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

BMGF Reinvent the Toilet Challenge

Create a waste treatment and toilet system that is …

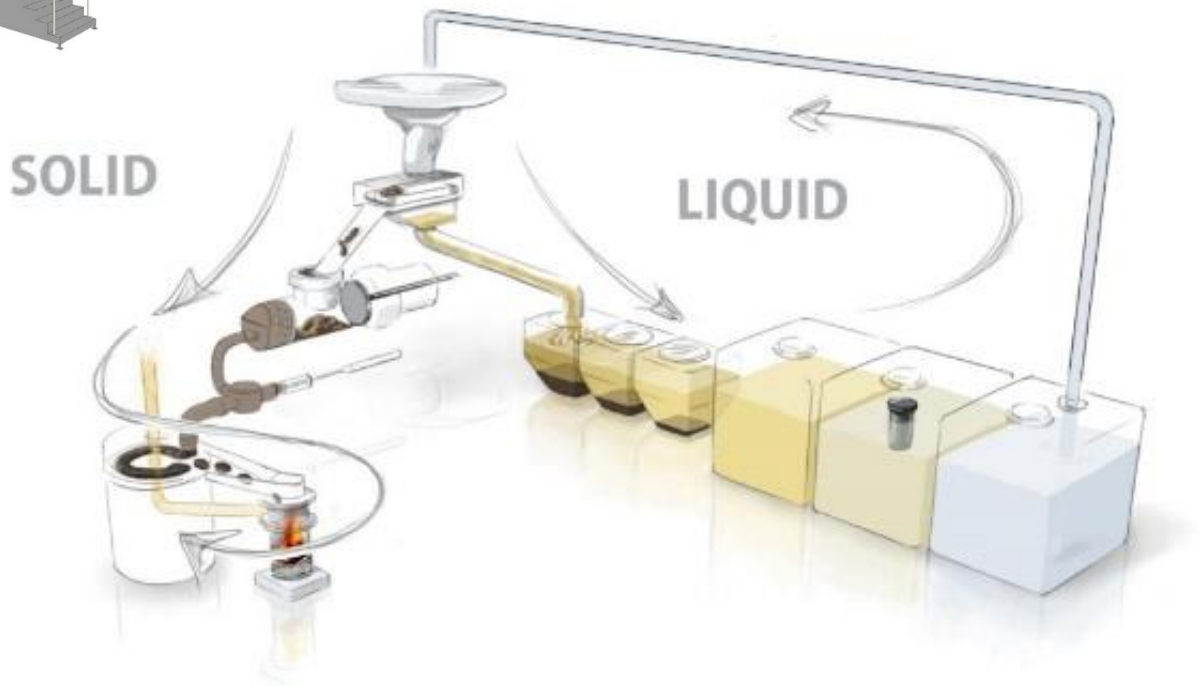
1. “Off-grid”. Does not require an external source of electricity, water or sewer

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
ज्ञानं विज्ञान सहितम्

Roca

Parryware

HI TECH
Healthcare Laboratory

KNOWLEDGE TO ACTION
phfi
PUBLIC HEALTH FOUNDATION OF INDIA

राष्ट्रीय डिज़ाइन संस्थान
NATIONAL INSTITUTE OF DESIGN

UMC City Collect

G K Controls Private Limited

FSM4

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

Progression of RTI RTT

- 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

- 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 Prototype

(Test system bounds)

Feb 2016 - July 2016

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

User Interface

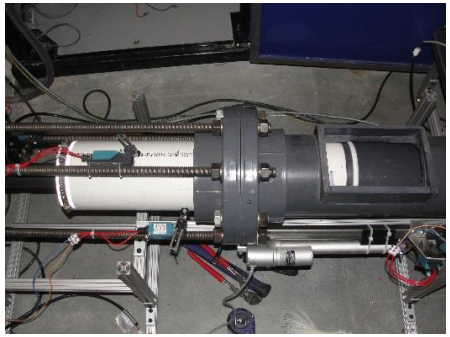
- Urinals on exterior (2)
- Enclosed user interface with elevated stair access
- Cabin Features
  - low-flush squat plate (1)
  - lockable door for privacy
  - natural and electric lighting
  - louvered windows
  - floor fan for ventilation (24v)
  - body wash area
  - pad chute
  - pad dispenser
  - 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



Treatment Verification @ CEPT Site

- 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

ISO 9001:2008 CERTIFIED

NABL Accredited Laboratory

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

User Findings: Water Reuse

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)

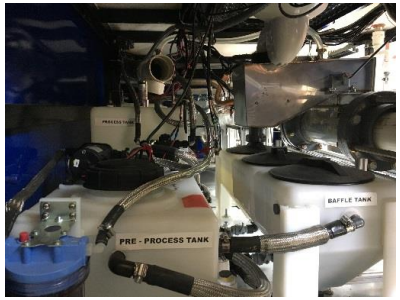
- Feedback for system design:
  - Absorbent use varies by age / culture
  - MHM product vending machine strongly endorsed, fits younger women habits
  - MHM disposal mechanism in high demand

- 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

WC RESEARCH LAB



FSM4

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:

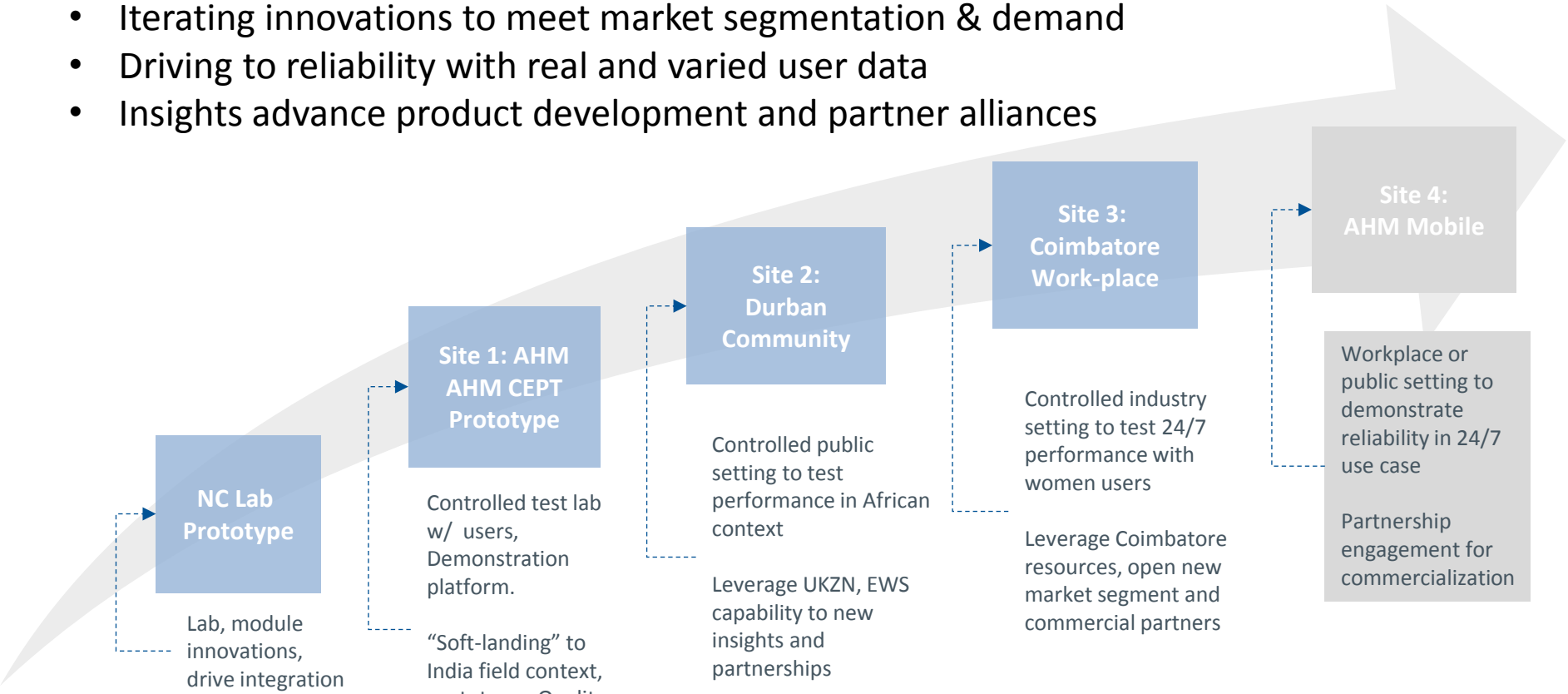
- Perceptions of on-site processing
- Attitudes about water reuse for body wash, anal cleansing
- Attitudes about water reuse for community / HH purposes
- Perceptions of emissions, and ash as discharge from on-site processing
- Attitudes about blood in reuse streams or solid material
- Odor tolerance 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



Contacts

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