Creation of a Filter Factory in Hammanskraal, South Africa:
Filter Optimization and Training Local Residents

2016-2017 Community-Based Undergraduate Research Grant (CBURG) Report

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Background

In 2015, a JPC team partnered with PureMadi and Khulisa to create the infrastructure for a ceramic water filter factory in Hammanskraal, South Africa. This includes a concrete open-air structure, a paved factory floor, a fence around the factory premises, a borehole for water supply, a hammer mill, a sieve table, and a filter drying rack. We returned to this factory in June 2016 with two primary objectives: First, conduct experiments to optimize the clay-sawdust-water formulation for filter manufacturing based on the available local materials, and second, teach local community members how to manufacture the filters.

Silver-impregnated ceramic water filters have been shown to be inexpensive, sustainable, and effective at purifying drinking water at the household level and therefore capable of improving human health in a developing-world setting (1-5). The filters, which are produced from primarily local materials (clay, water, sawdust) and labor can also provide economic stimulus, as local workers can manufacture and sell the filters, keeping financial resources within the community. The method to make the filters is relatively straightforward and outlined in four main steps:

1. **Acquisition of raw materials.** Clay is obtained from a natural source (e.g., riverbank) and left to dry on tarps. Once dry, it is crushed into a powder using an electric hammer mill. Sawdust is collected from a community source (such as wood shop or lumber

processing factory) and sifted to achieve consistent particulate using a manually-operated sieve table. Water is obtained from an on-site borehole via electric pump.

2. **Mixing and firing (production of ceramic).** Clay, sawdust, and water are mixed in a precise ratio and formed into a standard flowerpot shape using a manually-operated hydraulic press. They are then fired in a kiln for 6-8 hours according to a pre-programmed temperature profile. During this process, the sawdust combusts and leaves behind micropores in the clay. In addition, the oxygen molecules of the silicon and aluminum oxides in the clay particles bridge with each other, forming a durable ceramic. The micropores allow water to pass through the filter at a slow rate while the strong ceramic provides structural integrity.
3. **Testing.** Once the filters have been fired in the kiln, a potter takes them to a soak tank where they are dipped in a tank full of water for 10 seconds. This "pressure test" allows the potters to determine the presence of macroscale cracks in the ceramic. The filters are then soaked for 12 hours, allowing water to fully permeate the micropores. After suspending them above the soak tank, they are filled to the brim and allowed to sit for an hour, at which point the remaining water volume is measured and flow rate is calculated (the "flow rate test"). Filters that do not pass either test are either repurposed as flower pots or crushed.
4. **Silver application, packaging, and distribution.** Filters that have passed both the pressures test and flow rate test are taken inside the factory and painted with a suspension of silver nanoparticles. Once dry, they are packaged along with a water dispenser and distributed to various locations in the community and in the surrounding villages.

Over the past 5 years, PureMadi, a non-profit organization composed of UVA faculty, students, and alumni, has created a ceramic water filter factory in Limpopo Province, South Africa. In 2015, PureMadi entered into a partnership with Khulisa Social Solutions, a 300-employee South African non-governmental organization. In combination with a JPC team, PureMadi and Khulisa created the infrastructure for a second filter factory in Hammanskraal, South Africa. Last summer's achievements include (1) installing a steel open-air roofed structure, a paved factory floor, brick-enclosed office space, kiln, bathrooms, and a borehole and electric pump for water supply, (2) constructing a sieve table, ladder, and filter rack, and (3) transporting a hammer mill for the new filter factory.

To move forward with this factory, a number of infrastructure items were still needed, including additional shelving for filter drying and inventory, a soak tank for measurements of filter flow rate, a concrete floor for the remainder of the factory, security precautions, electric wiring, hiring managing personnel, and identifying sustainable sources for clay and sawdust. We hypothesized that local clay and sawdust can be used to manufacture the filters. In addition, the optimal ratio of clay, sawdust, and water had to be determined experimentally before large-scale filter production could occur. Finally, local residents required training in the filter manufacturing process.

Research Question and Rationale

Given certain unforeseen setbacks, we had to adapt our research question and goals for the project as the summer progressed. Initially, our research question entailed what the best clay-sawdust-water optimization formula for the water filter was along with how to train local workers. Once on site though, our group had to change our expectations because the factory still needed crucial infrastructure in order for it to function as stated above. Our research question changed direction to tailor to the infrastructure needs. The new question was what infrastructure issues can be achieved in an efficient and low cost manner.

Methodology

Before arriving in South Africa, we researched procedures for the manufacture of ceramic water filters by reviewing prior publications (1-5) and the Best Practices Manual for manufacturing ceramic water filters (7) during the Spring 2016 semester. In addition, we gained hands-on experience fabricating ceramic media at the ceramic manufacturing facility at the Observatory Mountain Engineering Research Center. Upon arrival in South Africa, the team had spend 1-2 weeks working at the existing PureMadi Ceramic Filter Factory in Limpopo Province. During this period, we worked side-by-side with factory workers to learn first-hand all the elements of filter manufacturing.

Our first day at the Hammanskraal site was spent taking inventory of the existing infrastructure and identifying areas of improvement. In addition, we were made aware of a persistent threat of theft and decided that security precautions should be taken before installing any expensive equipment. A thin fence guarded the premises, but the doors needed bolting and the windows needed bars to prevent a break-in. In addition, the cement enclosure where the silver nanoparticles (approximately $2,000) would be stored lacked walls that reached all the way to the roof. It was decided that metal rods that spanned the width of this empty space also needed to be installed.

After ensuring safety of the site, we identified a clay source and consulted local jurisdiction to obtain permission to withdraw clay from public land. We then constructed filter racks to dry and store finished filters. The cement floor within the office walls also needed to be replaced with a higher quality concrete and a floor was laid under most of the roof so expensive machinery could be bolted into the substructure. The concrete office was painted and signs were affixed to clearly mark the building as a water filter factory (a lack of an official address make the factory difficult to identify from the main road). A filter press was also transported from the University of Venda to the Hammanskraal site. Machinery such as a hammer mill (sediment grinder) and sieve table (for sawdust) were delivered from a local storage unit to the factory site. Lastly, factory management was hired to oversee the development of the factory in the coming months as well as continue to train local residents to staff the factory during its long-term operation.

Outcomes

Despite the previously mentioned setbacks we experienced at the Hammanskraal filter factory, we were able to accomplish the following during our stay:

1) Identifying a clay source, and securing rights from the local community to start mining there for future filter production.
2) Tightening security at the filter factory to minimize theft.
3) Establishing a floor plan for the future factory floor.
4) Ensuring filter production will begin within the next calendar year.
5) Training management so progress at the Hammanskraal filter factory will be expedited.
6) Furthering positive relationships with the Hammanskraal community.
7) Communicating to community members how the Hammanskraal filter factory will fit into their community.

We anticipate in the coming months that the current employees at the factory will find the optimal clay to sawdust ratio that we initially set out to find, and begin filter production under the supervision of the factory manager Nkosinobubelo Ndebele.

Personal Statement

In addition to improving human health, providing a foundation for international collaboration, and increasing the employment opportunities in Hammanskraal, this project offered an unparalleled opportunity for personal growth. The true power and promise of public health is realized when one can observe the tangible effect of volunteer efforts on a community that is unable to help itself. Hammanskraal is the perfect setting to not only gain an appreciation for the daily struggles of impoverished villages in developing nations but also fundamentally change the way we view public health efforts.

On top of the collective personal growth this experience provided us, we each had our own personal take aways from this once in a lifetime experience. Helena Gallagher found the experience invaluable to informing further engagement with projects abroad, especially falling under the umbrella of accessibility to water. She was able to gain relationships within the University and abroad (specifically in engineering fields) she would not have received through the normal undergraduate experience in the College of Arts and Sciences. This experience for Damaris Paris served as a practicum for future career opportunities she would like to engage in surrounding social change and social innovation. It also served as a source to learn additional skills such as grant writing, budget management, networking and teamwork. J.C. found the wholly collaborative nature of South African life particularly inspiring because the issues presented by global water shortages (and many projects in general) require a similarly community-minded approach to problem-solving. Through this project, Derek gained valuable insight on how to navigate through both personal and cultural differences to achieve a common goal. Furthermore, Derek learned to appreciate how complex problems often times can only be answered by equally as complex answers through observing the water sanitation issues South Africans experience each day.

The opportunity to directly engage in global water quality improvement is extremely rare during an undergraduate's academic career and we are very fortunate to have had the opportunity to achieve our proposed goals. The continuation of this project has the incredible potential to empower a historically underrepresented and underserved district of South Africa, and we look forward to engaging with the issue of water accessibility and quality in the future.

References

1) Kallman, E., et al. (2011). "Ceramic filters impregnated with silver nanoparticles for point-of-use water treatment in rural Guatemala." Journal of Environmental Engineering 137(6): 407-415.

(2) Oyanedel-Craver, V. and J. A. Smith (2008). "Sustainable colloidal-silver-impregnated ceramic filter for point-of-use water treatment." Environmental Science and Technology 42(3): 927-933.

(3) Ren, D., et al. (2013). "Evaluating the sustainability of ceramic filters for point-of-use drinking water treatment." Environmental Science & Technology 47(19): 11206-11213.

(4) Abebe, L. S., et al. (2014). "Ceramic water filters impregnated with silver nanoparticles as a point-of-use water-treatment intervention for HIV-positive individuals in Limpopo Province, South Africa: A pilot study of technological performance and human health benefits." Journal of Water and Health 12(2): 288-300.

(5) Mellor, J., et al. (2014). "Modeling the sustainability of a ceramic water filter intervention." Water Research 49: 286-299.

(6) Mellor, J. E., et al. (2013). "Modeling the complexities of water, hygiene, and health in Limpopo Province, South Africa." Environmental Science & Technology 12(24): 13512-13520.

(7) Ceramics Manufacturing Working Group (2010). Best practice recommendations for local manufacturing of ceramic filters for water treatment. Seattle.