1.782 Environmental Engineering Masters of Engineering Project

Fall 2007 - Spring 2008

REQUEST FOR PROPOSALS

Household or Community-Scale Water Treatment for Low-Income Communities in Northern Ghana

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NOTICE TO PROSPECTIVE BIDDERS

Pure Home Water is seeking proposals from qualified bidders to expand access to safe drinking water via household drinking water treatment and safe storage (HWTS) technologies and other viable community-scale water treatment approaches in the Northern Region, Ghana. The anticipated effort will require up to 1600 hours of technical effort (maximum of 4 MEng. students) leading to a draft final report on Friday, April 11, 2008. Following review by sponsors, a final report is due on May 9, 2008. In addition, the successful team will be expected to make one or more oral presentations to the client and the public.

To be considered, prospective bidders are asked to forward a letter of intent (LOI) with team qualifications to the above address by COB, Friday, October 5. The LOI should be no longer than 2 pages, exclusive of resumes, and should outline the team's preliminary plans for the project. Bidders will be notified by October 12 if they have made the short list, and successful bidders will be asked to submit a full technical plus cost proposal by December 7, 2007. Details of the proposal follow.

BACKGROUND – PURE HOME WATER

Pure Home Water (PHW) is a social enterprise and legally registered non-profit organization in Ghana founded in 2005 and supported with two-year start-up funds by the Conrad N. Hilton Foundation. PHW's first goal is to provide safe drinking water to people through dissemination of household drinking water treatment and safe storage (HWTS) products in Ghana, with a special focus on low-income households in Northern Ghana, where drinking water conditions are the most dire in the country. PHW's second goal is to become locally self-sufficient and financially self-sustaining. PHW is the first organization of its kind in Ghana. In broadest terms, PHW intends to learn, by trial and

error, the process of scale up of HWTS in an extremely challenging environment (multiple tribes and local languages, strong religious identities - Christian, Moslem, traditional- poverty, water scarcity, low population densities).

In Year 1, PHW began by selling a range of HWTS, but it soon became apparent that because of our limited capacity (2 full-time local staff in Year 1 with no prior experience of HWTS -- these products barely existed in Ghana at the time), we could promote and disseminate one product well, or many products poorly, so we narrowed our focus to the ceramic Potters for Peace-type pot filter, which PHW has locally branded as the *Kosim*[1] filter. We focused solely on the *Kosim* filter in Year 2 because in our judgment the *Kosim* filter is currently a good choice, culturally, technically, financially, socially, also given the challenging conditions of the particular water sources, such as dugouts and river water, which are commonly used as drinking water sources by people in Ghana, especially in the North. While we currently promote and market the *Kosim* filter, MIT teams, which support PHW with research and development studies and monitoring and evaluation assessments, have actively researched additional water treatment and storage products to add to PHW's product line. This research can be accessed at: http://web.mit.edu/watsan/meng_ghana.html. PHW's mid-term goal is to market a range of household or community scale water treatment and storage products successfully – this RFP's individual projects support that effort.

CONDITIONS IN GHANA

Three documents provide the reader with a good overview of the conditions in Ghana:

Introduction to Ghana – presents key information and data on the environment, population demographics, culture, economics, water/sanitation and health as it pertains to Ghana generally and the Northern sector of Ghana specifically – this is provided in the accompanying PowerPoint Show. (Annex A).

Ghana and the Millennium Development Goals for Water/Sanitation - reviews the current status of the Millennium Development Goals (MDGs) for water and sanitation (Goal 7, Target 10) in Ghana. This is provided through an excerpt from Michael Forson of UNICEF-Ghana (Annex B) and Table 1 below:

[1] *Kosim* is a Dagbani work meaning "water from a ceramic pot" and "the best water." It is the drinking water that is served to guests.

Table 1: MDGs - Water Supply and Sanitation Access for Ghana (World Bank/African Development Bank, 2004)

		2000			MDG			GAP (2000-2015/2020)		Total Investment ($m)
		Pop (m)	Access (m)	Access (%)	Pop (m)	Access (m)	Access (%)	Added (m)	Investment ($m/yr)	
Water (MDG 2015)	Rural	11.8	5.2	44%	17.1	12.5	73%	7.3	29	329
	Urban	8.4	5.1	61%	13	11.4	88%	6.3	57	657
	Total	20.2	10.3	51%	30.1	23.9	79%	13.6	85	986
Sanitation (MDG 2020)	Rural	11.8	1.3	11%	19.3	10.8	56%	9.5	25	377
	Urban	8.4	3.4	40%	15.1	12.1	80%	8.7	57	879
	Total	20.2	4.7	23%	34.4	22.9	67%	18.2	81	1253

The values highlighted in blue in Table 1 show the number of people (in millions) who need to be added for Ghana to reach the MDG for water access and the estimated investment.

3.3 Water Quality of Dugout Water in Northern Region, Ghana). This is a "Photo Tour" of the dams/dugouts and the people whose drinking water comes from these sources, together with a map of the locations in Tamale District only (Annex C).

The water quality conditions of surface waters in Northern Ghana are difficult for those who have not witnessed them to appreciate. Dams/dugouts and other surface waters manifest typical high coliform concentrations seen in many developing country situations, but atypically, they manifest extremely high turbidities, which are a big challenge to effective water treatment. While the WHO recommends that the median turbidity should ideally be below 0.1 NTU for effective disinfection, the turbidities of surface water supplies that are consumed as drinking water by the many people in Ghana and especially the Northern Sector of Ghana are frequently above 50 NTU, and turbidities can reach as high as 1,000 NTU to 2,000 NTU. Moreover, these surface water supplies are also contaminated with coliform and other microorganisms. Tables 2a and 2b gives data on these water quality conditions.

Table 2a: *E coli*, total coliform and turbidity of raw water samples from selected dugouts during the rainy season in Tamale and Savelugu Districts (Foran, 2007)

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

Table 2b: Average E coli, total coliform and turbidity of raw water samples from selected dugouts during the dry and rainy seasons in Tamale and Savelugu Districts (Foran, 2007; Johnson, 2007)

	E. coli (CFU per 100 mL)	Total Coliforms (CFU per 100 mL)	Turbidity (NTU and TU)
Average Dry Season	779	26,357	238 (NTU)
Average Rainy Season	438	12,797	690 (TU)

These data indicates that one cannot simply disinfect the water as a sole treatment step, for example via chlorination or solar disinfection, because such applications typically assume low source water turbidities. A particle removal step via sedimentation, coagulation/flocculation and/or filtration is essential when treating such waters. This has been an important realization of the PHW team, as we have sought to provide safe drinking water through products that “do the job.” The *Kosim* filter is one such product.

Figure 1: Before & After Treatment of Water from Jantong Dagshl Dam with *Kosim* filter

MASTER OF ENGINEERING PROJECTS

Now in its third year of existence, Pure Home Water has a good foundation regarding local environmental and social conditions, as well as a grasp of the viable and promising household and community-scale water treatment and safe storage options. This RFP seeks to expand the knowledge base of water treatment and storage options. All projects will involve interface with local hosts and users who have varying degrees of knowledge and experience with PHW products, and also potentially with Sloan School of Management's Global Entrepreneurship team(s), and/or MIT's Poverty Action Lab. A successful bid on this project can be on project topics provided below and/or the bidders are encouraged to propose their own specific projects based on their interests and talents. High priority projects #3, #4 and #10 are designated as such in the individual project titles below.

CHARACTERIZATION AND MAPPING

1. Physical, Chemical and Microbiological Water Quality Characterization of Dugouts

Dugouts (also known locally as dams) are water supply structures that collect rainwater and intermittent stream flow water. They were reputedly built by Peace Corps and other international aid groups, beginning in the 1960s, to supply water in the water-scarce savannah and Sahel environments of Sub-Sahara Africa and elsewhere. Dugouts are a primary drinking water supply source in many Northern Region districts of Ghana. For example, in Savelugu and Tolon Districts, more than 50% of water to households is

obtained from dugouts. Although originally introduced from outside, these structures have become widely embraced by local people as a readily available water source. Despite their acceptance, there are several dramatic unintended consequences of this intervention. First, dugouts are breeding grounds for the Cyclops that is the vector of guinea worm. Second, they supply water not only for human domestic use but also water for cattle and other animals. Third, their high turbidity makes this source difficult to treat. This project would involve a study of the physical, chemical and microbiological characteristics of these water structures.

2. GIS Mapping of Unimproved Water Sources including Dugouts and *Kosim* Filter Dissemination among Communities Using those Sources in Northern Region, Ghana

Several M.Eng and other students working on this project, Jenny VanCalcar, Rachel Peletz, Sophie Johnson, Kelly Doyle and Mathilde Lerminiaux, have collected GPS data and/or created maps of various aspects of water quality and PHW *Kosim* filter dissemination in the Northern Region of Ghana. This project would entail expansion of the work of mapping improved and unimproved sources of water, including dugouts as well as *Kosim* filter and other water treatment dissemination efforts. The researcher would be teamed with a local translator and guide who would travel from village to village. This sub-project would potentially entail living under challenging local conditions in traditional villages (sleeping in huts, eating local food, potential exposure to insects, unsanitary food and poor quality drinking water). The researcher electing this project should read the thesis of VanCalcar (http://web.mit.edu/watsan -> Ghana and discuss the capacity to handle the challenges, especially potential health consequences, with the project supervisor. Alternatively, this project could be performed in conjunction with several of the other studies listed below.

DESIGN, TREATMENT, ASSESSMENT

3. * PRIORITY PROJECT *****
Performance, Consumer Preference, Proper Use and Sustained Use of the Ceramic Pot *(Kosim*) filter + Chlorine Disinfection with Aquatabs.

A technically "ideal" household drinking water treatment system would take out turbidity and disinfect. One of the current best household options for achieving this under the environmental conditions of Northern Ghana is the ceramic pot (*Kosim*) filter combined with the household chlorine product, Aquatabs, by manufactured by Medentech. This project will look at several major aspects of this "ideal" household treatment system for Ghana – its technical performance via water quality testing, consumer preference for either product, both products together or neither product, and product sustainability including proper use and adherence ("sustained use").

Two distinctly different demographics will be considered: urban (modern) households and rural (traditional) households. Modern homes in Ghana are typically of concrete or brick construction, have a concrete or other floor and tin or tile roof, and have access to some form of "improved" water supply and adequate sanitation facility. Traditional households are of mud-brick, thatch roofs, with dirt floors. Traditional households often do not have access to an "improved" water supply and, lacking any sanitation facility, practice open defecation.

A randomized study design may be applied to this project, following the guidance of MIT's Poverty Action Lab.

4. * PRIORITY PROJECT *****
Comparison of Two Chlorine Products - Aquatabs vs. HTH Calcium Hypochlorite for Application in Ghana

In order to ensure microbiologically safe drinking water, a disinfection process needs to accompany a particle separation process (sedimentation and/or coagulation and/or filtration are the three simplest particle separation options) In prior research by Master of Engineering (M.Eng) and Harvard School of Public Health (HSPH) Masters students, solar disinfection options which were innovative variations on SODIS (solar disinfection in PET plastic bottles) have been investigated and dismissed as viable household-scale disinfection approaches on account of challenging local conditions: high turbidity source waters and Harmattan dust storms from November - March and rainy season conditions from June – August both of which are substantially blocking in-coming solar radiation (See Master thesis work of Iman Yazdani and Melinda Foran at: http://web.mit.edu/watsan/meng_ghana.html)

The logical disinfection approach in Northern Ghana that can complement filtration of water, via ceramic filtered water via Pure Home Water's *Kosim* filter, the biosand filter, or some other product, is chlorination. There are two potential products available in Ghana at this time. One is Aquatabs, which utilize the active ingredient sodium dichloroisocyanurate (NaDCC), also known as sodium troclosene and sodium dichloro-s-triazine trione. The other is HTH dry calcium hypochlorite, packaged in granular form, (chlorine content of 68%), manufactured by Arch Chemicals and locally distributed by Dagyeis Co.

This project would entail a comparison of these two products on the basis of performance, cost and appropriate application. Whereas Aquatabs can be applied either at the household scale, HTH calcium hypochlorite is designed for community-scale applications only. This project could potentially interface with a similar project currently underway in Western Kenya, lead by a team from Harvard and UC-Berkeley.

5. Comparison of Indigenous Practices of Sedimentation and Alum Coagulation with Proctor and Gamble's PuR.

Indigenous practices embody local knowledge regarding methods to improve water quality. The two chief indigenous methods of water treatment observed in Ghana include sedimentation by gravity settling in large clay storage vessels, and alum coagulation on a seasonal basis using a local alum product. This project would entail detailed investigation of the advantages and disadvantages of the local practices versus application of the Proctor & Gamble product, PuR. Performance, proper use, social acceptability and willingness to pay are the key factors of interest in this project.

6. Design Modification of the Biosand Filter for Treatment of High Turbidity Waters

International Aid is a Christian charity involved in dissemination of an injection-molded plastic biosand filter in Ghana and several other countries. The biosand filter has proved to be efficacious in numerous settings, however, it has not been proven under the challenging conditions of high turbidity waters in Northern Ghana. Slow sand filters, of which biosand filters are a sub-category, are meant to handle turbidities no greater than 50 NTU. No known data exists on the performance of biosand filters under high turbidity conditions.

Multi-stage filtration is a drinking water treatment process successful in handling high turbidity water. This project could entail one or two parts: an investigation of the performance of the International Aid biosand product under turbid conditions and/or the design, pilot testing and comparison of a variation on the biosand filter that draws design insight from centralized multi-stage filtration systems applied in Peru and elsewhere, but never yet adapted to household scale. The researcher who selects this project will be offered specific guidance and also put in touch with the work of a Geraldo Galvis (2004).

OPERATION AND MAINTENCE, MONITORING AND EVALUATION

7. Standardizing Training on Proper Operation and Maintenance of the Ceramic Filter

The Potters for Peace type ceramic pot filter, of which Pure Home Water's locally branded *Kosim* filter is one example, has expanded its reach into eight countries over the past ten years. Locally manufactured versions can now be found in the following countries: Cambodia, Ecuador, Ghana, India, Nepal, Nicaragua, Thailand, Vietnam

Moreover, early stage pilot manufacturing and dissemination is occurring in the following seven additional countries: Colombia, Dominican Republic, Indonesia,

Kenya, South Africa, Tanzania, Yemen.

While a manual has been written and while training materials have been freely shared among implementers, to date there has not been any systematic attempt to standardize instruction and training in proper operation and maintenance. This project would begin with a literature review and collection of training materials, proceed with a field survey of the O&M methods used to train users of the *Kosim* filter and would then determine best practices for ceramic pot filter disseminators. This project would entail extensive contact with ceramic pot filter implementers around the world. It would also involve the development of training materials that would be posted on the MIT water/sanitation and/or the Potters for Peace Web sites.

8. Monitoring and Evaluation Framework for Household Drinking Water Treatment and Safe Storage Dissemination

This project could interface with the Global Monitoring and Evaluation of Household Drinking Water Treatment and Safe Storage M.Eng.team project. It will propose a monitoring and evaluation (M&E) framework for household drinking water treatment and safe storage (HWTS) in Ghana, and pilot test a set of monitoring and evaluation indicators. It will apply this framework and set of indicators to the *Kosim* filter, Aquatabs, cloth filter and biosand filter dissemination efforts to date in Ghana. This will be a potential model for other HWTS M&E efforts beyond Ghana, especially those by the World Health Organization's International Network to Promote Household Drinking Water Treatment and Safe Storage.

9. Rainwater Harvesting in Northern Region, Ghana

This project would be offered in collaboration with the Rwanda team's rainwater harvesting project. Northern Ghana is located in a savannah zone, which is a semi-arid area receiving between 900 – 1100 mm/year. Rainwater harvesting has been promoted in Northern Ghana by the Presbyterian Church, with whom our project has a close working relationship. The exact nature of this rainwater harvesting project is "to be determined." Background to rainwater harvesting in Ghana in terms of this season's conditions is as follows: Ghana experienced poor rainfall from the onset of the rains during June. In mid July rainfall became very heavy, causing localized flooding in Northern Ghana and throughout West Africa. While precipitation has lately become significantly reduced, there are now concerns of widespread crop failures beginning to emerge from Northern Ghana. This erratic pattern of rainfall clearly has a bearing on the role of rainwater harvesting structures in supplying or supplementing water for domestic and/or agricultural purposes. One potential project would be to survey the households using the newly installed rainwater harvesting systems to find out what role rainwater plays in their water supply usage patterns.

IMPLEMENTATION

10. *** PRIORITY PROJECT ***
Consumer Choice of a Wide Range of Household Drinking Water Treatment Systems

This project is a consumer choice study related to perceived comparative value and actual comparative value/cost of various household drinking water treatment and safe storage options in Ghana. It will entail a baseline survey of two urban and two rural communities, choices of products offered at various prices and users followed over a six-month period. This project would be conducted with Pure Home Water staff and potentially with others (MIT's Poverty Action Lab, Sloan G-Lab and/or Harvard Economics Dept). The person selecting this project will be the team engineer, responsible for water quality testing of a range of product choices, which will include a subset of the following:

Disinfection-Only Options

- Aquatabs (household or community scale)
- Dagyeis (Arch Chemicals) calcium hypochlorite (community-scale only)
- Solar disinfection

Particle Removal Options

- Sedimentation
- Alum and/or Natural Polymer Coagulation
- Biosand Filter – International Aid Plastic Version
- Doulton Candle Filter
- Okay Candle Filter
- Ceramic Pot Filter (Pure Home Water's *Kosim* filter)
- Guinea Worm Cloth Filter

Combined System (Particle Removal + Disinfection) Options

- PuR
- Bagged water (a.k.a. "sachet water")
- Mission Filter

11. Guinea Worm Cloth Filter Dissemination (G-Lab)

A cloth filter has been disseminated for free to users in Ghana as part of the Guinea Worm Eradication Program (GWEP). Using randomized, controlled methods, this project will investigate the success of this free dissemination model and compare it to the Pure Home Water social enterprise model, in which filters are sold at two different prices, depending on whether the customer is from an urban or rural household. Does free dissemination undermine long-term sustained use, and if so, does charging a price increase a sense of ownership and personal responsibility. It will answer the question – which model – free distribution or a social marketing model (or other?) - will quickly and effectively reach millions of people in Ghana and throughout West Africa?

MANAGEMENT, PERSONNEL, SCHEDULE AND BUDGET

The full proposal should include a breakdown of responsibilities by staff member, including the name of a project manager; schedule for completion including project milestones and progress reports; and details regarding cost, expressed in terms of hours of effort by job classification (staff engineer, project manager).

BASIS FOR SELECTION

Proposals will be evaluated on a competitive basis using the following criteria:

- Does the proposal address the client's needs?
- Originality;
- Likelihood of success;
- Cost (expressed in terms of people-hours).

10.0 References

Foran, M. 2007. An Analysis of the Time to Disinfection and the Source Water and Environmental Challenges to Implementing a Solar Disinfection Technology (SolAgua) Harvard University, Harvard School of Public Health Masters Thesis. June 2007 http://web.mit.edu/watsan/meng_ghana.html.

Johnson, S. Health and Water Quality Monitoring of Pure Home Water's Ceramic Filter Dissemination in the Northern Region of Ghana. Massachusetts Institute of Technology, Civil and Environmental Engineering Dept., Master of Engineering Thesis. June 2007. http://web.mit.edu/watsan/meng_ghana.html.

The World Bank / African Development Bank in its *Millennium Development Goals (MDGs) for Water and Sanitation: Country Assessment: Ghana Report* (February 2004) Millennium Development Goals for Water and Sanitation 194.242.113.59/fileadmin/wma/Country_Profiles/Documents/Ghana_Country_Assessment_020104oc.doc - Supplemental Result - (Accessed July 30, 2007)