Reinvent the Toilet
Development and field testing of a decentralized, self-contained toilet that converts human waste into burnable fuel and disinfected liquid

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RTI International and Duke University
Colorado State University
Create a waste treatment and toilet system that is ...

1. “Off-grid”. Does not require an external source of electricity, water or sewer

2. A waste treatment system treats all pathogens on-site

3. An affordable system operating on no more than 5 cents per person / per day

4. An aspirational waste treatment & toilet system with appeal for developed and developing countries applications
On-site Waste Treatment
On-Site Waste Treatment Prototype Site
Site Build Through India Partnerships

- SEWA
  Self Employed Women's Association
- neerman
- CEPT University
- Roca
- Parryware
- HiTECH Healthcare Laboratory
- PHFI Public Health Foundation of India
- NID National Institute of Design
- G K Controls Private Limited
- FSM
Summary: Field Prototype #1 @ CEPT

- Alpha installed at CEPT Sept 2015, Beta installed Sept 2016

- Regular users (~10-15/day), managed access

- Batch processing solid and liquid waste, recycling liquid for flush water. Supply fresh water for body and handwash

- Solid-liquid separator and macerator processing waste to dried fuel, ~1kg / week

- Aspirational cabin design featuring quality space, lighting, ventilation, ergonomics, safety, privacy and MHM

- User feedback positive on processing approach, very positive on amenities in cabin design

- Lessons learned working in field setting, regular users, and locally managed operations
• Defined use patterns
  • 2L urine & 1 defecation/ person /day)
  • Goal: 10 users/day
• Demonstrated EC inactivation of bacteria in wastewater
• Evaluated electrode materials

Pre-Alpha prototype
(Proof of concept)
2014

Alpha Prototype
(Efficacy demonstration)
Jan 2015 – Jan 2016
• Constructed functional liquid system
• Processed real urine and feces
• Run in manual mode
• Examined effects of water recycling on EC disinfection
• Began CEPT technology testing

Beta Prototype
(Test system bounds)
Feb 2016 - July 2016
• Integrated controlled system
• Defined “steady state”
• Identified EC parameters factors effecting energy demand
• Refined test parameters
• Identified areas for energy optimization
• Daily processing with weekly disinfection verification at CEPT

Beta 2.0 Prototype
(Energy optimization)
Aug 2016 - Present
• Automated and integrated with automated solid system
• Evaluated & Implemented strategies for energy reduction
• Increased usage and disinfection processing at CEPT with weekly disinfection verification
Urinals on exterior (2)
Enclosed user interface with elevated stair access
Cabin Features
- low-flush squat plate (1)
- lockable door for privacy
- natural and electric lighting
- louvered windows
- floor fan for ventilation (24v)
- body wash area
- pad chute
- pad dispenser
- handwash sink, mirror inside
- expanded cabin size
Liquid Processing

- Multi stage baffle tank
- Pulsing electrochemical disinfection
- Dual voltage 24v, 36v at different intervals
- 30 liter batch processing
- Post baffle filter for helminth egg removal
- Evaluating post treatment polishing step
- 120 liter storage tank
- Disinfected liquid recycled for flush water
Solid Processing

- Liquid / solid separation after toilet use
- Conveyor with mesh belts for initial separation
- Baffle tanks in liquid stream provide additional settling
- Solids flow through a macerator, dewatered
- Extruded onto drying plate
- Sized as small fuel chip
- Fuel is prepared for combustion
- Combustion provides heat to dry
- Process heat 250-320 degrees C
- 4kg /day capacity
- Combustion generates energy for powering liquid disinfection
Independent, certified lab completing regular liquid and solid tests

Waste treatment QA/QC for testing on-site demonstrates consistent pathogen kill

**Routine Lab Tests**

**Liquid:**
- pH
- Electric Conductance
- Chemical Oxygen Demand (COD)
- Total coliform max
- Solid content (TSS) max
- Chloride
- Ammonical Nitrogen
- TKN

**Solid Pellets:**
- Coliform
- Moisture content
Leveraging Site for Technology Stress-testing

Sampling of Lessons

1. Solid accumulation – overflow of feces into S/L separator
   Led to re-engineered S/L capacity and altered controls parameters

2. Solid / Liquid separator – belt failures (multiple occasions)
   Led to understanding of cleaning agents used is 14.5 w/v HCL

3. Animals / rodents – damage to wires / hoses
   Led to better protection to wires, hoses, closing space gaps
Product Adoption User Findings

• Liquid treatment
  – Positive views on water-saving features
  – Interest in water treatment simplicity
  – Positive views on reuse, varying reaction to specific uses

• Solid Waste Combustion
  – General comfort/familiarity with burning solid waste
  – Overall excitement in potential to generate energy

• MH absorbents
  – Discrete disposal at-site is highly valued feature
  – Strong support for incineration as strategy on-site

• Key Questions / Challenges:
  – Liquid recycled: color and smell
  – Macerator/drying: odor management
  – Solid: smell from smoke and reactions to emissions
  – Solid waste: management of paper and MH absorbents
Reuse applications:

- Flushing
  - High acceptance, with no direct contact
- Body wash / Anal cleansing
  - Mixed acceptance: men widely accept, mixed views among women & older mixed gender groups
- Hand-washing
  - Concern about water purity: many suggested “re-wash” necessary (e.g. before eating, praying)
- HH / community uses
  - Possible use recycled water for bike washing, clothes washing, household cleaning
  - Taboos regarding use of “impure water” widely vary (e.g. no use on items that bring money, living things, before prayers)
User Findings: MHM

• MHM identified as potential adoption factor
  – Public toilet use declines during menses when not safe or private
  – Privacy is highly sought during menstruation
  – Preference for features that maintain/increase privacy (site access, water, product disposal, MH product access)

• Feedback for system design:
  – Absorbent use varies by age / culture
  – MHM product vending machine strongly endorsed, fits younger women habits
  – MHM disposal mechanism in high demand

• Questions:
  – MHM product disposal incineration popular but not universally accepted
  – Perceptions of purity of recycled water
Ahmedabad: CEPT Demonstration Site (#1)

- Facilitating controlled stress-testing and use
- Enabling performance tests & user studies in accessible research site
- Capable India on-site management, QC function on new modules
- Demo site for RT approach, platform inviting visitation & partnership
Durban, South Africa: Candidate Site (#2)

- Demo in low-income community shared toilet block
- Collaborative community with relatively well-functioning CABs
- Target unit servicing CAB waste, preference for women’s toilet block
- Prospect to expand to greywater applications
Coimbatore: Candidate Site (#3)

- Demo for workplace sanitation
- Textile spinning mill with residential worker
- On-site low-income resident migrant workers
- Target unit servicing women’s hostel toilet / shower block
- Prospect to expand to greywater applications
Knowledge Gaps

Site engineering performance insights required:
- Performance under varying site placements, environmental settings, user traffic
- Ability to manage paper / solid waste & energy contributions
- Optimization / reliability of continuous batch processing in varied use scenarios
- Processing product sizing / fit for market segments (e.g. workplace, community, school, public spaces)
- Insulation to harness energy minimize thermal losses

User / Product Tester Insights Required:
- Perceptions of on-site processing
- Attitudes about water reuse for body wash, anal cleansing
- Attitudes about water reuse for community / HH purposes
- Perceptions of emissions, and ash as discharge from on-site processing
- Attitudes about blood in reuse streams or solid material
- Odor tolerance and site management strategies for 3 sources:
  - user interface
  - processing unit
  - discharge
- Menstrual hygiene waste disposal strategies
Levering Additional Programs

Natick **TOWR** (Toilet with On-site Remediation)
Scaling Demonstrations to Meet Varied Products Markets

- Staged risk management and problem-solving
- Iterating innovations to meet market segmentation & demand
- Driving to reliability with real and varied user data
- Insights advance product development and partner alliances
http://abettertoilet.org/

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