWTS technologies (e.g. chemical disinfectants).

Resources or Reference:

1. Coerver, A. , Ewers, L., Fewster. E., Galbraith, D., Gensch, R., Matta, J., Peter.M. (2021). Compendium of Water Supply Technologies in Emergencies (1st Edidtion). WASH Sector - Cox's Bazar/ Bangladesh, UNICEF.
2. Molelekwa, G. F., Mukhola, M. S., Van der Bruggen, B., & Luis, P. (2014). Preliminary studies on membrane filtration for the production of potable water: a case of Tshaanda rural village in South Africa. PLoS One, 9(8), e105057.
3. Just One Africa. (2021). Hollow Fiber Membrane Water Filter. Questionnaire survey (16 November 2021).

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** The Household Membrane Filters are relatively innovative in aspect of improving treatment capacity. The production rate of the Household Membrane Filters can be a 2-35-fold increase compared to the production rate of the BSF.
Stage of technology	**Commercial**
Application level	Household
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Emergency and Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	20-350 L/d
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	Turbidity: <0.1 NTU Protozoa, bacteria: 99.9999% (6 Log) Viruses: 99.999% (5 Log)
Complies with the standards	WHO drinking water quality standards (2017)
O&M Requirement	• Most membrane filter products require regular backwashing and cleaning. • Some products recommend or incorporate a pre-filtration step such as straining through a cloth, settling, or sand filtration to reduce inlet water turbidity • Require membrane replacement every 1–2 years.
Capital cost and investment cost (USD and USD/m^3)	**15–250 USD/unit** Remark: Product cost depending on types of applied filters.
O&M cost (USD/year)	**3-200 USD/year** Remark: Depending on applied types of filters and raw water quality.
Durability/Lifespan (years)	1-5
Manufacturer/Products name/ Brand	Just One Africa (Inventor)
Reviewed countries of application	South Africa
Countries of product available	Africa
After sale services	Yes

6. COMPLETE WATER FILTRATION SYSTEM

WATER

TECHNOLOGY DESCRIPTION

The Complete water filtration system (UZ-2 UZIMA®) is a complete water filtration system that combines the UZ-1 water filter with ready-to-use water containers that will have you filtering water in a matter of minutes. The UZ-2 is a Hollow Fiber Membrane technology. Each filter contains bundles of hollow fibers designed to allow only water molecules to pass through the filter, filtering out anything larger than 0.1 microns. Each UZ-2 comes with a water tap to dispense clean water and a filter cleaner to back flush the filter. The UZ-2 is built to be highly effective at bacteria removal, easy to use, durable, and inexpensive, with a high flow rate and long life-span.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Manpower and gravitational flow**
Energy consumption (kwh/d)	None
GHG Emission (kg CO_2 eq./ annum)	None
Remark	None

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding, Sea-level rise, Extreme heat** Projected increases in flooding, drought, decreasing water availability, and sea level rise have both direct and indirect effects on drinking water quality. the UZ-2 can increase resilience to water quality degradation by enabling users to improve water quality at the point of use.
Development impact: Environmental and health benefits	The complete water filtration system could provide a safe water and improve health of people under hazard conditions from climate change impact.
Climate risks	**Yes** **Extreme heat** Water quality problems, e.g. due to increased proliferation of pathogens in the harvested water (and consequent health effects, e.g. in waterborne diseases)
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Extreme heat** 1. Including treatment of drinking water by heating. 2. Using some HWTS technologies (e.g. chemical disinfectants).

Resources or Reference:

Resources or Reference:

1. Uzima (2021). UZ-2 COMPLETE WATER FILTRATION SYSTEM. Avialable: https://uzimafilters.org/our-products/uz-2/#prettyPhoto (Accessed 10 January 2022)
2. Engineering for change (2021). Household Water Filter: Uzima. Avialable: https://www.engineeringforchange.org/solutions/product/uz-1-household-water-filter/ (Accessed 10 January 2022)
3. Uzima Clean Water Mission. (2021). UZ-2 Water Filtration System. Questionnaire survey (17 November 2021)

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** UZ-2 is a complete water filtration system is more effective than the conventional HWT systems in term of treatment efficiency and together with sustainable material when compared to the conventional filtration technology (Biosand filtration).
Stage of technology	**Commercial**
Application level	Household
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Emergency or Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	40L/h
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	Turbidity: 99% Protozoa, bacteria: 99.9999% (6 Log)
Complies with the standards	N/A
O&M Requirement	Requiring regular back flushing filter with clean water
Capital cost and investment cost (USD and USD/m^3)	**39 USD/unit** *Remark: Product cost*
O&M cost (USD/year)	**N/A** **N/A**
Durability/Lifespan (years)	5-10
Manufacturer/Products name/ Brand	Uzima/ UZ-2
Reviewed countries of application	Asia, Africa, Europe
Countries of product available	Asia, Africa, Europe (Regional offices)
After sale services	Yes

7. FOOT-OPERATED HANDWASHING STATION

HYGIENE

TECHNOLOGY DESCRIPTION

Foot-operated handwashing station helps in sanitizing hands without physically touching the water tap and soapy water or other liquid soap dispensers. The station is mechanically operated by foot. A container filled with water, fitted with a push tap at the base. The tap is connected to a foot pedal so th sat when the pedal is pressed the tap opens to allowing water flowing out. The dispenser of the liquid soap is connected to a second foot pedal. A bucket or bowl is placed under the tap to collect wastewater, or the ground under the tap should be covered in stones to help drainage of wastewater. The container can be linked to a rainwater harvesting scheme or guttering to keep it filled with water. This technology can provide advantages of being more durable than a conventional handwashing technology, easy to construct using locally available materials, can link the container to rainwater harvesting, as well as being controlled by pedal power for which excess water use can be minimize. Also, It is safe for usage as foot operated, sanitizing hands without direct physical touch to any surface as can be a long-term solution.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Manpower and gravitational flow**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./ annum)	**None**
Remark	None

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding, Extreme heat** This technology is one of keys of the promoting hygiene practices to protect vulnerable populations from the hygienic impacts of climate change in the form of increased tropical storms, drought, flooding and extreme heat frequencies causing enhanced severity of natural disasters spread in vector and water borne diseases. As the design of the product for reduction of water use for handwashing activity, hence this product can reduce water use in municipal systems also contributes to climate change mitigation by decreasing energy consumption and greenhouse gas emissions.
Development impact: Environmental and health benefits	This technology can be applied to prevent the a spread in vector and water borne diseases in flood-prone area as well as the area facing extreme heat, tropical storms, and drought conditions.
Climate risks	**No** **None**
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**None**

Resources or Reference:

1.) WaterAid Bangladesh. (2020). Pedal operated handwashing station responding COVID-19 pandemic. WaterAid, . Available from: https://www.wateraid.org/bd/sites/g/files/jkxoof236/files/2020-05/Pedal%20Op%20Handwashing%20Final.pdf (Accessed: 22 September 2021).

2.) SNV. (2020). Practical options for handwashing stations: A guide for promoters and producers, technical paper. The Hague, SNV, Tanzania.

3.) United Nations Human Settlements Programme. (2020). Community support is key to successful hand-washing stations to combat COVID-19 in Myanmar. Available from: https://unhabitat.org/community-support-is-key-to-successful-hand-washing-stations-to-combat-covid-19-in-myanmar (Accessed: 22 September 2021).

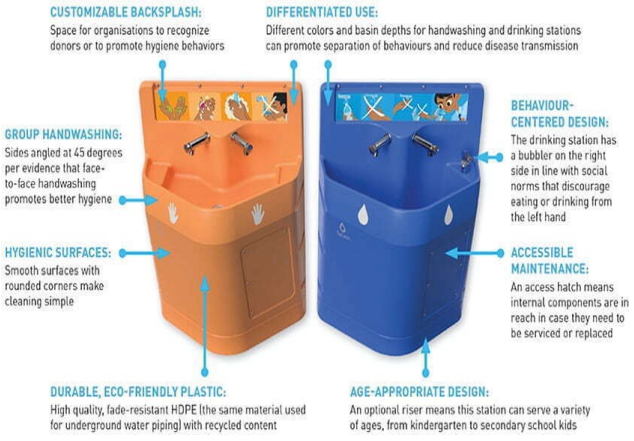
Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** Compared to the conventional tap with/without basin facilities, this technology can provide the better reduction of energy consumption for water transport as well as hygienic conditions.
Stage of technology	**Commercial**
Application level	community, Institution
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Emergency or Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	300 -500 L of a storage tank
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal* *COD removal* *TKN or TN removal* *E. coli % and Log reduction* *Helminth egg* **Water and Hygiene** *Depend on each technology*	None
Complies with the standards	The input water quality should be met to the recommended handwashing water quality by the UNICEF, 2020 (Handwashing Stations and Supplies for the COVID-19 response).
O&M Requirement	• The soap constantly restocked. • Regular cleansing the of the container and other components is needed. • Requires regular container refills depending on volume of the container.
Capital cost and investment cost (USD and USD/m^3)	**100-550 USD/unit** *Remark: Materials, installation and construction costs*
O&M cost (USD/year)	**0.02 – 0.04 USD/use** *** combined soap and used water costs (Whinnery et al., 2016)* *Remark: Operational and maintenance costs such as soap and water used.*
Durability/Lifespan (years)	-
Manufacturer/Products name/ Brand	No respective manufacturer as it can be constructed locally.
Reviewed countries of application	Asia such as Nepal, Bangladesh, India, Myanmar
Countries of product available	Asia, Africa, Europe
After sale services	No

8. SPLASH HANDWASHING AND DRINKING STATIONS

TECHNOLOGY DESCRIPTION



The Splash handwashing and drinking stations are stations built to provide safe, clean water to children in schools and low-resource institutions. The triangular handwashing stations are orange, while the drinking stations are blue for easy differentiation. The handwashing and drinking stations are designed to be triangular to allow children to see one another and interact while washing their hands side by side. To differentiate the stations, the drinking stations are blue and the handwashing stations are orange. The orange handwashing stations have shallow basins to discourage accidental drinking of the non-potable water, while the blue drinking stations have deeper basins to allow filling of water bottles up to 1.5 liters. The drinking stations also include a water fountain on the right side for children who may not have water bottles. The water is filtered using the Antunes water filtration system.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./annum)
Treatment processes	**None**
Disposal	**None**
Remark	None of GHG from the Treatment processes

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Man powered and gravitational energies**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./ annum)	**None**
Remark	None

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Extreme heat** This technology is one of keys of the promoting hygiene practices to protect vulnerable populations from the hygienic impacts of climate change in the form of increased droughts and water Tropical storms, drought, flooding and extreme heat frequencies and severity of natural disasters; spread in vector and water borne diseases.
Development impact: Environmental and health benefits	This technology can be applied to prevent a spread out of vector and water borne diseases in flood-prone area as well as the area facing extreme heat, tropical storms, and drought conditions.
Climate risks	**Yes** **Tropical storms, Flood** Physical damage to water supply infrastructure, including pipeline and and treatment systems.
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	1. Flood protection (such as levees, drainage ditches, artificial waterways, etc.) 2. Provide elevated storage tanks 3. Raising the basement of the systems.

Resources or Reference:

1. Splash Social Enterprises (2021). Clean Water: Ensuring access to safe drinking water.Available: https://splash.org/our-work/water (accessed: 20 Febuary 2022).
2. Engineering For Change. (2021). Splash Stations: SplashAvailable from: https://www.engineeringforchange.org/solutions/product/splash-stations/ (Accessed: 20 Febuary 2022)

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** When compared to the conventional facilities, this product can provide the features of differentiating the stations with colors for drinking stations (blue) the handwashing stations (orange) making them it eye catching and remind users to wash their hands.
Stage of technology	**Commercial**
Application level	Community, Institution
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	1800 L/hr
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms *Sanitation* *BOD removal* *COD removal* *TKN or TN removal* *E. coli % and Log reduction* *Helminth egg* *Water and Hygiene* *Depend on each technology*	Turbidity: < 0.5 NTU Bacteria: >99.9999% (6 log)
Complies with the standards	WHO drinking water quality standards (2017)
O&M Requirement	-
Capital cost and investment cost (USD and USD/m^3)	**175 USD/ station** *Remark: Product cost*
O&M cost (USD/year)	N/A N/A
Durability/Lifespan (years)	>10
Manufacturer/Products name/ Brand	Splash™
Reviewed countries of application	Africa and Asia
Countries of product available	Africa and Asia
After sale services	Yes

9. SOLAR POWERED AUTOMATED HAND WASHER

HYGIENE

TECHNOLOGY DESCRIPTION

The Solar Powered Automated Hand Washer so called "SolaWash" is a hand-washing station that is both touch-free and solar-powered, invented in Ghana at the beginning of the COVID 19 pandemic. dual storage container holds 140litres of clean water and 70litres wastewater capacity are twinned in a single stand made from recycled metal barrel. It has a single tap outlet for water and liquid soap. Upon detection of a hand under the tap, the system gives its first alert with a beep that releases liquid soap, giving interval for thorough handwashing, a second alert follows that releases clean water for rinsing off lather and a third and final beep which makes up the 25 seconds.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./annum)
Treatment processes	**None**
Disposal	**None**
Remark	None

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Solar power**
Energy consumption (kwh/d)	**N/A**
GHG Emission (kg CO_2 eq./ annum)	**None**
Remark	Due to this technology employs solar powered energy, it can anticipate no GHG emission from the energy use.

Total GHG emission	**None**	kg CO_2 eq./annum
	None	kg CO_2 eq./m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought, Flooding, Extreme heat** The SolaWash can support multiple communities and are helping to sustain life, in a region that is highly prone to drought and f flooding tropical storms. As such, the solar powered water systems are helping to improve resilience. By ensuring that the power supply would not be impacted by electricity cuts during/ following storms and floods.
Development impact: Environmental and health benefits	The SolaWash can be applied to prevent a spread out of vector and water borne diseases in flood-prone area as well as the area facing extreme heat, tropical storms, and drought conditions. Also, as this technology apply solar powered energy, which is renewable, it can create a positive impact on the climate change mitigation as estimated GHG emission reduction is observed in the system.
Climate risks	**No** **None**
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**None**

Resources or Reference:

1. Oxfam's Water, Sanitation and Hygiene Promotion Resources (2022). Handwashing Stations Technical Briefing Note. https://www.oxfamwash.org/en/hygiene/handwashing (Accessed 22 March 2022)
2. United Nation. (n.d). UN Call for Technology Solutions for addressing the COVID-19 pandemic and its impacts. https://sustainabledevelopment.un.org/content/documents/26915UN_Call_for_COVID19.pdf (Accessed 22 March 2022)
3. NPR. (2021). A Tale Of The Taps: Which Hand-Washing Station Is Best In Emergencies?. https://www.npr.org/sections/goatsandsoda/2021/02/24/970525891/a-tale-of-the-taps-which-hand-washing-station-is-best-in-emergencies (Accessed 22 March 2022)

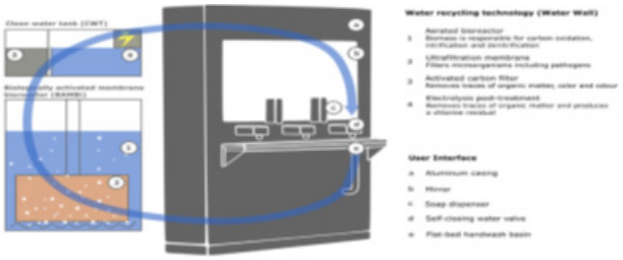
Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** The solar-powered HW system is considered as an innovative HW technology as it can use a renewable energy source. Hence it reduces the need for energy derived from fossil fuels, thus reducing the system's carbon footprint and improving air quality compared to other types of the technology. Also, as quipped with the sensor system, It is a technology that allows touchless use.
Stage of technology	**Pilot**
Application level	Community
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Emergency and Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	80 L storage tank of clean water
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms *Sanitation* *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* *Water and Hygiene* *Depend on each technology*	None due to no equipped treatment units
Complies with the standards	The input water quality should be met to the recommended handwashing water quality by the UNICEF, 2020 (Handwashing Stations and Supplies for the COVID-19 response).
O&M Requirement	Sensors can be easily faulty and would require regular maintenance.
Capital cost and investment cost (USD and USD/m^3)	**390 USD/ station** *Remark: Product costs*
O&M cost (USD/year)	N/A N/A
Durability/Lifespan (years)	5-10
Manufacturer/Products name/ Brand	SolawashTM / Kwarteng Richard as an inventor
Reviewed countries of application	Africa such as Ghana
Countries of product available	Africa
After sale services	N/A

10. AUTARKY HANDWASHING STATION (AHWS)

TECHNOLOGY DESCRIPTION



The AHWS is a promising handwashing technology providing onsite recycling of handwashing water, thus minimizing the need for external water input. The AHWS consists of a frontend user interface and a backend water recycling technology. The frontend user interface consists of a variable number of self-closing taps, foaming soap dispenser and handwash basin. The backend water recycling technology is referred to as the "Water Wall" and consists of four treatment stages, namely (i) an aerated bioreactor in which organic matter and nitrogen are degraded, (ii) an ultrafiltration membrane retaining pathogens, (iii) an activated carbon filter removing color, smell, and traces of organic matter and (iv) electrolysis post-treatment producing chlorine for safe water storage. Additionally, the technology can provide the advantages of equal accessibility and affordability, low energy requirements, technical reliability, independence of the water and sewage grid, safe treated water as well as reducing wastewater generation. On the other hands, there some limitations on the technology, namely high initial investment and operating costs, need of reliable power and requiring well-trained operators.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./annum)
Treatment processes	**0.65 kgCO2 eq /m³** *treated wastewater*
Disposal	**None**
Remark	Annual GHG emission (kg CO2 eq./annum) of the technology was not reported. Rather, it was estimated based on volume of treated wastewater.

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	Electricity
Energy consumption (kwh/d)	**0.4 kWh/m³** (system with high water flux) - **6.9 kWh/m³** (system with low water flux)
GHG Emission (kg CO_2 eq./ annum)	**0.2 – 3.45 kgCO2 eq /m³** *treated wastewater*
Remark	Annual GHG emission (kg CO_2 eq./annum) of the technology was not reported. Rather, it was estimated based on volume of treated wastewater.

Total GHG emission	**N/A**	kg CO_2 eq./annum
	0.85 – 4.10 kgCO2 eq /m³ *treated wastewater*	kg CO_2 eq./m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical storms, Drought,** The AHWS can provide the advantage of reducing water use in municipal systems also contributes to climate change mitigation by decreasing energy consumption and greenhouse gas emissions due to water production processes as same as the water conservation can lead to large savings in the energy used to transport, treat, and distribute piped water. Also, as the AHWS is a technology that can recycle the handwashing greywater for the handwashing activities with high quality water, this water reclamation and reuse can and have been shown to be effective for adapting water resource management in the face of the drought condition.
Development impact: Environmental and health benefits	This technology can contribute to the environmental pollution protection by which the used water (greywater) from handwashing activities is managed by the equipped water recycling system.
Climate risks	**Yes** **Extreme heat** Increase in pathogens in the recycled water.
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Extreme heat** Detail consideration Improvement the processes of pathogenic removal by whether enhancing performance of the electrolysis or integrating other additional disinfection units

Resources or Reference:

1. Eawag. (2018). Guiding principles for Autarky water module. Available from: https://www.eawag.ch/fileadmin/Domain1/Forschung/Menschen/Abwasser/autarky/Autarky_booklet.pdf (Accessed: 21 September 2021).
2. Sutherland, C., Reynaert, E., Sindall, R. C., Riechmann, M. E., Magwaza, F., Lienert, J., ... & Udert, K. M. (2021). Innovation for improved hand hygiene: Field testing the Autarky handwashing station in collaboration with informal settlement residents in Durban, South Africa. Science of the Total Environment, 796, 149024.
3. Reynaert, E., Greenwood, E. E., Ndwandwe, B., Riechmann, M. E., Sindall, R. C., Udert, K. M., & Morgenroth, E. (2020). Practical implementation of true on-site water recycling systems for hand washing and toilet flushing. Water research X, 7, 100051

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** The AHWS is a novel HW technology that can recycle the handwashing greywater for handwashing activities with high quality water; hence produce no wastewater from the activities.
Stage of technology	**Pilot**
Application level	community, Institution
Geographical location:	Urban residential area, Rural residential area, Mountainous area, Urban slum
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	75-350 L/d (from low to high flux operations)
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms *Sanitation* *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* *Water and Hygiene* *Depend on each technology*	**Efficiencies:** • COD: 99 % • Total nitrogen: 97 % • Total phosphorus: 90-99 % **Effluent (recycled water)** • COD:< 36 mg/L • pH: 7.1–8.3 • Chlorine: 1.9 mg/L • E. coli: <1 MPN/100mL • Turbidity:< 0.8 NTU • TSS: < 0.4 mg/L
Complies with the standards	The recycled water quality can be satisfactory with the recommended handwashing water quality by the UNICEP (2020): Handwashing Stations and Supplies for the COVID-19 response
O&M Requirement	• The Prototype was to be check that all system parts worked properly two times a week. • Regular water quality monitoring is required. • External water refill once per week.
Capital cost and investment cost (USD and USD/m^3)	**N/A** **N/A**
O&M cost (USD/year)	**N/A**
Durability/Lifespan (years)	>10 years
Manufacturer/Products name/ Brand	Eawag (Inventor)
Reviewed countries of application	South Africa and Netherland
Countries of product available	South Africa and Netherland
After sale services	N/A

11. SOLAR SEPTIC TANK (SST)

SANITATION

TECHNOLOGY DESCRIPTION

An innovative decentralized wastewater treatment system was constructed and tested at the household scale in a community in central Thailand and southeast asia. The SST is a modified conventional septic tank with a solar-heated water system from solar panal to create higher temperature than ambient inside the septic tank. The enhancement of temperature promotes the biodegradation of organic matter and methane formation. Furthermore, temperature also has a significant effect on the settleability and degradation of biological solids and pathogen inactivation.

SST is suitable to apply for blackwater with high strength organic content due to it is high rate degradation system. Advantages of this system are reduction of sluge accumulation, high removal efficiency and high pathogen inactivation. However, there are some disadvantages which are it requires energy to heat up the system and demands large rooftop area for installation of solar heating device.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**1,833**
Disposal	**1,125**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Solar energy, Electricity**
Energy consumption (kwh/d)	**48** (solar energy) **0.5** (electricity)
GHG Emission (kg CO_2 eq./annum)	**91**
Remark	-

Total GHG emission	**3,050**	kg CO_2 eq./annum
	6,100	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient	**Yes** **Cold climate, Flood** This technology can be resilient to cold climate because the system can be well performed with external heated supply to facilitate organic degradation inside the system. Adatation to flood might be optional which can coustruct the system in elevated form.
Development impact: Environmental and health benefits	This system can be applied for preventing infectious microorganisms into water bodied with high pathogen inactivation such as E.coli and Ascaris egg.
Climate risks	**Yes** **Drought** Prolonged drought can affect the water availability to use for flushing and it is consequent to pipe blockage and sytem failure.
Adaptability: Climate proof design	**Drought** • Securing sufficient volumes of water for flushing and operation. • Regular maintenance to avoid pipe blockage. • Construction of system with hand washing station and recycling water for flushing.

Resources or Reference:

1. Thammarat Koottatep, Stephanie Connelly, Tatchai Pussayanavin, Sopida Khamyai, Wattanapong Sangchun, William Sloan, Chongrak Polprasert (2020) 'Solar septic tank': evaluation of innovative decentralized treatment of blackwater in developing countries Journal of Water, Sanitation and Hygiene for Development
2. Stephanie Connelly, Tatchai Pussayanavin, Richard J Randle-Boggis, Araya Wicheansan, Suparat Jampathong, Ciara Keating, Umer Z Ijaz, Willian T Sloan, Thammarat Koottatep Solar Septic Tank: Next Generation Sequencing Reveals Effluent Microbial Community Composition as a Useful Index of System Performance, Water
3. Questionnaire survey

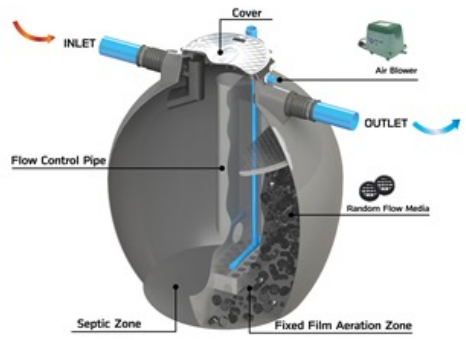
Remarks: N/A: not available data

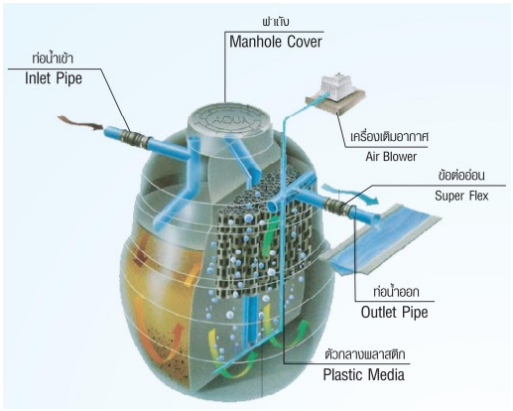
TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** • Prolong emptying service due to high degradation of solid • High pathogen reduction without disinfectant agents • Solar energy usage
Stage of technology	**Pilot**
Application level	Household, community, Institution
Geographical location:	Urban residential area, Rural residential area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	0.5
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms	BOD removal : 83 BOD removal : 83 COD removal) : 88 N removal) : 40 Pathogens : 99.9 (3 log reduction) Reduction as E.coli
Complies with the standards	National standards
O&M Requirement	• Regular desludging • Checking heating supply part
Capital cost and investment cost (USD and USD/m^3)	**2,500 USD/system** Products, materials, installation costs
O&M cost (USD/year)	**50 USD/year** Energy costs, operational, maintenance and repair costs
Durability/Lifespan (years)	>30
Manufacturer/Products name/ Brand	Pilot stage of Asian Institute of Technology (AIT)
Reviewed countries of application	Thailand, Cambodia, India
Countries of product available	Thailand
After sale services	N/A

12. AERATED SEPTIC TANK

Technology Description





Aerobic treatment system is the modern option which is similar to septic systems in that both treat wastewater using natural processes. However, the aerobic system supplies oxygen into the tank using air pump or blower to facilitate the microbial activities in septic system. The compartment of tank can be both concrete structure and fiber glass.

The benefits of this systems are odor avoiding, able to remove organic mattet and nutrients under standard meeting and reducing methane gas. However, most of treatment needs power supply to operate air pump. There are some companies that can provide air pump using energy from solar panal which can be environment-friendly alternative for human waste treatment.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**191**
Disposal	**219**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Electricity**
Energy consumption (kwh/d)	**1.224**
GHG Emission (kg CO_2 eq./annum)	**223**
Remark	-

Total GHG emission	**634**	kg CO_2 eq./annum
	396	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient	**Yes** **Flood** This technology can be resilient to flood which might be coustructed the system in elevated form.
Development impact: Environmental and health benefits	This aerobic system can reduce organic content such as BOD to lower concentration than anaerobic systems which are benefit to prevent organic pollutants to environment.
Climate risks	**Yes** **Drought and extreme cold** • Drought can affect the water availability to use for flushing and it is consequent to pipe blockage and sytem failure. • Cold climate can reduce degree of biodegradation.
Adaptability: Climate proof design	**Drought** • Securing sufficient volumes of water for flushing and operation. • Regular maintenance to avoid pipe blockage. **Extreme cold** • Providing thick Insulator for maintaining warm temperature

Resources or Reference:

1. Aqua Nishihara Corporation Limited (2015, May 5). AQUA SEPTIC BIOFILM (STBF). Instruction for package wastewater treatment systems, 07-67.
2. Tilley, E. (2014). Compendium of sanitation systems and technologies. Eawag.
3. Questionnaire survey

Remarks: N/A: not available data

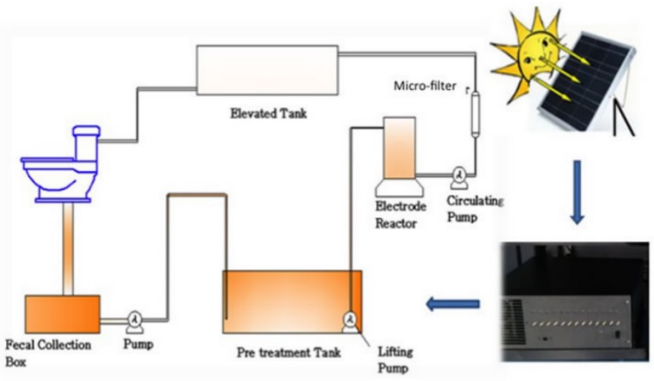
TECHNOLOGY SPECIFICATIONS

Innovative technology	**No**

Stage of technology	**Commercial**
Application level	Household, community , Institution
Geographical location:	Urban residential area, Rural residential area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	1.6-2.7
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms	BOD removal : 89-92
Complies with the standards	National standards in southeast asia countries
O&M Requirement	• Regular air pump maintenance • Air diffuser cleaning and changing
Capital cost and investment cost (USD and USD/m^3)	**950 USD/system** Products, materials
O&M cost (USD/year)	**30 USD/year** Energy costs, operational and maintenance cost
Durability/Lifespan (years)	15
Manufacturer/Products name/ Brand	Fibertech Co., Ltd., Aqua Nishihara Corporation
Reviewed countries of application	Thailand, Myanmar, Laos, Cambodia, India and Bangaladesh
Countries of product available	Thailand
After sale services	N/A

13. ECO-SAN TOILET

TECHNOLOGY DESCRIPTION



ECO-SAN or Solar-powered toilet has been developed CALTECH as invovative technology which employs electrochemical reaction supplied by solar energy for removal of chemical oxygen demand and pathogen inactivation via chlorine disinfection and recycling of disinfected and clarified water for use as toilet flushing water.

This system utilize an array of mixed-metal oxide semiconductor anodes with stainless steel cathodes, which can be powered by photovoltaic (PV)-panels for decentralized toilet wastewater treatment.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**N/A**
Disposal	**N/A**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**None**
Energy consumption (kwh/d)	**None**
GHG Emission (kg CO_2 eq./annum)	-
Remark	-

Total GHG emission	-	kg CO_2 eq./annum
	-	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient	**Yes** **Drought** This technology can be resilient to drought for supply solar energy to the system.
Development impact: Environmental and health benefits	Infectious microorganism can be highly inactivated and some nutrients can be recoverd to valuable resource.
Climate risks	**Yes** **Extreme cold** Cold climate can affect freezing of wastewater and lack of sunlight for solar power
Adaptability: Climate proof design	**Extreme cold** Providing thick Insulator for maintaining warm temperature and adjust temperature inside the system room.

Resources or Reference:

1. https://sanitation.ansi.org/EcoSanToilet
2. http://www.eco-san.cn/e_main.html
3. Huang, X., Qu, Y., Cid, C.A. Finke, C., Hoffmann, M.R., Lim, K., & Jiang, S.C. (2016). Electrochemical disinfection of toilet wastewater using wastewater electrolysis cell. Water Research.92, 164-172.

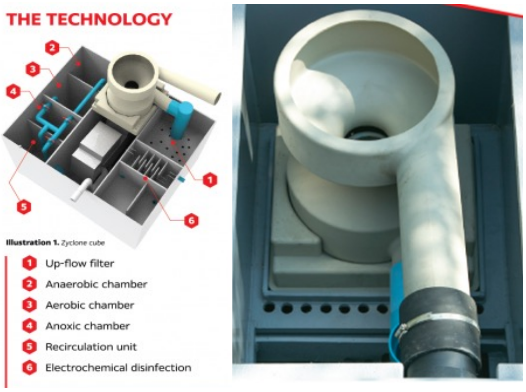
Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** • System can produce disinfectant agent to kill pathogens via electrochemical reaction using composition in fecal waste as reactant. • Solar power supply in system. • Recycling treated water to toilet activity.
Stage of technology	**Commercial** (Small number of piloting)
Application level	Community, Institution
Geographical location:	Urban residential area, Rural residential area , Emergency case
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	4-5
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms	COD removal) : 85 N removal) : 87 Pathogens : 99.99(4 log reduction) Reduction as Total coliform
Complies with the standards	National standards
O&M Requirement	• Cleaning and changing electrodes • Regular emptying twice a year • Replacing membrane filters
Capital cost and investment cost (USD and USD/m^3)	N/A -
O&M cost (USD/year)	**5,840** (Based on maximum 800 flushs per day) Energy costs, operational, maintenance and repair costs
Durability/Lifespan (years)	10
Manufacturer/Products name/ Brand	Yixing Eco-Sanitary Manufacture Co.,Ltd.
Reviewed countries of application	USA, China, South Africa
Countries of product available	USA, China
After sale services	N/A

14. ZYCLONE CUBE

TECHNOLOGY DESCRIPTION



Zyclone cube" is a novel on-site sanitation technology manufactured by SCG company, Thailand. This system relied on mechanical and biological processes for treating the fecal waste from toilets.

Solid part in wastewater was separated by cyclone unit using centrifugal force. Separated solid then flow into unit of screw-heater drying and disinfection to produce dry solid as reusable by-product. Liquid part was flowed into different biological treatment chambers including filtration, anaerobic, aerobic and anoxic processes. Ultimately, treated wastewater was therefore disinfected in electrochemical chambers before discharging.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**N/A**
Disposal	**N/A**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Electricity**
Energy consumption (kwh/d)	**8**
GHG Emission (kg CO_2 eq./annum)	**1,460**
Remark	-

Total GHG emission	**1,460**	kg CO_2 eq./annum
	-	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient	**Yes** **Drought and flooding areas** This system can be employed both drought and flooding areas because solid and liquid parts of wastewater from toilets are not affected from hot climate and it can be constructed flooding areas using elevated form.
Development impact: Environmental and health benefits	Infectious microorganism as E.coli can be highly inactivated upto 6 log reduction
Climate risks	**Yes** **Extreme cold** Cold climate can affect the centrifugal force of in liquid-solid separator unit
Adaptability: Climate proof design	**Extreme cold** Providing thick Insulator of seperator for keeping warm temperature.

Resources or Reference:

1. https://www.scgchemicals.com/en/products-services/technology solutions/reinvented-toilet-total-solution
2. https://sanitation.ansi.org/ZycloneCube
3. Koottatep, T., Chapagain, S.K., Polprasert, C., Panuvatvanich, A. and Ahn, K.H. (2018). Sanitation situations in selected Southeast Asian countries and application of innovative technologies, Environment, Development and Sustainability, 20, 495-506.

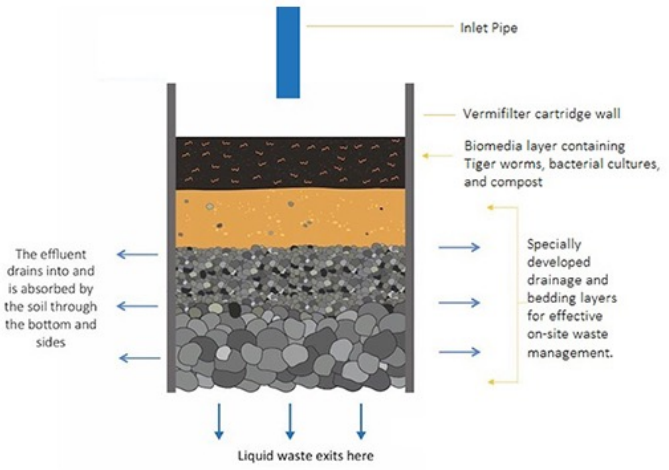
Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** • System can produce disinfectant agent to kill pathogens via electrochemical reaction. • Mechanical separation unit before biological treatment
Stage of technology	**Commercial**
Application level	Community, Institution
Geographical location:	Urban residential area, Rural residential area , Emergency case
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	0.2
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms	COD removal) : N/A N removal) : N/A Pathogens : 99.9999(6 log reduction) Reduction as E.coli
Complies with the standards	ISO 30500
O&M Requirement	• Replacing media every 3 years • Electrode changing every 3 years
Capital cost and investment cost (USD and USD/m^3)	N/A -
O&M cost (USD/year)	**4,745** (Based on maximum 130 users per day) Operating cost
Durability/Lifespan (years)	15
Manufacturer/Products name/ Brand	SCG Co.,Ltd.
Reviewed countries of application	Thailand
Countries of product available	Thailand
After sale services	N/A

15. VERMICOMPOSTING TOILET

TECHNOLOGY DESCRIPTION



Worm-based sanitation systems ('vermifilters') provide a solution since they can reduce the solids in the system, due to the net loss of biomass and energy when the food chain is extended. This approach has the potential to reduce both the frequency of emptying and the size of the sanitation system. Furthermore, worms are able to reduce pathogens to the level where the waste can be safely applied to land The by-product, vermicompost, is dry, making it easier to handle and transport.

The tiger Toilet is an innovative water flushing on-site sanitation system and works by vermifiltration. The Tiger Toilet is currently being developed and sold by EaSol Pvt Ltd.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**N/A**
Disposal	**N/A**
Remark	-

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**None**
Energy consumption (kwh/d)	**-**
GHG Emission (kg CO_2 eq./annum)	**-**
Remark	-

Total GHG emission	-	kg CO_2 eq./annum
	-	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient	**Yes** **Flooding and drought areas** Vermicomposting toilet is an innovative technology that can applied to less water supply in toilet due to drought impact and flood prone areas with raised design. However, moisture in this system should be maintained at 60-80% and recommended water for flushing is from 1.0 to 1.5 litres per person per flush.
Development impact: Environmental and health benefits	Vermicompost from system can be used as fertilizer.
Climate risks	**Yes** **Extreme cold** Cold climate can affect earth worm for toilet waste decomposition.
Adaptability: Climate proof design	**Extreme cold** Providing thick Insulator of seperator for keeping warm temperature.

Resources or Reference:

1. Furlong, C. , Gibson, W.T., Templeton, M.R., Taillade, M. , Kassam, F., Crabb, G.,...Patankar, R. (2014, December). The Tiger Toilet: From Concept to Reality, IWA specialist conference on Municipal Water Management and Sanitation in Developing Countries. Organized by International Water Association, Bangkok, Thailand.
2. Furlong C., Templeton M.R., and Gibson W.T. (2014). Processing of human faeces by wet vermifiltration for improved on-site sanitation. Journal of Water, Sanitation and Hygiene for Development, 4 (2): 231-239.

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** • Reducing emptying frequency • Transforming fecal waste into vermicompost at site
Stage of technology	**Commercial/Application**
Application level	Households, Institute
Geographical location:	Peri-urban residential area, Rural residential area with long term using
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	1.2 (when liquid part is filtered by bedding)
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms	COD removal) : 87 Pathogens : 2 log reduction Reduction as E.coli
Complies with the standards	N/A
O&M Requirement	• Monitoring system every 3 months • Maintain moisture in system to be good to earthworm
Capital cost and investment cost (USD and USD/m^3)	350 Materials
O&M cost (USD/year)	**N/A** -
Durability/Lifespan (years)	10
Manufacturer/Products name/ Brand	TBF Environmental Solutions Pvt. Ltd.
Reviewed countries of application	India
Countries of product available	India, Africa
After sale services	N/A

16. OMNI PROCESSOR

TECHNOLOGY DESCRIPTION

Omni Processor is a decentralized waste treatment system that kills pathogens while recovering valuable resources. It starts with solids fuel combustion. Fecal sludge, biosolids, or other wet waste streams enter a dryer where the moisture is evaporated. The dried, solid waste is now a fuel that is burned in a combustion chamber, reducing the solids to dry fly ash. The heat that is generated in the combustion chamber is used in a boiler to generate high-pressure, high-temperature steam. This steam is sent to a steam expander (e.g. steam engine or steam turbine), which turns a generator to produce electricity. This electricity is then used to power the whole J-OP AND there is often surplus electricity produced that can be sold back to the utility grid or used for other processes locally. The exhaust steam from the expander travels back to the heat exchanger surfaces of the dryer where it provides the energy required for drying the incoming wet waste. In transferring its heat back, the exhaust steam is condensed back to water and pumped back to the boiler, completing the Rankine cycle. The water that is evaporated from the wet waste is captured. This vapor is filtered before being condensed back to water. If desired, this water can then be treated all the way to clean drinking water standards, or be used for other recycled or reuse water applications. Useful heat can also be captured from the condenser to be used for a variety of purposes.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./annum)
Treatment processes	**33 – 64**
Disposal	**N/A**
Remark	The system does emit limited amount of CO^2, however, technology eliminates production of methane completely

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**N/A**
Energy consumption (kwh/d)	**N/A**
GHG Emission (kg CO_2 eq./annum)	**N/A**
Remark	N/A

Total GHG emission	**33 – 64**	kg CO_2 eq./annum
	N/A	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Cold climate** During initial stage few technical difficulty was faced, such as rip in rubber seal due to cold climate. However, changes and adaptability has been improved and such issue does not occur.
Development impact: Environmental and health benefits	The system is designed to be flexible, modular, and scalable to different needs. It can serve populations ranging from community to city level in both developing and developed countries. With minor adjustments to the inputs, specific outputs can be optimized over others in response to needs. For example, in locations where the value of electricity is high, the omni processor power production can be optimized. Conversely, where clean water is especially valuable, the system's water production can be prioritized to increase the quantity of that output. This optimization can be done easily without any design or hardware changes.
Climate risks	**Yes** The harsh UV and salty air highlighted the need for careful material selection and coating. This was first experienced during the pilot scale implementation in Dakar.
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	Component upgrade has been to protect agains extreme climates, drying retrofits to improvement in the fuel supply quality. Remote operation: Central Command Center in Washington monitor every aspect of the technology remotely and provide 24-hour support or by request.

Resources or Reference:

1. sedron Technologies' Janicki Omni Processor (J-OP): https://www.sedron.com/janicki-omni-processor/overview/
2. Janicki., P (n.d.): Omni Processor: https://swedishwaterhouse.se/wp-content/uploads/Peter-Janicki.pdf
3. Trimmer JT, Byrne DM, Lohman HAC and Guest JS. Preliminary Greenhouse Gas (GHG) Emissions Analysis of Four Gates Sanitation Systems: Emissions During Steady-State Operation, Gates Open Res 2020, https://doi.org/10.21955/gatesopenres.1116564.1

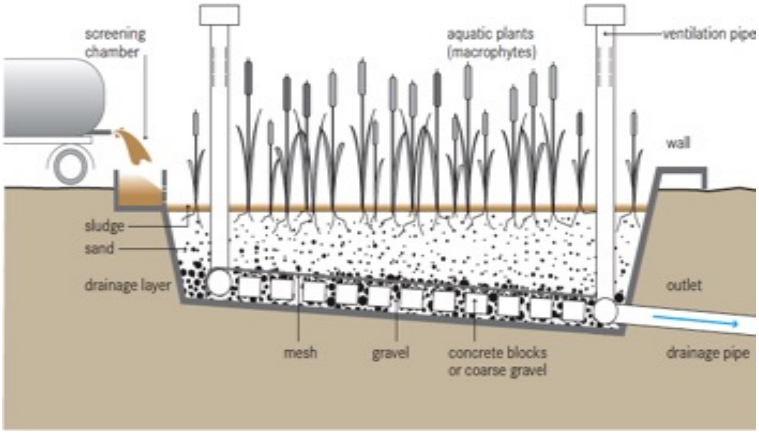
Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** Omni Processor boils the sewage at a temperature of 1000C in a drying tube to separate it into dry solids and water vapor. The dry solids are then fired to turn water vapour into steam that is used to power a steam engine and generate electricity. The steam is condensed back into safe drinking water. With the electricity generated sufficient to power the cycle, the technology offers a self sustaining method of power and water generation.
Stage of technology	**Commercial**
Application level	Community and city scale
Geographical location:	Urban residential area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	92.3
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal* *COD removal* *TKN or TN removal* *E. coli % and Log reduction* *Helminth egg* **Water and Hygiene** *Depend on each technology*	The technology completey destroys fecal sludge and pathogens through combust and fully converts sewage sludge into valuable source such as drinking water.
Complies with the standards	Meets US EPA standards for emissions
O&M Requirement	Day to day operatiion should be oberved to provide real time status which includes video feeds.
Capital cost and investment cost (USD and USD/m^3)	**Capital cost: USD 1.5 million** Omni Processor with Single-stage Dryer (boiler and dryer capacity)
O&M cost (USD/year)	**N/A** N/A
Durability/Lifespan (years)	N/A
Manufacturer/Products name/ Brand	Sedron Technologies
Reviewed countries of application	Senegal and India
Countries of product available	Senegal and India
After sale services	Yes

17. PLANTED DRYING BED

Technology Description



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

(Planted Drying Bed followed by Horizontal Planted Gravel Filter, and polishing pond)

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**1,891,500**
Disposal	**428,707**
Remark	N/A

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**N/A**
Energy consumption (kwh/d)	**N/A**
GHG Emission (kg CO_2 eq./annum)	**N/A**
Remark	N/A

Total GHG emission	**2,320,207**	kg CO_2 eq./annum
	N/A	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Cold climate** Planted Drying Bed can be converted into greenhouses to improve treatment quality, especially in cold winters
Development impact: Environmental and health benefits	• Planted Drying Bed Technology is flexible for extreme weather conditions. • Gravity based system, based on natural and biological treatment with no use of chemicals and electricity • Minimal odour and aesthetically designed to locate near human settlemet • Operator are planning to develop a plant nursery where the treated water and compost will be used for greenification project. This water can be utilized in nearby children park creating green space and urban farms.
Climate risks	**Yes** **Flooding and heavy rainfall** PDB works best in dry places with sunlight as the sludge dries quickly and the bed is ready for its next load. In the heavy rain and frequent flooding, the drying beds should be covered to keep water from filling the bed and overflowing. Covering the bed will affect the rate of drying so this method may not be suitable.
Adaptability: Climate proof desig	**Cold Climate** • In winter, septic tanks freeze and cannot be desludged so the treatment plant is shut for 4 months, but the treatment of old sludge continues under the sunlight. • The beds have to be checked thoroughly for blockages that prevent water percolation and algae growth on the fecal matter, among others. • Although designed for high altitude and cold weather, careful monitoring is required to understand the performance and compliance with regulations and standards. • Building more Planted Drying Bed will double the capacity of treatment (extra space has been retained for expansion in future)

Resources or Reference:

1. NIUA (2019), COST ANALYSIS OF FAECAL SLUDGE TREATMENT PLANTS IN INDIA. Life Cycle Costing & Contracting Models of FSTPs
2. TILLEY, E. ULRICH, L. LUETHI, C. REYMOND, P. ZURBRUEGG, C. (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)
3. Rath, Manas; Schellenberg, Tatjana; Rajan, Pallavi; Singhal, Geeta. 2020. Decentralized Wastewater and Fecal Sludge Management: Case Studies from India. Asian Development Bank Institute.
4. Vinod Vijayan, Mrinal Mallik and Sama Kalyana Chakravarthy 2020, Performance Evaluation: How Faecal Sludge Treatment Plants Are Performing, Centre for Science and Environment, New Delhi.
5. FSM for Leh: https://www.borda.org/wp-content/uploads/2018/08/BORDA_FSM_for_Leh_HF.pdf
6. Questionnaire Survey
7. Ecam Tool

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**None** • Oldest form of technology • Natural and biological treatment with no use of chemicals or electricity – green and ecofriendly • High pathogen removal with low retention time.
Stage of technology	**Commercial**
Application level	Community Scale
Geographical location:	Mountainous area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	12
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	BOD (removal) : 50 – 75% COD (removal) : 40% TKN or TN (% removal) : 35 - 55% Pathogens (reduction of TC, FC and EC) : 1 – 3 log reduction of FC (80 – 99.9%)
Complies with the standards	Meets India's National Standard
O&M Requirement	• Simple and minimal operation with no skilled staff is required for regular and proper functioning. • The drains must be maintained and the effluent properly collected and disposed of. • The plants should have grown sufficiently before applying the sludge. • The acclimation phase is crucial and requires much care. • The plants should be periodically thinned and/or harvested. • After 3 to 5 years the sludge can be removed.
Capital cost and investment cost (USD and USD/m^3)	Capital cost: USD 130,000 (FSTP + Truck + Land etc.) Construction cost: USD 68,100 / 6,500 USD/m^3 • Planted Drying Bed: 10 units (design size: 8m X 6m X 2m) • Horizontal Planted Gravel Filter: 2 units (design size: 10m X 6m X 0.6m) • Polishing Pond: 1 unit (design size: 5.6m dia X 1m depth) • Suction truck: 3000 L capacity
O&M cost (USD/year)	**4,060** General management and supervision.
Durability/Lifespan (years)	N/A
Manufacturer/Products name/ Brand	Blue Water Company / BORDA / CDD
Reviewed countries of application	Leh, Ladakh, India
Countries of product available	Asia and Africa
After sale services	N/A

18. THE BLACK SOLDIER FLY (BSF)

SANITATION

TECHNOLOGY DESCRIPTION

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

Black soldier fly larvae would be capable of consuming up to 130 mg of human faeces per larva per day. In other words it would require around 10,000 larvae to process the faeces from one person per day.

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**N/A**
Disposal	**N/A**
Remark	N/A

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**Electricity; Solar energy**
Energy consumption (kwh/d)	**Electricity: 2,900; Solar energy: 12,000**
GHG Emission (kg CO_2 eq./annum)	**5,736**
Remark	N/A

Total GHG emission	**5,736**	kg CO_2 eq./annum
	N/A	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Temperate and Tropical Climate** Ideal temperature is between 24 and 30°C with humidiy ranging from 30 – 90%. The ideal temperature can be achieved in a controlled environment that will mimic habitat of BSF. This will encourage mating, reproduction and growth cycle to regularly process waste.
Development impact: Environmental and health benefits	BSF are vociferous eaters of all organic wastes (including fecal sludge) and will reduce the volume of sludge by 40 – 50%. They also reduce foul odor.
Climate risks	**Yes** **Extreme cold and heat** • Too hot the larvae will crawl away from the food in search of a cooler location. • Too cold, the larvae will slow down their metabolism, eat less and develop slower. • Without careful supervision from experts it is hard to achieve favourable environment for BSF
Adaptability: Climate proof design *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**None**

Resources or Reference:

1. Verhagen. J., and Scott, P., (2019), Safely Managed Sanitation in High-Density Rural Areas: https://openknowledge.worldbank.org/handle/10986/32385
2. Dortmans B.M.A., Diener S., Verstappen B.M., ZurbruÃàgg C. (2017), Black Soldier Fly Biowaste Processing - A Step-by-Step Guide Eawag: Swiss Federal Institute of Aquatic Science and Technology: https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/BSF/BSF_Biowaste_Processing_LR.pdf
3. Torondel., B (2010): Sanitation Ventures Literature Review: on,Äêsite sanitation waste characteristics
4. ISF-UTS and SNV, Treatment technologies in practice: On-the-ground experiences of faecal sludge and wastewater treatment, The Hague, SNV Netherlands Development Organisation, 2021.

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** BSF plays a vital role in effectively reducing fecal waste and larvae are sold as a animal feeds. BSF help reduce biowaste and production of greenhouse gases.
Stage of technology	**Commercial**
Application level	Community Scale
Geographical location:	Urban residential area and Urban slums
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	7 tons currently and 200 tons planned
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	BOD (removal) : N/A COD (removal) : N/A TKN or TN (% removal) : N/A Pathogens (reduction of TC, FC and EC) : Pathogen reduction is achieved through reduction of waste quantities in a controlled manner, rather than pathogen Inactivation.
Complies with the standards	N/A
O&M Requirement	• Routes for delivery of garbage and pickup of residue should be well maintained and easily accessible throughout the year • Skilled and semi-skilled professionals are required to accommodate a laboratory • Water and electricity supply and wastewater management options should be available. • Adequate environmental buffers e.g. open areas, trees, fences, etc. should be maintained • Facility should be downwind from the residential areas. • Closed and ventilated room for the rearing and sunlight for the mating • Sheltered area without direct sunlight for the treatment containers
Capital cost and investment cost (USD and USD/m^3)	Capital cost: USD 7 million • The area required is approx. 500-750 m2 per ton of dry solids processed per day with an additional 60 m2 per ton required for a waste receiving area and to accommodate a laboratory, office and storage facilities. • Cost will reduce depending on the scale of business
O&M cost (USD/year)	**N/A** Staff ranging from semi-skilled (emptiers) to skilled (engineers and researchers)
Durability/Lifespan (years)	N/A
Manufacturer/Products name/ Brand	Sanergy
Reviewed countries of application	Kenya, EU and South Africa
Countries of product available	Kenya, South Africa, Soudi Arabia, South Korea, United Kingdom, EU, United Arab Emirates
After sale services	Yes

19. CO-COMPOSTING

SANITATION

TECHNOLOGY DESCRIPTION

Biological process to decompose and stabilize organic matter to valuable products (like soil amender) under controlled aerobic environment

Typically, two types:

- Open (windrow composting – heaps in open, takes up larger space)
- Closed (boxed composting – heaps in walled enclosures, less space than open composting)

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**4,645,607**
Disposal	**N/A**
Remark	N/A

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**N/A**
Energy consumption (kwh/d)	**N/A**
GHG Emission (kg CO_2 eq./annum)	**N/A**
Remark	N/A

Total GHG emission	**4,645,607**	kg CO_2 eq./annum
	N/A	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Heavy rain** As moisture plays vital role in the composting process, covering facilities is needed where there is heavy rainfall.
Development impact: Environmental and health benefits	Co-composting fecal sludge and municipal solid waste is advantageous because the human waste is relatively high in N content and moisture and the municipal solid waste is relatively high in organic carbon content and has good bulking quality. Moreover, both waste materials can be converted into a useful product. High temperatures attained in the composting process are effective in inactivating excreted pathogens contained in the fecal sludge and can be converted both wastes into a hygienically safe soil fertilizer.
Climate risks	**Yes** **Cold climate** Might not be efficient during extreme cold because pathogen inactivation is achieved during the time of high temperature.
Adaptability: Climate proof desig *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**None**

Resources or Reference:

1. NIUA (2019), COST ANALYSIS OF FAECAL SLUDGE TREATMENT PLANTS IN INDIA. Life Cycle Costing & Contracting Models of FSTPs
2. TILLEY, E. ULRICH, L. LUETHI, C. REYMOND, P. ZURBRUEGG, C. (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)
3. Enayetullah, I. (2015). Co-composting of Municipal Solid Waste and Faecal Sludge in Kushtia, Bangladesh. International Solid Waste Association (ISWA), Vienna, Austria
4. Tayler, K. (2018) Faecal Sludge and Septage Treatment: A guide for low- and middle-income countries, Rugby, UK, Practical Action Publishing
5. Co-composting of Municipal Solid Waste and Faecal Sludge in Kushtia Bangladesh: https://www.unescap.org/sites/default/files/Waste%20Concern,%20Bangladesh.pdf

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**Yes** By combining fecal sludge and municipal solid waste the benefits of each can be used to optimize the process and the output product. Co-composting is a natural process allowing good hygienisation of sludge in a relatively short time. This is due to high temperature of 50 to 70 degree celcius, which is reached during thermophilic degradation process. Even for large sludge volumes co-composting of pre-treated and thickened fecal sludge with solid waste might be a good solution.
Stage of technology	**Commercial**
Application level	Community Scale
Geographical location:	Peri-urban and rural residential area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	4 tons/ day
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal, COD removal, TKN or TN removal, E. coli % and Log reduction, Helminth egg* **Water and Hygiene** *Depend on each technology*	BOD (removal) : N/A COD (removal) : N/A TKN or TN (% removal) : N/A Pathogens (reduction of TC, FC and EC) : Helminth egg: Absent; Salmonella: Absent
Complies with the standards	Meets Bangladesh's Standard limit set by Ministry of Agriculture
O&M Requirement	• The mixture must be carefully designed so that it has the proper C:N ratio, moisture and oxygen content. If facilities exist, it would be useful to monitor helminth egg inactivation as a proxy measure of sterilization. • A well-trained staff is necessary for the operation and maintenance of the facility. • Maintenance staff must carefully monitor the quality of the input material, and keep track of the inflows, outflows, turning schedules, and maturing times to ensure a high quality product. • Forced aeration systems must be carefully controlled and monitored. • Turning must be periodically done with either a front-end loader or by hand. Robust grinders for shredding large pieces of solid waste and pile turners help to optimize the process, reduce manual labour, and ensure a more homogenous end product.
Capital cost and investment cost (USD and USD/m^3)	**80,000** Capital cost without land cost
O&M cost (USD/year)	**10,000** Salary for supervisor and labor, saw dust for compost etc.
Durability/Lifespan (years)	N/A
Manufacturer/Products name/ Brand	Owned by local municipality but contractual agreement with the Environmental Resource Advancement Services (ERAS),
Reviewed countries of application	Bangladesh and India
Countries of product available	Asia, Africa, Western Europe and North America
After sale services	N/A

20. ANAEROBIC DIGESTION

TECHNOLOGY DESCRIPTION

Employs sludge digestion under anaerobic condition to yield biogas and nutrient rich stabilized sludge

High-rate systems

- Characterized by short hydraulic retention time (HRT) and long sludge retention time (SRT)
- Kind of continuous systems - sludge are retained and digested for biogas production while liquid flows out of system for further treatment
- Suitable for FS treatment
- Example systems: biogas settlers, ABRs, AFs and UASB

Low-rate systems

- Characterized by high and equal HRT and SRT as digested exit system as slurry
- Suitable for all kinds of biodegradable slurries like animal manure, mixed organic solid waste
- Batch based system or continuously stirred tank reactors
- Example systems : Biogas digesters

Nothaburi Municipality, Thailand (Treatment process: Anaerobic Digester + Sludge Drying Bed + Effluent Treatment Pond)

CLIMATE RELEVANT SPECIFICATIONS

MITIGATION

SCOPE 1 DIRECT EMISSION

Process	GHG emission (kg CO_2 eq./ annum)
Treatment processes	**1,723,501**
Disposal	**N/A**
Remark	N/A

SCOPE 2 INDIRECT EMISSION

Detail	Data
Energy sources	**N/A**
Energy consumption (kwh/d)	**N/A**
GHG Emission (kg CO_2 eq./annum)	**N/A**
Remark	N/A

Total GHG emission	**1,723,501**	kg CO_2 eq./annum
	N/A	kg CO_2 eq./yr- m^3

ADAPTATION

Climate-resilient *Remarks: New WASH technology to counter the increased specific climate risks*	**Yes** **Tropical regions** Temperature of digester affects the activities of the anaerobic bacteria and waste decomposition. The rate of degradation and biogas production is enhanced at higher temperatures.
Development impact: Environmental and health benefits	Anaerobic digestion can be used for most organic waste. It gets interesting when there is a demand for biogas as a renewable energy source and where the fertilising sludge can be reused for agriculture.
Climate risks	**Yes** **Cold climate** • Freezing issue can obstruct microbial processes, reducing biogas production, and can lead to clogging • Fluctuating temperatures prevent consistency in the microbial population and can cause system failure.
Adaptability: Climate proof desig *Remarks: the additional detail of equipment or practices (installation and SMART monitoring and etc) to adapt and respond to changing conditions while maintaining functionality*	**Cold climate** Incorporating external heating, with an emphasis on both passive and active methods.(Controlled testing and laboratory analysis is underway for better performance)

Resources or Reference:

1. Strande, L., Ronteltap, M., Brdjanovic, D. (2014). Faecal Sludge Management: Systems Approach for Implementation and Operation.
2. AIT (2019). Sampling And Analysis Conducted By Ait For Project Titled: Policy Dialogue & Network Building Of Multi-Stakeholders On Integrated Decentralized Domestic Wastewater Management In Asean Countries. (Total of 7 samples were collected: 3 influent, 3 effluent and 1 dry sludge. As samples were collected on the same day the average unit has been computed)
3. Questionnaire Survey
4. Ecam Tool

Remarks: N/A: not available data

TECHNOLOGY SPECIFICATIONS

Innovative technology	**None** None
Stage of technology	**Commercial**
Application level	Community Scale
Geographical location:	Urban residential area
Phase	**Non-emergency**
Unit capacity or Treatment Capacity (m^3/d)	40
Treatment efficiencies (%) on Carbon, Nitrogen and on Microorganisms **Sanitation** *BOD removal* *COD removal* *TKN or TN removal* *E. coli % and Log reduction* *Helminth egg* **Water and Hygiene** *Depend on each technology*	BOD (removal): N/A COD (removal): 95% TKN or TN (% removal): 90% Pathogens (reduction of TC, FC and EC): N/A
Complies with the standards	Meets Thailand's National Standard
O&M Requirement	De-sludging not required but cleaning (removal of stones and other indigestible material) may be useful
Capital cost and investment cost (USD and USD/m^3)	Capital cost: **USD 313,333** Construction technology and materials; 4 trucks
O&M cost (USD/year)	**25,746** • Regular maintenance • Fuel for vechicles
Durability/Lifespan (years)	N/A
Manufacturer/Products name/ Brand	Nonthaburi City Municipality
Reviewed countries of application	Thailand
Countries of product available	Asia, Western Europe, African, Mediterranean and Middle East
After sale services	N/A

WATER 

HYGIENE 

SANITATION