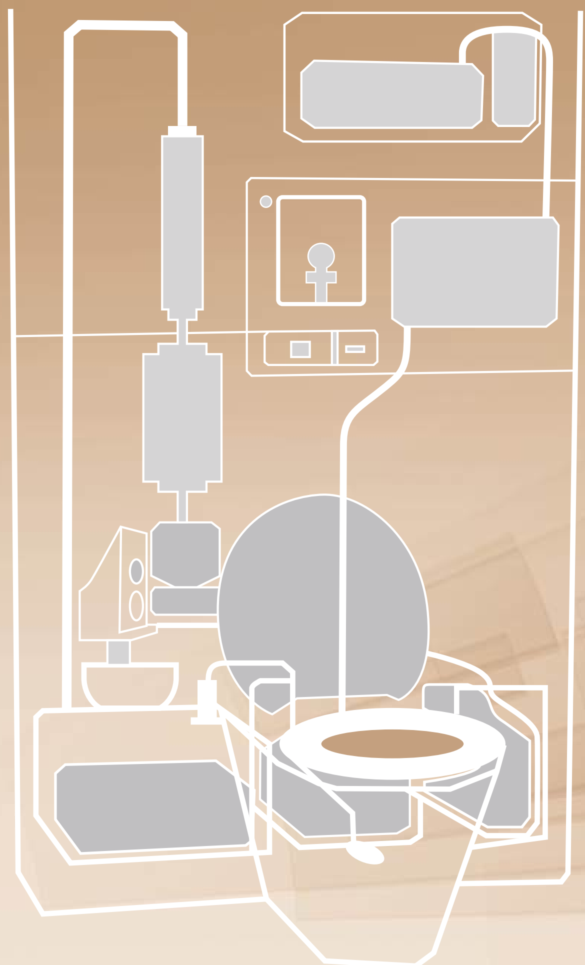
GUIDELINE ON
TRANSFORMATIVE SANITATION TECHNOLOGY



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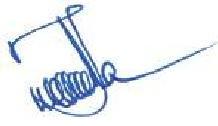
Foreword

The Department of Public Health Engineering is pleased to introduce the guidance document on Transformative sanitation technology, which will serve as an essential reference book providing comprehensive information and insights for stakeholders during the technology selection process of sanitation projects.

This guidance document contains a technology matrix that enables individuals to select state-of-the-art technologies for implementation in sanitation-related projects in Bangladesh, with the primary objective of disseminating knowledge on recent innovations within the sanitation sector. The matrix includes information on each technology's technical specifications, key features, development status, use cases, inputs, outputs, treatment and business consideration factors. The matrix serves as a valuable tool for stakeholders to make informed decisions and choose the most appropriate transformative sanitation technology for their projects based on their specific needs. This document also includes a reference segment about International Standards for treatment outcomes, which will further enhance the benchmarks for innovative sanitation technology selection.

I hope this document will enlighten us with promising solutions to some of the most urgent issues confronting societies globally. By turning waste, especially wastewater and human waste, into valuable resources, this groundbreaking approach brings a wide array of benefits that go beyond just managing waste. By implementing transformative sanitation technology, we can address not only the sanitation challenges but also contribute to sustainable development, environmental protection, resource recovery, and public health improvement. The approach outlined in this guidance document aligns with global efforts to achieve Sustainable Development Goal (SDG) 6. As we delve into the details of each technology and its potential applications, we hope that this document will serve as a guide for decision-makers, engineers, practitioners, and policymakers in the field of public health and sanitation. Together, we can work towards building healthier, more sustainable communities through the adoption of transformative sanitation technology.

I want to express my appreciation to the CWIS FSM Support Cell, DPHE, for creating this valuable document that will make a significant contribution towards advancing the sanitation sector and reaching SDG Goal 6.



Tushar Mohon Sadhu Khan
Chief Engineer
Department of Public Health Engineering

Acknowledgement

The Department of Public Health Engineering is pleased to present the guidance document on **Transformative Sanitation Technology**. This document provides comprehensive information for stakeholders to aid in the technology selection process for sanitation projects.

The document features a technology matrix that helps users select advanced technologies for sanitation projects in Bangladesh. It includes detailed information on each technology's technical specifications, features, development status, use cases, inputs, outputs, treatment, and business considerations. This tool enables informed decision-making to choose the most suitable transformative sanitation technology based on specific needs. Additionally, it includes a section on International Standards for treatment outcomes, enhancing benchmarks for technology selection.

I hope this document offers promising solutions to critical global issues. Transformative sanitation technology turns waste into valuable resources, offering benefits beyond waste management, such as sustainable development, environmental protection, resource recovery, and public health improvement. This approach aligns with the global goal of achieving Sustainable Development Goal (SDG) 6. We aim for this document to guide decision-makers, engineers, practitioners, and policymakers in public health and sanitation, fostering healthier, more sustainable communities.

To finalize this document, I would first like to express my deepest gratitude to Mr. Tushar Mohan Sadhu Khan, Chief Engineer of the Department of Public Health Engineering, for his precise guidance. My sincere thanks also go to Mr. Md. Shafiqul Hassan, Co-chair of the CWIS-FSM Support Cell, along with the respected Project Directors and officials of DPHE who provided invaluable feedback and insightful advice throughout the finalization process. Sincere thanks to the partners of the CWIS-FSM Support Cell (ITN-BUET, WaterAid, Practical Action, SNV, Athena Infonomics, Global Water and Sanitation Center-GWSC, AIT, FANSA and Others) for bringing knowledge which are immensely valuable while deliver this document. Lastly, I extend my heartfelt appreciation to all the officials of the CWIS-FSM Support Cell, whose commitment and hard work from the beginning to the end were crucial in bringing this document to completion.

Dr. Abdullah Al-Muyeed
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Department of Public Health Engineering

D P H E

জনস্বাস্থ্য প্রকৌশল অধিদপ্তর

Contents

Chapter 1: Transformative Sanitation Technologies

1.1 Introduction

Transformative sanitation technology is a wastewater treatment technology approach which converts waste, such as wastewater and fecal matters, to resources.[1] A variety of technologies and techniques treat the wastewater and reclaim valuable resources such as nutrients, energy, and water for reuse purposes. Transformative technology uses biological, chemical, physical, and thermal processes to treat wastewater. The singular or combined application of technologies ensures that the water is free from contaminants and safe to reuse. It averts chemical treatments which substantially reduces the operation and maintenance cost of the sanitation technology. Omni Processor (OP), Non-sewered Sanitation System (NSSS) such as Single Unit Reinvented Toilets (SURTs), Multi Unit Reinvented Toilets (MURTs) are the example of the transformative sanitation technology which operates independently with frontend and backend system.

Transformative sanitation technology stands as a beacon of hope in addressing some of the most pressing challenges faced by societies worldwide. By converting waste, particularly wastewater and fecal matter, into valuable resources, this innovative approach offers a range of benefits that extend far beyond mere waste management. One of the most significant societal advantages of transformative sanitation technology lies in its potential to revolutionize resource scarcity. In a world grappling with water scarcity and depletion of vital nutrients, these technologies offer a sustainable solution. By reclaiming nutrients, energy, and water from wastewater, societies can alleviate pressure on dwindling resources, ensuring a more resilient and self-sustaining future. Moreover, the application of biological, chemical, physical, and thermal processes to treat wastewater demonstrates a commitment to environmental conservation. Transformative technologies minimize reliance on harmful chemical treatments, reducing pollution and safeguarding ecosystems. This translates into healthier aquatic environments, improved soil quality, and better air quality for communities.This transformative sanitation technology represents a paradigm shift that transcends waste management, offering society a multi-faceted solution to resource scarcity, environmental protection, public health, and economic sustainability. By harnessing the power of innovation and science, these technologies have the potential to uplift communities, create more resilient societies, and pave the way for a brighter, more sustainable future.

1 https://www.gwsc.ait.ac.th/transformative-sanitation-technology/#:~:text=Transformative%20sanitation%20technology%20is%20a,and%20water%20for%20reuse%20purposes.

1.2 The journey of the Reinvented Toilet

Reinvented Toilets are a new generation of toilets that treat waste and kill pathogens without the need for connections to sewers, treatment plants, water supply, or continuous electricity. These new toilets use a variety of innovative technologies to break down human waste and destroy germs, leaving behind clean water and solid that won't harm people or the environment. The toilets can be used either for individual households known as SURT or multiple stall facilities that can serve local communities, schools, apartment buildings, and commercial enterprises known as MURT. The MURT is a central processing unit that connects to multiple toilets to treat waste and recycle wastewater for flushing for many users.

10 years back in 2011, Bill & Melinda Gates Foundation open a challenges for the researchars around the world on safe sanitation challenges. In that challenges, they asked everyone to Reinvent the toilet in a way that will work without a sewage system or running water. Hundreds of scientist and researchers from top most university across the globe developed ideas within the last 10 years and they created toilets that convert feces into valuable resources, including fertilizer, clean water, and electricity.. These technology are potentially life changing for the 3.5 billion people around the world who lack safe sanitation, especially those living in crowded urban areas, in regions that are flood-prone, or where land, water, and resources for infrastructure are scarce. The Reinvent the Toilet Challenge continues today and supports the development and commercialization of products that:

- Remove harmful pathogens from human waste and recover valuable resources such as energy, clean water, and nutrients
- Operate "off the grid" without connections to water and sewers and require minimal electricity
- Cost less than US$.05 cents per user per day
- Promote sustainable and profitable sanitation services and businesses in poor urban settings
- Can appeal to everyone, in developed as well as developing nations

Technology Matrix

			OMNI Processor	Generation II Reinvented Toilet (G2RT)	The Clear toilet or Biological Reinvented Toilet	The Oystra or Mobile Septage Treatment System	Nanomembrane Toilet or Dry Combustion Reinvented Toilet	The Empower Sanitation or Dry Combustion Reinvented Toile	EAWAG Reinvented Toilet	Eco San or Electrochemical Reinvented Toilet by CalTech	E-Toilet or Electrochemical Reinvented Toilet	HTCLEAN or High Temperature Processing Reinvented Toilet	ZYCLONE Cube or Biological and Electrochemical Reinvented Toilet	NEWGenerator or Biological and Physicochemical Reinvented Toilet	The Toronto Toilet or Dry combustion Reinvented Toilet
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Overview	Input	Raw Sludge	●	●	●	●	●	●	●	●	●	●	●	●	●
	Output	Treated Water/ Distilled Water	●	●	●	●	●	●	●	●	●	●	●	●	●
		Dry pellet		●			●	●				●			
		Ash/Fertilizer/ Biogas/Fuel	●				●			●			●	●	●
		Electricity	●												
Status of Development		Developed	●	●	●					●			●		
		Underdeveloped				●	●	●	●		●	●		●	●
User Type/ Capacity		Single User (SURT)		●	●		●	●				●	●		●
		Multiple Use (MURT)			●	●				●	●			●	
Life Expectancy (Years)			10	--	10	20	10	10	10	10	10	20	15	15	15
Costing/ Capex (USD)			$ 1.5 million USD	$ 500 USD	$ 50,000 USD	--	--	--	--	--	$13,500 USD	--	--	$45,000 USD	

Chapter 2: Different Transformative Sanitation Technology

2.1 OMNI Processor

The Omni Processor is a state-of-the-art decentralized waste treatment system that processes all biodegradable and non-biodegradable waste including human waste to produce electricity and distilled water as fuel. Omni processors usually combine 3 processes. The steps of waste treatment of Omni processor are mentioned below,

Figure1: Janicki Omni Processor (J-OP) developed by Sedron Technology

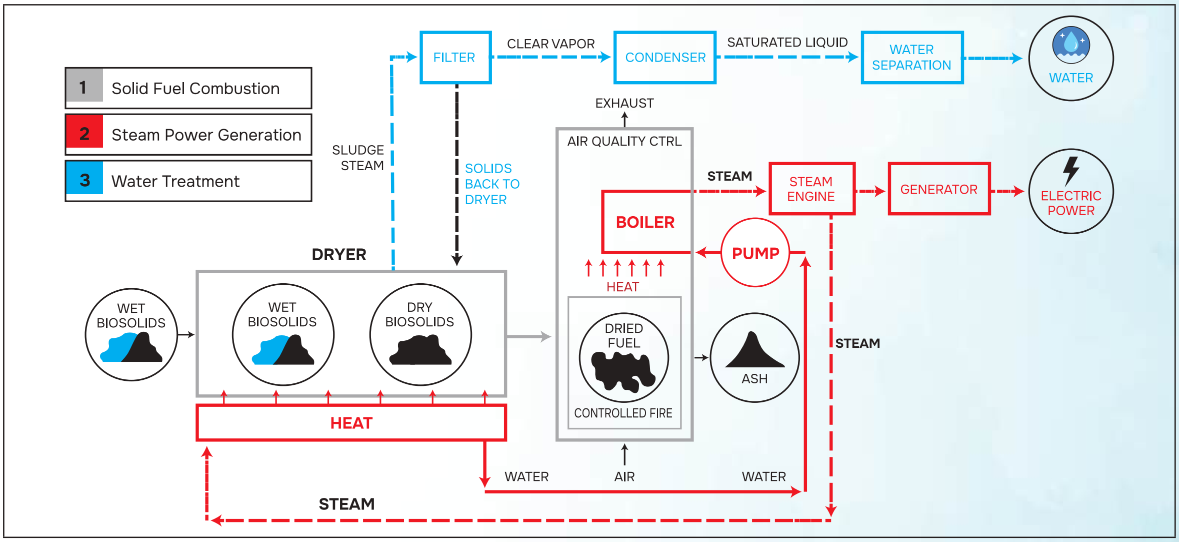


Figure 2: Process flow of OMNI PIrocessor

1) Dry Fuel Combustion: The inorganic and organic part of the waste coming from City-Corporations and Municipalities is converted into dry fuel by applying heat through dryer to reduce the moisture content. This dry fuel is then combusted in a controlled fire in the presence of airflow in the combustion chamber. In most of these combustion processes, plasma gasifiers are used to convert the waste into refined gas and slag/ash. At the end of combustion, the volume of waste is significantly reduced to produce ash / biochar / slag, which can be reused later. On the other hand, emissions are managed by controlling the air quality by purifying the synthesis gases released from this combustion process. In this process harmful gases such as methane, fluorine, dioxin, furan etc. are not released.
2) Power generation: The water obtained in the process of reducing the humidity by applying heat through the dryer is pumped into the boiler which creates vaporizer in the combustion process. This boiler is fed through a steam engine which produces electricity through a generator. This generated electricity is used to run the Omni processor and the excess electricity is commercially salable. On the other hand, the steam from the steam engine is reused to heat the dryer. In this process, the Rankine cycle of thermodynamics is constantly repeated.
3) Water production: The aqueous portion of the waste from the dryer is successively passed through filters, condensers to obtain a condensed liquid, from which the final water is separated. This water is available as distilled water which can be sold commercially.

2.2 Generation II Reinvented Toilet (G2RT)

The Generation 2 Reinvented Toilet (G2RT) is developed by Georgia Institute of Technology combining the best of the ideas featured in the Reinvented Toilet challenge back in 2011 and packaged them into one new, low-cost toilet that takes the entire process of sewer sanitation and places it inside a toilet the size of a washing machine. This system basically a miniaturised treatment system" comprising ultrafiltration and a reverse osmosis (RO) unit as well as a drying operational unit. Since the waste will be treated in situ, the energy requirement is more efficient than that of a traditional waste disposal system. In a traditional system, once the toilet is flushed, the waste and several liters of water move through a pipe to a pumping station and then to a centralised wastewater treatment plant where the water is recovered and the waste is processed and treated. But in this system after flushing with only a small amount of water—the Generation 2 Reinvented Toilet (G2RT) separates solid waste from liquid waste. The urine and flush water are filtered to produce clean water, which is then recirculated to flush the toilet. The feces are either pasteurized or combusted, producing pressed cakes or dried ash, which falls into a receptacle that users dispose of in the trash or compost. G2RT's Volume Reduction (VR) process uses a pasteurizer to kill the fecal pathogens. The system's filter press module flattens and squeezes excess moisture out of the feces; this creates small cakes that are then dried further. Helbling's micro Super Critical Water Oxidation, or mSCWO, takes the fecal waste through a miniature reactor until the water reaches a "super-critical" temperature of 375 degrees Celsius and 220 bar, at which point the feces spontaneously combust and turn into ash.

In 2022, G2RT began its field tests in people's homes in South Africa, India, and China. The Yee toilet's current cost—approximately $450—still presents a challenge for many, requiring governments and private entities to help support the innovation in the poorest parts of the world. This can be useful as an Individual household treatment systems (SURTs)

Figure 3: Generation II Reinvented Toilet

2.3 The Clear toilet or Biological Reinvented Toilet

The Clear toilet uses a full-water cycling process for treatment of the sewage. A rain water collecting system can also replenish the water to the processor for self-renewal. Blackwater from the toilet is pumped up to the sewage processor for treatment and then recycled to the storage tank for flushing. An advanced unique Biofilm-MBR treatment process is employed as the core technology for treatment, producing a stable and clean effluent that is further disinfected to ensure safety of the effluent for reuse.

Key Features:

- Current design has four stalls and three urinals and can serve up to 1000 users/day
- Ability to operate in remote, or water-scarce conditions where there is not existing sanitation solutions such as sewers
- Wifi and media player features available

Status of Development

TRL 8

Concept → Early Prototype → **Product Available**

Clear prototype development and testing complete in China

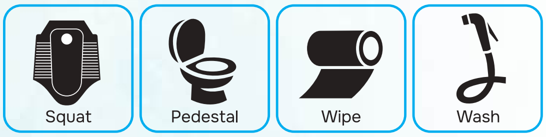
Over 100 units have been sold and are in operation at sites across China

Use Cases:

Household: Technology could potentially scaled down to serve as a single household unit, up to 10 users per day

Multi-unit: Design of system is most readily applicable to tourism sites, school, or public/ community applications

Product is Appropriate For:



1000	$0.03	10
Capacity (users/day)	Est. Cost ($/user/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: Compatible with multiple front ends, currently designed as a multi-seat unit. The wastewater is grounded and lifted to the treatment unit.
- Processing: Initially treated with physical precipitation. A special aerobic media is placed in the aerobic reactor and proprietary bacteria, specifically developed for treating wastewater, is attached on the media as a biofilm. This biofilm can effectively biodegrade more than 50% of the organic pollutants and reduce its concentration. The wastewater is then treated by a MBR (membrane biological reactor) to separate pollutants in large size, which can be refluxed in the biodegrade process, producing clean water. Finally, the produced clean water is further disinfected via UV to kill all bacteria in the water.
- Power System: The system requires external power either from grid electricity, or from solar panels. Estimated requirements is 5.65kWh/day.

Inputs

- ✓ Does the system require an external source of electricity?
  Yes. Currently either grid or solar panels
- ✓ Does the system require the use of water?
  Yes. Rainwater collection is required for startup only. Flush water is recycled.
- ✓ Does the system require any other "consumable" inputs?
  No

Outputs

- ✓ How much energy will be recovered?
  None. Energy is used in process
- ✓ How much water will be recovered?
  Water is recycled to be self-sustaining
- ✓ How much fertilizer or other byproducts will be produced?
  None

Treatment

- ✓ Treats solid and liquids
- ✓ Pathogen treatment success? Confirmed total pathogen removal
- ✓ Are chemical processes used? Yes
- ✓ Are biological processes being used? Yes
- ✓ Does the system require any off-site or additional processing? Yes. Solids are required to clear every year

Business Considerations

- ✓ Estimated daily operating cost $0.03/user/day
- ✓ Estimated capex $50,000 (TT-1 model)
- ✓ Size L 6.06m x W 5.96m x H 5.04m
- ✓ Maintenance Requirements Membranes to be monitored and replaced as needed every two years. Solids may need to be emptied every year.
- ✓ Life expectancy 10 years

Figure 4: Biological Reinvented Toilet frontend

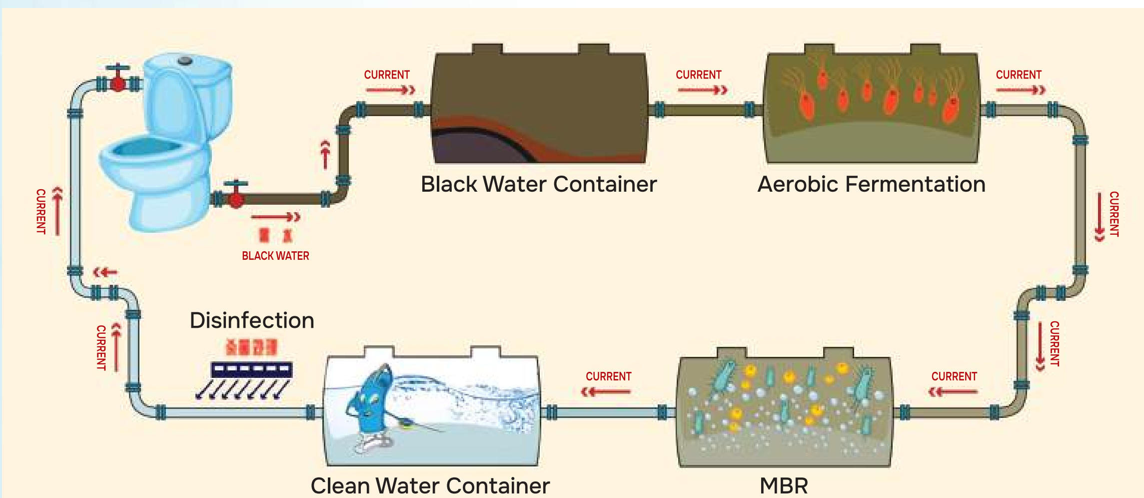


Figure 5: Biological Reinvented Toilet treatment flow

2.4 The Oystra or Mobile Septage Treatment System

The Oystra Mobile Septage Treatment System (MSTS) is a new sanitation system that processes human fecal sludge into non-potable water for agricultural or industrial use or safe discharge. Oystra is a truck-mounted dewatering system for use in areas like dense urban settlements where poor sanitation poses the greatest risks to human health. The latest generation prototype will be more cost effective, transportable, and easier to maneuver in crowded informal settlements than traditional septage collection methods.

Key Features:

- Makes septic tank emptying and treatment safer and less expensive
- Pre-processes the septage from pit latrines or septic tanks to discharge clean, safe water
- Results in reduced solids volume to transport to treatment, therefore reducing transport cost

Status of Development

- In 2016, Crane built the initial Oystra Mobile Septage Treatment System (MSTS) prototype and tested locally in 2017
- The second generation prototype is complete and began field testing in October 2018

Use Cases:

Pit and tank empties: Designed to be used by pit/tank emptier who collect and transport septage from containment sites to treatment facilities

Product is Appropriate For:

Oystra

3 L/S	TBD	20
Capacity	Est. Cost ($/user/day)	Life Expectancy (Years)

How Does it Work?

Inputs

- ✓ Does the system require an external source of electricity?
  Yes. Currently powered by truck-mounted diesel generator (<60kW steady state)
- ✓ Does the system require the use of water?
  No
- ✓ Does the system require any other "consumable" inputs?
  Diesel fuel

Outputs

- ✓ How much energy will be recovered?
  None. Energy is used in process
- ✓ How much water will be recovered?
  50-80% of intake volume discharged as safe industrial or agricultural water
- ✓ How much fertilizer or other byproducts will be produced?
  None

Treatment

- ✓ Liquid Separated, treated, then discharged
- ✓ Solids Not treated
- ✓ Are chemical processes used? No
- ✓ Are biological processes being used? No
- ✓ Does the system require any off-site or additional processing? Yes. Concentrated septage to be transported to treatment facility

Business Considerations

- ✓ Estimated daily operating cost (not available)
- ✓ Estimated capex (not available)
- ✓ Size H 3.2m x W 2.2m x L 4.5m (processor)
  H 2.8m x W 2.4m x L 9.4m (with truck)
- ✓ Maintenance Requirements Filters to be replaced every 6-12 months, daily cleaning after shift
- ✓ Life expectancy 20 years

Figure 6: The Oystra Mobile Septage Treatment System (MSTS)

2.5 Nanomembrane Toilet or Dry Combustion Reinvented Toilet

This system is a fully self-contained household toilet system. Frontend resembles a Western-style pedestal toilet with a novel waterless swiping flush mechanism, and all waste processing components are housed within the pedestal. In the backend, solids are extracted by a specifically designed screw, then dried and combusted, while liquids are preheated and purified with a hydrophobic membrane.

Key Features:

- Single household system: up to 10 users/day
- System design is completely self-contained, no water or power connections are required
- Unique waterless flush system minimizes water requirements
- Heat from the combustion process is used to drive water through the membrane
- System produces clean water each day for household use
- Ash requires occasional disposal

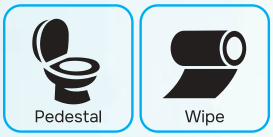
Status of Development

- Optimized subcomponent performance
- Frontend and backend component prototypes developed in Cranfield, UK
- Frontend tested in households in Durban, South Africa. Full system to be tested in 2019

Use Cases

- Household: Designed as a self-contained household unit up to 10 users per day
- Multi-unit: Core processing technology could be scaled for school, or public/community application

Product is Appropriate For:



10	TBD	10
Capacity (users/day)	Est. Cost ($/user/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: User encounters a pedestal toilet with a unique waterless flush system. A rotating odor barrier and scraper mechanism manages odor and enables dry flushing.
- Urine/Feces Separation: Solids and liquids are separated by gravity sedimentation. Liquids flow over a weir to liquids processing, while the solids are extracted using a screw.
- Liquid Processing: A hydrophobic membrane separates clean water from the contaminated urine. The clean water is then sent to a storage tank for later use.
- Solids Processing: Solids are dried, pelletized and combusted resulting in ash. The combustor being developed is a micro-combustor that can be fed at < 1 g/min of dried fecal waste.
- Power System: The lifting of the toilet seat powers the bowl. Excess heat from the combustor is used as the driving force for water separation. There are opportunities for electrical energy generation under development from thermal and electrical gradients, to offset residual power requirements.

Inputs

✓ Does the system require an external source of electricity?

No. Energy is generated mechanically and potentially through thermal and electrical gradients.

✓ Does the system require the use of water?

No

✓ Does the system require any other "consumable" inputs?

No

Outputs

✓ How much energy will be recovered?

None. Recovered energy is used in process

✓ How much water will be recovered?

>10 liters/day usable

✓ How much fertilizer or other byproducts will be produced?

10g ash/user/day

Treatment

- ✓ Solids treatment Combustion
- ✓ Liquids treatment Membranes
- ✓ Pathogen treatment success? Confirmed total pathogen removal
- ✓ Are chemical processes used? No
- ✓ Are mechanical processes being used? Yes
- ✓ Are biological processes being used? No
- ✓ Does the system require any off-site or additional processing? No

Business Considerations

- ✓ Estimated daily operating cost (not available)
- ✓ Estimated capex (not available)
- ✓ Size L 1.25m x W 0.75m x H 1.0m
- ✓ Maintenance Requirements Water/ash to be emptied daily (by user). Ash to be emptied weekly, and membranes to be cleaned four times a year
- ✓ Life expectancy 10 years

Figure 7: Dry Combustion Reinvented Toilet

2.6 The Empower Sanitation or Dry Combustion Reinvented Toilet

Community toilet with both liquid recycling and solids processing. The toilet is compatible with pedestal and squat plate styles. Onsite processing includes electrochemical disinfection and recycling of liquids, and drying and sterilization of solids with optional combustion. User amenities may include body wash and hand wash stations and menstrual pad dispenser and disposal options.

Key Features:

- User options developed through four year in-field household and community design studies
- Liquids processed via active filtration and electrochemical disinfection, meeting ISO discharge standards
- Independent solid and liquid processing modules can be paired with other technologies to create a suite of sanitation products
- Examples of new products include The Reclaimer, a liquid recycling unit, and a stand-alone menstrual waste management unit

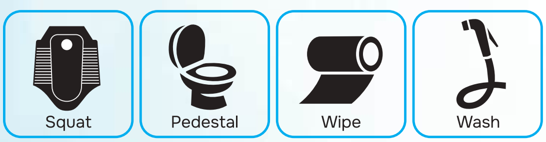
Status of Development:

- Third generation (TRL 7) prototype in active testing in Coimbatore, India and Durban, South Africa; Coimbatore testing focuses on women and girls
- Both liquid recycling and menstrual pad processing products will be tested first in India in January 2019

Use Cases

Household and Community: Designed for 10 to 50 users per day. The processing system can be adapted to service multiple seats in a community block.

Product is Appropriate For:



10 to 50	TBD	10
Capacity (users/day)	Est. Cost ($/user/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: Compatible with both pedestal and squat plate interfaces
- Urine/Feces Separation: Mesh belts used for initial separation. Baffle tanks in liquid processing stream allow for additional settling of solids

- Liquid Processing: (blue) Hybrid processing includes activated carbon filtration with electrochemical disinfection. A post baffle filter is used for Helminth egg removal. The disinfected liquid is recycled for flush water.
- Solids Processing: (red) After initial separation, solids are dried at 90˚C. Combustion option may increase solids processing capacity across multiple units
- Power System: Currently power by grid power. Optional solar panels (500 W) for supplemental and off-grid energy.

Inputs

✓ Does the system require an external source of electricity?

Yes. Requires 5-7kWh/day, currently provided through grid power (deep-cycle batteries) or 500 W photovoltaic panels.

✓ Does the system require the use of water?

Wash and/or flush water 30L initial charge, otherwise recycled water is used in system.

✓ Does the system require any other "consumable" inputs?

No

Outputs

✓ How much energy will be recovered?

None. Energy is not used in process

✓ How much water will be recovered?

10-30 L/day-excess water will be discharged after disinfection, remainder is used for flush water

✓ How much fertilizer or other byproducts will be produced?

Sterilized dried solids may be collected or incinerated onsite.

Treatment

✓ Liquids Electrochemical and activated carbon

✓ Solids Therma

✓ Pathogen treatment success? Confirmed total pathogen removal

✓ Are chemical processes used? Ye

✓ Are mechanical processes being used? Yes

✓ Are biological processes being used? No

✓ Does the system require any off-site or additional processing? No

Business Considerations

✓ Estimated daily operating cost (not available)

✓ Estimated capex (not available)

✓ Size L 1.5m x W 2.0m x H 1.25m

✓ Maintenance Requirements Ash/dried solids emptied weekly (by user)

✓ Life expectancy 10 years

✓ Other Features Menstrual pad disposal

Figure 8: The Empower Sanitation or Dry Combustion Reinvented Toilet

2.7 EAWAG Reinvented Toilet

EAWAG exhibits two products: the Blue Diversion Autarky toilet, which separates and treats urine, solids, and flushing water on site. Urine is chemically stabilized and concentrated. Solids are processed with supercritical water oxidation. The water treatment module combines a biological membrane reactor, activated carbon, and electrolysis to provide safe recycled water. The water treatment is available as a stand-alone handwashing station called Water Wall. Urine and solids treatment can also be provided as separate units.

Key Features:

- Source separation allows for water recycling, nutrient recovery and optimal disinfection
- Modular design: all treatment units can be operated alone or integrated in other systems
- Superstructure allows integration of other treatment units
- Attractive frontend developed with partner EOOS offers hygiene and comfort of modern water flushed toilets

Status of Development

- Water Wall has TRL 6. Field tests in East Africa and Zurich
- Urine module and user interface TRL 4. Field tests ongoing
- Exhibited toilet unit TRL 4, does not include faces module
- Feces module TRL 3. Field tests in the beginning of 2019

Use Cases

✓ Household or single stall: Current Blue Diversion Autarky Toilet is designed for 10 users per day

✓ School: Current Water Wall can be used as a hand washing station with three faucets

Product is Appropriate For:

10+	TBD	TBD
Capacity (users/day)	Est. Cost ($/user/day)	Life Expectancy (Years)

How Does it Work?

➪ Frontend: Water-flushed urine-diverting pedestal, waterless urinal and hand washing washbasin. Water is recycled.

➪ Urine/Feces Separation: Source-separating unit designed by EOOS. Urine is separated in a urine-diverting pedestal (NoMix toilet). Solids are separated in an Aquatron.

➪ Liquid Processing: Urine processing (3): Urine is chemically stabilized then undergoes passive evaporation, resulting in a solid product that can harvested as fertilizer. Water processing (4): Three units are used for treating the used flushing water and handwashing water: membrane bioreactor with ultrafiltration, activated carbon filter, and electrolysis to produce residual chlorine.

➪ Solids Processing: Feces, toilet paper, and some flushing water are fed into a small-scale, batch-processing supercritical water oxidation reactor developed by the University of Applied Sciences and Arts, Northwestern Switzerland (FHNW).

➪ Solids Processing: Water Wall and urine processing can be operated using solar power. SCWO reactor is still too early in development to assess energy requirements.

Inputs

- ✓ Does the system require an external source of electricity?
  All units require power supply
- ✓ Does the system require the use of water?
  Water is internally recycled. Some water will have to be refilled
- ✓ Does the system require any other "consumable" inputs?
  Calcium hydroxide for the urine stabilization

Outputs

- ✓ How much energy will be recovered?
  None. Energy is used in process
- ✓ How much water will be recovered?
  <10 liters/day produced. Designed to be recycled, none is intended for discharge
- ✓ How much fertilizer or other byproducts will be produced?
  Nutrient recovery: >70% nitrogen, >80% phosphorus, >70% potassium, and others

Treatment

- ✓ Solids: Yes, supercritical wet oxidation
- ✓ Liquids:Yes, urine (chemical stabilization and evaporation); wash water (membrane bioreactor, ultrafiltration, activated carbon, electrolysis)
- ✓ Pathogen treatment success? Autarky system will have total pathogen removal
- ✓ Are chemical processes used? Yes
- ✓ Are mechanical processes being used? Ye
- ✓ Are biological processes being used? Yes
- ✓ Does the system require any off-site or additional processing? No

Business Considerations

- ✓ Estimated daily operating cost (not available)
- ✓ Estimated capex (not available)
- ✓ Size Blue Diversion Autarky Toilet: L 2.2m x W 1.9m x H 3.4m (without stairs) Water Wall: L 1.9m x W 0.9m x H 2.3m
- ✓ Maintenance Requirements Water refill, fertilizer harvest from urine and feces treatment, supply of chemical reagent
- ✓ Life expectancy 10 years

 Rendering of the Blue Diversion Autarky toilet shown at RTE. © Eawag/EOOS	 © Eawag/EOOS

Figure 9: EAWAG Reinvented Toilet

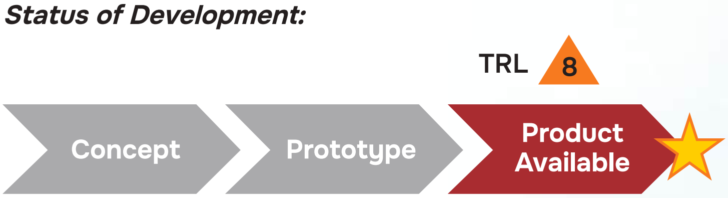
2.8 Eco San or Electrochemical Reinvented Toilet

Eco-San is one of the leading developers of the CalTech technology, focusing on school and public toilets, and containerized toilet units. The backend processing technology capitalizes on anaerobic digestion of solids and an electrolysis system to convert waste into water, hydrogen, and solid fertilizer. Eco-San is piloting three units in China, and two in South Africa. Eco-San's sister company, Yixing, Entrustech, is producing and reducing the cost of the electrodes that drive the electrolysis treatment process to make available to all

Key Features:

- Design can be fully containerized, or with separate digestion tank
- Patented electrochemical cells process mixed wastewater
- Can recycle process effluent as toilet flush water, notable in water scarce areas
- Compatible with any type of flush toilets (squat pan, western style, urinals, etc.)

Status of Development:



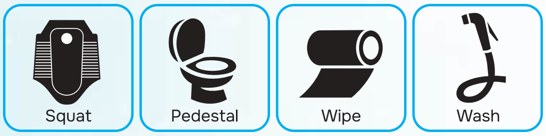
✓ Eco-San is piloting three units in China, two at tourist locations: a park and a temple, and one at an elementary school

✓ Two units are being commissioned as community ablution blocks in Durban, South Africa

Use Cases

Multi-unit: Core processing technology scalable for school, or public/community application; capable of servicing 50-800 users per day with one system.

Product is Appropriate For:



800	$0.02	5-10
Capacity (flushes/day)	Est. Cost ($/fluse/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: Includes up to 8 toilets and urinals located near the backend processing components.
- Urine/Feces Separation: No urine/feces separation. Mixed waste passively settles in a separation tank with anaerobic digestion. Active pre-processing with an anaerobic/aerobic system is available.
- Liquid Processing: An elctrochemical system oxidizes the effluent from the septic tank and biological treatment unit at a semiconductor anode and water is reduced at the metal cathode to form H2. Chloride, from table salt, can be added if there is an insufficient amount in the waste. Membrane microfiltration is currently included for polishing the final effluent.
- Solids Processing: Feces are macerated with the urine and flush water, all are processed together. Undigested solids that have settled in the septic tank are estimated to require evacuation once a year.
- Power System: Solar panels, with energy storage via battery stack, and/or grid electricity. Estimated 18kwh required per m^3.

Inputs

✓ Does the system require an external source of electricity?
Yes. Provided by solar panels or grid

✓ Does the system require the use of water?
No

✓ Does the system require any other "consumable" inputs?
No

Outputs

✓ How much energy will be recovered?
None. Energy is used in process

✓ How much water will be recovered?
4-5m^3/day usable, not portable

✓ How much fertilizer or other byproducts will be produced?
1 ton per year

Treatment

✓ Treats Solids and liquids
✓ Pathogen treatment success? Confirmed total pathogen removal
✓ Are chemical processes used? Yes
✓ Are mechanical processes being used? Yes
✓ Are biological processes being used? Yes
✓ Does the system require any off-site or additional processing? No

Business Considerations

✓ Estimated daily operating cost $0.02/flush/day
✓ Estimated capex (not available)
✓ Size L 12m x W 2.2m x H 2.7m
✓ Maintenance Requirements Solid wastes to be emptied half a year (by user). Membrane filters to be replaced once a quarter.
✓ Life expectancy 10 years

Figure 10: Eco San or Electrochemical Reinvented Toilet's frontend

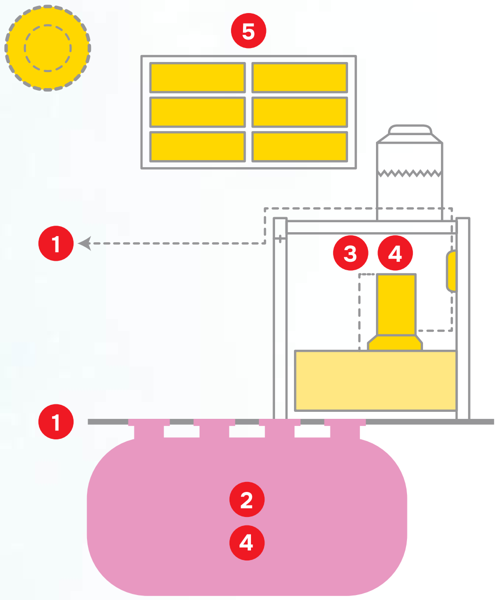


Figure 11: Eco San or Electrochemical Reinvented Toilet process flow

2.9 E-Toilet or Electrochemical Reinvented Toilet

Erams Scientific's eToilet incorporates a full treatment solution by integrating the existing eToilet technology deployed in over 3500 sites with novel treatment technologies stemming from the Reinvent the Toilet Challenge. The current prototype incorporates the CalTech electrochemical reactor to process the black water and produce reusable effluent, also safe for discharge. Additional prototype incorporating the University of South Florida treatment technology is also under development.

Key Features:

- eToilet features automated entry and self-cleaning of toilet bowls and floors for automated and unmanned operations
- Remote monitoring capabilities
- Sensor-enabled water minimization system
- Treated water from CalTech reactor is recycled back for toilet flush and floor wash
- Multiple potential business models being explored to support scale up of treatment units

Status of Development:

- eToilet with CalTech integrated treatment system prototype field testing in Coimbatore, India in late 2018 through 2019
- Additional prototypes incorporating USF technology to be built and tested in 2019
- Goal is for product availability by early 2020

Use Cases

Single-unit: Designed as a automated self-contained, toilet unit deployed in public sites, schools, or transport centers, capable of handling up to 100 users per day

Product is Appropriate For:

100	$0.07	10
Capacity (users/day)	Est. Cost ($/users/day)	Life Expectancy (Years)

How Does it Work?

➪ Frontend: Eram Scientific's eToilet, an unattended and automated self-cleaning electronic toilet cabin with remote monitoring and sensor enabled water minimization capability.

➪ Urine/Feces Separation: No separation is required.

➪ Liquid/Solids Processing: Waste stream is flushed and sent to the biological pretreatment holding tank. Waste is then pumped to the electrochemical reactor (ERC) based on the CalTech technology. The quality of the effluent following final filtration using water filters and strainer if confirmed using sensors and remote monitoring. Water is then stored for reuse as flushing water in eToilet.

➪ Power System: Currently powered by grid power.

Inputs

✓ Does the system require an external source of electricity?
Yes, grid electricity is required.

✓ Does the system require the use of water?
Yes, the personal hygiene taps and faucets require water.

✓ Does the system require any other "consumable" inputs?
No

Outputs

✓ How much energy will be recovered?
None. Energy is used in process

✓ How much water will be recovered?
All water used in the toilet is recycled for flushing and clearing

✓ How much fertilizer or other byproducts will be produced?
None

Treatment

✓ Treatment Biological pretreatment and electrochemical disinfection

✓ Pathogen treatment success? Confirmed total pathogen removal

✓ Are chemical processes used? Yes

✓ Are mechanical processes being used? Yes, water filter

✓ Are biological processes being used? Yes

✓ Does the system require any off-site or additional processing? No

Business Considerations

✓ Estimated daily operating cost $0.07/user/day

✓ Estimated capex ~$13,500 USD

✓ Size L 2.2m x W 1.7m x H 3.1m

✓ Maintenance Requirements (not available)

✓ Life expectancy 10 years

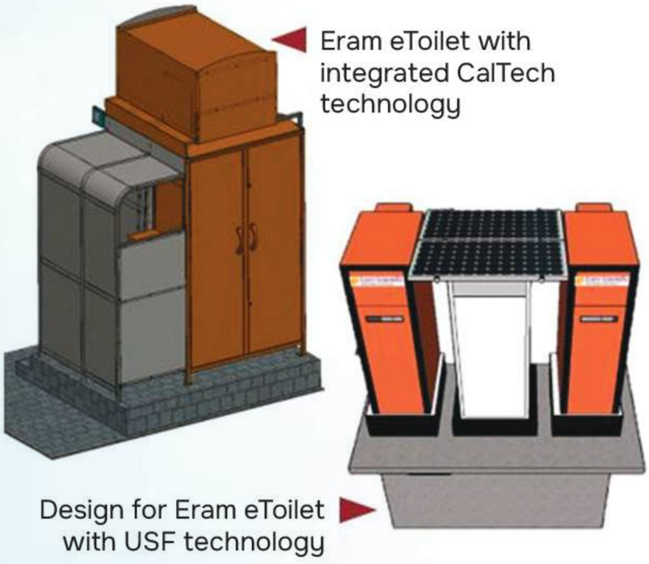


Figure 12: E-Toilet or Electrochemical Reinvented Toilet frontend

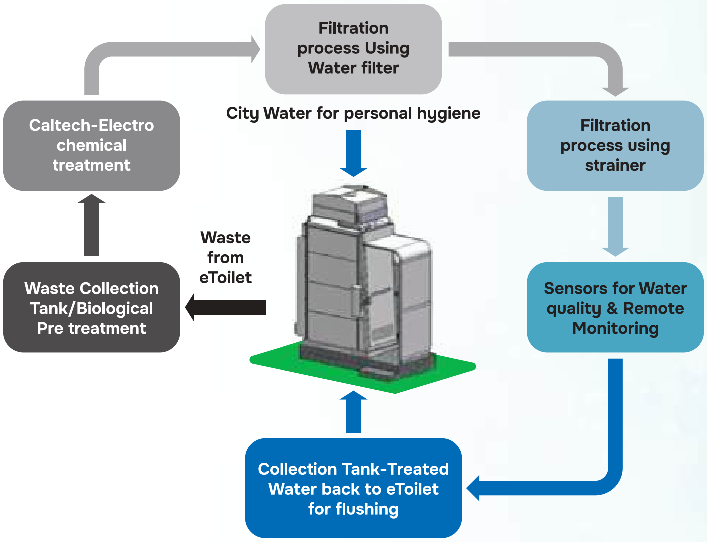


Figure 13: E-Toilet or Electrochemical Reinvented Toilet's process flow

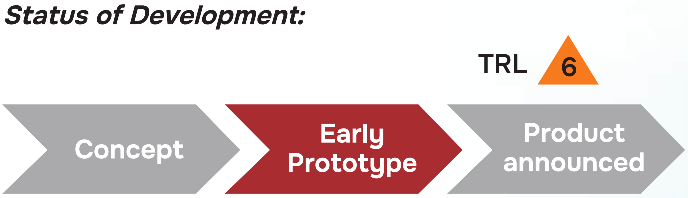
2.10 HTCLEAN or High Temperature Processing Reinvented Toilet

Helbling has been engaged by the Gates Foundation to develop HTClean, a next-generation Reinvented Toilet based on a high temperature and high pressure processing design. The toilet is being engineered specifically for the household. Intuitive visual cues on operation, maintenance, status, and usability are integrated.

Key Features:

- Self-sustaining toilet without water and sewage connection
- Single household system designed for 4-6 users/day, up to 10 users/day
- Vacuum flush system greatly reduces the flush water required (0.2-0.9 L)
- A unique, intuitive human machine interface (HMI)

Status of Development:



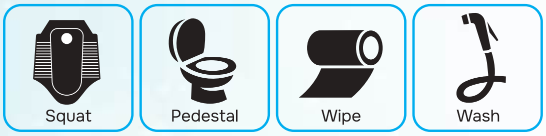
- Demonstrator unit developed and lab tested in Zurich, Switzerland
- Additional prototype testing and design improvements planned starting from January 2019

Use Cases

Household: Designed as a self-contained household unit for up to 10 users per day

Multi-unit: Core processing technology could be scaled for school or public/community application or by installing units in each stall

Product is Appropriate For:



10	TBD	20
Capacity (users/day)	Est. Cost ($/users/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: The input tank (10) is fed by the user input of the toilet (frontend, 11) through a vacuum pump including a macerator (19).
- Urine/Feces Separation: Solid/liquid separation is conducted after processing by a mechanical filter press (15).
- Processing: The user input is initially stored in a holding tank (10). The composited material from the storage tank is passed through a pre-heater (7), then loaded into a reactor chamber (4) and heated above 160˚C* (2), at a pressure up to 25 bar* . After cooling the reactor is discharged and solids and liquids are separated (15), resulting in a small filter 'cake' (13). The produced liquid is retained (14) and then cleaned for use in the toilet flushing system. Water vapor released from the reactor after processing is used for pre-heating (6) quenched in a bubble tank (12). The quenched water in (12) is also cleaned and combined with the flush water (20).

  * Optimum operational conditions are currently being identified

Inputs

✓ Does the system require an external source of electricity?
Yes

✓ Does the system require the use of water?
No, water is recycled within the system

✓ Does the system require any other "consumable" inputs?
No

Outputs

✓ How much energy will be recovered?
To be determined when optimal operation conditions are finalized

- ✓ How much water will be recovered?
  The flush water is a closed loop. Any excess water collected, due to urine deposits will be discharged
- ✓ How much fertilizer or other byproducts will be produced?
  20g filter cake/user/day

Treatment

- ✓ Treats Solids and liquids combined
- ✓ Pathogen treatment success? Total pathogen removal
- ✓ Are chemical processes used? Yes
- ✓ Are mechanical processes being used? Yes, water filter
- ✓ Are biological processes being used? No
- ✓ Does the system require any off-site or additional processing? No

Business Considerations

- ✓ Estimated daily operating cost (not available)
- ✓ Estimated capex (not available)
- ✓ Size L 1.2m x W 1.0m x H 1.9m
- ✓ Maintenance Requirements Non-hazardous, non-odorous, solid waste cakes and excess liquids to be regularly disposed by user.
- ✓ Life expectancy 20 years

Figure 14: High Temperature Processing Reinvented Toilet's frontend

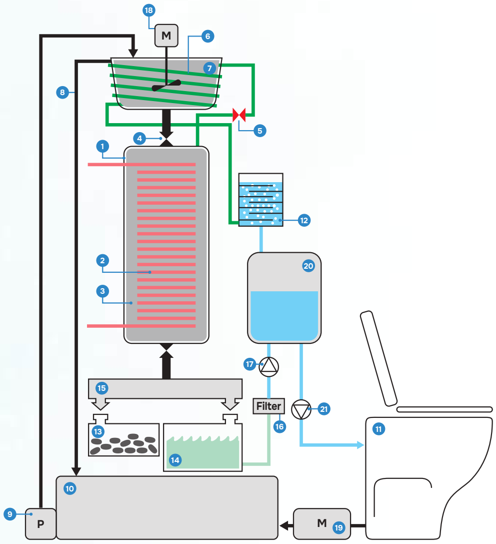


Figure 15: High Temperature Processing Reinvented Toilets process flow

2.11 ZYCLONE Cube or Biological and Electrochemical Reinvented Toilet

Integrating with a conventional flushing toilet, the Zyclone Cube is designed for efficiently separating and effectively treating both solid and liquid fractions. The unique Zyclone shape achieves liquid separation at greater than 98%. The solids fraction is dropped into a screw heating device that operates intermittently in dehumidifying and inactivating pathogenic contents. The liquid is further treated by integrated absorptive media (e.g. modified soil and zeolite) in a series of anaerobic aerobic, and anoxic chambers prior to a final step of electrochemical disinfection.

Key Features:

- Toilet system (1-4 toilets per one unit)
- Pout flush (1.5 Liters) up to 130 users/day
- Flushing (3.0 Liters) up to 70 users/day
- Ability to retrofit in existing system
- Encourages environmentally friendly fecal sludge management (FSM) practices in areas with limited access to FSM services or with temporary solutions (e.g. camp, natural sites, temporary festive event, refugee camp, medical triage)

Status of Development

- Original design by AIT initially tested in Thailand
- Design then adapted by SCG Chemicals to meet ISO 30500 standards and cost-efficient manufacturing
- 50 initial prototype units to be tested in Thailand in 2019

How Does it Work?

- ⇨ Frontend: User encounters a conventional flush toilet. It is possible to adapt to both a pedestal and squat plate flush interface.
- ⇨ Urine/Feces Separation: The unique shape of the Zyclone results in a solid/liquid separation effectiveness of greater than 98%.
- ⇨ Liquid Processing: The separated liquid is firstly filtered in a plastic media chamber (1) to remove coarse solid particles. The next two chambers (2, 3) are filled with synthesized media at 2cm and 1cm diameter, respectively. In the anaerobic chamber (2), the organic loading is reduced prior to an aerobic chamber (3) equipped with microbubble aeration that further removes COD, TN, and TP contents. In the next chamber (4), TN is greatly reduced by zeolite media in an anoxic condition. Chamber 5 (5) is designed to recirculate the treated liquid to the anaerobic chamber (2) in order to increase the overall treatment performance. The final chamber (6) is equipped with electrochemical electrodes that inactivate the pathogens remained in liquid prior to discharge.
- ⇨ Solids Processing: The separated fresh fecal matter (solid) is collected in a chamber located below the Zyclone separator and be disinfected and reduced the moisture content by screw heating device. The heating device could inactivate helminths 4-5 log values and E. coli by 6 log value.
- ⇨ Power System: The system requires electricity.

Inputs

- ✓ Does the system require an external source of electricity?
  Yes
- ✓ Does the system require the use of water?
  Yes, flush water
- ✓ Does the system require any other "consumable" inputs?
  Yes, media

Outputs

- ✓ How much energy will be recovered?
  None
- ✓ How much water will be recovered?
  200 liters/day
- ✓ How much fertilizer or other byproducts will be produced?
  10kg solids/month

Treatment

- ✓ Solids Treatment Thermal disinfection
- ✓ Liquid Treatment Biological and electrochemical
- ✓ Pathogen treatment success? Confirmed total pathogen removal
- ✓ Are chemical processes used? Yes
- ✓ Are mechanical processes being used? Yes, separation
- ✓ Are biological processes being used? Yes
- ✓ Does the system require any off-site or additional processing? No

Business Considerations

- ✓ Estimated daily operating cost $0.10 USD/day
- ✓ Estimated capex (not available)
- ✓ Size L 1.45m x W 1.25m x H 1.35m
- ✓ Maintenance Requirements
- ✓ Media to be replaced every 3 years
- ✓ Electrodes to be changed every 3 years
- ✓ Fertilizers to be collected every month
- ✓ Life expectancy 15 years

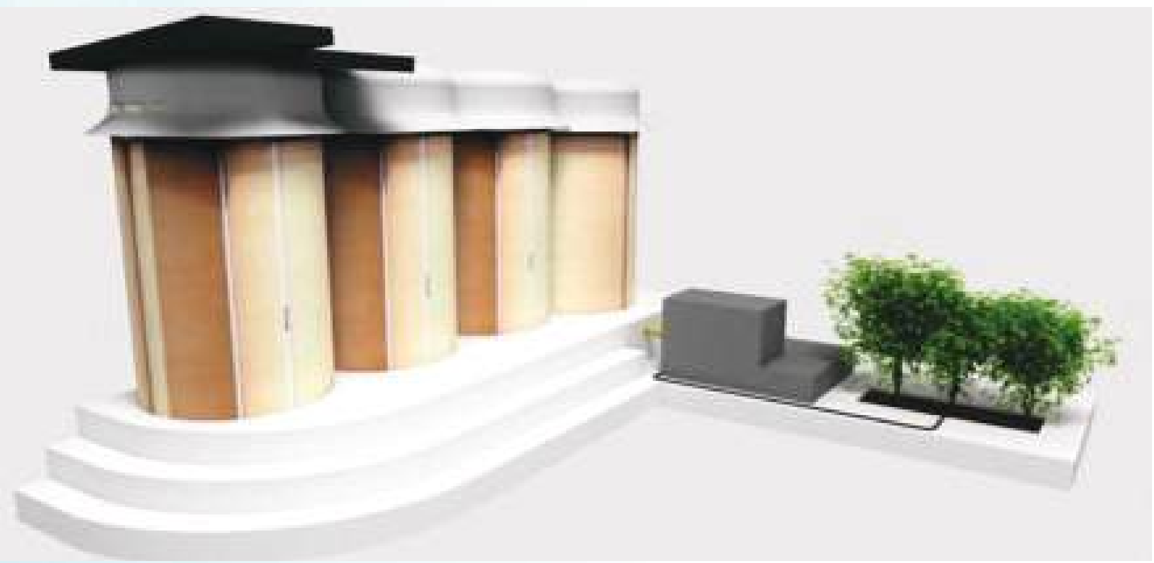
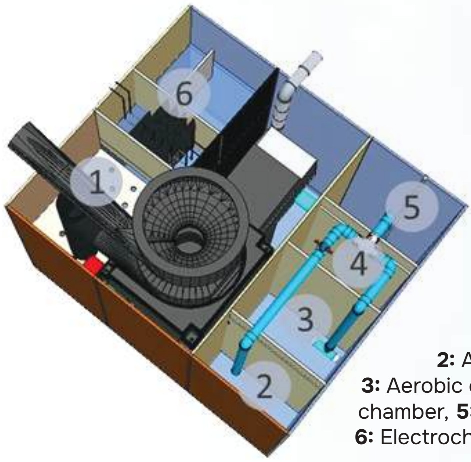


Illustration of how the Zyclone cube can be integrated with a conventional toilet and new design solar energy toilet system.

Figure 16: ZYCLONE Cube's frontend



1: Up-flow filter, **2:** Anaerobic chamber, **3:** Aerobic chamber, **4:** Anoxic chamber, **5:** Recirculation unit, **6:** Electrochemical disinfection

Figure 17: ZYCLONE Cube's process flow

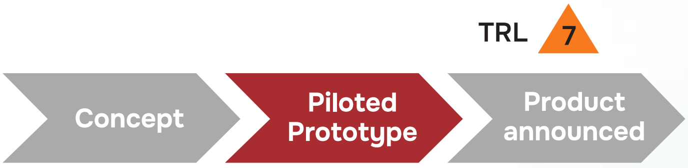
2.12 NEWGenerator or Biological and Physicochemical Reinvented Toilet

The NEW generator is a compact, portable, and modular resource recovery machine that eliminates waste while recovering fertilizer nutrients, renewable energy, and clean water. The system uses an anaerobic baffled reactor design followed by a nanomembrane filter operated at sub-critical water flux to extend the longevity. Permeate from the filter is treated for reuse as flush water by electrochemical chlorine production from table salt.

Key Features:

- Anaerobic membrane bioreactor processes solid and liquid in a single, dilute waste stream
- Minerals and nutrients are removed from the wastewater by a hydroponic/biosorption system
- Biogas from waste product digestion is collected for use outside of the system (e.g. cooking/heating)

Status of Development



Pilots in Kerala, India (2016) and in an informal settlement in Durban, South Africa (Fall 2018)

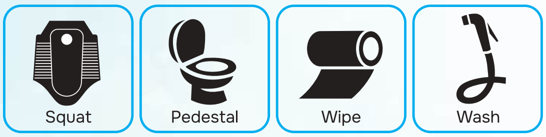
A next-generation, high capacity unit (1000 uses/day) to be tested in South Africa in 2019

Partnering with Eram Scientific and BIRAC (India) to produce integrated treatment unit with Eram eToilet

Use Cases

- Scalable system from single household (less than 10 users) and up to 1000+ users a day. Current design for 300 uses/day, or ~60 users
- Multi-unit: As an exterior system, most common use cases include community toilets, schools, and multi-unit dwellings.

Product is Appropriate For:



60+	$0.09	15+
Capacity (users/day)	Est. Cost ($/users/day)	Life Expectancy (Years)

How Does it Work?

➪ Frontend: Agnostic to user interface can be paired with a variety of designs.

➪ Urine/Feces Separation: No separation is required, urine, feces, and wash/flush water are processed as a single stream

➪ Liquid Processing: Mixed waste enters an anaerobic membrane bioreactor (AnMBR). Liquid is filtered with a commercially available nanomembrane, operated at sub-critical flux to optimize longevity of the membrane. Biosorption and hydroponic processing is used to remove additional organics and minerals. Electro-chlorination is the final polishing step.

➪ Solids Processing: Mixed waste stream (TSS range 100-15,000mg/L) is processed by an anaerobic microbial baffled reactor, where the organic materials are digested. Residual, undegraded solids will need to be removed; modeling indicated every 6-18 months, depending on waste composition.

➪ Power System: Currently using solar panels to charge deep-cycle batteries that power the system. Biogas generated is dependent on strength of the influent COD and can be used for various uses such as heating and cooking fuel. Estimated requirement of 0.5-1.7kWh per day.

Inputs

✓ Does the system require an external source of electricity?
Yes, supplied by solar panels

✓ Does the system require the use of water?
Yes, small input required to make up for any losses in system

✓ Does the system require any other "consumable" inputs?
Yes, salt for electrochlorination

Outputs

✓ How much energy will be recovered?
3kWh/d (as biogas) at 800mg COD/L

- ✓ How much water will be recovered?
  Up to 100% of influent can be recycled for reuse
- ✓ How much fertilizer or other byproducts will be produced?
  N, P recovered for onsite horticulture

Treatment

- ✓ Solids Treatment Yes, anaerobic digestion
- ✓ Liquid Treatment Yes, nanomembrane filtration followed by electrochlorination
- ✓ Pathogen treatment success? Confirmed total pathogen removal
- ✓ Are chemical processes used? Yes
- ✓ Are mechanical processes being used? No
- ✓ Are biological processes being used? Yes
- ✓ Does the system require any off-site or additional processing? No

Business Considerations

- ✓ Estimated daily operating cost $4-5 USD
- ✓ Estimated capex $45,000 USD (prototype)
- ✓ Size L 2.4m x W 1.5m x H 2.4m
- ✓ Maintenance Requirements
- ✓ Leveling tank cleaning every 6-18 months; preventive maintenance every 6 months
- ✓ Life expectancy 15+ years

NEWgenerator 100 v.1 (white unit) undergoing field-testing at a school in Kerala, India. The orange units are Eram eToilets serving as font-end units.

Figure 18: Biological and Physicochemical Reinvented Toilet's frontend

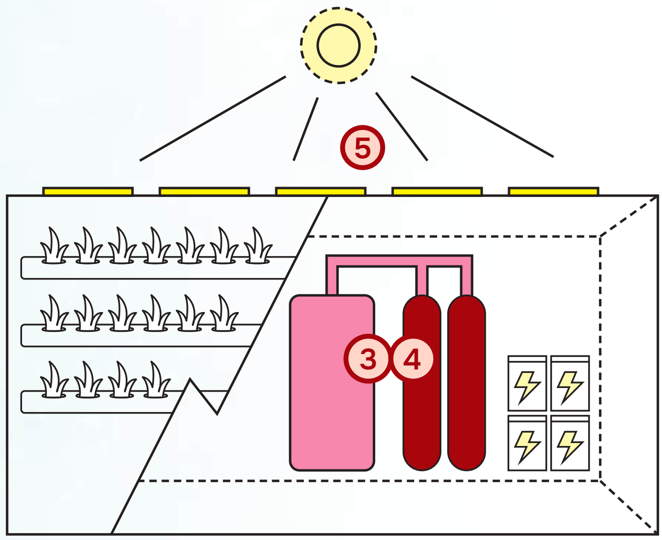


Figure 19: Biological and Physicochemical Reinvented Toilet's process flow

2.13 The Toronto Toilet or Dry combustion Reinvented Toilet

A household-scale system with solid and liquid disinfection in the backend. In the frontend, feces and urine/wash water are mechanically separated by a specifically designed mechanism that can be attached to standard squat plates. Attachment to pedestals is also possible. Dewatered fecal material is then mixed with granular particles and smoldered. Catalytic conversion of the generated is used to dry incoming fecal material in situ, and thermally disinfected liquid waste.

Key Features:

- Self-sustaining smoldering technology, under development since 2011, with TRL 4 results published in the journal Fuel in 2015
- Continuous smoldering process for processing of fecal matter and consistent heat production
- Catalytic conversion of the generated pyrolysis gases supplies additions heat, and mitigates emissions

Status of Development

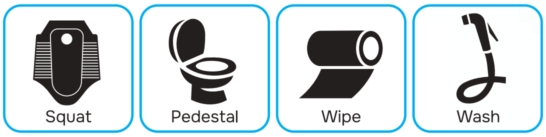
System integration work has led to iterative development of functional prototypes for laboratory testing in Toronto, and multiple field tests in Coimbatore, India with local workers user group.

Use Cases

Household: Designed as a self-contained, household unit, ranging from 5 to 20 users, accommodates variable input rates

Multi-unit: Can be scaled p to multi-stall community applications with one front end per stall, and a shared processing stall

Product is Appropriate For:



5+	$0.07	10-15
Capacity (users/day)	Est. Cost ($/users/day)	Life Expectancy (Years)

How Does it Work?

- Frontend: Currently used with a standard squat plate. Can be adapted to a pedestal.
- Urine/Feces Separation: Multiple gravity-based solid/liquid separation designs have been evaluated and field tested. Effective solid/liquid separation is achieved without modifying user behavior.
- Liquid Processing: Liquid pasteurization is achieved by recovering the heat captured in steam during solid drying process. Further effluent treatment is intended to be adopted from other projects being conducted in the BMGF portfolio.
- Solids Processing: Solid fecal material (fuel) is transferred via a pump and is injected into a column where it is in-situ mixed with granular beads which are still hot from the preceding smoldering cycle. Once the mixing/drying process concludes, air is introduced and smoldering begins. Post smoldering gases pass through a catalyst for further treatment and heat generation.
- Power System: Solar panels or other off-grid energy source may be used to supply the <200 watts per day required. The aspirational goal that projections show is possible is to achieve a power requirement low enough to fit within the capacity of solar or other off-grid home systems that are common in many regions.

Inputs

✓ Does the system require an external source of electricity?
Yes, solar panels or other power source

✓ Does the system require the use of water?
Not required. Accepts 30L flush/wash water

✓ Does the system require any other "consumable" inputs?
No

Outputs

✓ How much energy will be recovered?
None, energy is used in process

✓ How much water will be recovered?
10-50 liters/day, not potable

✓ How much fertilizer or other byproducts will be produced?
10g ash per person, per day produced by solids processing, emptied monthly by user

Treatment

✓ Solids Thermal processing (0.6-3kg/day capacity)

✓ Liquids Pasteurization with 35 L/day capacity

✓ Pathogen treatment success? Confirmed total pathogen removal

✓ Are chemical processes used? Yes

✓ Are mechanical processes being used? Yes

✓ Are biological processes being used? No

✓ Does the system require any off-site or additional processing? No

Business Considerations

✓ Estimated daily operating cost $0.07/user/day (initial estimate based on electricity use and six users)

✓ Estimated capex (not available)

✓ Size L 1.7m x W 1.5m x H 1.0m

✓ Maintenance Requirements Solids (ash) to be emptied monthly by user

✓ Life expectancy 10-15 years

✓ Other features Catalytic conversion of outlet air from smoldering process to reduce

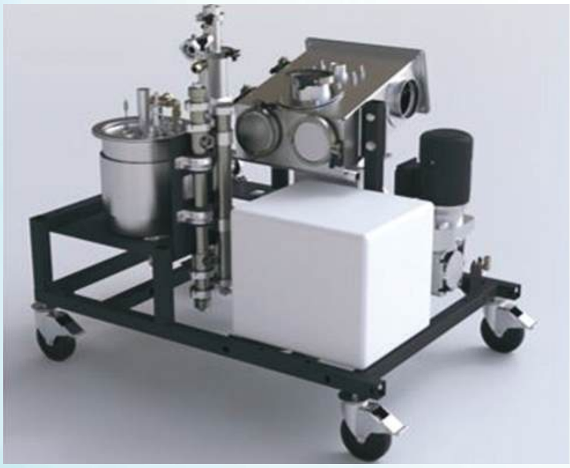


Figure 20: The Toronto Toilet's frontend

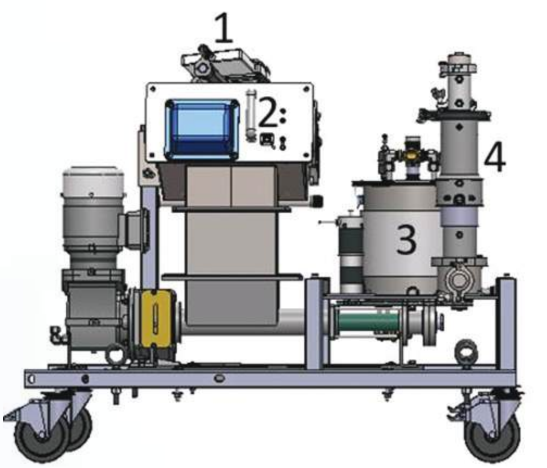


Figure 21: The Toronto Toilet's process flow

Chapter 3: International Standards for treatment outputs (ISO 31800)

3.1 Pathogens and indicator organisms for solid

The presence of pathogens and indicator organisms in solid outputs from treatment units shall not exceed the thresholds specified in the following table,

Table 1: Solid output validation thresholds for human health protection

Parameter (Pathogen class)	Human enteric bacterial pathogens	Human enteric viruses	Human enteric Helminths	Human enteric Protozoa
Indicator organism	using E. coli as surrogate, measured in CFU	using Somatic Coliphage as surrogate, measured in PFU	using all human enteric helminths viable ova	using Cryptosporidium parvum as surrogate, measured in oocyst
Max concentration in solids [#/g (dry solids)]	100	10	<1	<1

3.2 Requirements for trace elements in solid outputs

The presence of trace elements in solid outputs from treatment units shall not exceed the thresholds specified in

Table 2: Solid output trace elements thresholds

Metal	Maximum concentration in solids (mg/kg dry mass basis)
Arsenic, As	75
Cadmium, Cd	20
Chromium, Cr	3000
Copper, Cu	1000
Lead, Pb	750
Mercury, Hg	16
Molybdenum, Mo	75
Nickel, Ni	300
Selenium, Se	100
Zinc, Zn	2500

3.3 Alternative requirements for solids for disposal

Solid outputs for disposal that do not meet the thresholds in Table 2 shall pass a toxic characteristic leaching procedure (TCLP) and soluble threshold limit concentration (STLC) following using the thresholds in the following Table 3.

Table 3: Maximum concentration in extract for TCLP and STLC

Contaminant	**TCLP max. mg/l**
Arsenic, As	5.0
Cadmium, Cd	1.0
Chromium, Cr	5.0
Lead, Pb	5.0
Mercury, Hg	0.2
Selenium, Se	1.0
	STLC max. mg/l
Copper, Cu	25
Molybdenum, Mo	350
Nickel, Ni	20
Zinc, Zn	250

3.4 Pathogens and indicator organisms for Effluent

The presence of pathogens and indicator organisms in effluent output from the treatment unit shall not exceed the thresholds specified in following table,

Table 4: Liquid effluent validation threshold for human health protection

Parameter (Pathogen class)	**Human enteric bacterial pathogens**	**Human enteric viruses**	**Human enteric helminths**	**Human enteric protozoa**
Indicator organism	using E. coli as surrogate, measured in CFU	using Somatic Coliphage as surrogate, measured in PFU	using all human enteric helminths viable ova	using viable Clostridium perfringens spores as surrogate, or Cryptosporidium parvum, measured in CFU or oocyst, respectively
Max. concentration in liquids (number/l)	100	10	<1	<1

3.5 Effluent performance thresholds for environmental parameters

Effluent from the treatment unit shall not exceed the water quality thresholds specified in table 5,

Table 5: Effluent performance thresholds for environmental parameters

Parameter	Threshold
BOD (mg/l)	≤25
COD (mg/l)	≤100
pH	6 to 9
Temperature (°C)	≤45
Total nitrogen (mg/l)	≤15
Total phosphorous (mg/l)	≤2
TSS (mg/l)	≤30

3.6 Requirements for trace elements in effluent outputs

Effluent from the treatment unit shall not exceed the concentrations of the pollutants listed in table 6,

Table 6: Threshold levels of trace elements in effluent

Polluting substance	Threshold value for unfiltered sample (mg/l unless otherwise specified)
Aluminium, Al	5
Arsenic, As	0.1
Beryllium, Be	0.1
Cadmium, Cd	0.01
Chromium, Cr	0.1
Cobalt, Co	0.05
Copper, Cu	0.2
Fluoride	1
Iron, Fe	5
Lead, Pb	5
Lithium, Li	2.5
Manganese, Mn	0.2
Molybdenum, Mo	0.01
Nickel, Ni	0.2
Selenium, Se	0.02
Vanadium, V	0.1
Zinc, Zn	2

3.7 Air emission parameter requirements

Treatment units utilizing a thermal treatment process or processes that include combustion shall meet all emissions thresholds given in following table 7. Non-thermal units shall only meet the requirement for total dust.

Table 7: Air emission parameter requirements

Emission threshold values (mg/m³ normalized) for thermal systems using faecal sludge as a fuel, 7% O2, 0°C, dry		
Pollutant	Thermal load up to 1 MW	Thermal load 1 MW up to 5 MW
CO, mg/Nm^3	440	140
NOx, mg/Nm^3	880	466
SO2, mg/Nm^3	---	2 000
Total dust, mg/Nm^3	47	47
Dioxins and furans, ng/m^3	Average emission threshold value (ng/Nm^3) for dioxins and furans, combined, over a sampling period of minimum 6 h and maximum 8 h	
	0.18	0.18
	Average emission threshold values (mg/Nm^3) for the trace elements at left, combined, over a sampling period of a minimum of 30 min and maximum of 8 ha	
Arsenic, As, mg/m^3	0.7	0.7
Cadmium, Cd, mg/m^3	0.07	0.07
Mercury, Hg, mg/m^3	0.07	0.07

3.8 Odour and Noise

Odour emitted from the treatment unit shall not exceed 15 OUE/m^3 at 15 m distance and beyond from the unit boundary for heights between 0 m and 6 m.

Ambient noise from the treatment unit shall not exceed 55 dB(A) at 15 m from the unit boundary. If measurements at 15 m are not possible, measurements at shorter distances may be conducted, and then normalized to 15 m equivalent

References:

1) American National Standards Institute, Reinvented Toilet Technology in Development
2) Generation 2 Reinvented Toilets, Georgia Institute of Technology, https://yeelab.gatech.edu/g2rt/
3) Faecal sludge treatment units – Energy independent, prefabricated, community-scale, resource recovery units – Safety and performance requirements (ISO 31800:2020 E)
4) Sedron Technologies' Janicki Omni Processor (J-OP), www.sedron.com

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