1.782 Environmental Engineering Masters of Engineering Project

Fall 2007 - Spring 2008

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

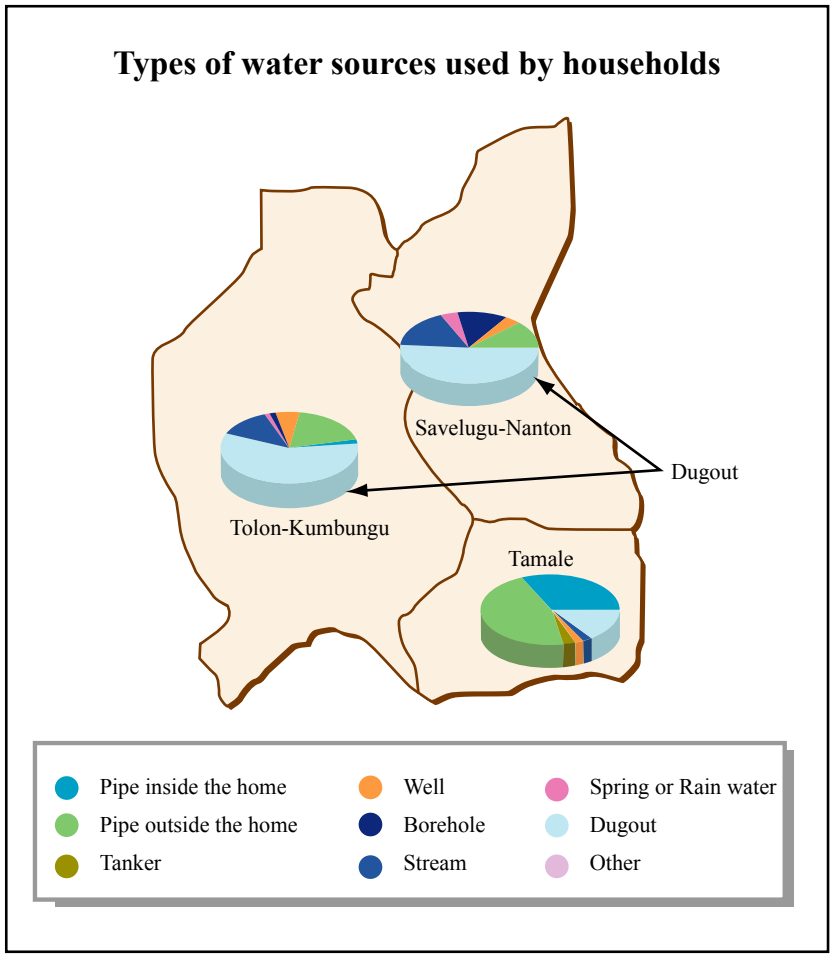
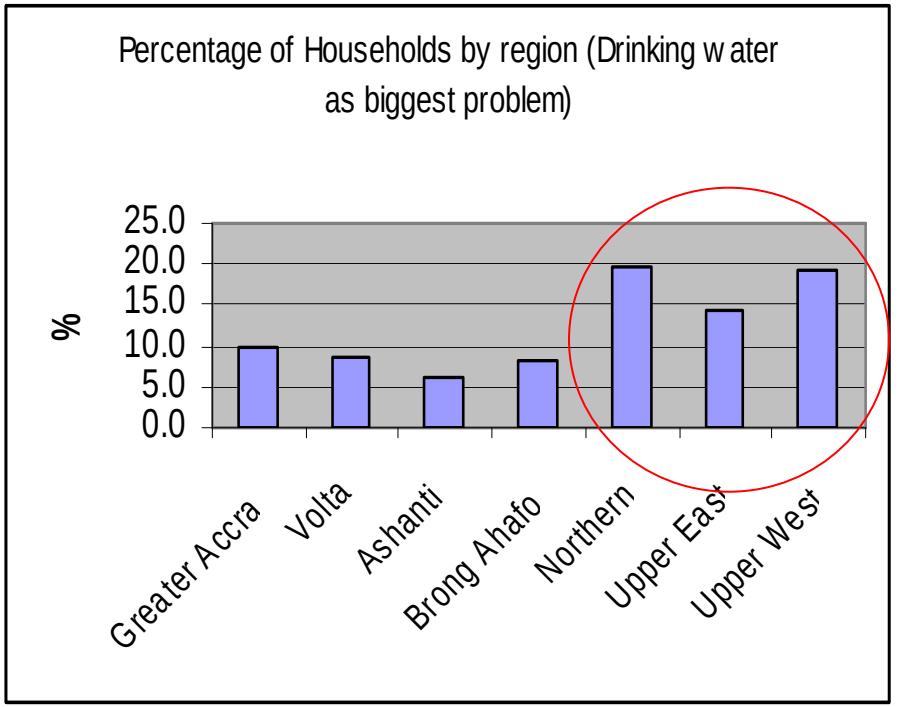


Figure by MIT OpenCourseWare.

Large Percentage of Water Source is Dugouts



(National Statistical Services Survey -CWIQ 2003)

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

Dungu Dam

Dugouts

St. Mary's Dam

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

Location	Date (2006)	E. coli (CFU per 100 mL)	Total Coliforms (CFU per 100 mL)	Turbidity (TU)
Ghanasco Muali Dam, TD	20-Jun	169	6,621	~1,600
Kaleriga Dam, TD	22-Jun	754	13,475	> 2,000
Bipelar Dam, TD	27-Jun	100	21,667	38
St. Mary's Dam, TD	29-Jun	1,650	52,110	>2,000
Dungu Dam, TD	4-Jul	133	4,540	400
Libga Dam, SD	6-Jul	0	500	75
Bunglung Dam, SD	11-Jul	200	5117	300
Diare Dam, SD	13-Jul	0	3,417	23
Libga Dam, SD	17-Jul	50	1,408	50
Gbanyami Dam, TD	19-Jul	367	19,150	~1,000
Vitting Dam, TD	25-Jul	1,400	12,767	~125
Average		**438**	**12,797**	**690**

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

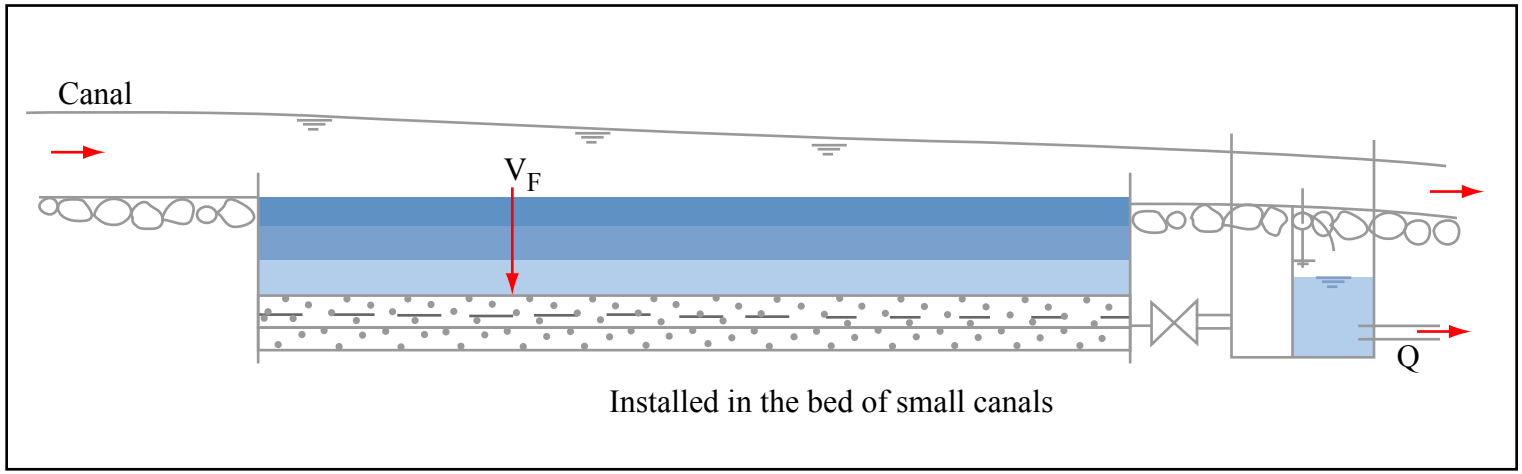
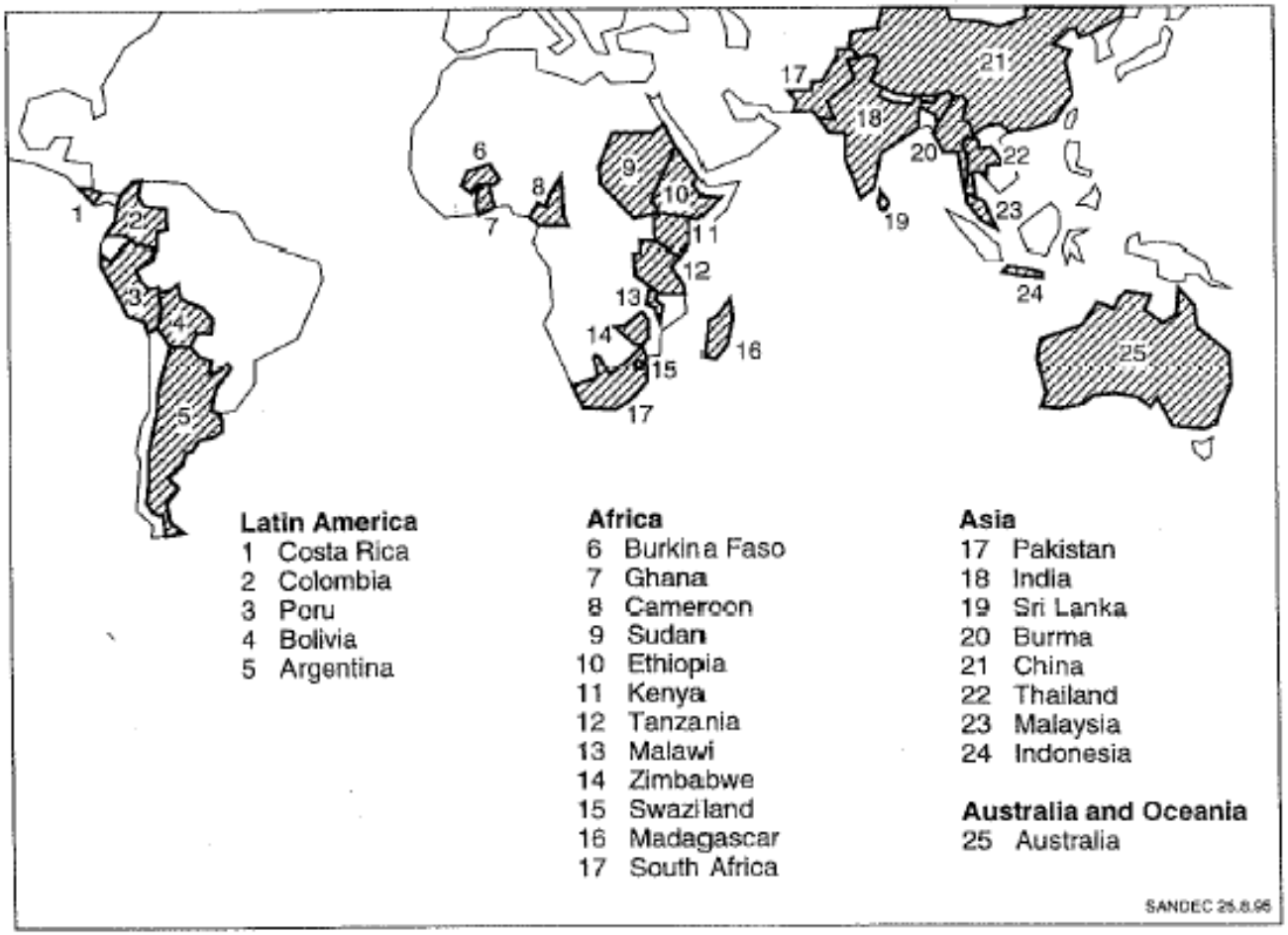


Figure by MIT OpenCourseWare.

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:

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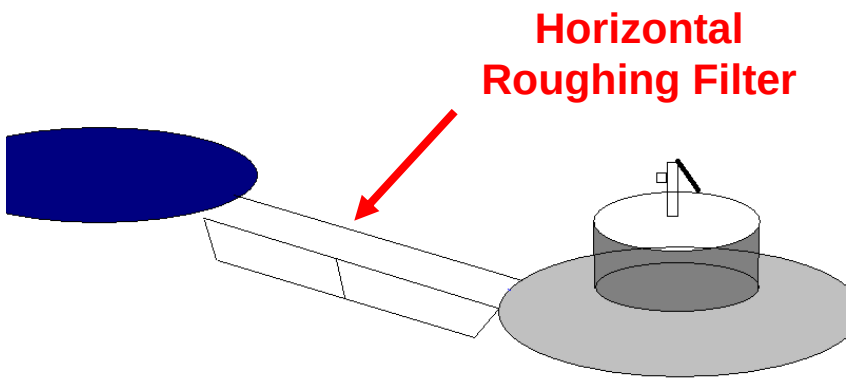
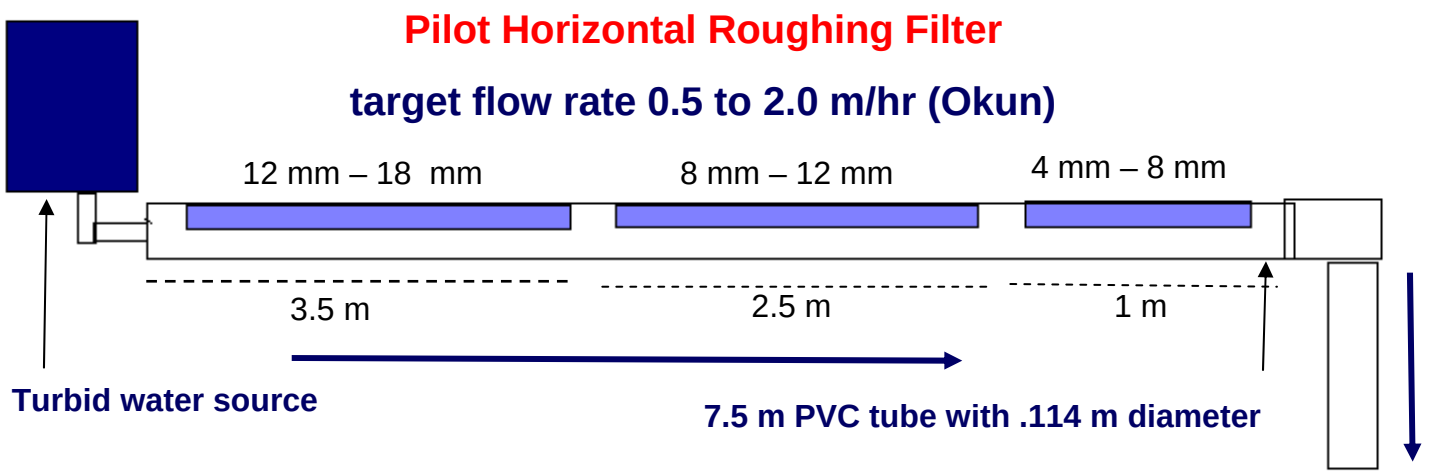
Community Pre-Filtration of Dugout Water

- **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



MIT/Ghana Pilot Test

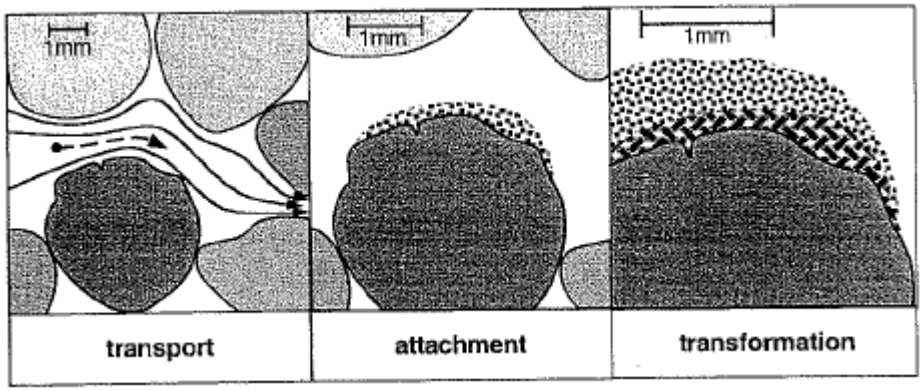
- **Target turbidity removal rate to reach 20 NTU effluent**
- **Design variables** (Wegelin)
  - Filtration rate (m/h)
  - Filter media size (mm) and type (gravel and broken clay)
  - Length of each specific filter medium (m)
  - Number of filter fractions
  - Height and width of filter bed area (m^2)
- **Evaluate system based on:**
  - Head loss
  - Filtration rate
  - Influent and effluent water quality



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

Literature Reviewed

APSU (2006) Ahmed, Farooqque. *Optimising Multi-Stage Filtration Units for Use in Bangladesh: Research Findings*. (2006) Arsenic Policy Support Unit (APSU), Ministry of Local Government Rural Development and Cooperatives.

Gerardo G, Latorre J, Sánchez A, and Sánchez LD. *Multi-Stage Filtration.* Oct 2006. IRC International Water and Sanitation Centre. Thematic Overview Paper 15.

Murcott S., Johnson S., Foran M., Yazdani I., and Doyle K. *Water Quality of Dugout Water in Northern Region Ghana and Methods to Reduce Turbidity, Microbes, and Guinea Worm*. June 2007. Draft internal report

Ochieng G.M.M.., Otieno F.A.O.., Ogada T.P.M., Shitote S.M. and Menzwa D.M. (2004). *Performance of multistage filtration using different filter media against conventional water treatment systems.* Water SA 30(3) 361-367.

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

Wegelin, Martin. (1996) *Surface Water Treatment by Roughing Filters: A Design, Construction, and Operation Manual.* Swiss Federal Institute for Environmental Science and Technology (EAWAG) Department Water and Sanitation in Developing Countries (SANDEC). Report 2/96.

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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)

Household Treatment of High Turbidity Water

Objective:

Establishment of Household Treatment Method

for High Turbidity Water

Modification of Biosand Filter

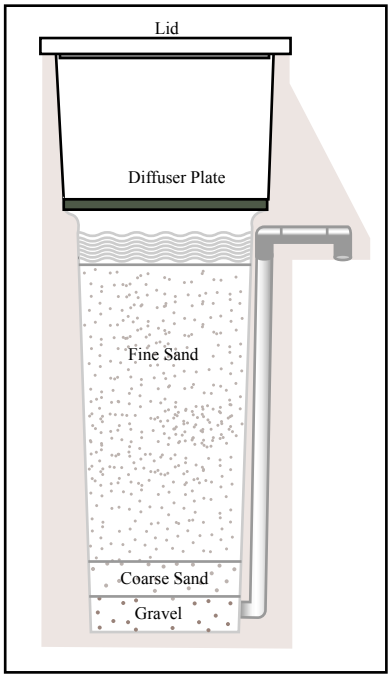

Figure by MIT OpenCourseWare.

Approaches:

- sedimentation/ rough filtration
- circulation of water flow within the filter

S. Murcott; Biosand Filter – International Aid Plastic Version HWTS Product and Implementation Fact Sheet (July 2007)

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

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

- S.Murcott, *Biosand Filter-International Aid Plastic Version. Household Water Treatment and Safe Storage (HWTS) Product and Implementation Fact Sheet*, July **2007**
- B.J.Buzunis, *Intermittently Operated Slow Sand Filtration: A New Water Treatment Process*, March **1995**
- T.Lee, *Biosand Household Water Filter Project in Nepal*, June **2001**
- S.Murcott; S.Johnson; M.Foran; I.Yazdani; K.Doyle, *Internal Report Water Quality of Dugout Water in Northern Region Ghana and Methods to Reduce Turbidity, Microbes and Guinea Worm*, Jun **2007**
- Optimising Multi-Stage Filtration Units for Use in Bangladesh

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Ceramic *Kosim* Filter and Aquatabs

Image of Kosim Filter removed due to copyright restrictions.

Image of Aquatabs packaging removed due to copyright restrictions.

- 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

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

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

Literature Reviewed

Aquatabs

- Medentech Ltd. Contribution to the Millennium Development Goals & Ghana: Aquatabs. Internal Unpublished Plan. February 2007.
- Blanton, L. The Health Impact Study of Aquatabs in Tamale: A Work in Progress. Presented at MIT November 17, 2006.
- Medentech Ltd. Tanzania: The Aquatabs Experience. Internal Unpublished Plan. November 2006.
- Medentech Ltd. Material Safety Data Sheet. 2001.
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HTH Calcium Hypochlorite

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- Cairncross, S., Feachem, R. *Environmental Health Engineering in the Tropics: An Introductory Text, Second Edition.* John Wiley & Sons. August 1993.
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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

Description of Survey Instrument

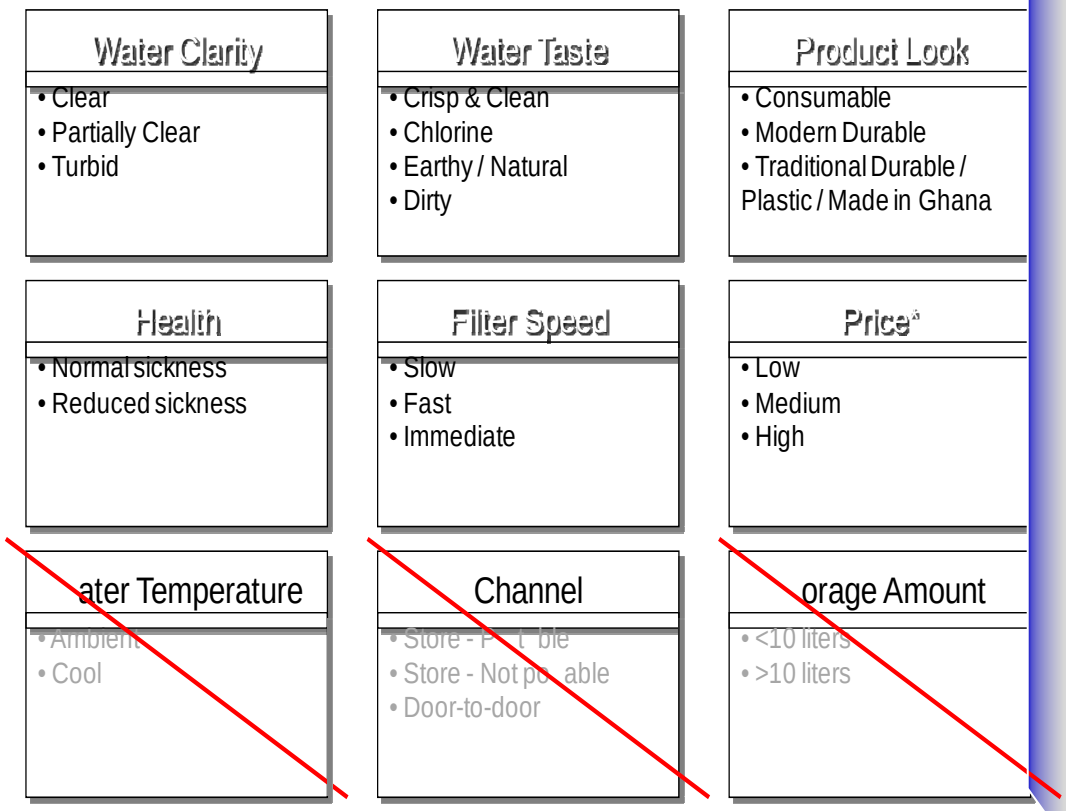
Designed to define customer groups with distinct behaviors and preferences, desired HWTS product features will then be assessed for each segment

	Household Profile	Conjoint Analysis
Goal	▪ Define actionable market segments for HWTS products in Northern Ghana ▪ Assess differences behavior and beliefs cross market segments.	▪ Understand product feature preference ▪ Assess variations in ideal HWTS product by customer segment
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	▪ 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?

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.

Attributes and Levels



Note: Price randomized based on feature set

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.

Conjoint Delivery

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

Example Feature Set - Comparison #1*

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

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)

Activities & Process

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)