2006-90: SERVICE LEARNING AT CINCINNATI: RESEARCHING WATER TREATMENT FOR EMERGING ECONOMIES

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Service Learning at Cincinnati: Researching Water Treatment for Emerging Economies

Abstract

Of the nearly six billion human inhabitants of planet earth, nearly two thirds lack access to sufficient quantities of potable water and access to basic sanitation. These appalling conditions result in the deaths of millions of children each year from preventable waterborne diarrheal disease. At the University of Cincinnati, two female graduate students have undertaken MS degrees with the specific objective of performing service learning where the research focus of their respective degrees is validating and deploying appropriate technology for water quality treatment in developing countries. This presentation will highlight the results of these research projects as well as the difficulties associated with implementing a service-learning approach to MS degrees within a traditional research-intensive graduate program.

Introduction

Sustainability, defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1], has emerged as a critical component of research and education within the field of Environmental Engineering. As reflected in presentations and lengthy discussions at the semi-annual gathering of the Association of Environmental Engineering and Science Professors (AEESP, 2005), a major challenge for incorporating sustainability into a graduate research program is the need to identify appropriate projects and interested students producing the quantity and quality of research results comparable to other traditional areas of Environmental Engineering. Often, research in sustainability must be boot-strapped from piecemeal funding opportunities, and it must leverage a diverse collection of interested parties including Non Government Organizations (NGOs), student activists, and willing segments of society. At the University of Cincinnati, we have adopted a service learning approach wherein targeted research questions are integrated with an opportunity to practice the tenants of sustainability in the context of an engineering design and build project.

Targeted Research Questions

The microbiological quality of water is a major factor in the spread of waterborne infectious disease. Fecal-oral exposure due to contamination of drinking water supplies is a major public health concern for emerging economies. Two sustainable approaches to address this concern include: (1) pollution prevention where education can be a primary means of improving microbiological water quality; and (2) cost efficient, point of use (POU) drinking water treatment and storage. A number of competing technologies have been developed as POUs for drinking water treatment in emerging economies. These technologies range from less sustainable solutions such as disinfection and/or coagulation using chemical addition versus more sustainable solutions such as slow sand filtration, filtration with porous pots, or filtration with cloth materials.

Although limited prior work has evaluated the ability of each of these alternative POU technologies to provide safe drinking water, a systematic study of the efficacy of the filtration technologies to simultaneously remove model microbiological contaminants is needed. Thus, the specific research questions to be addressed during the course of the MS degree are: (1) do filtration technologies provide differential removal of viruses, bacteria, and protozoa?; and (2) do conventional measures of reductions in fecal pollution correlate to actual removal efficiencies for viruses, bacteria, and protozoa? To answer these questions, representative POUs have been constructed in the laboratory. The two technologies under evaluation include custom built slow sand filters and commercially available porous pot filters. As part of the laboratory-based study, existing cultivation and novel molecular biology based techniques are being employed to quantify the efficacy of removing Polio LVS, *Pseudomonas aeruginosa*, *Clostridium perfringes*, and *Naegleria fowleri* as a model virus, gram negative bacteria, gram positive bacteria, and protozoa, respectively. Removal efficiencies for these microorganisms in saline buffer are being compared to measurements of removal efficiency for culturable fecal coliform bacteria in raw Ohio River water and saline buffer dosed with *Escherichia coli*.

Context for the Engineering Design and Build Project

To provide a field-based, service learning component to this research project, the MS students teamed with the Village Life Outreach Program (VLOP) headquartered in Cincinnati, OH. The VLOP is a group of professionals including medical personnel who volunteer time, talent, and treasure to help the people in and around the village of Roche, Tanzania. VLOP volunteers visit Roche annually with the objective of improving the overall well-being (e.g., morbidity, mortality, and education) of the community. In October of 2005, VLOP volunteers provided medical care and nursing for 155 patients suffering from diseases that could have been significantly diminished or eliminated with proper drinking water supplies and sanitation (e.g., urinary tract infections, malaria, amebiasis, helminthiasis, schistosomiasis, and taeniasis). Based upon their prior experience working in Roche, the leadership team of the VLOP recognized the need to provide improvements in water supply infrastructure and sanitation as a long-term solution to improve public health in the village.

The village of Roche is located in the Tarime District of northern Tanzania, Africa just south of Lake Victoria. The infrastructure in Roche is limited: in fact, there are no facilities for drinking water or wastewater treatment, and electrical power is not available. Travel is primarily by foot or bicycle along packed dirt roads. The landscape is semi-arid, so the villagers have constructed two ponds to provide water for livestock and household uses (e.g., washing and cooking). Often, the pond reserved for household uses is exhausted and the remaining pond is used for both livestock and households. During the site visit, it was observed that the cattle are free range, and have been allowed to consume water from both ponds. Drinking water is provided for the village using a single bore-hole well equipped with a hand pump. Unfortunately, the distance between the well and the village is greater than the distance to the ponds. Thus, many villagers use pond water as a source of drinking water.

Water is transported from the ponds and the well to homes and schools in narrow-mouthed plastic containers. Although personal interviews with the villages indicated that they were aware that boiling of the pond water was necessary before consumption, many indicated that the

associated costs for fuel for boiling the water were significant. Furthermore, it was observed that many children consumed water before it had been boiled thus being exposed to the fecal pollution clearly present in the ponds. Finally, it was observed that the drinking water from the well was collected and transported in the same containers used to collect water from the ponds without appropriate disinfection of the plastic containers. Thus, fecal contamination of the drinking water in Roche is clearly a significant problem.

Appropriate Methods of Water Treatment

Based upon a literature review, five major technologies were identified for drinking water treatment in developing countries, namely: 1) Sand Filtration, 2) Porous Clay Filters, 3) UV/ Sunlight Disinfection, 4) Chlorination, and 5) Distillation[2]. Sand filtration makes use of local materials including gravel and sand as well as storage containers to provide slow sand filtration. Porous clay filters can be constructed from local materials, but they require high temperature ovens to fire the clay, and available design instructions indicate the need for colloidal silver as an additional coating for the clay to reduce microbial contamination. UV/sunlight disinfection shows promise for sustainable use, but the particulate load on the source water must be sufficiently low to permit penetration of UV irradiation into the water. Chlorination requires either on-site generation of chlorine or the purchase and transport of clorine from a vendor, and distillation is an energy intensive process equivalent to boiling. Based on available resources within the village and considering issues of sustainable design, Sand Filtration or Porous Clay Filters were evaluated as the most appropriate methods for treating drinking water in Roche. These two methods were reviewed in depth, and laboratory-scale mock-ups of each technology were constructed at the University of Cincinnati. During these laboratory-scale trials, it was observed that the Porous Clay filters suffered an unacceptable rate of failure during manufacturing and transport. Furthermore, the Porous Clay Filters require the use of colloidal silver, which was determined to be unavailable in Roche. Thus, although the original focus on Porous Clay Filters as a means of drinking water treatment and cottage industry for the village appeared promising, the Porous Clay Filters were abandoned in favor of Sand Filtration.

In October, 2005 during the annual visit of the VLOP to Roche, three slow sand filtration units were constructed. Unsorted earthen material was collected from a quarry and sorted by size using sieves. Dust was removed by 'washing' the three fractions with wind and water. PVC piping imported from the United States was assembled to create a drain and siphon. Coarse gravel was hand packed to a depth of three inches; coarse sand was hand packed to a depth of two inches; and fine sand was packed to a depth of sixteen inches. The sand was packed in the housing while it was filled with water to remove air bubbles and prevent short circuiting during filtration.

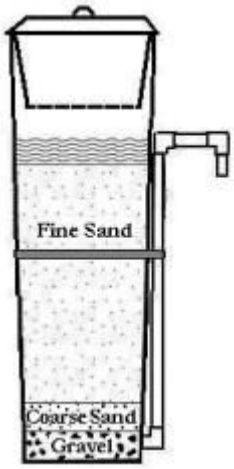

Figure 1. Schematic of a slow sand filter. Water is maintained in the filling chamber. Filtration occurs on the surface of the fine sand (e.g., schmutzdecke) while the coarse sand and gravel provide a support for the sand and a drain for the filter, respectively.

After construction, pond water was tested with the HACH PathoScreen Field Test Kit both before and after filtration. Prior to filtration, the sample turned black, indicating presence of fecal material. After filtration, the samples produced negative results with the test kit indicating that the filters were successfully removing measurable levels of fecal material from the water. As of January, 2006 the filters were operating to purify drinking water in Roche. Follow up efforts in 2006 are expected to results in the construction of additional filters in the village.

In the first year, major accomplishments of the project included: (1) performing a literature review to identify suitable POU technology; (2) evaluating POU technology for sustainability and appropriateness for the local setting of Roche, Tanzania; (3) acquiring representative POU technology and performing preliminary testing in the laboratory at Cincinnati; and (4) site visit to Roche, Tanzania and installation of three Sand Filters. In the second year of the project, we expect to perform laboratory-scale characterization of the Sand Filters for removal of representative viruses, bacteria, and protozoa; and we will re-visit Roche to inspect and evaluate the continuing performance of the existing filters and to construct additional filters.

Concerns for Service Learning within a Research Intensive Program

The ongoing collaboration between MS students in the Environmental Engineering and Science Program at the University of Cincinnati, the members of the Village Life Outreach Program, and the villagers in Roche, Tanzania is an excellent example of service learning where classroom skills are put to use to solve a real world problem. The challenge for this project was identifying an appropriate research question that could be performed in parallel to the service learning activity. The construction of slow sand filters in Roche, Tanzania can be viewed as a useful learning activity but it is limited in terms of research findings. Therefore, to provide an appropriate degree of rigor necessary to complete a graduate degree in a research intensive program the MS candidates are integrating advanced analytical techniques and laboratory-scale model systems to address relevant research questions for the slow sand filters constructed in the field.

Although feedback from the participants indicates that the approach described above successfully integrates research and service learning, an unexpected finding was that the time needed to successfully implement such an extensive service learning activity (e.g., more than two weeks in the field; and nearly four months of intensive preparation) competed with the time available to complete the prescribed research and necessary class work. Thus, although the research and service learning activities were designed to follow a parallel track, the project suffered from insufficient overlap between the two activities resulting in an unacceptable demand on the time of the students. When the project is repeated in 2006, it is expected that the preparation and visit to Roche will demand less time as compared to the inaugural visit. At that time, it will be possible to provide an honest assessment if the approach described here within represents a viable option to link graduate-level research and service learning. Alternatively, course credit may be assigned to the service learning activity resulting in a less demanding course load; but this option seems less favorable as the research intensive nature of the program already minimizes the course load to the most basic subjects.

Conclusions

Two female graduate students at the University of Cincinnati have embarked upon a novel program for the MS degree designed to link service learning with research appropriate for the production of a thesis. During the past year, a field visit to Roche, Tanzania was completed, and three slow sand filters were constructed. Although this service learning activity demanded a significant investment of time and effort, the process was an exceptional learning experience with practical, real-world value. Over commitment of time on the part of the student participants appeared to be a major concern. It is expected that repeating the field visit during the second year of the MS degree will require a less intensive time commitment, and leave a greater proportion of time available to pursue the laboratory-based research question. Future projects attempting to integrate service learning and research should consider the time commitment of the participating students.

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References

1. Brundtland Commission, 1987, Our Common Future.
2. Lantagne, D. S. (2001) Investigation of the Potters for Peace colloidal silver-impregnated ceramic filter: intrinsic effectiveness and filed performance in rural Nicaragua. Alethia Environmental, Allston, MA 02134, USA