1.782 Environmental Engineering Masters of Engineering Project
Fall 2007 - Spring 2008

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MIT Clean Water 4 All, Inc.

Cash Fitzpatrick  
Izumi Kikkawa  
Andrew Swanton  

Vanessa Green  
Tamar Losleben

December 7th, 2007
Meeting Agenda

- Ghana: Background and Logistics
  - Horizontal Roughing Filtration: Tamar Losleben
  - Household Filtration: Izumi Kikkawa
  - Ceramic Pot (Kosim) filter + Chlorine Disinfection with Aquatabs: Andrew Swanton
  - Chlorine Products: Cash Fitzpatrick
  - HWTS Consumer Choice Study: Vanessa Green
Background

Types of water sources used by households

Percentage of Households by region (Drinking water as biggest problem)

Local Perception: Lack of Clean Drinking Water is a Major Problem

Large Percentage of Water Source is Dugouts
### E-Coli, Total Coliform, and Turbidity of Raw Water Samples from Selected Dugouts During the Rainy Season in Tamale and Savelugu Districts

<table>
<thead>
<tr>
<th>Location</th>
<th>Date (2006)</th>
<th>E. coli (CFU per 100 mL)</th>
<th>Total Coliforms (CFU per 100 mL)</th>
<th>Turbidity (TU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghanasco Muali Dam, TD</td>
<td>20-Jun</td>
<td>169</td>
<td>6,621</td>
<td>~1,600</td>
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<tr>
<td>Kalerga Dam, TD</td>
<td>22-Jun</td>
<td>754</td>
<td>13,475</td>
<td>&gt;2,000</td>
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<td>Bipelar Dam, TD</td>
<td>27-Jun</td>
<td>100</td>
<td>21,667</td>
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<tr>
<td>St. Mary's Dam, TD</td>
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<td>1,650</td>
<td>52,110</td>
<td>&gt;2,000</td>
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<tr>
<td>Dungu Dam, TD</td>
<td>4-Jul</td>
<td>133</td>
<td>4,540</td>
<td>400</td>
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<tr>
<td>Libga Dam, SD</td>
<td>6-Jul</td>
<td>0</td>
<td>500</td>
<td>75</td>
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<td>Bunglung Dam, SD</td>
<td>11-Jul</td>
<td>200</td>
<td>5117</td>
<td>300</td>
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<td>Diarc Dam, SD</td>
<td>13-Jul</td>
<td>0</td>
<td>3,417</td>
<td>23</td>
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<tr>
<td>Libga Dam, SD</td>
<td>17-Jul</td>
<td>50</td>
<td>1,408</td>
<td>50</td>
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<tr>
<td>Gbanyami Dam, TD</td>
<td>19-Jul</td>
<td>367</td>
<td>19,150</td>
<td>~1,000</td>
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<tr>
<td>Vitting Dam, TD</td>
<td>25-Jul</td>
<td>1,400</td>
<td>12,767</td>
<td>~125</td>
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<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>438</strong></td>
<td><strong>12,797</strong></td>
<td><strong>690</strong></td>
</tr>
</tbody>
</table>

Source: Foran, 2007
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Horizontal Roughing Filtration:

- Low-cost community pre-treatment to make slow sand filtration a viable option for highly turbid waters
  - Effluent target of 20 NTU
  - 85 - 90% removal efficiency for high turbidity (150-500 NTU)
  - Effectiveness highly dependent on controlling filtration rate
  - Cleaning media difficult and labor-intensive

Figure by MIT OpenCourseWare.

Wegelin 1996
Horizontal Roughing Filtration: Geographic Distribution of Use in 1995

Courtesy of SANDEC. Used with permission.

http://www.eawag.ch/organisation/abteilungen/sandec/schwerpunkte/ws/documents/surface_water_treatment
Horizontal Roughing Filtration: Community Pre-Filtration of Dugout Water

- **Objective:** Improve the effectiveness of horizontal roughing filters (HRF) at removing turbidity from highly turbid dugout surface water.

- **Tools:**
  - HRF Pilot Tests – MIT(1) and Ghana(2)
  - Examine effectiveness of existing HRF in Ghana
  - Characterize dugout physical water quality
Horizontal Roughing Filtration:
MIT/Ghana Pilot Test

- **Target turbidity removal rate to reach 20 NTU effluent**
- **Design variables** (Wegelin)
  - Filtration rate (m/h)
  - Filter media size (mm) and type (gravel and broken clay)
  - Length of each specific filter medium (m)
  - Number of filter fractions
  - Height and width of filter bed area (m²)
- **Evaluate system based on:**
  - Head loss
  - Filtration rate
  - Influent and effluent water quality

**Pilot Horizontal Roughing Filter**

**target flow rate 0.5 to 2.0 m/hr (Okun)**

- 12 mm – 18 mm
- 8 mm – 12 mm
- 4 mm – 8 mm
- 3.5 m
- 2.5 m
- 1 m

**Turbid water source**

**7.5 m PVC tube with .114 m diameter**
Horizontal Roughing Filtration: Influent and Effluent Physical and Microbial Water Quality

- **Turbidity** – turbidity meter (NTU)
- **Filtrability** – relative efficiency of HRF in solid matter removal (instead of suspended solids concentration)
- **Settleable solids** – solid removal by sedimentation (Imhoff cone)
- **Suspension stability** – settling properties
- **Sequential filtration tests** – particle size suspension characteristics
- **3M Petrifilm E.coli/Coliform** – indicator for fecal contamination

Courtesy of SANDEC. Used with permission.

Wegelin 1996
January Timeline

January 3rd 
Arrive in Accra, Ghana

January 4th – 5th
Travel to Tamale and orientation, bike/walk to dugouts, meet Peace Corps Volunteer

January 6th
Collect materials and meet people

January 7th – 9th
Set up HRFs. Take dugout samples.

January 9th – 26th
Run HRFs and test daily water quality
Continue to take dugout samples.
Visit existing HRFs and test water quality.

GOALS while in Ghana:

- Run pilot systems and set up system for data collection for February
- Visit as many existing HRF and understand design and filter efficiency
- Meet with UNICEF Water and Sanitation officer
- Meet with Peace Corps Health APCD
Horizontal Roughing Filtration:

Literature Reviewed


Schulz C and Okun D. Surface Water Treatment for Communities in Developing Countries. (1992) John Wiley and Sons, Inc. Great Britain.

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Household Treatment of High Turbidity Water

Biosand Filter

» Household treatment
» Intermittent Slow Sand Filtration

» Removes:
  » >90 % of *E. coli* bacteria
  » 100 % of protozoa and helminthes (worms)
  » 50-90 % of organic and inorganic toxicants
  » <67 % of iron and manganese
  » most suspended solids

» Being applied to various communities, countries

» Disadvantages:
  » does not suit treatment of high turbidity water
    - Decline in treatment efficiency, frequent clogging and maintenance requirement

S. Murcott; Biosand Filter – International Aid Plastic Version Household Water Treatment and Safe Storage Product and Implementation Fact Sheet (July 2007)
Objective:
Establishment of Household Treatment Method for High Turbidity Water

Modification of Biosand Filter

Approaches:
- sedimentation/rough filtration
- circulation of water flow within the filter
Household Treatment of High Turbidity Water
Approaches & Evaluation

Biosand Filter
- material and size of media
- altering flow path

Sedimentation Unit
- Sedimentation tests in Ghana

Rough Filtration
- altering material and size of conventional media
- disposable material…?

Ideally combined into one process…

Evaluation
- Turbidity removal
- total coliform, E.coli
- Head loss
- Flow rate
- residence time
- Clogging time
- frequency of maintenance

MIT Clean Water 4 All, Inc.
Household Treatment of High Turbidity Water

MIT Clean Water 4 All, Inc.

Schedule

- Day 1-3  Visiting local dugouts
  Cleaning and setting up working site

- Day 4-7  Setting up biosand filters and columns

- Day 8-14  Running biosand filters, columns
  (formation of biofilms and schumutzdecke)
  Sedimentation tests/ Rough filtration tests

- Day 15- 21  Evaluation of biosand filters
  Combining sedimentation/
  rough filtration units
Literature Reviewed


- Optimising Multi-Stage Filtration Units for Use in Bangladesh
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Ceramic *Kosim* Filter and Aquatabs

- 100-1000 NTU waters
- 99.7% Removal of E.Coli
- Ceramica Tamakloe Ltc. – 2000
- UNICEF-Ghana – 5000
- Oxfam – 500

- NaDCC
- 5 NTU waters
- CDC Study – 240 households
- Flood Victims – 10 million
Research Plan

- Develop proper dosing protocol for the Kosim + Aquatabs system
- Water Quality Testing: turbidity, E.Coli, total coliform, chlorine residual
- Technical functionality: flow rate new/old, breakage rates
- Evaluate proper use
- Survey user acceptability
Activities - Daily

**Jan 5-11**
- Offer Combined System – 10 households

**Jan 12-18**
- Return to households – follow-up, water samples

**Jan 19-26**
- Return to households – follow-up, water samples

**Everyday**
- Perform tests on *Kosim* filter at lodging site – water quality, flow rate
- Perform water quality tests on one of following – water source, pre-treatment/post-treatment storage
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Objectives

Pilot study to compare:

Community-scale system using HTH Calcium Hypochlorite

And

Ceramic *Kosim* filter + Aquatabs
Chlorine Products

MIT Clean Water 4 All, Inc.

Criteria

- **Water Quality**
  - Free and Residual Chlorine Tests
  - Turbidity, pH, microbial analysis

- **Proper Use**
  - Correct dosing procedures for Aquatabs
  - Operation and maintenance of HTH system

- **Consumer Preference**
  - Either product, neither product
  - Adoption (taste, odor)

- **General Sustainability**
  - Ability to be maintained
  - Capital and maintenance cost
Chlorine Products

Research Plan

- **January 5-12**
  - Identify appropriate doser location
  - Acquire needed parts and materials
  - Acquire approval for installation
  - Assembly and construction

- **January 13-20**
  - Collect pH, turbidity, microbial, and free & total chlorine data
  - Optimize system
  - Document O&M practices of system
  - Assist as needed the Aquatabs + Kosim filter option

- **January 21-26**
  - Identify an individual or organization to take over after January
  - Train them to effectively manage system
Chlorine Products

MIT Clean Water 4 All, Inc.

Literature Reviewed

Aquatabs


HTH Calcium Hypochlorite

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Ghana Consumer Choice Project:

Objectives

Assess product consumer research on product choice for a select group of available HWTS options in Northern Region Ghana including:

- Disinfection-Only (Aquatabs)
- Particle Removal (Kosim filter, Doulton Candle Filter, Okay Candle Filter)
- Combined System (PuR, Kosim / Aquatabs)
- Sachet Water
Ghana Consumer Choice Project: MIT Clean Water 4 All, Inc.

Description of Survey Instrument

Designed to define customer groups with distinct behaviors and preferences, desired HWTS product features will then be assessed for each segment.

**Goal**
- Define actionable market segments for HWTS products in Northern Ghana
- Assess differences in behavior and beliefs across market segments.

**Research Questions Addressed**
- Demographics – Gender? Age? Family size? Number of children under 5?
- Purchaser identification - Who makes the buying decision? Who influences? Where are products bought?
- Ability to pay - Profession? Fuel type?
- Water treatment, sanitation and health practices and beliefs - Source? Current treatment system? Satisfaction? Amount filtered daily

**Household Profile**

**Conjoint Analysis**
- Understand product feature preference
- Assess variations in ideal HWTS product by customer segment
- What features of an HWTS product are most important to Ghanaian customers?
- How much would they pay for each feature? Existing products?
- Which existing product is most attractive to customers?
- How could existing products be improved to be more attractive to customers / better meet needs?
Ghana Consumer Choice Project: 
MIT Clean Water 4 All, Inc.

Conjoint Methodology

We have selected six product attributes to test and each attribute is divided into two to four levels. Three potential attributes were eliminated.

<table>
<thead>
<tr>
<th>Attributes and Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Clarity</strong></td>
</tr>
<tr>
<td>• Clear</td>
</tr>
<tr>
<td>• Partially Clear</td>
</tr>
<tr>
<td>• Turbid</td>
</tr>
<tr>
<td><strong>Water Taste</strong></td>
</tr>
<tr>
<td>• Crisp &amp; Clean</td>
</tr>
<tr>
<td>• Chlorine</td>
</tr>
<tr>
<td>• Earthy / Natural</td>
</tr>
<tr>
<td>• Dirty</td>
</tr>
<tr>
<td><strong>Product Look</strong></td>
</tr>
<tr>
<td>• Consumable</td>
</tr>
<tr>
<td>• Modern Durable</td>
</tr>
<tr>
<td>• Traditional Durable / Plastic / Made in Ghana</td>
</tr>
<tr>
<td><strong>Health</strong></td>
</tr>
<tr>
<td>• Normal sickness</td>
</tr>
<tr>
<td>• Reduced sickness</td>
</tr>
<tr>
<td><strong>Filter Speed</strong></td>
</tr>
<tr>
<td>• Slow</td>
</tr>
<tr>
<td>• Fast</td>
</tr>
<tr>
<td>• Immediate</td>
</tr>
<tr>
<td><strong>Price</strong></td>
</tr>
<tr>
<td>• Low</td>
</tr>
<tr>
<td>• Medium</td>
</tr>
<tr>
<td>• High</td>
</tr>
<tr>
<td><strong>Water Temperature</strong></td>
</tr>
<tr>
<td>• Ambient</td>
</tr>
<tr>
<td>• Cool</td>
</tr>
<tr>
<td><strong>Channel</strong></td>
</tr>
<tr>
<td>• Store - F - I - able</td>
</tr>
<tr>
<td>• Store - Not available</td>
</tr>
<tr>
<td>• Door-to-door</td>
</tr>
<tr>
<td><strong>Volume Amount</strong></td>
</tr>
<tr>
<td>• &lt;10 liters</td>
</tr>
<tr>
<td>• &gt;10 liters</td>
</tr>
</tbody>
</table>

Water Clarity – Team will carry vessels of each water type to show visual difference.

Water Taste – Team will carry vessels of each of four water types. “Crisp & clean” will be factory produced sachet water. Chlorine water is correctly dosed using Aquatabs. Earthy/natural will be ceramic filtered water. “Dirty water” is boiled dugout water.

Product Type - Pictures of three of each product type will be provided. For example, one picture would show three consumable types, including Aquatabs, PuR, and sachet water. Etc.

Health - Descriptions and/or pictures of three or more symptoms associated with typical Ghanaian waterborne diseases (e.g., person with diarrhea, child with distended belly) and reduced levels of waterborne disease

Speed of treatment - Described and/or shown as minutes per 10 liter volume.

Price - Price based on GHS per liter.

Note: Price randomized based on feature set
Ghana Consumer Choice Project: MIT Clean Water 4 All, Inc.

Conjoint Delivery

There will be 8 -10 selection sets from which one box can be chosen

Example Feature Set - Comparison #1*

<table>
<thead>
<tr>
<th>Feature Set #1</th>
<th>Feature Set #2</th>
<th>Feature Set #3</th>
<th>Do Not Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Clarity: • Clear</td>
<td>Water Clarity: • Turbid</td>
<td>Water Clarity: • With Sediment</td>
<td>Water Clarity: • Clear</td>
</tr>
<tr>
<td>Water Taste: • Crisp and Clean</td>
<td>Water Taste: • Earthy</td>
<td>Water Taste: • Earthy</td>
<td>Water Taste: • Crisp and Clean</td>
</tr>
<tr>
<td>Product Type: • Consumable</td>
<td>Product Type: • Modern Durable</td>
<td>Product Type: • Consumable</td>
<td>Product Type: • Modern Durable</td>
</tr>
<tr>
<td>Filter Speed: • Slow</td>
<td>Filter Speed: • Slow</td>
<td>Filter Speed: • Immediate</td>
<td>Filter Speed: • Slow</td>
</tr>
<tr>
<td>Health: • Normal Sickness</td>
<td>Health: • Reduced Sickness</td>
<td>Health: • Normal Sickness</td>
<td>Health: • Reduced Sickness</td>
</tr>
<tr>
<td>Price: • TBD</td>
<td>Price: • TBD</td>
<td>Price: • TBD</td>
<td>Price: • TBD</td>
</tr>
</tbody>
</table>

Note: Recipient chooses #1,#2,#3 or #4. Number of “Feature Set Comparisons depends on number of attributes and levels selected. Assuming six attributes (as shown on slide 10), survey recipients will be shown 8 “Feature Set Comparisons”

The survey instrument was developed in English, but the comparison sets shown to recipients will have pictures and may also be read (respondents may not be literate and there are a large number of potential tribal languages)
Field Study Process:

- Baseline survey of 300 low and middle income households -- includes households from rural areas and also from Tamale (<200K people)
- Four sets of local surveyors will be trained by the MIT/PHW team
- A two day pilot study will be conducted followed by 14 days of surveying
- Water quality tests will be conducted for each household: proposed tests include turbidity (on-site); the 3M™ Petrifilm™ test for E.Coli and total coliform and, where appropriate, chlorine residual.

Proposed analysis

- Market segmentation / customer profiles
- Preferred product features assessments
- Mapping to existing products
- Product modification / pricing
- Selling strategy

Project Team:

- Vanessa Green (M.Eng. Thesis)
- G-lab team (4 Sloan students overseeing development of conjoint)
- Ghanaian survey and marketing team (~8 individuals)
Ghana Consumer Choice Project: MIT Clean Water 4 All, Inc.

**Draft Timeline**

**Fall Term Activities (Status):**

- Determine survey scope and scale (Complete)
- Background research on Ghana, consumer choice ect. (Complete)
- Finalize baseline survey instrument (Complete, pending conjoint pairings)
- Successfully conclude MIT COUHES approval (Mid-December)
- Logistical Planning / Develop Surveyor Training Materials (Mid-December)

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<td>Consumer Choice Survey Instrument</td>
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<td>Water Quality Assessment</td>
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</tbody>
</table>

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**Key Dates:**

- Revised Proposal to PATH / M.Eng. Proposal Presentation
- Check-in with PATH
- Check-in with PATH
- Draft Report to PATH / M.Eng. Thesis Due
- June 30/08 - Report to PATH