Anaerobic Digestion of Latrine and Black Water at a Hospital Complex in Haiti

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HAITI

- Large impact of the earthquake on Haitian infrastructure presents an opportunity for sustainable reconstruction
- 600,000 people remain in tent cities
- Only 30% of the population has access to basic sanitation and 10% has access to electricity
- Feasibility studies revealed the cost of centralized sewage treatment exceeds the population’s capacity to pay

Tent Cities – February 2011

Waste treatment pipe to a ditch

Charcoal - primary energy source
Research Objectives

1. Assessment of wastewater and energy needs in the post earthquake environment

2. Creation of an appropriate design for wastewater treatment, energy production, and liquid fertilizer

3. Implement the biodigestion system for meeting increased energy and water demand
Anaerobic Digestion

- Microbial Process
- Organic material $\rightarrow$ $\text{CH}_4$ and $\text{CO}_2$

**Series of Reactions occurring in Stepwise Fashion**

- **Hydrolysis**
  - Organics $\rightarrow$
    - Simple sugars
    - Fatty acids
    - Amino acids

- **Acetogenesis**
  - Products of hydrolysis $\rightarrow$
    - Organic acids
    - Alcohols
    - Acetate

- **Methanogenesis**
  - Acetate/methanol/H$_2$ $\rightarrow$
    - Biogas
    - Methane
    - Carbon dioxide
Numerous Feedstocks

**Substrates**
- Animal & livestock manure
- Human waste
- Food waste
- Energy crops

Sources: (Akinbami, 2001; Bi, 2006; Voegeli, 2008)

Photo Credits: (U.S. NRCS, Jean Ryder, www.docklandsrecycling.co.uk)
Use of Products

- **Biogas**
  - Directly: Cooking, Heating, Lighting
    (Munyaheeirse & Kabanda, 2008; Mi, 2007; Singh & Sooch, 2004)
  - Generator: Electricity
    (Lansing et al., 2008)

- **Effluent**
  - Fertilizer
  - Feed

- **Solids**
  - Compost
Research Site
Digestion Design

- Collect wastewater samples
- Survey Hospital Complex
- Work with Haitian Counterparts
- Prepare Digestion Site
Wastewater samples were collected from six locations seven times from March 2010 to February 2011:

1. Inside the school latrine pit
   - Latrine waste from 1000 children and black water from 3 toilets

2. Inside the external clinic latrine pit
   - Latrine wastes from 500 patients and black water from 7 toilets

3. Grey water from the kitchen

4. Grey water from the hospital complex

5. Grey water from the external clinic

6. Inside the hospital septic tank
   - Black water from 104 patients and grey water from surgery rooms
Latrine wastes had organic matter concentrations similar to dairy manure.

Latrine wastes had two orders of magnitude more COD than the septic pits and grey water.
Biochemical Methane Potential

- Test biodegradability of a substrate
- Determine potential biogas production
- Substrates incubated in 250 ml serum bottles
- Inoculated with digester solids and nutrient media
- Incubated in 45 retention time
- Gas collected and analyzed on gas chromatograph
Biochemical Methane Potential (BMP)

- Dairy manure had the highest methane potential.
- The latrine waste had 10-12 ml/CH4 per ml of substrate.
- The grey water samples had little to no methane production.
Digester Design

- **Goal:** build a sustainable biogas system in a developing country that moves concentrated wastewater without use of pumps/electricity.

- Each toilet flush conveys 6.1 L of wastewater, with only 0.2 L of fecal matter (organic matter), allowing for conveyance via gravity, but with a low biogas potential (3.85 L/day).

- The latrine wastes are difficult to convey via gravity, with up to 25% solids, but the latrine wastes have 543% higher biogas potential (24.7 L/day) than the black water.
Latrine

Figure 1. Section of a simple pit latrine

Figure 2. Section of an offset pour-flush pit latrine
Black Water

Composed of 5 parts

• A.) Latrine
• B.) Tipping Bucket Mechanism
• C.) Raceway to convey wastewater
• D.) Three-cell digestion systems
• E.) Post-treatment wetlands
Half-pipes rest on rebar cross-stays and are prevented from sliding forward by concrete confluence structure.

Bottom of 6" (0.152 m) Sch 40 PVC outlet pipe is situated 1" from floor.
Digester Operation

- Dairy manure will be added as an inoculum source.
- Estimated latrine usage of 500 people/day and wastewater flow from toilets of 365 L/day.
- Estimated methane production for the waste entering the digester is 48 m$^3$/day.
- The grey water is conveyed directly to the post-treatment wetland/trickling filter system.
Zanmi Lasante Flushing Latrine and Anaerobic Digestion System

Capacity - 600 people/day

Process - Solid human waste and black water from the new latrine structure will channel down through a conveyance and screening system to the latrine pipe outlet. This will flow into the digester influent box - a catchment box where cow manure and other materials may be added to facilitate the system - and then be directed into a series of 2.8m diameter, 4m long, nearly cylindrical digesters (total liquid capacity - 12m³).

Products - The generation of methane from the digesters will offset the Zanmi Lasante hospital cooking fuel costs - roughly $1,600 U.S. per month. In addition, the digester effluent will provide an abundant fertilizer source for local agriculture, including mango stands.
Influent black water piping coming in at roof level from line behind external clinic.

Spillway hole in pad providing the tipping bucket access to the troughs or "raceways" below.

Women's Latrine - Changing station just inside entrance on right?

Doors - Corrugated tin with rebar or wood frames?

Men's Latrine with urinal. - Gray water providing minimal flow to flush urinal?

Screen Access Structure
Conclusions

- Small-scale digester designs must be site-specific.
- Efficacy of cholera treatment during digestion will be explored in future research.
- Shared digester design with USAID-Haiti and other NGOs in Haiti interested in implementation.
- ENST Senior Capstone students were integral to the project design and presented their designs at the American Ecological Engineering Society conference.
Future Research: Microbial Fuel Cells and Anaerobic Digestion

- Anaerobic digestion breaks down complex materials into dissolved acetic acids - used by methanogens.

- MFCs use acetic acid for direct electricity production at a greater efficiency than AD but tend to clog.

- Feeding the effluent from the digester feeds into a MFC, resulting in both biogas production (AD) and direct electric current (MFC), with greater treatment efficiency.
Questions

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