
KENYA WATER AND SANITATION PROGRAM

PROJECT PROPOSAL

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1 Introduction

We submit this proposal with the hope that we may assist in Kenya's development and progress towards safe water and sanitation for all. MAJI has dedicated a great deal of time, effort, and thought into the studies proposed, and looks forward to your consideration. This proposal provides a brief overview of Kenya and its water needs in the introduction section. A detailed overview of the studies and solutions we propose, as well as the services we will provide follow in Sections 2 through 9. Finally, we've included a comprehensive schedule, cost estimate, and résumés of all project members.

1.1 Background

MIT Aqua-social Journeys, International (MAJI) is responding to your September 24, 2004 Request for Proposal regarding the research and implementation of the World Health Organization's plan for household drinking water and safe storage technologies in the nation of Kenya. After careful scrutiny of your request, MAJI has assembled an outstanding team of engineers and scientists to address the issues at hand. Our multi-disciplinary and multi-cultural team has a wealth of experience in earth and environmental science, civil and environmental engineering, chemistry, city planning, and management. All team members have participated in international ventures, and many speak multiple languages. The combination of technical and cultural skills possessed by MAJI makes them an ideal group to address Kenya's household drinking water treatment and safe storage concerns. The MAJI team will tackle a broad range of topics.

1.2 Geography

Kenya, on the Earth's equator, varies climactically from tropical in the coastal areas to arid in the west. It is bordered by Somalia to the east, Ethiopia to the north, Sudan to the northwest, Uganda to the west, and Tanzania to the south. Two water bodies, the Indian Ocean to the east and Lake Victoria to the west, also share a border with Kenya.

Kenya experiences two rainy seasons- one from October to December and another from April to June. Portions of Kenya are struggling to meet the water demand of its 31,540,000 people. Two thirds of Kenya is arid or semi-arid; therefore access to water in many parts of the country is scarce. Many women spend several hours each day collecting water from distant sources, and share the water source with animals that both drink from it and contaminate it.

While Kenya is classified as a "water scarce" country by the United Nations, different regions receive drastically different amounts of rainfall. In the northeast, rainfall can average only 13 in/year. Yet in the Lake Victoria basin, where our research will take place, rainfall ranges from 70-80 in/year. In January, the month during which the research for this project will be conducted, the average high and low temperatures for western Kenya are 93°F and 57°F, respectively (Southtravels.com, 2004).

Kenya is a noted tourist destination, in part, due to its varied landscape. To the east are lowland coastal plains that are relatively fertile. To the west are the Kenyan highlands, defined by land over 900 meters in elevation (Figure 1). The Rift Valley, which runs from Syria south to Mozambique, is seen in Kenya running from the north at Lake Turkana southwest to Lake Victoria.



Figure 1: Physical Map of Kenya (www.maps.com, 2004).

1.3 Water and Sanitation in Kenya

Access to Safe Water

About 31% of Kenyans receive their drinking water from a pipe (household or communal tap), while 37% obtain water from an open spring, stream, or river. The rest get water from wells, water vendors or other sources (Central Bureau of Statistics, 2004). WHO estimates that in 2002, 38% of Kenyans lacked access to safe drinking water. However, when looking only at rural areas, this number increases to 54% (WHO, 2004).

In the Nyanza Province, where some of the team will focus their investigations, only 14% of people receive their drinking water from a pipe. The percentage of people using open water sources such as springs, streams, and rivers amounts to nearly 58% (Central Bureau of Statistics, 2004). In such open water systems, the likelihood of contamination is significantly higher than for piped and treated water systems. Point-Of-Use drinking water systems, the subject of most of the investigations, provide a simple and cost effective way to treat contaminated drinking water.

Access to Improved Sanitation

WHO estimates that in 2002 52% of Kenyans did not have access to improved sanitation. In rural areas, 57% of people lacked sanitation coverage (2004). About 11% of all Kenyans use flush toilets. The most common form of sanitation facility is a pit latrine, which is used by nearly 64% of the population, while more than 16% have no facility and defecate in the brush, a field or in the open. Apart from those that do not use a latrine, 49% share their toilet with other households (Central Bureau of Statistics, 2004).

Sixty six percent of the people in the Nyanza Province use a pit latrine, only 2% have a flush toilet and over 26% have no facilities at all. Over half of the people that have access to a toilet in Nyanza share this latrine with other households (Central Bureau of Statistics, 2004).

1.4 MAJI Services Offered

For this project, MAJI intends to perform background research while at MIT and field testing, experiments, sampling, and user surveys of point-of-use drinking water treatment systems and sanitation facilities in various locations in Western Kenya. We will explore issues surrounding safe water storage, several methods of microbial removal, ecological sanitation, denitrification, and water and sanitation project implementation. At the end of the field work and further lab exercises, our findings and conclusions will be submitted in a report.

1.5 Deliverables

The final deliverables in the report for this program will include 1) findings and recommendations from the specific topical research areas (individual investigations), and 2) general implications of our research on water and sanitation in these locations (collective recommendations).

1) Topical reports will provide in-depth study into specific technical research areas. The findings of the research will analyze data collected in Kenya and note strengths and weaknesses of the technologies. The recommendations from the research will suggest optimal use of these technologies within the constraints local setting (organizational, economic, social, and environmental). The subjects of topical reports will include findings and recommendations regarding:

- The **safe storage** of household water supplies
- Microbial removal by household **ceramic filtration**
- Microbial removal by solar disinfection systems (**SODIS**)
- New methods for **denitrification** of drinking water
- Household's use of **ecological sanitation** facilities
- Tools for **program implementation**

2) The implications of the above research on the local organizational landscape working will provide feedback to the Kenyan government, NGOs, and international development organizations. It is anticipated that this will help to better inform these entities about their choices in available small-scale water and sanitation technologies.

2 Safe Water Storage Studies

Leads: Michael Pihulic & Suzanne Young

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2.1 Background

One component of CARE Kenya's Nyanza Healthy Water Project is the use of locally produced clay pots modified for safe storage of drinking water in the home, which is ongoing since 2001. CARE is an international non-governmental organization that has contributed to poverty reduction in Kenya for the last 32 years. The practice of using modified clay pots is developed in three districts of Kenya's Nyanza Province: Homa Bay, Rachuonyo, and Suba (all of which are located on the shores of Lake Victoria, the largest freshwater lake in Africa and the main source of the Nile River).

Traditionally, people in these communities store drinking water in locally produced wide-mouth clay pots. These vessels are widely accepted by the people because they have an evaporative cooling effect on water and give the water a palatable taste. According to Nuffic & UNESCO/MOST *Best Practices*, "Water is drawn from the pots using a calabash or a cup. Often the cups, or the hands holding them, are contaminated. As a result, the water is contaminated and those who drink it become infected." Water contamination during storage and handling has resulted in a high incidence of diarrheal diseases, mainly in children under the age of five.

The *modified* clay pot includes the following changes: narrow mouth, lid, spigot to access water, flat base for easy water extraction, and a space at the bottom (below the spigot) to retain sediment. The form, color, and function of the clay pot are essentially retained. However, there are several weaknesses associated with the modified clay pot's design. These include fragility of the structure, leakage around the metal spigot, and a non-standard size as a result of manual molding. Because CARE is promoting treatment of water with a 1% sodium hypochlorite solution at the household level, a standard size is essential to choose the proper dose. Moreover, from an economic standpoint, there is interest to replace the metal spigot with a different type of tap because the metal spigot itself costs about the same as the entire modified clay pot.

2.2 Objectives

The goal of the safe water storage systems study is to document, analyze and suggest improvements for the production and design of modified clay pots in the Lake Victoria Region of Kenya. During this process we will be mindful of locally available materials and our recommendations will be limited to those that are realistic within the local context.

2.3 Research Objectives

Process Documentation

One of the largest barriers to promoting effective off-site development of safe household water systems is a dearth of easily accessible knowledge regarding locally available manufacturing resources, supplies, and implementations of clean water systems. Mr.

Pihulic and Ms. Young will visually document the household water storage container manufacturing process at the Oriang Women's Pottery Group in Homa Bay, the Society for Women and AIDS in Kenya (SWAK) in Asembo, and a third local pottery consortium. They will record several different potters from each of the consortiums at each step of the manufacture process in order to document variations in local techniques. Additionally, they will photographically document the failure modes of the pottery at step for future research. The different pottery designs and methods will be compiled into a visual catalog to aid future work. Finally, user feedback will be gathered through surveys to determine the life expectancy of the current designs and to characterize their use.

Tracking System

In conjunction with this documentation process, Mr. Pihulic and Ms. Young will explore the feasibility of incorporating an identification system so that the storage units may be later tracked and dated to assess product lifetime.

Colloidal Silver

Colloidal silver may be used to augment the current safe water storage systems. Colloidal silver has been utilized as a biocide in filters; however it might be possible to incorporate it into current pottery production in Kenya. Short-term investigations will document whether colloidal silver, when applied to a container with a large volume to surface area, will provide any added protection. Long-term investigation will assess whether this enhanced protection can be guaranteed for the life of the container.

Taps

Another area that has been identified for improvement in Kenyan pottery water storage container is the metal tap. The tap represents a significant investment, costing more than all the other materials required to make the container. The techniques for attaching the tap also have not been perfected and often create leaks that reduce the effectiveness of the containers. The goal is to design a replacement tap using locally available resources that will significantly reduce the cost of the safe water storage container and at the same time reduce leaks.

The following alternatives to the current spigot design were developed:

- (1) Attach a calabash (ladle) to the inside of the pot by hooking it under the lid.
- (2) Design a carriage to hold the pot and allow user to tilt to pour.
- (3) Drill a hole on the side of the pot near the bottom and plug it with a stopper.
- (4) Place a rubber gasket around the metal spigot currently used.
- (5) Embed a metal washer in the side of the pot, drill a hole through the center of the washer, and attach a tube.
- (6) Design a cone-shaped rubber spigot with a lip and place in a hole drilled on the side of the pot near the bottom.
- (7) Design a wooden tap similar to those found on European wooden beer casks.
- (8) Replace metal spigot with plastic spigot.
- (9) Design a manual pump attached to a tube.
- (10) Insert a tube and use simple plastic clamp to regulate flow.

To evaluate our designs, we used the following criteria: cost, leakiness, access to materials, kid friendliness, ease of construction, social acceptability, likelihood of contamination, and maintenance. We evaluated each design alternative against the current design.

While in the field, local craftsmen will be consulted to refine designs and help with implementing and testing. Ensuring that the local population is comfortable with any technique used is also a high priority.

Standardization

In order to implement a disinfection protocol that is simple and easy to use, either a very versatile disinfection system is required or a standardized container should be introduced. Given the variation in the size of household water storage containers, and the fact that most are not calibrated, it is not feasible to design a simple disinfection procedure. The currently favored method is to use a pre-measured dose of a 1% sodium hypochlorite solution for a known volume of water. Mr. Pihulic and Ms. Young will investigate methods for standardizing the size of the clay pot during production. Preliminary ideas include either placing a metered wooden stick with disks in the center of the potter's wheel or placing wooden calipers on the outside of the pot to fix the width of the pot.

3 Microbial Removal by Ceramic Filtration Systems

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3.1 Background

Microbial Indicators

Microbial contamination of drinking water is a major factor in the spread of disease. Pathogens are the agents responsible for infectious disease, and can be grouped as either protozoa, helminthes, bacteria, or viruses. Pathogens can infect humans via ingestion, inhalation, or contact with skin, wounds, eyes, or mucous membranes (WHO Ch. 7, 2004). Most pathogens are introduced into drinking water sources by human or animal waste, and can not proliferate in water (WHO Ch.11, 2004). Pathogens transmitted through this route are dubbed "enteric" because they initially occupy a niche in the intestines, or enteron, of their host. Upon leaving their host, the viability and infectivity of pathogens tend to decrease exponentially (WHO Ch. 7, 2004). Pathogens possessing a high resistance to decay are the most problematic parasites when it comes to waterborne disease.

Due to the large variety of pathogens and the complexity of testing methods, it is unrealistic and often difficult to test for individual species. This is where indicator microorganisms come into play. The idea behind indicators is that certain non-pathogenic microorganisms are present in the feces of all warm-blooded animals (Gerba, 2000). These microbes are easily isolated and quantified using simple microbial methods. The presence of microbial indicators reveals that fecal contamination has

occurred and that enteric pathogens are likely present in the water (Gerba, 2000). Several criteria have been established for ideal microbial indicators. According to the World Health Organization (WHO) Guidelines for Drinking-Water Quality, an indicator should:

- “be universally present in the feces of humans and animals in large numbers;
- not multiply in natural waters;
- persist in water in a similar manner to fecal pathogens;
- be present in water in higher numbers than fecal pathogens;
- respond to treatment processes in a similar fashion to fecal pathogens; and
- be readily detectable by simple, inexpensive methods (WHO Ch. 11, 2004).”

Several microorganisms have emerged as suitable indicators, but to date no single microorganism fits all the criteria. Some of the most frequently used bacterial indicators include *Escherichia coli*, intestinal enterococci, and *Clostridium perfringens*. Certain bacteriophages are often used as viral indicators. In this research, *E. coli*, total coliforms, and F-RNA coliphages will be used to evaluate the effectiveness of ceramic water filters at removing bacteria and viruses from water contaminated by fecal pollution.

Total Coliforms

Total coliforms are defined as all aerobic and facultatively anaerobic “gram-negative, non-spore-forming, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties, oxidase-negative, fermenting lactose at 35-37°C with the production of acid, gas, and aldehyde within 24-48 hours (Dufour et. al, 2003).” Total coliforms have been used in the past as indicators of water contamination. However, because coliforms have the ability to survive and multiply in natural waters, their effectiveness as indicators of fecal contamination is compromised. Additionally, studies have shown that there is no direct correlation between the presence of pathogens and the presence of total coliforms (Low, 2001). Instead, total coliforms can be better used to assess treatment methods; their presence in filtered or disinfected water reveals inadequate treatment (WHO Ch. 11, 2004). Total coliforms will be used in the course of this research to indicate the effectiveness of ceramic water filters at removing bacterial contamination.

Escherichia coli

Escherichia coli are thermotolerant coliforms that belong to the total coliform group. Thermotolerant coliforms are capable of fermenting lactose at 44-45°C. *E. coli* are differentiated from this group by their ability to “produce indole from tryptophan or by the production of the enzyme β -glucuronidase (WHO Ch. 11, 2004). *E. coli* is believed to be of purely fecal origin, and has been found to be present in fresh feces in concentrations as high as 10^9 per gram (Dufour et. al, 2003). The presence of *E. coli* is also detectable by simple, inexpensive methods (Dufour et. al, 2003). For these reasons, and because environmental conditions are unlikely to support *E. coli* growth outside of the intestine, this organism has come to be the preferred indicator of choice for fecal contamination. In the course of this research, *E. coli* will be used in conjunction with total coliforms to reveal the effectiveness of ceramic water filters at removing bacterial contamination.

F-RNA Coliphages

Bacteriophages are viruses that use bacteria as hosts for replication (WHO Ch. 11, 2004). One type of bacteriophage, the F-RNA coliphage, infects *E. coli* and other gram-negative bacteria possessing fertility fimbriae, which are coded for by the F-plasmid. F-RNA coliphages consist of “an icosahedral capsid with a diameter of about 0.025 μm and a single strand (ss)-RNA genome (Grabow, 2001). F-RNA coliphages may serve as useful indicators of water quality for several reasons. First of all, F-RNA phages adsorb only to the sex-pili produced by bacteria possessing the F-plasmid. These pili are synthesized at temperatures above 30 °C, meaning that it is unlikely that F-RNA coliphages will infect bacteria and replicate in environments other than the gut of warm-blooded animals. F-RNA coliphages also possess many attributes of human enteric viruses, including morphology, physical structure, composition, and size and site of replication. Additionally, F-RNA coliphages are resistant to various chemicals, heat, UV light and sunlight, chlorination, and water treatment processes (Grabow, 2001). However, F-RNA coliphages are still lacking in certain criteria associated with ideal indicator organisms. For example, as of yet there is no direct correlation between the number of coliphages and the number of enteric viruses present in polluted water (Grabow, 2000). Thus coliphages can not be used to indicate the amount of viruses present in the water. The ability of F-RNA coliphages to serve as indicators may be better applied to evaluating the performance of water treatment or disinfection processes. In the course of this research, ceramic water filters will be evaluated on their ability to remove F-RNA coliphages.

Ceramic Filters

Ceramic water filtration is a popular method of treating contaminated water at the household level (Dies, 2003). Ceramic filters come in a variety of shapes and sizes, including candle filters, disk filters, and pot filters; and can be composed of a variety of materials, including red terracotta, white kaolin, diatomaceous earth, black clay, etc. Ceramic water filters are made by mixing clay with a combustible material, such as sawdust, flour, etc. The filter is then fired and the combustible material disappears, leaving pores in the clay. These pores allow for the water to move through the filter. By adjusting clay type, combustible material, firing temperature, and filter shape, a multitude of filters can be created, each of which possesses unique properties for water purification. Ceramic water filters can be evaluated based on flow rate, and their ability to remove microbial contamination, reduce chemical content, reduce turbidity, and improve taste and/or odor (Ceramic Water Filter Technologies, 2004).

In this study, several locally produced and/or distributed ceramic water filters in Kenya will be evaluated based on cost, flow rate, and bacterial and viral removal efficiencies. Other brands of filters, including the Katadyn® filters and British Berkefeld Gravity filter will be tested back at the MIT facilities.

3.2 Objectives

The goal of this study is to assess the performance of locally produced and/or distributed ceramic water filters in Kenya. These filters (and several others) will be evaluated according to the following parameters: cost, flow rate, and bacterial and viral removal

efficiencies. The novel parameter in this study is the evaluation of filters based on viral removal efficiencies. F-RNA coliphages will serve as the viral indicator of choice. Due to the minute size of F-RNA coliphages (0.025 μm), physical filtration may not be sufficient to remove adequate quantities of this virus. For this reason, alternative removal mechanisms may be examined. These methods may include: addition of colloidal silver to filter element; application of positively-charged substances to filter element (e.g. coal plus iron or alum); coagulation-flocculation treatment pre-filtration.

3.3 Research Plan

Schedule

November-December:

- Identify several methods that detail the detection and enumeration of total coliforms, *E. coli*, and F-RNA Coliphages
- Practice assays in lab
- Practice flow rate tests in lab

January:

- Test for total coliforms and *E. coli* in drinking water sources in Kenya
- Test effectiveness of locally produced and/or distributed ceramic water filters at removing total coliforms and *E. coli*
- Test flow rate
- Compare cost and availability of filters in Kenya

February-April:

- Test filters that had 100% bacteria removal for their ability to remove F-RNA coliphages
- Test filters for flow rate
- Analyze collective results
- Make recommendations based on conclusions

Study Design

Water samples will be collected from several local sites in Kenya and tested for the presence of total coliforms and *E. coli*. Several different ceramic water filters, including the Kissi candle filter, Katadyn® filters, and British Berkefeld Gravity filter will then be tested for flow rate and the bacterial removal efficiencies using the locally collected water. Tests for viral removal efficiency using F-RNA coliphages will be performed back at MIT using Charles River water and/or spiked water samples. Filters will be evaluated according to the parameters listed above. Recommendations will be made based on results of the study.

Methodology

Each filter will be evaluated for flow rate and bacterial and viral removal efficiencies. Flow rate tests will be performed in triplicate for each filter. Membrane filtration (MF) will be used to detect and enumerate total coliforms and *E. coli*. For each water site tested, three water samples will be obtained and each will be tested in triplicate using the MF test. The ability of each filter to remove total coliforms and *E. coli* will then be examined, with three trials per test per filter. Back at MIT, water samples will be tested

in triplicate pre- and post-filtration for the presence of F-RNA coliphages. If no F-RNA coliphages are found in local water sources, samples will be spiked with F-RNA coliphages, tested in triplicate, filtered, and tested in triplicate again. Comparison of unfiltered and filtered water samples will be used to calculate bacterial and viral removal efficiencies.

Membrane Filtration Test for Total Coliforms and E. coli

The membrane filtration test will be used to quantify the amount of total coliforms and *E. coli* present in contaminated water sources. Filtered water will be tested and compared to unfiltered water to determine bacterial removal efficiencies of the studied ceramic water filters. This method was selected over alternative methods for several reasons. First of all, the MF method is the only technique that allows for the quantification of microorganisms (Water Microbiology, 1992). Additionally, the MF method can detect the presence of total coliforms and *E. coli* simultaneously (USEPA, 2003). The simple assay also uses easily transportable equipment, allowing for tests to be carried out in the field. When compared to other methods, the MF method reveals results in a relatively short period of time.

Single Agar layer Procedure for the Detection and Enumeration of F-RNA Coliphages

EPA Method 1602: Male –specific (F⁺) and Somatic Coliphage in Water by Single Agar Layer (SAL) Procedure will be used to quantify the amount of F-RNA coliphages present in contaminated water sources (Method 1602, 2001). This method was generously donated to the author by Douglass Wait of UNC’s microbiology lab. This method was selected for its clarity and ability to quantify the amount of coliphages present in a sample. Filtered water will be tested and compared to unfiltered water to determine viral removal efficiencies of the studied ceramic water filters.

4 Semi-Continuous Solar Disinfection (SODIS)

Lead: Brian Loux

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4.1 Background

As described earlier, the largest impediment for water purification is the lack of infrastructure and capital for typical purification technologies. The idea for solar disinfection as a means of purifying water comes from an early civilization practice of placing soaked dining ware in sunlight for an extended period of time to cleanse the pieces. In 1984, Professor Aftim Acra at the American University of Beirut, Lebanon found that infected water in clear plastic bottles left in direct sunlight would drastically reduce the microorganism levels within one to two days. Since this initial study, solar disinfection has rapidly grown in popularity, culminating with the founding of SODIS, a Swiss-led organization dedicated to the spread and improvement of the methodology in impoverished areas.

The problem remained as to how to better serve a large family with the technology. A large family would need to fill and carry between 13 and 57 bottles of water a day to

satisfy their needs. In 2003, MIT Student Xanat Flores designed SC-SODIS, a semi-continuous system designed to deliver a constant flow of clean water to a family with little effort on the part of the user. Flores cut and pasted pairs of bottles end to end, then linked a start and collection barrel to let gravity and valves direct flow through the bottles. The system was tested in Nepal with great success, and cost less than \$1 to construct.

While Flores' system addresses a great number of problems, she noted a number of concerns that should be addressed in further research. The first concern was the creation of dead zones, or areas with no flow, in the system. The gravity-fed start barrel distributes the water to all the bottles evenly, though differences in height often result in slight differences in flow between the bottle pairs. In addition, bottle pairs tend to develop small air bubbles, which have not been analyzed for effect. It is quite possible that the air bubbles aid in distributing oxygen into the water, though it is uncertain. Oxygenation is a critical concern for SODIS systems as studies have recently shown that photooxidation, is the primary process of disinfection in SODIS systems. Oxygenated systems were shown to have decreased the sterilization time threefold. The bubbles are evident that the gravity system cannot entirely distribute water to every bottle.

Since the inception of the project, PET (polyethylene terephthalate) plastic bottles have been used because of their initial success and large-scale availability. Acra et al did use a PVC bottle for preliminary testing, but concluded that it was not as effective as PET. However, PET's plastic has a rather low tolerance for heat, deforming at approximately 65 degrees Celsius. While Peter Oates (2001) noted that temperatures inside bottles seldom get above 30 to 40 degrees Celsius and negates the chance of sterilization by heat, the likelihood of warp and wear on the bottles is likely. The advised lifetime of a PET bottle recommended by SODIS is six months. Most plastics have a better heat resistance than PET bottles. It is possible that a different type of plastic would be better suited for solar disinfection.

We wish to examine if a different semi-continuous disinfection system (e.g. bottles set up in series, no flow through bottles) or other types of plastics will be more effective in killing microorganisms in water. Ultimately, this project will focus on four key issues:

1. System Layout and its affects on oxygenation/disinfection
2. Type of plastic and its durability/effectiveness
3. Improvements for bottle welding in SC-SODIS
4. Other minor improvements to SC-SODIS

4.2 Objective

The objective of this work is to improve on the SC-SODIS system by testing two new designs for microbial removal that tailor the oxygen concentration and the container qualities to the requirements of water disinfection.

4.3 Research Plan

Experimental Design

We will design a simulated UV radiation system to test point of use water treatment setups similar to the one described in Abbaszadegan et al (1996). We will then proceed to create at least three different designs of semi-continuous systems.

The primary system we seek to test is the bottles linked in series with the middle bottle exposed to the atmosphere to equalize the oxygen concentration and wrapped in cloth to prevent particles entering from the air and to cool the water temperature to increase dissolved oxygen capacity. In this system, instead of the start tank linked to a laterally distributing PVC pipe, the tank will go straight to a first set of bottles and will proceed to snake down between the bottle sets.

Additionally, we will create a “batch” system, in which a series of valves control the filling and emptying of the bottles from the start tank and into the collection tank. There will be no flow through the system, and as such will not be a continuous solution.

As a control, we will recreate both Flores’ system and a single PET bottle. These systems will then take in and treat water with a fixed concentration of E.coli. The residence times (if applicable) of the systems will be designed such that we would expect 30 litres of water to be processed over a time period of one day. We will then analyze which system had the most successful disinfection rate and attempt to optimize its oxygenation rate through architectural changes in its structure. Subsequent tests will seek to discover if these improvements in oxygenation have any effect on the rate of disinfection.

Subsequently, we will purchase clear plastic bottles of equal volume ranging from types 1 through 7. Once again, a fixed volume of water with a fixed concentration of E.coli will be introduced to the bottles. Tests on these bottles will be done through the traditional batch method of bottling, shaking and capping individual plastic bottles and leaving them for a period of one day. Should frequent tests reveal that one plastic consistently outperforms PET, we will conduct a literary review of that plastic’s durability and potential toxicity.

Activity in Kenya

Purchase of all the requisite materials aside from a collection barrels will be made before the January trip. The system will be constructed in Kenya and a duplicate system will attempt to be made with materials found locally. During the course of the two weeks, we will attempt to see if both our laboratory system and field-designed system can recreate the disinfection results found in under laboratory conditions.

Additionally, we will seek out different types of plastic, especially if some plastics have been proven to fare better than PET. We will discuss availability of these plastics with the local villagers and try to identify a contact in a local or national bottling plant in order to discuss changes to bottle design at a later date.

Upon return to MIT, it is our hope to participate in the IDEAS competition to bring semi-continuous solar disinfection systems. Our IDEAS project would seek to accomplish the following goals.

1. Designing a construction manual for the optimized chosen system to be used for SODIS and local teams.
2. Possibly organizing a microfinance venture with a reliable and knowledgeable community members in Kenya to spread the newer SC-SODIS system.
3. Working with local plastic bottle manufacturers (e.g. Coca-Cola) on introducing a newer plastic bottle if a superior plastic to PET is found.
4. Sharing our findings with SODIS and community organizations.

5 Point-of-Use Water Systems Assessment

Lead: Pragnya Alekal

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5.1 Background

In response to Kenya's very large drinking water problem, several products are being researched and developed to make the water safer and more potable. Few are financially viable, particularly for the factions of community that we are targeting.

Two products have been found to be most effective in poor communities in Kenya, with a possible third for the future. They are:

- Safe Water System (SWS, Waterguard®): SWS is part of a larger program that includes water treatment, storage and education. The research for this portion will focus predominantly on the water treatment aspect.

The water treatment system is better known as Waterguard®. Primarily a disinfectant, it consists of NaOCl solution. It is easy to use and abundantly available. Typically, a dosing factor of 3.75 is used for 20 Liters of clear water and 7.5 for 20 Liters of turbid water. It comes in bottles priced at 35 Ksh, and can purify about 2000L of water (a family of five can subsist on this amount for three months).

The catch is that Waterguard® is effective only in a non-turbid environment. Most of our target populations (generally the economically challenged) get their water from very turbid sources, rendering this technique is virtually ineffective.

- PuR® Water-System: PuR® was developed as part of a collaborative effort between the Centers for Disease Control (CDC) and Proctor & Gamble (P&G) mostly to address turbidity issues that Waterguard® was unable to. It grew from an idea of trying to "bottle" an entire water treatment process in a small sachet. PuR® cleans highly turbid water by using precipitation, flocculation, coagulation and finally, disinfection. The primary agents are Ferric Sulfate and Calcium Hypochlorite.

PuR®'s amazing properties come at a price. A sachet priced at 5 Ksh can only purify about 10L of water (a family of 5 can subsist for a half-day on this amount).

PuR® primarily employs a coagulation technique and therefore works best under turbid conditions.

- Moringa Seeds: There is an alternative for the very expensive PuR® product - an ancient traditional medicinal tree called Moringa. In addition to being locally available, Moringa seeds have been found to have amazing coagulation properties. Moringa is also highly nutritional, drought resistant, and fast-growing and showcases signs of anti-microbial properties. It is hoped that the results of testing Moringa will lead to a better understanding of the seed, and possibly to the development of an efficient, and locally available alternative to PuR®.

The downside to Moringa is that little research has been performed on its properties or possible applications. Much time will need to be invested in order to understand the future applications of this plant.

Both Waterguard® and PuR® have repeatedly proven to be effective; however their efficacy is drastically reduced if they are not used correctly. Since their introduction into the Kenyan communities, little is known about the practices surrounding the system – are they being marketed and used correctly? Is this just a select household that is deviant, or is it the whole village that is being affected?

In order to find answers to these questions, *MAJI, Inc.* is sending an interdisciplinary team of business strategists to examine and propose solutions. Ms. Alekal will serve as the technical consultant on this team and her research will go to further larger marketing and microfinance objectives outlined by the strategists.

The team’s research will be based largely in the town of Asembo. Asembo is a short ride from Kisumu and is an area primarily consisting of rural farm counties. The target group we will work with is the Society of Women with AIDS in Kenya (SWAK). This group was chosen because of their willingness to cooperate in the research project and their ideal socio-economic circumstances.

5.2 Objectives

The objectives of the research being conducted by Ms. Alekal is to assess the correctness of use of Point-of-Use Water Systems viz. “PuR”, SWS, and Moringa. Three concrete targets have been formulated in order to address efficacy and suitability:

1. Micro-level Assessment: Correctness of use of the systems at a house level. Are the people using the systems correctly? Do they know what they are doing? Do the implementation/education methods need to be changed?

Research Plan: House-to-house measurement of turbidity and chlorine levels of treated water during unannounced field visits.

Method: Field-survey and water testing

2. Macro-level Assessment: Correct availability of PuR® . Is it being used in the right place (turbid water areas)? Does it need to be marketed differently?

Research Plan: Village-to-source-water measurement of turbidity and chlorine levels.

Method: Field tests on source water vs. house tests from

3. Moringa Seeds: Development of a Moringa treatment system. Can Moringa work as an alternative to PuR® ?

Research Plan: Laboratory tests on water purification using Moringa

Method: Field and Lab testing

5.3 Research Plan

Ms. Alekal will use three techniques – field surveys, field testing, and lab testing.

Objective 1: Micro-level Assessment: Correctness of use of PuR® and Waterguard®

1. Field test of treated samples of water. Parameters examined will be turbidity and chlorine levels. These will be tested during random, unannounced visits to the houses and compared to turbidity/chlorine levels from source waters.
2. Field Survey of houses using techniques:
 - Which technique do you use? Why?
 - Where/who do you obtain your filter from?
 - Who introduced you to this filter? What did they tell you?
 - Average income?
 - How often do you use it?
 - Any incidence of sickness using filtered water?
 - Do you think you have benefited from use of this product? How?
 - Are you happy with the quality/price of the filter?
 - What is your water source?
 - What are your complaints/problems with the system?
 - Could these be fixed? How?

Objective 2: Macro-level Assessment: Correct availability of PuR®

Use information gathered for Objective 1 to do assessment of village to source-water. Compare source-water turbidity calculations to that of filtered water from houses that use that source-water. The study will assess whether all the huts are using the right treatment scheme (PuR® vs. Waterguard®), and how effective PuR® is at decreasing turbidity.

Objective 3: Research on Moringa: Developing an alternative to PuR®

Field work in Kenya will depend on availability of field sites and time for testing while there. If there are available households that use Moringa, then field surveys will be used. Else, samples of Moringa will be collected and tested (time permitting, in the field or) upon return to MIT. Water quality will be spiked to compare to those available in Kenya. Turbidity removal will be tested and compared to that of PuR®. The objective is to work on developing an alternative to PuR®.

6 Denitrification of Household Drinking Water

Lead: Hongchul Jang

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6.1 Background

Toxicology studies indicate that certain families of nitrogen-containing disinfection byproducts (DBPs), such as N-nitrosamines, halonitromethanes and nitriles, exhibit far higher toxicities than currently regulated DBPs. As a result of the higher concentrations of dissolved organic nitrogen in wastewater effluents, wastewater discharges could significantly increase nitrogen-containing disinfection byproducts precursor concentrations in surface waters. If these precursors persist, they could cause further DBP formation during disinfection operations occurring when these waters are exploited as drinking water sources by downstream communities.

Therefore, denitrification should be performed before conducting household chlorine disinfection. Bacterial denitrification involves the formation of gaseous nitrogen (N_2) through intermediate nitric oxide (NO) and nitrous oxide (N_2O), from nitrate or nitrite [Knowles (1982)]. Each step of this process is catalyzed by an enzyme system. This enzyme system is composed of nitrate reductase and nitrite reductase and nitrous oxide reductase in the periplasmic and/or inner membrane [Mellor et al. (1992), Shapleigh et al. (1987)]. This dissimilatory nitrate reduction requires an electron donor such as NADH; carbon sources are necessary to regenerate it.

Many oxidoreductases containing denitrifying enzymes utilize cofactors (e.g. NAD^+ , $NADP^+$, NADH, NADPH) in the formation of each product molecule. These cofactors are quite expensive, so regeneration is required. In this research, enzymatic reactions could be coupled with electrode reactions, so that electrons from the electrode can be transferred to enzymes via mediator as electron carrier [Kano and Ikeda (2000)].

6.2 Objectives

The following are the objectives of the proposed research:

- The development of a novel denitrification system having several distinctions compared to existing denitrification methods. First, control of the specific biological reaction is possible by means of nonspecific electricity. Second, the use of mediators can decrease overpotential necessary for electron transfer to denitrifying enzymes. And the regeneration of the mediator is possible if the reducing power is continuously supplied from the electrode. Third, the denitrification reaction would be attained by permeabilized bacteria containing denitrifying enzymes. In the case of permeabilized cells, the permeability barrier of the cell membrane could be lowered and energy consumption for cell growth could be avoided [Felix (1982)]. Finally, a development of novel methods of immobilization of biocatalyst will make this system continuous.

- The application and analysis in Kenya project. The comparison of residue toxic chemicals through various disinfection techniques before and after this denitrification pre-treatment.

This study will be helpful to obtain a substantial understanding for electrochemical bioreactors containing cofactor-dependent enzymes. The study will also aid in the possible development of an advanced disinfection system.

6.3 Research Plan

For preparations of permeabilized whole cells,

- Need to select the most efficient organic solvent for the cell I will choose.
- Expect to chloroform would be worked well based on previous studies [Flores et al. (1994), De Leon et al.(2003)]
- Scanning electron micrograph (SEM) and Transmission electron micrograph (TEM) to confirm the effect with organic solvents

For measuring Enzyme activity & cell viability assay [Chauret and Knowles (1991)],

- UV meter, Centrifugator, ion-chromatography, and other relevant chemicals

For comparison of mediators,

- Cyclic Voltammetry to study the mediated electron transfer from the electrode to the enzymes
- High Performance Liquid Chromatography (HPLC) to find out which mediator is efficient in bioelectrochemical nitrate reduction, the amount of removed nitrate was compared [Ikeda and Kano (2001), Mary and Richard (1982)]

For immobilization of the permeabilized cells to the electrode,

- Employ the entrapment method using gel and polymer matrix [Schuhmann (2002), Mukund and Elizabeth (1990)]
- Sodium alginate, calcium chloride, graphite felt electrode, potassium phosphate buffer, potassium chloride, and pyrrole

For optimization of cell immobilization method,

- Can be determined after conducting researches above

For application of Kenya project,

- Need to build up the bioreactor at MIT and bring it to Kenya for in-situ study with combination of chlorination or SODIS technology
- Must analyze effluent after water treatment with or without this system before conducting other treatment technique in Kenya

For scale up and commercialization

- Need to study other biotransformation reactions containing cofactor-dependent enzymes to be substituted with this bioelectrochemical system
- Market analysis for success

7 Ecological Sanitation and Excreta Reuse

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7.1 Background

Ecosan

In addition to lack of access to safe water, lack of access to sanitation has a great impact on human health. Ecological sanitation, or ecosan, seeks to create a closed loop sanitation system in which excreta is retained on-site and reused. In ecosan systems, excreta is collected and processed in a manner such that 1) there is no pollution from excreta to water systems (and, therefore, no pathogens enter drinking water sources), 2) the material is processed sufficiently such that it is safe for human handling, and 3) the waste can be utilized in ways that take advantage of its nutrient properties (i.e. agricultural fertilizers, aquaculture feedstock) (Esrey, 1998; Esrey 2001; GTZ, 2001).

The ecosan process can be thought of as a cycle of material flows. The cycle starts with human consumption of food, which then leads to excretion of “wastes.” The excrement then lies fallow in a vault for a processing time (6-12 months for anaerobic conditions). Later it is brought to its reuse destination, where it is distributed to land to be absorbed by plants and/or crops. If these plants are crops, nutrients from the former excrement are consumed again by humans. Conventional (industrialized) sanitation systems break this loop by omitting the processing and reuse steps in the cycle. This research will focus on the point in the cycle in which the material has been processed and is ready for reuse.

Much research has been conducted to characterize the nutrient content of human excreta. An individual’s excreta will vary greatly depending on diet. However, Feachem (1983) compiled results to provide averages of nutrient contents in human excreta. Urine is, on average, 15-19% nitrogen and 11-17% carbon by dry weight. Fecal matter is, in comparison, 5-7% nitrogen and 44-55% carbon by dry weight (Feachem, 1983).

While the value of human excreta as a fertilizer has been recognized for at least 1000 years (Peasey, 2000: 3), ecosan has only recently begun to gain recognition as a technical option that could be institutionally promoted and implemented on a wide scale. In the past few years, there has been an explosion of published material in the field of ecosan¹ (note publications by Sida, EcoSanRes, the United Nations Development Program, the London School of Hygiene and Tropical Medicine, the World Bank, and GZT), and many international development organizations around the world are now studying and implementing various types and designs.

Urine separating toilets offer the most potential for efficient excreta reuse. Urine is the most nutrient-rich component of waste and can be used directly as a crop fertilizer, in

¹ Seminal works published by Sida in the mid 1990’s include Winblad, 1985, Winblad, 1997 and Esrey 1998.

nearly the same nutrient proportions as commercially available fertilizer. The feces can be left to decompose and can be reused, mainly as a soil conditioner (as opposed to a direct fertilizer), after six months to one year. NGOs near Kisumu insist that recently there has been voluntary uptake of the Skyloo, despite only half (8 out of 15) of the facilities built in 1999 were still in use in 2002 (World Bank WSP-AF, 2004).

Motivation

Much ecosan research to date focuses on the health aspects of these systems, yet little work is available on the user's perspective of the theoretical ideal of ecological sanitation. Many practitioners have reported that most ecosan systems are not used in the way that fulfills the real potential of these systems, that is, complete reuse of human excreta (Knapp, 2004). However, little documentation exists on reasons specific users avoid use of the material in places such as local farms or household garden plots.

If there are significant long-term barriers (no demand, not socially acceptable, etc) for use of human excreta from the Skyloo that cannot be overcome, the Arborloo or a more traditional ventilated improved pit (VIP) latrine might be a better option. The Skyloo would, in that case, create a maintenance burden on the community and should not be promoted. If, however, there are opportunities that are not being tapped in the community, these could be identified and ways to capitalize on them could be explored. This research focuses on the barriers of excreta reuse, further developments will be needed to determine if these barriers could be overcome in time.

7.2 Objectives

Research Questions

This thesis is intended to fulfill requirements of degree requirements for a Master in City Planning and Master in Engineering. Therefore, the focus of the research is twofold, and will be integrated the maximum extent possible. The research questions that this research explores are:

- 1.) What are the opportunities for and the barriers to re-use of human waste from an end-users perspective?
- 2.) What is the quality of the reuse material (safe for reuse and nutrient value)?

The first question investigates what is done with excreta after it has been processed. The second question will verify the safety and agricultural potential of the material. In combination, these questions will identify issues related to the "material production" stage of the ecological sanitation cycle. Relationships between perceived safety and actual safety of processed excreta will be noted, as will the relationship between perceived and actual agricultural value. The widespread resource potential of excreta from the systems will be explored.

This research will investigate the research questions by gathering primary data from users of the ecosan facilities through household surveys, and through laboratory analysis of processed excreta samples taken from their facilities. Surveys will be conducted and

samples will be taken during January 2005. Several organizations have been identified that have ecological sanitation projects in western Kenya. A compatible organization will be identified, and the research will be conducted collaboratively in January.

Goals

While there is much documented experience on ecosan promotion and implementation, there is little that speaks to the end user's perspective on the processed material. This research seeks to better understand the point of view of users who are in a position to reuse human waste as fertilizer and the actual reuse potential of the material. It is anticipated that this research will help inform organizations as to the potential for excreta reuse in this area, the safety & nutrient value of the household's composted material, the need for (or success of) previous education campaigns, and how systems can be better adapted to meet the end user's needs.

7.3 Research Plan

There are three main types of ecosan toilets in Kenya: the Arborloo, the Fossa Alterna, and the Skyloo (World Bank WSP-AF, 2004). The Skyloo (the only urine separating device in Kenya) will be the focus of this research². A survey instrument will investigate how households reuse processed excreta and urine, or what households do with the material after processing (e.g. soak-away pit, burial, treated as solid waste, sale/trade to farmers). Users will be asked what aspects of reuse are important to them, if there are ways systems could be improved (from the perspective of reuse of the material), and, if they do not reuse the material, what the main reasons are that the material is not reused. Samples of processed excreta and urine will be tested for fecal coliform, total coliform, nitrogen, and phosphorous and potassium to verify the safe operation of the ecosan facilities and the nutrient content (fertilizer potential) of the material.

Household Survey

Questionnaire Topics

The household survey inquires about user's use of material from the Skyloo and some of the related qualities of the material. Potential questions that will be asked in the survey include:

Processing storage/time

- How do you store your material during the processing time?
- How long do you store it before you use it?

Use

- How do you use after it has been processed?
- How much do you use?
- What do you use it on?
- Do you have any left over?

²For details on the Arborloo and the Fossa Alterna, please see World Bank WSP-AF, 2004. The Arborloo, while popular and highly replicated, has great potential for ground water contamination and, therefore, source water contamination in communities that use groundwater for drinking. The Fossa Alterna is an alternate focus of this research if the partner organization is most interested in this technology.

- What do you do with the left over material?
- Value
- The things I like about my ecosan toilet are (check all that apply):
 - o It is not susceptible to flooding
 - o I do not have to move it when it becomes full
 - o The material that I can use on crops or my garden
 - o It is clean and the materials are nice
 - o Other _____
 - The thing I like MOST about my ecosan toilet is (check only one):
 - o It is not susceptible to flooding
 - o I do not have to move it when it becomes full
 - o The material that I can use on crops or my garden
 - o It is clean and the materials are nice
 - o I like all of these things equally
 - How valuable do you consider composted excreta? (Very valuable, somewhat valuable, not valuable)
 - Do you think you have benefited from use of this material? How?
 - Are you happy with the quality material?
 - Could you use more? (Are you happy with the quantity of the material?)
 - Does it increase your crop yield (if use is on crops)?
 - Do you give any of it to others? (Note these people for subsequent surveys). How much?
 - Do you use other fertilizers? How much? What kinds (animal, commercial)?
- Problems
- What are your complaints/problems with the system?
 - Could these be fixed? How?

Physical Samples

In addition to user surveys, samples of urine and/or feces will be taken from the material that is ready for reuse from existing ecosan facilities to determine proper safe processing of the material. Laboratory samples of excreta and urine will include the following procedures:

- Fecal coliform tests on excreta and urine for each facility
- Nutrient tests on excreta and urine for each facility

8 Evaluation of Program Implementation

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8.1 Background

Over the course of the past five years, the MIT Department of Civil and Environmental Engineering's Master of Engineering program has conducted numerous projects involved with the design and implementation of household drinking water treatment and safe storage (HWTS) systems. These past projects have been conducted in Nepal, Haiti, Nicaragua, the Dominican Republic, and Peru with the current year's project team

focused on Kenya. These individual and team projects have brought the overall household water treatment and safe storage program to a point where a comprehensive evaluation of program implementation practices is now possible and of great interest.

8.2 Objectives

The primary objective of this component is to generate a program implementation tool to aid in the implementation of point-of-use household water treatment and storage systems for local communities in developing nations. The tool is intended to take into account all facets of program implementation and is to be designed with an inherent flexibility in order that it be used by both local communities as well as global agencies, organizations, and enterprises involved in program implementation.

The development of the tool would require a comprehensive evaluation of current point-of-use household water treatment system implementation practices in developing nations. This would be a stand-alone type of analysis that would serve to summarize the currently available point-of-use household water treatment technologies and the agencies involved in their implementation. The analysis would also attempt to identify trends in technology development as well as current and past problems and successes faced in program implementation. Specific areas of interest and issues to address in this analysis include, but are not limited to, the following:

1. **Implementation:** Have past programs been effective in implementing household water treatment systems? What are common problems encountered in regards to these specific areas: role of training and education, correct use, logistics, financing, role of local and national government, local communities and culture, non-profit organizations and aid agencies, job creation, monitoring and data collection and management, locally available materials and resource for construction and repair, available skills, management, and timelines? Are there any problems in scaling-up the projects?
2. **Operation and Maintenance:** What has been the long-term effectiveness of these projects? Is operation and maintenance being performed regularly and properly?
3. **Social Acceptability:** Do residents like the methods presented?
4. **Technical Performance:** Did these systems have the impact for which they were intended?
5. **Improvement:** What improvements could be made to the general implementation process? What problems do new researchers face in the field?
6. **Evaluation:** What are reasonable criteria for judging if systems are truly effective? Are there continuous monitoring programs/systems in place that can track the progress of these systems?
7. **Financial and Human Resources:** What is the role of other agencies in the implementation process? Are the resources of these agencies utilized to their full potential? What roles do local governments play in the implementation process?

The accumulation and review of information on these areas alone may already serve to aid in overall program implementation; however, a more exact application of compiled

information is warranted and subsequently addressed in the development of the program implementation tool. For the purposes of this project, the said tool to be developed will have the specific purpose of facilitating program implementation through the selection of the appropriate technology to be implemented for a particular community of concern. In this context, all of the data collected in regards to program implementation will be analyzed and utilized to generate a mechanism to be used by a number of potential entities to ascertain the technology most suitable for a certain area. It is an inherent assumption, therefore, that by the selection of a proper technology, overall program implementation will have a much greater chance of being effective and successful.

It is anticipated that such a tool will have several applications specific to the entities that see to benefit from more efficient program implementation. As previously mentioned, the tool is to be designed with an inherent flexibility that would allow for its use by both local communities as well as global agencies, organizations, and enterprises involved in program implementation.

For example, one such application might be a tool designed principally for use “by the local community” and not “for the local community” meaning that it will be made to promote a community’s own recognition and comprehension of both the need and the appropriate means of addressing problems related to adequate water quality and supply. The overall intent of such a tool would be to encourage local communities to take matters into their own hands, taking firm and immediate action to address problems threatening community health and well-being, and hopefully imbuing a community to have even more pride and unity in all facets of day-to-day life.

In this context, the tool is not meant to undermine the impressive work being done “for” these communities by local agencies and global organizations, but is instead meant to supplement it. It is a daunting task to reduce by half by the year 2015 the proportion people in the world without access to safe water as stipulated in the millennium development goals, it seems apparent that a unified approach must be taken on a global level to adequately address this problem. With adequate knowledge and motivation, local communities in developing nations can take initiative and determine beforehand what types of systems would be most suitable for their particular situation. With this part of the process accomplished, a community could subsequently contact the appropriate agency, organization, or enterprise and hopefully acquire their aid, or financing in the implementation of these household water treatment systems. It is assumed that the agency, organization, or enterprise in question would welcome such an approach as a large percentage of the work typically required in program or product implementation would have already been completed, the agency or enterprise does not have to inform the community of available technology or even determine if their technology is suitable for the said community. At the very least, the community would have already laid the groundwork and collected the pertinent data for program or product implementation and the agency or enterprise would now only have to verify the data and move forward to subsequent parts of the implementation process. To make things even more favorable, it would already be assumed that the community would welcome the said program, further

facilitating overall program implementation. With this type of grass-roots approach, the global problem of access to safe water might be that much closer to being solved.

The specific tool in question would be a type of business plan with a simplified approach to addressing the problem of adequate water quality and supply. The tool would be designed for use by leaders or local organizations with adequate knowledge of the community in regards to demographics and current water/sanitation/hygiene needs and conditions. The plan would start with the initial goal of providing information about the effects of inadequate water quality and would then provide a discussion of the solutions and technologies available to address such problems. The plan would then take the community leader or local organization representative through a step by step "fill in the blanks" type of process in which pertinent data about the community would be entered. Such data would include but not be limited to the following areas: material availability, local entrepreneurs, social acceptance, and willingness to pay. Upon inclusion of all the said data, the plan, through simple arithmetic, would then produce a score that would indicate the most feasible type of technology. The plan would then provide the community or local organization with the knowledge of how to go about implementing such programs, instructing the community on what steps should be taken next and also directing the community to the pertinent organizations that would be able to help in providing the said technology.

The above discussion pertains to only one application of the said tool. This application could be modified for use by other entities in that an agency could append the plans produced by communities with data that may be more accurate or specific in regards to their type of technology. Or alternatively, an agency in question might use the same parameters utilized by community-based tool in order to develop an entirely different agency-based tool that would have the ultimate purpose of ascertaining whether their particular technology is applicable for implementation to a community in question. A government organization may also use a similar type of tool in determining what particular regions would most benefit from the implementation of a said technology for which funding is already available. Or technologies in the early stages of development might also employ this tool to determine what changes need be made and for such a technology to be effectively implemented in the field.

It is clear that such a tool has the potential of having numerous applications. Furthermore, the said tool addresses one particular method of facilitating program implementation: technology selection. Although it is anticipated that an overall framework from effective program implementation will be established in the development of the said tool, it is apparent that the scope of this project is not sufficient to address all facets of program implementation. Therefore, it is intended that the said tool be modified incrementally in the future to suit different goals and types of program implementation, whether water related or not.

Finally, it is pertinent to emphasize these objectives within the current situation in Kenya. As the Kenya is the specific focus of Team Maji, all objectives mentioned will be made with the current parameters of Kenya in mind. This requires that a bulk of the

technologies and agencies evaluated will be those that are currently present and applicable to the country and that the subsequent tool developed will be geared more for use by local communities in that area. Although an effort will be made to make the document applicable to a range of communities in developing nations, it must be cited that the initial development of the tool will have been produced for current conditions in the nation of Kenya.

8.3 Research Plan and Methodology

Research for the project will be accomplished through the following approach: (1) a review current literature and past projects focused on HWTS program implementation, (2) development of a survey instrument with potential global applicability, to collect data on HWTS programs, (3) pre-testing of the survey instrument through phone interviews, (4) conducting this survey in Kenya during January 2005 through interviews with Kenyan agencies involved in the implementation of various point-of-use household water treatment technologies, and (5) survey analysis and development of the implementation tool.

As a starting point, a comprehensive review and analysis of available literature and past projects focused on program implementation will also be performed. The purpose of the literature review is to provide background information that will assist in the development of a survey instrument. For instance, the Master of Engineering Program at MIT has produced several theses that have touched upon factors to be considered in the implementation of point-of-use household water treatment technologies. The information contained in these theses is valuable in that several important variables have been identified in the selection and review of these systems, some of these variables being social acceptance, financial viability, and ease of operation and maintenance. Several select theses will be reviewed in reference to general obstacles encountered during the implementation process. Observations in regards to the execution of these technologies will be consolidated for consideration in the future implementation of other programs. Apart from this, there have been several publications on the current state of global water supply and sanitation and the applicability of point-of-use household water treatment. These will be reviewed as well.

The survey of global and local Kenyan agencies involved in implementation of various household water treatment and safe storage technologies (HWTS) will be accomplished through the development of a standard, comprehensive, and efficient survey tool that will be used to acquire data through various media from agencies and organizations involved with program implementation. The tool will be used prior to the Kenya site visit to acquire as much data as possible regarding available household scale water treatment and storage technologies from an assortment of agencies dealing with these types of technology. The term “agencies” actually encompasses all organizations, universities, enterprises, and local and national government entities that might be involved with the promulgation of household water treatment technologies. These agencies will be selected based on their experience with the implementation of household water treatment and other similar systems on both a global and a local scale. Some of the global agencies selected are the CDC (Center for Disease Control and Prevention), CARE (a

Humanitarian Organization Fighting Global Poverty), CAWST (Centre for Affordable Water and Sanitation Technology), Potters for Peace (an independent, nonprofit, international network of potters concerned with peace and justice issues) and UNICEF (United Nations International Children's Emergency Fund). These global agencies will also be selected both for their direct application to the Kenya as well as for the global impact of their projects. Similar technologies being produced by private companies such as Procter & Gamble's PuR water purification sachets will also be evaluated as well as select universities and educational institutions around the world currently involved with household water treatment. In addition to these sources, it is also intended that data and input be gathered from renowned experts in the field of water and sanitation in developing nations

The bulk of the previously mentioned data gathering using the said survey tool is intended to be accomplished as much as possible before the site visit to Kenya in January, 2005. This is done both in order to gain insight into the effectiveness and uniformity of the survey tool as well as to gather preliminary data prior to the hitting the ground. Through these phone interviews, the survey tool will be modified to correct potentially vague areas and to generally hone in on the specific information that is most important and readily available. The survey tool will be streamlined in anticipation of time constraints and a lower available margin of error in the field. Upon modification, the survey tool will be in a condition to effectively collect data in a more efficient and clear manner for use in the field.

The said survey will then be continued during the site visit to Kenya. Local agencies and organizations with outfits in the country will be visited personally to conduct interviews and general methods of program implementation will be observed. Such relevant local agencies include but are not limited to the Kenya Water for Health Organization (KWAHO), the Kenya Ministry of Health, the Kenya Ministry of Local Government, the City Council of Nairobi, the Nursing Council of Kenya, and the Oriang Women's Pottery Group. These agencies will aid in determining reasonable criteria for judging if systems are truly effective and whether there are continuous monitoring programs in place that can track the progress of such systems. The methods and procedures used by these agencies will be analyzed for effectiveness and applicability to a household level. Local government entities will aid in identifying the social impacts of such systems and the overall approach desired in the implementation of such systems.

Additionally, current MAJI projects will be evaluated to determine, on a first-hand basis, the typical challenges to a technology during the early stages of research design and development. Many of these projects are associated with larger implementation programs, and these too will also be evaluated.

All research conducted and data collected will be organized and evaluated for consideration in the generation of the implementation tool to be used in the selection of appropriate water treatment technologies. The information obtained will be presented as parameters in the tool that need to be determined for system evaluation. The final product will be an all-inclusive tool that would have taking into account practices and experiences

from a multitude of global and local agencies. Past research pertaining to household water treatment and storage systems will also be assimilated into the said tool.

Time permitting, the evaluation tool will be field tested by applying it to a current model community in the spring of 2005.

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Appendix A: Team Resumes

Michael P. Pihulic

pihulic@mit.edu

Term: 3 Ames Street ; Cambridge, MA 02142 ; 617.225.9561

Home: 5321 NW Glenn ; Lawton, OK 73505 ; 580.353.8556

Objective	To obtain a position in environmental engineering with areas of interest that include modeling, transport processes, and policy.		
Education	2000 - present <i>Proposed Curriculum:</i> <i>Graduation date for MEng degree:</i> <i>Current GPA:</i> <i>Coursework:</i>	MIT SB in Environmental Engineering MEng in Environmental Engineering June, 2005 4.6	Cambridge, MA
	Environmental Engineering: Transport Processes, Air Pollution: Processes and Controls, Hydrology, Groundwater Hydrology, Water Quality Control, Geology, Environmental Microbiology Engineering: Mechanics and Materials I, Introduction to Robotics, Circuits and Electronics, Signals and Systems Policy: Public Policy, Policy Analysis, Society and Environment,		
Relevant Experience	Summer 2004 <i>Graduate Researcher</i> – Investigated the role vortices serve in transport in open channel vegetated systems using Laser Doppler Anemometry. Developed techniques for visualizing vortices created by shallow-shear-layers in vegetated beds.	Parsons Laboratory	Cambridge, MA
	2002 - 2003 <i>Undergraduate Researcher in the Responsive Environments Group</i> – Assisted in the fabrication and implementation of several projects. Designed and constructed a showcase for SIGGRAPII 2003. Worked on the fabrication of an ultra-low cost sensor network for use with large-scale interactive events. Fabricated a densely packed distributed sensor network for developing pushpin computing. Prototyped and designed a parasitic power harvester that converted mechanical motion into electrical power for a remote control.	Media Laboratory	Cambridge, MA
	Summer 2001 <i>Undergraduate Researcher</i> – Worked with a team of undergraduates to fund, to design, and to implement an introductory seminar into mechanical engineering for freshmen. The seminar culminates in the design and creation of a remote control car using the basic machine shop tools and plastic injection molding. The program is currently in its fourth year and is one of the staple pre-orientation programs for freshmen.	Dept. of Mechanical Engineering	Cambridge, MA
Skills	<i>Programming Languages:</i> Java <i>Tools:</i> Solidworks, Protel, ModFlow, Matlab, Lathe, Mill, <i>Photography:</i> Experienced in printing, developing and shooting		
Activities	Served as the Photography Editor and the Living Groups Editor for the MIT yearbook, Technique Member of the MIT varsity fencing team for four years		

SUZANNE E. YOUNG

Current: 305 Memorial Drive
Cambridge, MA 02139
suzanne@mit.edu
617.225.9823

Permanent: 14134 Daylight Ridge
San Antonio, TX 78230
yangcuiyi@yahoo.com
210.558.8711

OBJECTIVE

A full-time, entry level environmental engineering position with a focus on integrated water resources engineering and management.

EDUCATION

Massachusetts Institute of Technology

Cambridge, MA. Master's of Engineering in Environmental Engineering. **June 2005**

Bachelor of Science in Environmental Engineering. Minor in Chinese. GPA 4.2 / 5.0. **June 2004**

Relevant Courses: Design of Water Resource Systems; Fluid Transport and Processes; Fluid Mechanics; Hydrology, Applications of GIS in Environmental Engineering, Database, Internet and Systems Integration Technologies.

Health Careers High School

San Antonio, TX. Graduated third in class of 220. GPA 99.3/100. **May 2000**

EXPERIENCE

Environmental Engineering Clinic

February – June 2004

M.I.T., Cambridge, MA. Predicted how changes in Nile River flow caused by climate change will affect the power generated by Sudan's Merowe Dam. Discovered drier climates may not cause the dam to produce less electricity due to inter-monthly flow variations among climate scenarios.

M.I.T. Undergraduate Research Opportunities Program

June 2003 – May 2004

M.I.T., Cambridge, MA. Assisted in development of models for nutrients behavior in urban watersheds by measuring the fluxes of nitrogen in the Aberjona Watershed to identify sources of nitrogen, determine seasonal changes, and determine magnitude of transport occurring in the Aberjona River.

Study Abroad and Internship in China

June – December 2002

Tsinghua University, Beijing, PRC. Actively engaged in intensive studies of the Chinese environment, industry, language, and history. Traveled extensively to see first-hand environmental conditions and environmental projects.

NASA Summer High School Apprentice Research Program (SHARP) Plus

June – August 1999

Stanford University, Stanford, CA. Designed and constructed a miniature satellite with a laser payload inside of a soda can and a ground control station. Earned amateur radio license.

SKILLS

Computer: MATLAB, Arc GIS, C++, Microsoft Word, Excel, Power Point.

Languages: Fluent in English, nearly fluent in Mandarin, proficient in Spanish and Cantonese.

HONORS

Target All-Around Scholar, Advanced Placement Scholar, National Honor Society.

INTERESTS

Certified lifeguard, captain of intramural ice hockey team, reading historical fiction, playing Scrabble.

Amber Franz
amfranz@alumni.unc.edu

Current School Address
350 Memorial Drive
Cambridge, MA 02139
(857)-225-0406

Permanent Address
8712 Mariner Drive
Raleigh, NC 27615
(919)-846-2939

Objective: To improve water sanitation and purification practices in developing countries

Education: **Massachusetts Institute of Technology** – September 2004-June 2005

- Candidate for Master of Engineering degree in Civil and Environmental Engineering
- Concentration: Environmental and Water Quality
- Related Coursework: Groundwater Hydrology, Applications of GIS in Environmental Engineering, Aquatic Chemistry, Environmental Microbiology

University of North Carolina at Chapel Hill (UNC-CH) – August 2000-May 2004

- Bachelor of Science in Chemistry (Biochemistry track) with Honors: GPA 3.5/4.0
- Honors: Dean's List 5 semesters
- Related Coursework: Biological Chemistry, Organic Chemistry, Inorganic Chemistry, Biochemistry Lab, Analytical Chemistry and Lab, Physical Chemistry and Lab, Economics, Statistics

Study Abroad/Exchange: University of New South Wales: Sydney, Australia – spring 2002

- Related Coursework: Biological Organic Chemistry and Lab

Experience: **MIT Master of Engineering Project**, Water Quality Researcher, Kenya or Nepal – January 2005

- Plan to assess and improve the quality of household drinking water for occupants of rural areas

UNC-CH Pharmacology Department, Diabetes Researcher – March 2003-April 2004

- Determined the effects of the glitazones, zinc, and a cinnaman compound on proteins involved in the glucose metabolism pathway of 3T3-L1 mouse adipocytes

GlaxoSmithKline, Metabolic Disease Intern, RTP, NC – May-August 2003

- Developed an assay for measuring fatty acid oxidation in rat tissue homogenates for use in obesity research
- Measured the effects of drugs on fatty acid oxidation of H9C2 rat cardiomyocytes

Rex Hospital, Volunteer, Raleigh, NC –February 2002

- Interacted with patients and assisted nurses with the distribution of food, linens, and other necessities

GlaxoSmithKline, Quality Control Intern, Zebulon, NC – May-August 2001

- Revised laboratory methods; organized information for filter validation; prepared samples for quality assessment

Leadership: **UNC-CH Chemistry Department**, Speaker at chemistry commencement ceremony – May 9, 2004

Carborro Elementary, Reading Tutor, Carborro, NC – October 2003-April 2004

- Aided individual first and third grade students in the development of reading skills

UNC-CH Women's Club Soccer Heels, Captain/Treasurer – August 2002-April 2003

- Collected and allocated funds for tournaments and gear
- Advertised and organized Sports Club Boat Race Fundraiser
- Designed T-shirt logo for Boat Race

Healthy Start Academy, After-school Tutor, Durham, NC – October 2002-April 2003

- Supervised and assisted groups of elementary students with reading and homework

Skills/Interests:

- Computer Skills: Microsoft Office, Data Studio, Mathcad
- Extracurricular Interests: soccer, tennis, art, skiing, swimming, reading, traveling

B.Loux

Pragnya Alekal

350 Memorial Dr., #307, Cambridge, MA 02139
(617) 225-7398 pragnya@mit.edu

Interests

Sustainable Design, Technical and Management Consulting, Environmental Policy and Education

Education

Massachusetts Institute of Technology (MIT) *Cambridge, MA*
Candidate for Master of Engineering in Environmental Engineering, June 2005
Coursework: Environmental Law, Sustainable Design, GIS Systems, Hydrology, and Chemical Transport.

University of California, Los Angeles (UCLA) *Westwood, CA*
Bachelor of Science in Civil and Environmental Engineering, June 1999
FE Certified, 1999 School of Engineering Commencement Speaker, 1999 UCLA Engineering Achievement Award, 1998 Samuel Fletcher Tapman Scholar, 1995-1996 Dean's Honors List, Chi Epsilon Honor Society, several team awards for ASCE student-chapter work.

Experience

Hostelling International (HI), Fellow – 2003-2004 *Seoul, South Korea*
Youth Festival for Peace - Jan-July 2004
Interfaced with a team of HI and UNESCO employees to design, construct and implement an International Youth Festival for Peace in South Korea. Facilitated all aspects of the Festival - from conceptualization to planning to execution. Edited and consolidated key material for the Festival. Succeeded in bringing together over 400 youth from 35 countries across all 5 continents.

Learning Centers for Peace - Aug-Dec 2003 *Assisi, Italy*
Worked independently with HI and UNESCO to promote "Peace and Understanding" through youth activity. Initiated and implemented peace workshops for children (age 13-18) in local schools. Networked with local organizations to coordinate an International Conference on Peace, and Italy's largest peace march.

American India Foundation, Service Corps Fellow – 2002-2003 *India*
Served out a 10-month Humanitarian Fellowship in India. Worked with local organizations to support education, health, and environmental awareness. Assessed existing health programs and implemented new ones (field work); performed experiments with local school children; produced educational materials, such as books, videos, and science articles. Targeted underprivileged women and children. Traveled extensively.

ProjectDesign Consultants Inc., Assistant Civil Engineer - 2001 *San Diego, CA*
Designed and supported the design of several land development projects. Executed drainage and utility studies. Performed pre/post-submittal plan checks. Prepared plot plans. Worked extensively on AutoCAD 14 and 2000. Acted as primary group liaison to the City of San Diego.

United States Navy, Officer Candidate - 1999-2000 *Pensacola, FL*
Attended Naval Officer Candidate School. Performed various duties including mentoring boot camp graduates, medical assisting, and postal clerking. Learned valuable leadership skills. Honorably discharged.

Center of Environmental Risk Reduction, Intern - Summer 1998 *Westwood, CA*
Studied the effects of perchloroethylene (PCE) in groundwater. Conducted research necessary to calculate the mass transfer coefficient of PCE.

Skills

Computer: AUTOCAD 14/2000, Softdesk, Windows XP, basic HTML

Personal: Strong interpersonal, public speaking, and writing skills; Fluent English, Hindi, Konkani; Basic Italian.

Hongchul Jang

Term Address

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Cambridge, MA, 02139, U.S.A.
1 (617) 577 – 5797, Email : hongchul@MIT.EDU

Home Address

129 - 1301 Solecity, BojungRi, GusungEup,
YonginSi, KyunggiDo, 449-913, Republic of Korea,
82 (2) 544- 0555

OBJECTIVE : Apply Chemical and Environmental Engineering knowledge towards a position with a consulting firm or in industry which will utilize my interpersonal engineering, particularly in environmentally benign energy including Fuel Cell and in Water Quality.

QUALIFICATIONS : Highly experienced and enthusiastic Chemical Engineering graduate skilled in project management and various computer languages. Fluent in Korean and English; conversant in Japanese.

EDUCATION

Massachusetts Institute of Technology (MIT), Cambridge, MA

Candidate for Master of Engineering in Civil & Environmental Engineering Sep. 04 - Present

- Degree Concentration in Environmental Chemistry & Microbiology, and Water Quality.

Yale University, New Haven, CT

Master of Science in Chemical Engineering, May 2004 Sep. 02 – May. 04

- Specialization in Catalytic Reaction, Environmental Engineering and Biological Applications.
- Research Assistantship (Spring 04, Fall 03), Faculty of Engineering Fellowship (Spring 03, Fall 02)

Korea University, Seoul, Korea

Bachelor of Engineering in Chemical and Biological Engineering, February 2001 Mar. 95 - Feb. 01

- The Excellent Student Award (Fall 02), Awarded Outstanding Scholarship (Spring 98), Dean's list

University of California at Berkeley, Berkeley, CA

Exchange Student with full scholarship, mini-MBA in the Haas School of Business Jul. 00 - Aug. 00

- Developed business skills in Competitive Strategy, Marketing, Management, Accounting, Presentation, and Negotiation.

WORK AND RESEARCH EXPERIENCE

Seoul National University, Seoul, Korea

Research Assistant, Enzyme & Environmental Biotechnology Laboratory Jun.04 – Aug.04

- Participated in a project to the removal efficiency of nitrate in the bioelectrochemical system.

Yale University, New Haven, CT

Research Assistant, Environmental Organic Chemistry Laboratory Jul. 03 - May. 04

- Participated in a project to prevent of the formation of N-Nitrosodimethylamine during wastewater chlorination.

Participant, Division of the Science

Jan. 03 - Jan. 04

- Manufactured a telescope and a small working engine.

Laboratory intern, Reaction and Catalytic Engineering Laboratory

Sep. 02 - May. 03

- Introduced to the area of reactions of jet fuel for micro combustor and micro fuel cell applications:

Korea Institute of Science and Technology (KIST), Seoul, Korea

Research Scientist, Energy Engineering Laboratory Aug. 01 - Jul. 02

- Collaborated on the development of a kW-class methanol steam reformer for fuel cell vehicle.

- Investigated various supported transition metal foundations for the POX reforming of iso-octane.

Part Time Intern, Energy Engineering Laboratory Aug. 00 - Jul. 01

- Focused on environmental pollution treatment based on Supercritical Water Oxidation (SCWO).

MILITARY SERVICE

Korean Army, Defense Security Command, Seoul, Korea Jan. 96 - Mar. 98

- Operated PGP (Pretty Good Privacy) program to code and decode classified documents.

SKILLS

Computer Applications

- Matlab, Simulink, Origin, Visio, Sigma Plot, Photoshop, MS Word, PowerPoint, Excel
- Program Language : C, C++, HTML, Fortran

PUBLICATION

Seo-Tae Choo, **Hongchul Jang**, Suk-Woo Nam, Jonghee Han, Sung Pil Yoon, Tae-Hoon Lim and Seung-Ahn Hong.
"Methanol steam reforming using ceramic foam", *Theories and Applications of Chemical Engineering*, Vol 8 (1), 2002.

OTHER ACTIVITIES

Vice President, Yale Korean Graduate Student Association (YKGA), New Haven, CT Sep. 03 - May. 04

President, Department of Chemical Engineering, Korea University, Seoul, Korea Sep. 98 - Feb. 99

Member, MENSA International Mar. 98 - Present

BRIAN E. ROBINSON

395 Harvard Street #6, Brookline, MA 02446

ber@mit.edu
<http://web.mit.edu/ber/www>

EDUCATION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY 2005
Master in Engineering Candidate, Water Resources (anticipated)
Master in City Planning Candidate, Environmental Planning
GPA: 4.6/5.0
Coursework:

- Water Resource Management
- International Planning
- Economics
- Chemical Fate and Transport
- Water Quality Modeling
- Environmental Policy
- Groundwater Hydrology
- Water and Sanitation Planning
- Statistics

GEORGIA INSTITUTE OF TECHNOLOGY 1999
Bachelor of Science, Earth and Atmospheric Science

AWARDS/HONORS

- Graduate Fellowship Award, 2 years (MIT, Department of Urban Studies and Planning)
- "Outstanding Senior in the Department" Award (Ga. Tech, Department of Earth and Atmospheric Sciences)
- HOPE Scholarship Recipient, 4 years (Ga. Tech)

EXPERIENCE

CONSERVATION LAW FOUNDATION VENTURES, INC. May 2004- August 2004
Consulting/Environmental Planning Intern; Boston, MA
Provided project support and analysis for the consulting arm of the Conservation Law Foundation.

- Strategically analyzed disposition options of decommissioned land for nuclear power client
- Addressed challenges of stakeholder engagement with industrial/utility clients

PATAGONIA, INC. January 2003- August 2003
Environmental Programs Coordinator; Boston, MA
Oversaw environmental events, donations, and budgeting for the Boston store.

- Oversaw \$8000 budget earmarked for grants and in-kind donations to local organizations
- Managed events schedule and invited speakers to give public presentations
- Assisted with product sales and customer education

UNITED STATES PEACE CORPS, SICHUAN UNIVERSITY June 2000- June 2002
Environmental Education Field Volunteer; Chengdu, China
Full-time instructor in the Department of Environmental Science and Engineering at Sichuan University.

- Taught a variety of classes including environmental science, outdoor recreation, and leadership training
- Planned, managed and secured funding for an independent ecotourism research project (see Research Section)
- Designed 10 environmental awareness student projects

RESEARCH

International Riverfront Planning and Development, MIT

- Participated in a planning workshop focused on infrastructure design and urban canal planning in Foshan, China

Collaborative Ecosystem Management, MIT

- Assisted Dr. Judith Layzer in research of US-based collaborative ecosystem management plans

Land Use and Ecotourism Development, Peace Corps

- Initiated and oversaw all aspects of a 10 week class and a 2 week field experience for a 13-person team

Hydrology and Geophysics, Georgia Tech

- Characterized the surficial aquifer and groundwater flow using geophysical exploration methods and well monitoring

SKILLS

Languages: Mandarin Chinese (intermediate skills, conversationally comfortable); Spanish (intermediate skills)

Computer Programs: Adobe Photoshop, Adobe Illustrator, ArcGIS, FORTRAN (programming language), Microsoft Office Suite, MX Dreamweaver, SPSS

Research: Qualitative data collection and analysis, well installation and hydrologic sampling methods, statistical research methods, geophysical research methods, Global Positioning System use in mapping

ROBERT MICHAEL N. BAFFREY
Civil Engineer

143 Thorndike Street Apt. 2, Cambridge, MA 02141
Telephone number: (617) 953-7542
E-mail address: baffrey@mit.edu

EDUCATION	Massachusetts Institute of Technology Cambridge, Massachusetts Master of Engineering in Environmental Engineering	June 2005
	University of the Philippines, Diliman Quezon City, Philippines Bachelor of Science in Civil Engineering (GPA: 3.2/4.0)	April 1999
WORK EXPERIENCE	CRW Engineering Group, LLC Anchorage, Alaska Civil Engineer Design engineer and inspector for general civil projects. Technical support for various water, wastewater, roadway, trail, and drainage improvement projects through CAD design and drafting. Preparation of sanitation facility master plans, feasibility studies, and business plans for rural communities in Alaska.	November 2001 – July 2004
	Vibrametrics, Inc. Quezon City, Philippines Jr. Structural Performance Engineer Analysis of structures, survey of structures including vibration measurement, computerized model construction, preliminary design of retrofit and rehabilitation schemes, and detailed preparation of contracts, reports, and presentations.	June 2000 – August 2001
	ASD Consultant Alabang City, Philippines Project Manager In-depth research, feasibility studies, and detailed fabrication of proposals for various projects. Direct and indirect supervision of ongoing construction projects. Assistant to the President of the company, Architect Antonio S. Dimalanta.	March 2000 – June 2000
	Procter & Gamble in Association with the National Engineering Center Research Assistant and Water Current Meter Operator Laguna River Dying Project, San Pablo City, Laguna, Philippines	April 1999
	National Engineering Center Researcher and Analyst Environmental Impact Assessment for Roxas City, Capiz, Philippines	March 1999
	Government Funded Taskforce BISA (Building Integrity and Safety Assessment) Building Inspector and Safety Analyst	Summer 1998
AWARDS AND HONORS	<ul style="list-style-type: none">➤ Licensed Civil Engineer. Placed 5th out of 5,980 examinees with an average score of 90.5 in the November 1999 Philippine Civil Engineering Board Examination.➤ Number 1 out of 34 successful University of the Philippines examinees in the November 1999 Philippine Civil Engineering Board Examination.➤ Second in Class, University of the Philippines B.S. Civil Engineering, 1999.	
SKILLS	<ul style="list-style-type: none">➤ Computer: Microsoft 2000 Word, Excel, PowerPoint, and Photo Editor. 2004 AutoCad R14 and Land Development Desktop. 2000 Adobe Photo Editor, 2000 Haestad Flowmaster, and 2004 Strand7 (Finite Element Analysis System).➤ Languages: English and Filipino, both written and oral.	
LEADERSHIP AND ACTIVITIES	<ul style="list-style-type: none">➤ Member. Philippine Institute of Civil Engineers (PICE).➤ Alumnus. Member. U.P. Association of Civil Engineering Students (UP ACES).➤ Officer. International Civil Engineering Quiz.➤ Member. U.P. Circle of Entrepreneurs (UPCE).➤ Athletics:<ul style="list-style-type: none">• Medallist on Championship Team (Ateneo Basketball League).• Captain on 4-time Engineering Championship Team (UP Diliman).	2000 – Present 1995 – Present 1996 – 1998 1997 – 1998 2001 1997 – 2001
PERSONAL DATA	Citizenship: American	

Appendix B: Team Schedule

Preparation for Fieldwork

October 8, 2004	Letter of Intent submitted
October 22, 2004	Interim research reports
November 1, 2004	Marketing/Sales team joins MAJI
November 8, 2004	Draft Proposal submitted
November 19, 2004	Background research complete
November 19, 2004	Finalized research plan with CDC
December 3, 2004	Final Proposal submitted
December 3, 2004	Final Proposal presentation

Fieldwork

January 2, 2005	Team arrives in Nairobi, Kenya
January 5, 2005	Travel to individual field sites
January 20, 2005	Fieldwork complete
January 27, 2005	Return to Cambridge, MA, USA

Post-fieldwork

February- April	Data Analysis/ Write-up
April-May	Submit Final Report

Appendix C: Team Costs

Labor Costs

Eight student researchers will be working in Kenya along with three supervisors. During the time in Kenya the team members will be working 8-hour days, from January 3-22. The duration of the trip is twenty days, resulting in a total of 1280 person-hours for the eight-member team. Post-trip work will include data analysis, further lab work, report writing and presentation. During February, March, and April, the team members will expend 20 per week, per person resulting in a total of 2240 hours. The total number of hours expected for the project is 3,520 hours.

Travel Costs

Additional cost will be incurred in the traveling expenses to Kenya. The current air ticket price to Kenya for team members averaged approximately US\$1,400. For eight team members, air travel costs total approximately US\$11, 200.

Materials Costs

The cost of equipment will be a significant amount of the total cost of the project. Each research area will have additional expenses related to laboratory analysis and specific research methodologies. In some cases, the POU systems employed in the study must be purchased along with the additional supplies needed for their installation. In others, materials to make filtration systems are needed.

The research methods for all programs have not been finalized and, as such, detailed reports of materials costs cannot be calculated. When research plans become final, the team's total materials, travel, and labor costs will be compiled into a summary budget.