* This case is based on a comprehensive business plan developed by a student group in the course entitled Sustainable Product and Market Development for Subsistence Marketplaces under the supervision of the instructor, Madhu Viswanathan. The case was prepared by Madhu Viswanathan, John Clarke and Srinivas Venugopal and copyedited by Tom Hanlon. We gratefully acknowledge the organizational sponsor of the project and the students who contributed to it.

Ensure every person has the ability
to provide clean, pure, and affordable
drinking water to their families

LAUREN VALENTINO; ISAK GRIFFITHS; GLORIA SEE; ANDREW HAGLUND; MARIA JONES
Thank you for your interest in learning about USAFI East Africa and about our product, WaziMaji. Please let us know if you have any questions or if you would like to talk with us about developing a partnership. We look forward to hearing from you.

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- OIKOS East Africa
- Nelson Mandela African Institute
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EXECUTIVE SUMMARY

Potable Water: A Local and Global Challenge

There are 770 million people worldwide who lack access to safe drinking water, which means that their water’s chemical, physical, and microbial characteristics do not meet World Health Organization guidelines or the national standards (WHO & UNICEF, 2013). As shown in Figure 1, in Tanzania alone, nearly half of the country’s population of 48 million does not have access to safe drinking water (WHO, 2012). USAFI, which translates to “purity,” aims to address this challenge by ensuring that every person has the ability to provide pure, clean, and affordable drinking water to their families.

Our interdisciplinary team at USAFI brings expertise from several engineering fields (including environmental, civil, and electrical), a variety of business specialties (including global business strategy, marketing, and corporate social responsibility), and a phenomenal talent for industrial design. Our diverse backgrounds allow us to draw from our expertise while conducting extensive research into the problem and potential solutions. This, in combination with our global partnerships with the Safe Global Water Institute and Oikos East Africa, serve as our foundation to build a successful business venture.
Commitment to Cleaner Water

USAFI is committed to helping communities provide water that is both free of harmful microbial contaminants and safe from naturally occurring, yet toxic levels of fluoride.

The primary source of water in Arusha is groundwater, or water from beneath the surface of the earth. Because Arusha is on and around Mount Meru, an active volcano, the regional earth and water have varying degrees of fluoride from the lava and volcanic rock (Fawell et al., 2006). The most viable options for drinking water without high levels of fluoride are to purchase water that has been imported, purchase it from regional companies that filter the water, or to filter the water at home.

Because the locally-sourced water is untreated, it also contains biological contaminants that increase the risk of contracting water-related diseases, which are prevalent in Tanzania. A lower incidence of disease could contribute to longer, healthier lives, lower medical expenses, greater productivity, and more time to pursue education and professional opportunities.

Our product, WaziMaji (which translates to “clear water”), is a modular water filter that will improve the lives of individuals, families, and communities through direct, rapid health benefits, long-term health benefits, and through fostering entrepreneurship. These benefits, along with the simplicity and efficiency of the product, the long-term cost savings, and the time that women and children will save, will significantly outweigh the small behavioral adaptations associated with use of our water filter.

To help generate interest in and sales of our product, USAFI will use multiple communication vehicles, which are shown in Figure 2, to promote our product and demonstrate its benefits. We will work with local women as sales agents, advertise through radio ads and mobile phones, provide a phone number for as-needed information and technical support, and staff a promotional mobile vehicle for water testing and education. Through the use of these promotional strategies combined with our multi-stage implementation plan, we believe that we can revolutionize safe water access within several years.

Figure 2. Communication Vehicles
During the nine-month pilot phase, we plan to target five primary schools and health clinics or dispensaries. Interacting with primary schools and health facilities provides several advantages. In addition to the obvious health and education benefits, teaching and promoting good habits in schools helps ensure that these benefits are long-term for children, their families, and the surrounding communities.

Phases 1 and 2 will follow the pilot phase, lasting for 20 and 18 months, respectively. Both of these phases will involve local entrepreneurs for material procurement, product manufacturing, product distribution, and continuing product support. Phase 1 will focus on households within the Arusha region of Tanzania, while we hope to penetrate the greater East African market during Phase 2. Our financial projections, presented in Figure 3, indicate that breakeven will occur after two years.

![Figure 3. Financial projections](image)

**Triple Bottom Line: Creating Value for the People, Increasing Planet Sustainability, Driving Profits**

To maximize the viability of our product, the relevance to our target market, and the appeal of the overall project, we have developed a product and a plan that has a solid triple bottom line.

**The People:** We seek to not only deliver a viable product, but also to help encourage people to adopt viable solutions. The short-term benefit of our product is fewer illnesses due to waterborne biological contaminants. The long-term benefits are better overall health due to better hydration, stronger bones and teeth due to reduced levels of fluoride, and less physical pain from both better hydration and a lower level of fluoride consumption. There is also an emotional benefit to parents in knowing that their children are safer from diseases and can spend more time in school preparing for future opportunities in life. An additional benefit is the use of a product designed to meet
their current needs and lifestyle, which is also modular and flexible enough to be adapted as their needs change.

**The Planet:** Currently, water is either purchased in plastic bottles and/or collected at water taps. The medical experts in Tanzania encourage locals to boil the water that they drink, consuming scarce woodlands as the fuel source for boiling. We seek to partner with Oikos East Africa in encouraging women to treat water more and boil water less. This will not only help preserve natural resources, but due to sanitation conditions, it will also help minimize the number of microbial contaminants reintroduced into their drinking water and into the region’s ecosystem.

**The Profit:** For our investors, we expect to earn 10,000 USD for every 0.01% of the population of East Africa that we serve. For our consumers, our product will save them the cost of water, the cost and/or time for fuel, medical costs, and the indirect costs of missing work and school due to waterborne illnesses. The expected savings to an average household is 10,000 Tanzanian shillings (TSH) a month, or roughly 10% of their monthly income. In addition to the cost savings, families will have the opportunity to earn more due to less time missed due to illness.
ACKNOWLEDGEMENTS

We would like to extend our gratitude to the following individuals and organizations for their help and support over the past year. We would like to give a special thank you to Professor Madhu Viswanathan for continual guidance and support. Your leadership and expertise are greatly appreciated. Second, we would like to thank the Safe Global Water Institute and Dr. Benito Mariñas for supporting our efforts. Finally, we would like to thank our collaborators: the team in CEE 449 Environmental Engineering Laboratory, Oikos East Africa, and the Nelson Mandela African Institute of Science and Technology.

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SITUATION ANALYSIS

**Strengths**
- Modular design
- Locally sourced materials
- Work with competitors
- Entrepreneurial opportunities
- Partnerships with local suppliers
- On-the-ground team
- Price flexibility

**Weaknesses**
- Market adoption dependent
- Lack of/improper training of entrepreneurs

**Opportunities**
- Wide target market
- Partner with competitors

**Threats**
- Inadequate existing knowledge
- Corruption in value chain

**STRENGTHS**

1. **Modular design with price flexibility**
   The modular design of the water filter makes it a very versatile product with everyday components. The modular design lets entrepreneurs customize different product specifications and sell the completed unit at the recommended prices. This design is intended to serve differing needs of community members; for example, those living farther from volcanic outflow may need only a housing that prevents inadequate sanitation habits from further contaminating the water and the ability to control pathogens in the water.

2. **Locally sourced materials**
   The product is made with 100% locally available raw and produced materials, including the bone char, ceramic filter, and the plastic housing. This gives the product a tremendous edge in the domain of environmental and business sustainability. For example, the number of miles the raw materials travel is reduced (which also helps in keeping our costs low), and it does not depend on an imported part that may potentially lead to problems with maintenance.

3. **Work with competitors**
   A unique aspect of the modular filter is the ability to work with existing competitor products for clean water, such as “WaterGuard.” People who are users of WaterGuard can opt for the model that contains bone char for the removal of fluoride. It will also allow the incorporation of other technologies as they become available.
4. **Entrepreneurial opportunities**
   Our product ecosystem has been designed while keeping in mind the number of people who would like an extra avenue to generate income for themselves and their families. Entrepreneurs exist in every aspect of the value chain from procurement, assembly, sales, and maintenance.

5. **Partnerships with local suppliers**
   USAFI has been able to contact, meet, and create positive relationships with suppliers of raw materials such as bone char and biosand. These partnerships will turn our suppliers into stakeholders in our product and, thus, help in the overall success of the product. There is also a local producer of plastic buckets; our product has been designed so that this local producer will be able to use existing technologies to produce the plastic housing as well.

6. **On-the-ground team**
   With the help of Oikos East Africa (OEA), we have an excellent on-ground team who has the resources and skills to be pioneers in education and training. OEA already has multiple projects in schools and homes with respect to water and sanitation education, and we can capitalize on OEA’s existing network, commitment to preserving the environment, existing relationships to focus on increasing and improving local entrepreneurship, and brand recognition.

7. **Price flexibility**
   The modular design concept gives us the ability to be flexible in pricing. This helps us target a wide range of customers who can get lower-priced models and upgrade to the full-fledged package. The product will allow people to only pay for the functionality they need or to build toward the complete system incrementally as their finances allow.

**WEAKNESSES**

1. **Market adoption**
   Our biggest strength is also our weakness. The model is dependent on market adoption, especially by entrepreneurs who are willing to try a new opportunity to generate revenue. The alternative to this weakness is for the Safe Global Water Institute (SGWI) to create an organization on-ground that will work with Oikos to develop into an organization that can support the product until locals start taking a vested interest.

2. **Lack of/Improper training of entrepreneurs**
   Training of entrepreneurs such as assemblers, storekeepers, and the female entrepreneurs is critical to the whole business. Improper training could lead not only to ineffectiveness of sales, but could potentially put people’s lives at risk (or for us to be sued) if filters are not fixed or maintained properly, or if entrepreneurs are not correctly marketing the product.
OPPORTUNITIES

1. **Wide target market**
   Due to our price flexibility and simple design, we believe we have access to a wide target market. Additionally, we are aiming to have financing models, which will reduce the price barriers. This gives us the ability to target customers living at the subsistence level in Tanzania.

2. **Partner and collaborate with competitors**
   Our product is uniquely designed to collaborate with competitors and create a win-win solution. Due to the modular design, customers can use products such as WaterGuard and purchase a fluoride removal unit, which ensures complete safety of water. Hence, there is an opportunity to partner with WaterGuard and use their existing distribution chain in return for percentage of the profits.

THREATS

1. **Inadequate existing knowledge**
   While education and awareness is a huge component of our marketing, the lack of existing knowledge is a threat. Most respondents in our interviews did not differentiate between fluoride and microbial contamination. Additionally, for a number of respondents, if they have not personally fallen ill from unsafe water, they are not motivated to use any product that will prevent diseases.

2. **Corruption in the value chain**
   Since our product has a large value chain that impacts multiple people through entrepreneurs, there is a very real threat of corruption by people who want to make money at the expense of providing safe water. Hence, we need to ensure that there are stringent quality controls and checks at every stage of the process.

MACRO ENVIRONMENT

MARKET

According to UNICEF and the World Health Organization, around 770 million people lack daily access to improved drinking water sources (WHO & UNICEF, 2013). Water available to such impoverished communities is usually highly contaminated physically, chemically, and microbiologically. In Tanzania, the water quality is affected by excessive amounts of fluoride, which cause dental and skeletal fluorosis (Fawell et al., 2006). The World Health Organization (WHO) recommends a fluoride content of 1.5 mg/L in drinking water; however, in parts of Tanzania, especially near Mount Meru, fluoride concentrations as high as 68 mg/L have been detected (Ghiglieri et al., 2010). In fact, prior to 2008, the national standard for fluoride in Tanzania was set at 8 mg/L (Gumbo & Mkgongo, 1995) because of the difficulty and expense in procuring water with lower fluoride levels.
Drinking water is the biggest contributor to fluoride exposure in Tanzania. A secondary source of fluoride intake is Magadi, a combination of sodium carbonate and bicarbonate ($\text{Na}_2\text{CO}_3\cdot\text{NaHCO}_3$) contaminated with some amount of fluoride (measured to be 0.58 mg F/g of Magadi). Magadi is commonly used in East Africa, as it softens food while cooking. Since the problem exists over such a wide area, and most of our target market does not currently treat their water for fluoride levels, we believe we have a significant mass market to target.

From what we observed, there is not a consistent level of education regarding clean water, a consistent message regarding the impact of drinking contaminated water, or large-scale efforts to drive a change in behavior or a change in the consumption of water. There are several NGOs and charitable groups that work in the area, but these are primarily driven by non-nationals who seem to be imposing a solution that sounds good but is not applicable in day-to-day life in rural Tanzania.

One is the NGO that collects cow bones and is the primary local source for bone char. Their fluoride filtration unit, which is shown in Figure 4, requires that the consumer add 20 liters of water to the unit and then wait three hours before accessing any of the filtered water. Since this is in an arid, tropical region, the only way to have access to treated water during that three-hour window is to transfer pre-filtered water into a separate (and typically non-sterile) storage container. However, improper sanitation habits make it likely that contaminants are reintroduced into treated water that is transferred to a different storage container. This organization’s filtration unit also consists of three separate containers at differing levels; consumers need to accommodate this system in their homes, giving up valuable space in typically very small homes. Furthermore, the biggest challenge with that system is that it only filters fluoride; water needs to be disinfected by the consumer prior or subsequent to using the system. This additional step is impractical enough to not be consistently used.

![Figure 4. Bone char filtration unit consisting of 2 buckets and a bone char column (center)](image)

The entire population of Tanzania, along with other East African countries, is a viable market for our product. Although people in the cities have more ready access to bottled water, WaziMaji could also offer them great savings and entrepreneurial opportunities. Rural Kenya and Uganda have similar challenges with access to clean and safe water, and the same opportunity for a viable solution is applicable in these areas. Additional communities throughout Africa and other developing regions can
be considered in the future, but the initial target market is a combined population of over 100 million people.

**COMPETITION**

Aside from WaziMaji, there are several options available to consumers in our target market who currently lack access to safe drinking water. These options range from very simple, inexpensive, and inefficient to advanced, expensive, and robust solutions. Options available to consumers include untreated and unfiltered water, bottled water, chlorine (WaterGuard), Solar Water Disinfection (SODIS), ceramic filters, biosand filters, bone char filters, and centralized treatment.

Our primary competition is bottled water, in particular the brand *Kilimanjaro*, which is produced by Bonite Bottlers LTD. This bottled water bears the Tanzania Bureau of Standards (TBS) mark of quality, which ensures that the water meets relevant Tanzanian standards for drinking water. The Tanzania standards include microbiological requirements of less than 3 coliform counts and 0 *E. coli* counts per 100 mL of water, and fluoride concentrations that fall within the range of 1.5-4.0 mg/L (Tanzania Ministry of Water and Irrigation, 2009). The typical price for a 1.5 L bottle of water is approximately 1000 TSH, which is equivalent to about 0.62 USD.

In addition to pre-packaged water, there are several products available for household water treatment, including WaterGuard. WaterGuard is commercially available in Tanzania as a form of free chlorine, which is a common and effective disinfectant. With the proper dose, WaterGuard can be used to eliminate most microbial contamination. However, it does not address fluoride present in the drinking water. The inability to address both the microbiological and chemical contamination of drinking water is the primary downfall of this chemical disinfectant.

Solar inactivation, also known as SODIS, uses the sun’s energy to inactivate microorganisms present in water. It consists of placing clear, plastic bottles in direct sunlight for at least six hours. SODIS is advantageous in that it is relatively simple, inexpensive, and does not require any chemical addition. Although SODIS can reduce the number of microbial pathogens present in water, it does not address the physical or chemical aspects of the water quality. In other words, it will not decrease the concentration of fluoride in water.

Ceramic filters are attractive because they provide a physical barrier to water contaminants and therefore do not require any chemicals for water treatment. Depending on the specific pore size of the ceramic material, the filters may be able to retain particulates, bacteria, and some viruses but not fluoride. Although decreasing the pore size to reject all contaminants seems intuitive, the necessary pore size would require a driving force, such as pressure, to push water through the filter. Thus, the overall cost increases and feasibility decreases.

Biosand filters can also be used to remove contaminants from drinking water. Biosand filters are filled with sand and gravel and are able to remove solids and most pathogenic microorganisms from
drinking water and require little to no maintenance. The sand and gravel are housed in a concrete structure, and this makes the overall initial cost prohibitively expensive. Biosand filtration units housed in concrete can be purchased in Tanzania for 150,000 TSH, which is equivalent to about 90 USD. This prohibitively high cost and the filter’s inability to address fluoride are the primary shortcomings of this technology.

Bone char filters are unique in that they are capable of reducing fluoride concentrations in drinking water to acceptable levels. The filter material consists of animal bones that are crushed and heated to extremely high temperatures for several hours. Like the other filtration processes, the bone char filtration process is relatively straightforward. Bone char is currently produced in Tanzania at the Ngurdoto Defluoridation Research Station, from which bone char can be purchased for 1,500 TSH (0.90 USD) per kilogram. A filtration unit consisting of a bone char column and two buckets is available for 25,000 TSH (15-16 USD). Despite this being the only household level treatment option that addresses fluoride, it does not decrease microbiological contamination. In fact, the filter may actually lead to an increased number of microorganisms post-filtration, and this is the primary weakness of this option.

Finally, we must consider centralized treatment as a competitor. This type of treatment uses facilities to treat large volumes of water for a variety of uses. Although centralized treatment would provide higher quality water that meets the Tanzania Bureau of Standards requirement, it requires a great deal of infrastructure and continuous maintenance, both of which necessitate large financial investments. As a result, centralized water treatment systems are often absent or inadequate in Tanzania.

Overall, our competitive analysis indicates that the currently available products and services all fall short in one way or another. While some products adequately address microbiological contamination, they fail to address fluoride, and vice versa. Aside from bottled water and centralized treatment, neither of which are household level treatment options, there is not a product capable of providing safe drinking water in regards to both the chemical and microbial contaminants. Furthermore, many of these solutions treat water quality but do not prevent the recontamination of water supplies during water storage and use in the home.

CONSUMER INFORMATION

Our initial market is the Meru people in Tanzania. Their main source of income is small-scale farming. Sub village A is especially known for its cultivation of tomatoes. An average monthly income per capita in rural areas in 2007 was about 28,400 Tanzanian shillings (TSH), where approximately 40% of the share is from agricultural revenue (National Bureau of Statistics, United Republic of Tanzania, 2009). Based on the exchange rate of 2013, the average monthly earning is about 17 USD. The ethnic language is the Bantu language of Meru (IstitutoOikos, 2011), and the majority of the population also speaks Swahili. While the Meru arrived to the ward about 200 years ago, the colonization of Mount Meru by the Meru began in a more official manner the late 1950s (IstitutoOikos, 2011). A single bottle of water,
averaging 0.62 USD for 1.5 liters, is cost-prohibitive to this target market since purchasing one bottle a day would cost more than the average local monthly income.

The cosmetic effects of exposure to high fluoride begin when there is roughly 1.5 mg/L of fluoride in the water; damage to teeth and bones being to occur around 4.0 mg/L (Fawell et al., 2006). Past research by the SGWI shows that levels of fluoride in the Arusha region are typically in the range of 5 to 20 mg/L. Moreover, almost every water sample tested throughout the region showed the presence of microbial contaminants including coliforms.

The primary motivator for drinking clean water was ensuring the health of children. The younger the child, the greater the concern regarding water quality seemed to be. Most children with whom we spoke were able to describe having had symptoms of waterborne illnesses within the past year; the most common symptom was diarrhea.

**Mission & Objectives**

USAfi, which means ‘purity’ in Swahili, aims to be a leading sustainable social enterprise that begins with a focus on the WaziMaji — or ‘clear water’ — household water purification and filtration system. Our mission is to **enable every person with the ability to provide clean, pure, and affordable drinking water to his or her family**.

Our objectives are the following:

- Increase education regarding the importance of safe drinking water and awareness of the illnesses caused by unsafe drinking water
- Develop an enterprise that can provide training and organize and manage the development, distribution, and sales of the water filter using local entrepreneurial skill and materials
- Increase adoption of the water filter by
  
  a. Proving that use of the product is advantageous
  
  b. Being consistent with consumer needs and values
  
  c. Reducing the complexity of solutions
  
  d. Providing the ability to try it
  
  e. Allowing people to see and taste the difference between safe and unsafe drinking water

Some of the specific benefits of WaziMaji are illustrated in Figure 5. The three dimensions of our triple bottom line are illustrated in Figure 6.
PEOPLE

Every aspect of our value chain involves people, from the raw material sourcing and procurement, product assembly, distribution, sales, and support/maintenance. As a people-centric organization, our product helps in increasing ownership of the product, easy product adoption (using word-of-mouth marketing), and creating opportunities for income generation. In addition, we are focusing on women’s development through the adoption of a multi-level marketing paradigm that includes door-to-door salesmanship, which is focused on selling and maintaining products. This model will allow us to train and educate women not just in the importance of safe drinking water but also in life skills of leadership, literacy, and basic computing.

PROFIT

We realize that being able to make money or save money are the major incentives that help in the adoption of new technology. Hence, WaziMaji is focused on creating multiple job opportunities at various levels of the value chain.

PLANET

This product offers tremendous value through being sustainable and environmentally friendly. By offering a method of treating water that is cheaper and much less labor intensive than boiling, the need to purchase and produce charcoal or cut down firewood is eliminated, and the rampant deforestation resulting from that need will be cut dramatically. In addition, the materials to produce the filtration product can all be locally sourced, increasing business opportunities in the local area and decreasing the carbon footprint required to transport materials long distances for production.
FIELD RESEARCH AND PRODUCT DEVELOPMENT

Learning from Virtual Immersion and Emersion

Our team spent many weeks in virtual immersion and emersion in subsistence contexts. Our activities included analyses and understanding of life circumstances through readings, a poverty simulation, interviews, videos, and case studies. Additionally, we studied and developed conceptual models of poverty, needs, products, and market interactions. As depicted in Figure 7, virtual immersion and emersion were our first steps in fully understanding the problem that WaziMaji would eventually address.

Figure 7. Overall process leading to the realization of WaziMaji

Our virtual immersion began with reading two novels. In *The Blue Sweater*, some of us experienced poverty for the first time with Jacqueline Novogratz, author of the personal memoir. We learned how capital investments could be used to empower people to make them self-sufficient and impact the lives of a large number of people. In *Nickel and Dimed: On (Not) Getting By in America* by Barbara Ehrenreich, we learned about the continuous struggles and constraints that someone living at the subsistence level faces on a daily basis.

Next, we participated in a poverty simulation in which each person assumed a role, such as a single mother, disabled adult, or senior citizen. With limited time, money, access to transportation, and...
an overall lack of resources, we were asked to meet basic housing, nutritional, and educational needs. This activity allowed us to experience the stress and obstacles of living in poverty firsthand.

In addition, we read in-depth interviews with people living at the subsistence level that allowed us to delve further into the complexities of poverty. The interviewees included women who represented different contributors to the regional marketplace including purchasers, vendors, suppliers, self-help group leaders, moneylenders, and more. These interviews highlighted gender disparities, the power of education, the benefits of empowering women, and the typical marketplace interactions in subsistence context. Abstracting insights from readings, images, and videos, such as *Shakti Rising*, we identified external factors that influence poverty and created poverty models that aimed to capture the multidimensional and complex nature of poverty.

Overall, these activities showed us that living in poverty is filled with endless challenges, but the effect that this has on an individual depends on the person’s environment and situation. Rather than feeling hopeless in the face of challenge, there may be a chance for personal transformation. Integrating and empowering women in society may play a key role in breaking the poverty cycle.

Our team also spent several weeks engaged in various subsistence emersion activities including readings, case analyses, and videos. The goal of the emersion exercises was to extract general principles on buyer and seller behavior and interactions; the purpose, methods of conducting, and benefits of market research; and the marketing elements for subsistence marketplaces. These exercises revealed several insights that must be considered in any approach to the design, marketing, and providing products in a subsistence context. Even the most optimistic and lucrative solutions must be tailored according to the target consumers and surrounding context.

Most importantly, these emersion activities have brought to light the enormous technology gap between developed and developing nations. This gap in technological knowledge limits how countries can create, access, and use the sciences to address common social and economic problems. With the world being increasingly driven by technology, modern solutions must incorporate elements for technology. Modern resources, methods, and engineering solutions can be implemented in developing nations and particularly rural areas, but the solutions must go beyond simply providing a product. They must provide the knowledge and opportunity to overcome the typical constraints of isolation.

With our newfound knowledge and understanding of poverty and the subsistence context, we identified the needs, drivers, and context surrounding the water crisis in Tanzania. Although our primary focus is providing safe drinking water, the case studies revealed that a product must satisfy a recognized consumer need to be successful. Therefore, increasing health and wealth through long-term changes in technology and behavior for the Maasai and Meru family units of Arusha is the basic need to be fulfilled. The things that drive people to satisfy this need include education, health, and productivity. The context surrounding the issue includes local culture, perceptions, and environment. Table 1 presents these needs, drivers, and context in more detail.
### Table 1. Needs, drivers and context framework

<table>
<thead>
<tr>
<th>Needs</th>
<th>Drivers</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase health &amp; wealth through long-term changes in technology and behavior for the Maasai and Meru family units of Arusha</td>
<td>Education</td>
<td>Maasai (livestock)</td>
</tr>
<tr>
<td></td>
<td>Health</td>
<td>Meru (agriculture)</td>
</tr>
<tr>
<td></td>
<td>Productivity</td>
<td>Water sources &amp; transport</td>
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<td></td>
<td>Financial gain</td>
<td>Water uses</td>
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<td></td>
<td>Simplicity</td>
<td>Education &amp; perception of clean water</td>
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<td></td>
<td>Aesthetics</td>
<td>Geology &amp; climate</td>
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<td></td>
<td>Reliability</td>
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</tbody>
</table>

From these exercises, we also began to identify what design elements we would need to incorporate to devise a viable and sustainable product that would be appropriate for people living with the needs and motivations listed above. Some of the possible design elements are presented in Table 2.

### Table 2. Possible design elements

<table>
<thead>
<tr>
<th>Scope</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water collection</td>
<td>Health information</td>
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<tr>
<td>Filtration &amp; disinfection</td>
<td>Water treatment</td>
</tr>
<tr>
<td>Use</td>
<td>Storage and handling</td>
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<tr>
<td>End of Life/disposal</td>
<td>Schools or markets as education medium</td>
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<tr>
<td>Infrastructure</td>
<td>Incorporate with animal care</td>
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<td>Source protection</td>
<td>Improve sanitation facilities/practices</td>
</tr>
<tr>
<td>Storage and handling</td>
<td>Women’s entrepreneurship</td>
</tr>
<tr>
<td>Water vendors</td>
<td>Technical viability</td>
</tr>
<tr>
<td>Treat rock/soil before contamination</td>
<td>Economic</td>
</tr>
<tr>
<td>Dietary supplements &amp; vaccinations</td>
<td>Environmental impact</td>
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<tr>
<td>Water filtration factory</td>
<td>Health and safety</td>
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<td>Ethics</td>
<td>Manufacturability</td>
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<tr>
<td>Social implications</td>
<td>Sustainability</td>
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<tr>
<td>Political implications</td>
<td>Ease of use</td>
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<tr>
<td>Religious implications</td>
<td></td>
</tr>
</tbody>
</table>

### Description of Idea Generation and Screening

Before generating ideas, our team spent several weeks working to fully understand the challenges with regards to safe drinking water access in Tanzania. The team explored the magnitude and complexity of the challenge and the health implications of poor water quality. Two team members that had experience working in Tanzania also shared stories of their experiences and understanding of the local culture. This knowledge allowed the team to begin to understand possible solutions and potential obstacles.

With a solid understanding of the core problem and surrounding context, our team continuously generated ideas. In the very early stages of our idea generation process, our team focused on unconstrained ideation. The solutions proposed were not limited by technological, scientific, or financial
restrictions and ranged from using a chemical treatment, similar to crop-dusting, to eliminate high fluoride concentrations from all soil in the target areas, to oral supplements to address post-consumption fluoride and pathogenic microorganisms in the human body. In addition to technologies that would address water contamination issues, we considered alternative water sources, improvements to the current infrastructure and water handling practices, disposal of used materials, and educational components. In general, our ideas were grouped into one of the categories shown in Figure 8.

Figure 8. Categories of initial, unconstrained ideas

These general categories presented in Figure 8 include solutions targeting several levels: community-based, household-based, and personal point of use. For each of these applications, we considered numerous water treatment technologies and ranked them on a five-point scale according to the following design criteria: treatment capacity, technical viability, economic feasibility, sustainability, ease of use, manufacturability, environmental impact, health and safety, and political considerations. Table 3 defines each of these criteria in more detail, and Table 4 presents the numerical ranking for the various filtration technologies considered.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment capacity</td>
<td>Target contaminant levels must be reduced to acceptable levels set by the Tanzanian government or recommended by the World Health Organization</td>
</tr>
<tr>
<td>Technical viability</td>
<td>Limited power supply and availability of raw materials</td>
</tr>
<tr>
<td>Economic feasibility</td>
<td>Limited financial resources and cost-effectiveness</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Beneficial to consumers over the product lifetime</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Limited time and technical knowledge of end user for operation and maintenance</td>
</tr>
<tr>
<td>Manufacturability</td>
<td>Limited technical knowledge of manufacturers</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>Minimal impacts on the surrounding natural habitats and ecosystems, consider fate of byproducts during treatment and manufacturing processes</td>
</tr>
<tr>
<td>Health and safety</td>
<td>Minimal health and safety hazards for end user</td>
</tr>
<tr>
<td>Ethical, social, and political...</td>
<td>Design must be socially acceptable and not affected by any cultural taboos that would discourage its use</td>
</tr>
</tbody>
</table>
### Table 4. Filtration ideas ranked according to design criteria

<table>
<thead>
<tr>
<th>Idea</th>
<th>Ethical</th>
<th>Social</th>
<th>Political</th>
<th>Sustainability</th>
<th>Ease of use</th>
<th>Technical viability</th>
<th>Economic</th>
<th>Env. Impact</th>
<th>Health &amp; Safety</th>
<th>Manufacturability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated carbon</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ceramic</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3.5</td>
<td>4.5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Membranes</td>
<td>4.5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>3.5</td>
<td>1</td>
<td>1.5</td>
<td>3.5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Rapid sand/granular</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Slow sand/biosand</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Ion exchange</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>2.5</td>
<td>3</td>
<td>1.5</td>
<td>5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Bone char/organic material</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Mechanical kidneys</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Personal point of use</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>2.5</td>
<td>4</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>Storage container/cooler</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4.5</td>
<td>44.5</td>
</tr>
</tbody>
</table>

Using this preliminary assessment of ideas from the various categories and points of application, the team continued to generate new ideas and refine current ideas as we gained a more thorough understanding of how we could best approach the challenges at hand, and obtained feedback from the Safe Global Water Institute.

**Market Research**

In an attempt to gain a deeper understanding of the marketplace prior to field immersion, we conducted virtual market research specifically focusing on Tanzania. We researched the existing technologies, current solutions, and previous findings of the CEE 449 students for water purification at various points of use. We began by trying to better understand the range of existing filtration
technologies, which are shown in Figure 9, and their associated costs and benefits. This provided additional context for what we would see and learn.

![Water Contaminants](image)

**Figure 9. Range of filtration technologies showing the different pore sizes of each and how the sizes of common water contaminants compare**

We also spent a significant amount of time understanding the cultural context of our target segment based on the experiences and insights of our team members in the same community. In the field in India and Tanzania, we conducted in-depth market research focusing on the consumers, stakeholders, entrepreneurs, community leaders, and non-governmental organizations involved. We spent time understanding the buyer-seller interactions in the marketplace and drivers behind behavioral change in communities.

We followed the concept of Human Centered Design (HCD) principles, which helped us to focus on people and their visible and latent needs. This method of interviewing and observing people not just about their thoughts about water but about their lives, their aspirations, goals, and needs helped us gain a holistic and invaluable understanding of the people for whom we are designing. Our research goals were focused on finding answers for certain key topic areas (below), and our research span included interviewing consumers (especially women), local entrepreneurs, educators, health practitioners, and community leaders. We also spent time observing how people collected, used, and stored water for various consumption purposes.

- **Habits:** What are the different uses for water? How is water prioritized or differentiated for different purposes?
- **Understanding Health:** Do people recognize sicknesses and connect them to issues with drinking water? What is considered as a serious illness?
- **Medium of Information:** Where do people get their information? How much importance do they place on different mediums and sources of information?
• **Current Methods of Treatment:** Do people currently treat their water? How do they do it? Are there any local and native remedies? What do neighbors/friends do? What are their preferences for themselves and their families?

• **Innate Knowledge of Water:** How do you know if your water is clean? What taste do you like?

• **Behavioral Modifiers:** What are the biggest motivators of behavioral change? What would make people adopt certain products or practices?

Finding answers to the above question areas helped us understand how to design our product and the business ecosystem around it for complete customer buy-in. For example, in India and in Tanzania, we saw how most of the current existing technologies are used, any why they are often not used.

We saw several varieties of sand and biosand filters. One example of a biosand filter is shown in Figure 10. In all cases, the existing products were large and heavy. Maintenance was anywhere from difficult to impossible. For example, the unit that is depicted below requires periodic cleaning, during which the consumer completely loses the ability to filter water during that time. It is also expensive enough that acquiring one is out of the reach for the average family unit without financial assistance. Production of the units is also very expensive in terms of costs and time because it included pouring concrete into a metal mold, manually packing the layers, filtering enough water to flush out contaminants introduced during assembly, and allowing time for a biological layer to develop on the top of filter media.

![Figure 10. Typical biosand filter; arrows represent the direction of water flow](image-url)
INDIA

In India, we were completely surprised by the level of awareness of the average subsistence consumer and the ready availability of drinking water. Some of our observations were the following:

- Canned delivery of water; high accessibility; relatively affordable prices
- Sale and delivery of municipal water (see the water truck in Figure 11)
- There are many opportunities for local entrepreneurship to provide cleaner water.
- Education is primarily spread by companies and vendors, schools, and medical care practitioners. They instill a sense of responsibility for drinking cleaner water at home. In short, there was value in understanding not just what they did, but why they were doing it.
- There was an awareness of seasonal variability in water quality and of the importance of "boiling water during the monsoon season."
- People had an understanding that taste did not necessarily reflect water quality, and that they liked the taste of water they were most used to drinking.
- Public education regarding water was not universal; the higher a person’s caste, the more access they had to current information and village-organized training.
- Children’s opinions mattered - in many cases, the preferences of the children dictated the water purchased by the family and/or treatment methods employed by the family.
- Women are powerful change agents although they are the buffer for homes.
- Women’s groups provide effective vehicles for introducing and reinforcing changes in behavior.
- Word of mouth is exceptionally powerful between families, neighbors, and villages.
- Education via TV is especially effective.

Figure 11. Truck supplying water in India
TANZANIA

- Stark contrast in the lack of awareness, lack of accessibility and affordability; not the same level of aspirations
- The primary sources of water are borehole wells and taps (shown in Figure 12) and, in areas with access to larger marketplaces, bottled water; the arid region results in little surface water.
- There are strong opinions and beliefs contrary to the use of chemical water treatments (e.g., WaterGuard).
- Few people liked the taste of water that had been boiled.
- There was confusion between fluoride and bacterial contamination: related effects; what is sickness; what is clean water?
- There were conflicting messages and confusion as to why clean water is important.
- There were common water distribution points such as KIA water (treated for bacterial contamination) and local bore wells.
- Feasibility and lack of proper usage of previous filters
- Education is powerful; however, men may have a more definitive say in what the family/woman does.
- There are needs such as economic feasibility, and if the technology makes no sense, even word of mouth is hard to convince people. They need to see different results or information (such as that provided by the biosand lady) on why they need to use clean water, filters
- There are major seasonal variations in the water.
- Education via radio ads
- Stored water, transporting water is more unclean than the water source
- Widespread use of mobile phones - even amongst the Maasai women

Figure 12. Maasai women in Tanzania collecting water from a community water tap
Concept Generation and Evaluation

Our team’s final round of initial idea generation and screening occurred after our emersion experience in Tanzania. At this point, we narrowed our focus to water treatment solutions but continued to focus our efforts on all three levels: community, household, and personal point of use.

For community level treatment, we designed a filtration unit that can be applied to community water access points. This system would utilize the pressure from a hand pump to drive water through the filter unit, as illustrated in Figure 13.

![Figure 13. Filter unit applied to community water pump](image)

As a midpoint between community and household level treatments, we proposed chemical sachets that could be added to water collection containers at the time of collection. During transport to the home, the chemicals would be released and react to treat the water, so that drinking water is treated by the end of transportation to the home. This concept is shown in Figure 14.

![Figure 14. Chemical sachets added for water treatment](image)

Additionally, we considered several solutions targeting the household level. These included a storage container that can serve both as a treatment vessel for chemical application and/or filtration
media, as shown in Figure 15. In the case that a filtration unit is included, the lid includes a device to track the number of filter uses to indicate when the filter media needs to be replaced. In an effort to prevent recontamination during water handling, the container is outfitted with a spigot.

![Water storage vessel for water treatment in the home](image)

Figure 15. Water storage vessel for water treatment in the home with a lid to track filtration usage and spigot to prevent recontamination

Also at the household level, we considered a modular treatment system that would consist of interchangeable components, which can be used to customize water treatment to meet specific user needs. The modularity also allows for the unit to be tailored based on specific water quality concerns. An initial sketch of this modular unit is illustrated in Figure 16.

![Modular filtration unit](image)

Figure 16. Modular filtration unit for household use

Finally, our ideas included a personal filter/treatment vessel contained inside a bag that can be easily carried on a continuous, daily basis. An illustration of this travel bag is shown in Figure 17.
Based on our findings in Tanzania, we were motivated to focus at the household level with a modular water treatment solution that facilitates safe water handling as our core product concept. Both the household level application and modularity were critical design considerations in selecting this as our core concept. This final concept actually incorporates attributes from several of the concepts presented previously, and one variation of this concept is shown in Figure 18. The device contains pre- and post-treatment storage and components that remove fluoride and inactivate pathogens from water. Additionally, the container is outfitted with a spigot and lid, both of which prevent the water from being recontaminated during storage and handling in the home.
Targeting consumers at the household level has several advantages. First of all, targeting consumers at this level eliminates this possibility for further or recontamination of water during transport, handling, and storage. Thus, household treatment can be considered more effective in comparison to other methods (Sobsey 2002). Household level water treatment can also provide rapid and direct health benefits to the end users. Finally, providing people with the tools and knowledge to treat their own drinking water supply promotes individual responsibility for personal water security.

The notion of modularity was also very attractive to our team because it also allows people to take control of their water security and gives consumers the power to choose. Additionally, modularity allows for customization based on targeted water contaminants. With the modular filtration unit, there are several variations that could be introduced into the core concept. These treatment technology variations are presented in Table 5.

<table>
<thead>
<tr>
<th>Fluoride removal</th>
<th>Pathogen control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone char filter</td>
<td>UV/SODIS</td>
</tr>
<tr>
<td>Other adsorbents</td>
<td>Biosand filter</td>
</tr>
<tr>
<td>Contact precipitation</td>
<td>Chlorine</td>
</tr>
<tr>
<td></td>
<td>Ceramic filter</td>
</tr>
</tbody>
</table>

Our team also had the advantage of working in parallel with a team of engineering students enrolled in an environmental engineering senior design course (CEE 449). Since January 2014, our team enrolled in BADM 532/533 has worked in parallel with the CEE 449 students to discuss potential product ideas, associated technical viability, and their feasibility in Tanzania. After once again generating ideas and consulting with the CEE 449 students, the team began to conceptualize how our ideas could be implemented. We used concept sketches to visualize possible solutions and different product variations. We also agreed upon upon metrics, which serve as the foundation for evaluating performance.

**EVALUATIONS**

Prior to the field research, we studied poverty and the subsistence marketplace in Arusha through bottom-up immersion tools such as poverty simulations, readings, and videos. Some of the elements we were considering while studying poverty in Arusha and the subsistence marketplace in that context are shown in Figure 19.
At that same time, we also studied poverty and the subsistence marketplace in Arusha through top-down emersion tools such as case studies and SGWI research notes. Figure 20 shows the questions we were asking while studying poverty in Arusha and the subsistence marketplace in that context.
We then summarized our learning through a framework of needs, drivers, and contexts that highlighted the relationships between factors we had to consider to maximize the possibility of success, whether looking at our subsistence marketplace from the inside out or from the outside in.
The final design concept selected by our group will be evaluated according to the metrics and specifications described in Table 6.

Table 6. Needs, metrics, benchmarks, and specifications

<table>
<thead>
<tr>
<th>Needs</th>
<th>Metrics</th>
<th>Benchmarks</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination</td>
<td>Reduce bacterial contamination</td>
<td>Microbes/Liter</td>
<td>0 microbes/L (WG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 microbes/L (WHO Guideline)</td>
</tr>
<tr>
<td></td>
<td>Reduce fluoride contamination</td>
<td>Milligrams/Liter (mg/L) F</td>
<td>0-2 mg/L F (BC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5 mg/L (WHO Guideline)</td>
</tr>
<tr>
<td></td>
<td>Not introducing new contaminants</td>
<td>Milligrams/Liter (mg/L) PO₄</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 mg/L PO₄- (TBS Standard)</td>
</tr>
<tr>
<td>Assembly</td>
<td>Assembly – time required</td>
<td>Minutes</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;60 minutes</td>
</tr>
<tr>
<td></td>
<td>Assemble using pictorial guide</td>
<td>Yes/no</td>
<td>None</td>
</tr>
<tr>
<td>Usage</td>
<td>Usage tracking</td>
<td>Filter runs</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Indicate when filter module needs to be replaced</td>
<td>Filter runs</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>90 filter runs</td>
</tr>
<tr>
<td></td>
<td>Filtration time</td>
<td>Hours to produce 20 liters</td>
<td>3 hours (BC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 hours</td>
</tr>
<tr>
<td></td>
<td>Device lifetime</td>
<td>Years</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Without cultural taboos</td>
<td>Yes/no</td>
<td>Acceptance of chemical treatment (WG), filtration methods (BC)</td>
</tr>
<tr>
<td>Cost</td>
<td>Affordability</td>
<td>Tanzanian Shillings (TSH)/person/year</td>
<td>Capital: 15 USD (BC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- 20 USD (BSF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Continual: 0.01 USD(BC) - 0.70 USD (WG)</td>
</tr>
<tr>
<td>Production</td>
<td>Locally sourced materials</td>
<td>Yes/No</td>
<td>Locally available components (BC and BSF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bone char and plastic components are locally available</td>
</tr>
<tr>
<td></td>
<td>Reusable materials</td>
<td>Yes/No</td>
<td>None</td>
</tr>
</tbody>
</table>

In addition to these metrics and technical specifications, concept testing was performed in partnership with Oikos East Africa in Tanzania. The concept testing consisted of many questions regarding water practices and perceptions. This was accompanied by some preliminary water quality data collected during our field emersion experience. Data on fluoride and microbial contamination was presented along with potential health effects of each and trends with seasonal variation. Figure
21 shows several 3M Petrifilm plates, which show the stark contrast in the microbial contamination characteristics of water collected at the tap vs. water collected from household storage containers.

![Image of 3M Petrifilm plates]

Figure 21. 3M Petrifilm plates containing water collected at a community tap (left) vs. a household (right). Each red and blue dot indicates a microbial colony.

After this introduction, our solution to these drinking water concerns was presented, as shown previously in Figure 18. The primary purpose of this concept testing was to evaluate the consumer response to our modular treatment system, the product variations, and the costs associated with various aspects of the product.

Overall, the concept testing reiterated the need and desire for education and awareness on these water quality issues, their potential health effects, and means to address these problems. There is a common misconception that water from the community taps is clean, and there is no need for further treatment. Taste is one such indicator of clean and fluoride-free water. For other water sources, participants acknowledged the need for water treatment but implied that they are constrained by time, money, and lack of treatment materials.

In regards to the actual product (Figure 18), the concept testing revealed that the spigot was the most attractive and desirable component of the unit. However, participants did not state any desire to change or modify any of the other attributes of the system. Responses to questions about the affordability of the product were more ambiguous, with participants offering to negotiate the final price. The detailed results from the concept testing can be found in the appendix.
Technical Specifications and Detailed Drawings

We believe that the most feasible, efficient, and sustainable approach to provide safe drinking water in Tanzania is based at the household level. Based on the water quality data collected during our field trip in February 2014, we learned that unhygienic handling of water during collection, transport, or storage in the home leads to increased microbial contamination in the home as compared to the original source water. Applying household water treatment can have direct, rapid, and positive health impacts for consumers who rely on source water that is contaminated or may become contaminated during the transport or storage in the home. In addition, the container lid and spigot facilitate hygienic handling and prevent contamination during water storage and retrieval.

In addition to the focus on the household level, there are several key categories that have driven the specifications of our modular filter concept. These include the produced water quality, assembly, usage, and production.

CONTAMINATION REMOVAL

Water quality data also revealed fluoride concentrations in excess of the World Health Organization’s guideline value of 1.5 mg/L. Although fluoride has beneficial effects on teeth at low concentrations in drinking water, excessive exposure to fluoride can result in adverse health effects that range from dental fluorosis to severe crippling skeletal fluorosis or even death. Fortunately, bone char has the ability to adsorb or uptake fluoride from water, and the technology is already under investigation and even in use in some regions of Tanzania.

In addition to focusing on the household level, there were several other components incorporated into the product design, including modularity. This modularity offers consumers a choice, primarily between technologies that can be applied for pathogen control. In the future, this modularity may allow for customization of the product based on various water concerns that may be present in other areas where piped water systems are not possible.

Among the available technologies, chemical disinfection using chlorine and physical removal using a ceramic filter were deemed most feasible and efficient. Either method may be incorporated into the filter, but there is a cost-time tradeoff with the ceramic filter presenting a higher capital cost and the chlorine presenting a lower but recurrent cost and additional effort by the user. More importantly, the less expensive alternative, chlorination, requires the use of chemicals, which may be objectionable for cultural reasons.

The modular filter is designed to efficiently remove contaminants for approximately three months before maintenance or media replacement is required. This is intended to justify the cost in time, effort, and expense required to use the filter. Moreover, the filter must remove contaminants to levels that meet guidelines and regulations set forth by the World Health Organization and the Tanzanian government. In addition, the filter itself must not increase any of the contaminants, nor introduce any new contaminants into the drinking water output by the product. To this end, we have
designed a lid to prevent new contaminants from entering the system. The only other interface users have is at the spigot output, so any potential contaminants from utensils, hands, or the environment are sequestered from the filtration system.

**ASSEMBLY**

Our filter is designed to have modular components that can be customized for the specific needs, concerns, and price points of individual households. To this end, the assembly must enable this customizability in the effort and complexity required. The time for assembly must also be acceptable for the users.

**USAGE**

The product must be easy enough to use that it facilitates clean water in the household. This drives a number of design features, such as pre- and post-storage areas, height of the overall assembly for pouring water in, the position for the output spigot, and a funnel to channel water into the filtration modules.

First of all, the total volume capacity of WaziMaji is crucial for viable household usage. The module was designed to hold 20 liters of water pre-storage as well as post-storage. The storage volume of 20 liters was selected because it is the current volume commonly collected in buckets at water sources. This allows the user to pour a full bucket of collected water into the top compartment, insert a WaterGuard tablet in the inlet, and return approximately three hours later to collect safe drinking water. Alternatively, if ceramic filters are used to remove pathogens from water, the user may simply pour in 20 liters of untreated water and withdraw the water from the post-filtration storage compartment at any time.

These pre- and post-treatment storage areas, along with treatment time and media replacement frequency, were all considered in regards to the technical specifications and dimensions for the overall product. The design target for bone char replacement was constrained to approximately three months, as this seems to be a reasonable time frame for replacement. Finally, the design and components must be appropriate to local traditions, style, and social requirements. In particular, there are religious constraints surrounding the use of pigs, requiring the bone char to be sourced from cattle. The lifetime of the overall product is expected to last at least five years to justify the initial investment by the household.

**PRODUCTION**

We intend the materials required for the product to be locally sourced. The biosand and bone char both have local facilities capable of sourcing. In addition, we are seeking to have these materials be reusable wherever possible. In particular, the bone char can be “regenerated” through another charring process. This can potentially provide additional pricing options for the consumer if the regenerated material is sold at a reduced price.
Considering the aforementioned criteria, the technical specifications of each component were optimized. The dimensions, all shown in centimeters, and a fully rendered image are shown in Figure 22 and Figure 23.

**Prototype**

We created a prototype, using three-dimensional printing, to evaluate this concept. We calculated appropriate dimensions and chemical dosages required for sufficient fluoride removal and
reduction of microbial contamination. Several images of the prototype are shown in Figure 24. We will present a storyboard to indicate proper usage of this product in the Marketing section of this report.

Figure 24. Images of the 3D printed prototype - side view of individual components (top left), top view of individual components (bottom left), and assembled side view (right)
MARKETING STRATEGY

The Strategy

Our marketing strategy can be divided into four P’s: product, price, place, and promotion, as shown in Figure 25. We are offering three variants of our products: only fluoride removal, only pathogen control, and a full set addresses both fluoride and microbial contamination. These options are priced at 8, 43, and 48 USD, respectively. This gives customers the ability to choose the product that best fits their current needs and finances. USAFI East Africa plans to target rural households in fluoride affected East African regions with a four-pronged promotional strategies discussed herein and presented in Figure 26.

Women as Sales Agents: In Tanzania, women are not only responsible for collecting water, but they are also responsible for collecting the firewood, which they use to generate income by making into charcoal. We hope to start social change by giving these women the opportunity to make money as door-to-door sales agents. As agents, the women will receive literacy and technical training, which will give them the ability to play a critical role in education, persuasion, and building customer relations.

24x7 Mobile Support: Mobile phone use is skyrocketing in East Africa, with 8 million subscribers in Tanzania alone. We are utilizing this existing business infrastructure to provide 24x7 customer support, based on insights from one of our interviewees. Additionally, customers will have the ability to make easy mobile financial transactions through M-Pesa for paying for WaziMaji.

Mobile Van: We will be tackling the lack of awareness of waterborne illnesses and fluoride contamination through our innovative water van. This mobile van will move to different locations – schools, marketplaces, and community events – to help in educating the community about importance
of clean water, while simultaneously promoting WaziMaji. The vans will also give customers an opportunity to experience and interact with our product.

**Radios:** Radios are the proven mass method of reaching over 90% of rural Tanzania. We will be using the radio (Radio Free Africa channel) primarily to advertise and promote WaziMaji.

**Positioning**

USAFI’s product will initially target women with children in Maasai and Meru communities in the Arusha regions of Tanzania. By supporting local entrepreneurial initiatives, we will improve local communities through health and quality of life. Products are designed to use locally-sourced materials, thus increasing local economic activity and creating a sustainable business at all levels of the value chain.

Table 7 shows how WaziMaji compares to the competition, with the green shading indicating the desirable attributes: better removal efficiency, less cost, and less time.

<table>
<thead>
<tr>
<th></th>
<th>Removal Efficiency</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Microbes</td>
<td>Fluoride</td>
</tr>
<tr>
<td>No treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WaterGuard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SODIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramic Filters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biosand Filter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone Char Filter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottled Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WaziMaji</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Target Market Selection**

Given that deaths associated with water-related diseases were estimated to exceed 5 million per year in the 1990s (Gleick, 2014), the need for a product that will provide safe drinking water is clear. Tanzania faces specific challenges due to the high fluoride content in many water sources, combined with microbial contamination.

Efforts through foreign aid are costly (161 million USD in 2008-2009) and poorly utilized due to the unpredictability of aid, seasonality, and poor implementation (WHO Press, 2012). Tanzania has also experienced a drop-off in the presence of water supply programs in the regions with particularly high fluoride content. They are generally semi-arid and require groundwater sources, often borehole wells. These regions are Arusha, Kilimanjaro, Mara, Mwanza, and Singyanga (Gumbo &Mkongo, 1995).
In 2008, access to clean water in Tanzania was reported to be 54% for the nation and 45% in rural areas (Gleick, 2011). This all adds up to a pressing need for a reliable and affordable household level treatment mechanism for drinking water. Since urban access to clean water is reported to be as high as 80% (Gleick, 2011), our product will have a greater impact in the rural areas within the high fluoride regions.

In addition, the women and children of the household primarily manage water. Duties utilizing water, such as cleaning, washing, food preparation, and cooking, were described as women’s work in interviews during our fieldwork in Tanzania. Women also have a major share in the responsibility for the health concerns of the household. All of these factors contribute to the selection of women, ideally younger mothers, as the primary demographic for marketing and outreach.

Marketing among women also helps to spread the word through word of mouth, with the outreach enhanced through rewards built into the marketing plan for identifying new customers.

**Sustainable Marketing Mix**

**SUSTAINABLE PRODUCT DESIGN**

A sustainable product can be described as one that meets current needs without compromising future generations. Our product design addresses product sustainability by taking a holistic approach and considering each stage in the product life cycle, as shown in Figure 27. Our life cycle approach includes ecological, economic, and social dimensions.

![Figure 27. Components of the life cycle analysis](image-url)
SUSTAINABLE RAW MATERIALS
On the ecological or environmental dimension, materials must be procured without depleting non-renewable resources. In other words, there must be a balance between resources use vs. resource preservation and replenishment. More importantly, materials contained our products will not increase or introduce potential health risks.

SUPPLY CHAIN
Our supply chain is managed in an environmentally, socially, and economically responsible way. For example, the product uses bone char; this is locally available in Tanzania to lower transportation and overall production costs. By locally producing our products, we aim to stimulate the local economy by creating jobs and leveraging local entrepreneurship with market advances with local culture.

MANUFACTURING
Our products are created using processes that minimize negative environmental impacts while conserving energy and other natural resources. A local production facility reduces environmental and economic impact of transportation.

PACKAGING AND DISTRIBUTION
Minimal and compact packaging is multi-purpose for promotion, education, and to maintain product integrity during transport. Through innovative packaging, we convey important educational information in regards to product use and benefits. Our local manufacturing facility minimizes transportation costs associated with product delivery.

PRODUCT USE
Our products are designed with quality in mind. The informational brochure provides clearcut instructions for proper use and information on water storage, handling, treatment procedures, and health benefits. The plastic housing is designed to last for five years. We aim to maximize efficient product use by eventually incorporating a device to count the number of filter uses and indicate when replacement of the filter material is required.

RESOURCE RECOVERY AND DISPOSAL
Improper disposal can be harmful to people or the environment. We offer options for our customers to responsibly dispose of their used filter materials and housing including collection and regeneration of the bone char and recycling of the plastic housing.

Product Ecosystem
WaziMajiis designed to be fully integrated into the life and community of its users by contributing at the individual, family, and community levels to overall health and economy. We do this by promoting and incorporating the product into various levels of the community, locally sourcing materials and labor, and creating new business opportunities for local entrepreneurs.
To support and engender the success of the project, we will leverage USAFI East Africa’s global ecosystem. This currently includes organizations like OIKOS East Africa, the Marketplace Literacy Project, and Safe Global Water Institute. We are working to bring the Tanzania Women’s Bank into our fold and can easily envision partnering with other NGOs and charity organizations once the product has been successfully introduced and received by the marketplace.

The product’s ecosystem also includes local and regional suppliers for everything from the plastic for the housing, to the provider of the bone char, and the vendor of the ceramic filter, etc. It also includes the village leaders and school administrators who have already pledged their support. We are honored to be part of such a vibrant and supportive global team that is working on creating a viable and sustainable solution to a global problem.
**ACTION PLANS**

**Sustainable Product Design**

Given the immense challenge of providing safe drinking water in Tanzania, product sustainability is of the utmost importance. First and foremost, our products must meet customer needs. With such limited awareness of water quality issues such as fluoride and pathogens, water storage, handling, treatment procedures, and health benefits are all included as educational aspects in the design.

Our products are sustainable throughout their life cycle. From procurement of the raw materials to resource recovery and disposal, our filter provides economic, environmental, and social benefits, while protecting health and the environment. An important component of the life cycle sustainability is that the filters and materials are produced locally. Using readily available materials for the plastic housing and filter materials lowers procurement, transportation, and energy costs. Local manufacturing facilities support the economy by creating jobs and stable incomes for craftsmen. The water quality indicator device ensures efficient product use, and recycling and regeneration of used filter materials allow for responsible end disposal. More details about the product life cycle can be found in the Marketing Strategy section.

In comparison to the competition, our product is superior in the way that it simultaneously addresses fluoride and pathogens, both of which are water quality concerns in Tanzania. However, this superior water quality comes with additional financial and time burdens that may not necessarily be associated with competing offers that address only a single water quality issue or are less robust.

**Sustainable Value Chain**

The sustainability of the value chain has been a critical factor in our product design. After creating the mold for the filter structure, producing the filter components is done with materials from local manufacturers. Assembly of the filter modules will be performed by local entrepreneurs who can sell them to suppliers or act as sales agents themselves. Women are preferentially targeted as sales agents to provide greater familiarity with the influencing factors of decisions on household well-being. The sales agents also help with maintenance issues and reminders, as well as financing arrangements for purchasing the filters. The exchange model for our sustainable value chain is shown in Figure 28.
Restatement of the Value Proposition

Our value proposition is to provide consumers with safe drinking water, which will lower the burden of waterborne illness in Tanzania. This lower incidence of disease suggests healthier, longer lives, less health and medical expenses, greater productivity, and more time to pursue education and professional opportunities. Our product will improve the lives of individuals, families, and communities through direct, rapid health benefits and fostering entrepreneurship. These benefits, along with the product simplicity and efficiency, significantly outweigh any financial cost, time commitment, and behavioral adaptions associated with the water filter. In other words:

**The People:** We seek to not only deliver a viable product, but also help encourage people to adopt viable solutions. The short-term benefit of our product is having fewer illnesses due to waterborne microbial contaminants. The long-term benefits are better long-term health due to better hydration, stronger bones and teeth due to reduced levels of fluoride, and less physical pain from both better hydration and lower level of fluoride. There is also the emotional benefit for parents in knowing that their children are safer from diseases and can spend more time in school preparing for more opportunities in life. An additional benefit is the use of a product designed to meet their current needs and lifestyle and is modular and flexible enough to be adapted as their needs change.

**The Planet:** Currently, water is either purchased in plastic bottles and/or collected at water taps. The medical experts in Tanzania encourage locals to boil all the water that they drink, consuming scarce woodlands. We seek to partner with OIKOS East Africa in encouraging women to treat water more and boil water less. This will not only help preserve natural resources, but due to improved sanitation
conditions, it will also help minimize the number of biological contaminants reintroduced into the ecosystem.

**The Profit:** For our investors, we expect to earn 10,000 USD for every 0.01% of the population of East Africa that we serve. For our consumers, our product will save them the cost of water, the cost and/or time for fuel, medical costs, and the indirect costs of missing work and school due to waterborne illnesses. The expected saving to an average household is 10,000 TSH a month, or roughly 10% of their monthly income. In addition to the cost savings, families will have the opportunity to earn more due to less time missed due to illness.

**Communication of the Value Proposition**

We will be communicating our value proposition to customers through:

1. Personal sales women who will help in persuasion, marketing
2. Store owners with brochures on helping customers find the right product
3. Radio ads on the benefits of having the product
4. Mobile phone call/text ads along with customer service hotline for repair, education

A sample of an informational brochure illustrating how to use WaziMaji is shown in Figure 29.
Ecological Forecast

Because of the decreased need for charcoal and firewood to boil water, we anticipate both a decrease in deforestation and improved soil conditions resulting from less runoff erosion during the rainy season. The decrease of wood burning also causes less pollutants and greenhouse gases to be released into the atmosphere.

Societal Forecast

In areas with high microbial content in the water, diarrhea is so prevalent it is not generally considered an illness. As a leading cause of death in children under five years, any decrease in mortality is profoundly impactful. Interviews with healthcare professionals indicated that as much as 30% of medical treatment is for water-related illness. Providing clean drinking water to decrease those medical expenses leads to improved health and happiness for users, as well as the accumulated savings of the associated medical expenses.
FINANCIALS

Cost Breakdown

The primary costs are projected to come from procuring raw material: bone char, ceramic filters, and internal molding for the holding various components. The secondary costs include those for labor, training and education, and renting a location. While it may be easy for an NGO to run the operation, our goal is to establish to community ownership and build local entrepreneurship and job opportunities. The full cost breakdown and product pricing are shown in Table 8.

Table 8. Cost breakdown and Product Pricing in Tanzanian Shilling (TSH)

<table>
<thead>
<tr>
<th></th>
<th>Complete Set</th>
<th>Anti-Microbial</th>
<th>Fluoride Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket and Lid</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Funnel</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Spigot</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Internal Containment</td>
<td>1000</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>Bone Char</td>
<td>6000</td>
<td>0</td>
<td>6000</td>
</tr>
<tr>
<td>Ceramic Filter</td>
<td>60,000</td>
<td>60,000</td>
<td>0</td>
</tr>
<tr>
<td>Per Unit Costs</td>
<td>73,500</td>
<td>66,500</td>
<td>13,500</td>
</tr>
<tr>
<td>Margins</td>
<td>7,800</td>
<td>6,500</td>
<td>1,500</td>
</tr>
<tr>
<td>Price of Item</td>
<td>81,300</td>
<td>73,000</td>
<td>15,000</td>
</tr>
</tbody>
</table>

Customer Analysis

Financial assistance will be offered to people through a pay by installment basis, which will also allow customers to buy a basic component and add to it when they are financially able. Financing schemes will be developed in partnership with the Tanzania Women’s Bank. Additionally, we will be working to allow payments through M-Pesa, a mobile financial transaction service popular in East Africa, especially Tanzania.

Phases of Implementation and Associated Costs

We have divided our product launch into a pilot and three phases that are focused on the market penetration with the product. Each of the phases has different costs associated with it, and these costs are discussed in detail below. Additionally, a financial forecast is provided that has helped us determine the breakeven point.

PILOT: 0 – 9 MONTHS: EARLY ADOPTERS

The pilot phase, which will last nine months, is focused on selling and distributing 50 units by targeting early product adopters. This will be done by selling the product to influential community members, providing them with educational material about clean and safe water, and thus enabling the
network effect. We will also be placing the product in five primary schools and five health dispensaries that will increase visibility of WaziMaji. The pilot phase will also help us in rapid product and marketing iteration based on the feedback we get from our early adopters. The pilot phase will also give us the ability to understand a better market and feasibility forecast. The financial information for the pilot phase is presented in Table 9.

<table>
<thead>
<tr>
<th>Table 9.PILOT – 50 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Tanzanian Shillings (TSH)</td>
</tr>
<tr>
<td>Revenues</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
</tr>
<tr>
<td>Trans &amp; SG&amp;A</td>
</tr>
<tr>
<td>Profit</td>
</tr>
<tr>
<td>Dollar Profit</td>
</tr>
</tbody>
</table>

**PHASE 1: 20 MONTHS: USAGE**

We aim to sell 5,000 units within 20 months after the pilot phase by focusing on Arusha and the Arumeru district, which have a combined population of 799,526 (i.e., target distribution of the water filter to 0.6% of the district population or 3% of all households within the district). This will help us to focus on increasing product usage while still focusing on education about clean water. In this phase, we also hope to include local entrepreneurs as a part of our business model by emulating the successful “water can” business we observed in India. We envision this happening by developing specification standards and developing training material that will enable us to train interested local community members in assembling, building, and selling the filters in local stores. Additionally, we hope to officially kick-start our women’s program of being door-to-door sales agents who will be responsible for educating and selling. The financial information for Phase 1 is presented in Table 10.

<table>
<thead>
<tr>
<th>Table 10.PHASE 1 – 5000 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Tanzanian Shillings (TSH)</td>
</tr>
<tr>
<td>Revenues</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
</tr>
<tr>
<td>Trans &amp; SG&amp;A</td>
</tr>
<tr>
<td>Profit</td>
</tr>
<tr>
<td>Dollar Profit</td>
</tr>
</tbody>
</table>

**PHASES 2 & 3: 31 MONTHS: PROLIFERATION**

In Phases 2 and 3, we want to broaden the target segment to non-users by focusing on mass media, such as radio ads. We plan to sell 10,500 units in the rest of Tanzania, and by broadening our scope to include Kenya and Uganda, countries along the East African rift valley that also suffer from high levels of fluoride. This will allow us to sell to a wider market and start transferring project leadership to local community. The financial details for Phases 2 and 3 are shown in Table 11.
Table 11. PHASE 2 & 3: 10,500 units

<table>
<thead>
<tr>
<th></th>
<th>PHASE 3</th>
<th>PHASE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(TSH)</td>
<td>(TSH)</td>
</tr>
<tr>
<td>Revenues</td>
<td>461,070,000</td>
<td>484,123,500</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
<td>377,460,000</td>
<td>396,333,000</td>
</tr>
<tr>
<td>Trans &amp; SG&amp;A</td>
<td>47,812,500</td>
<td>50,203,125</td>
</tr>
<tr>
<td>Profit</td>
<td>35,797,500</td>
<td>37,587,375</td>
</tr>
<tr>
<td>Dollar Profit</td>
<td>21,308</td>
<td>22,373</td>
</tr>
</tbody>
</table>

FINANCIAL PROJECTION

We are projecting total profits of 22,373 USD at the end of a five-year period, with an initial investment of 44,000 USD, as shown in Figure 30. As a business, we hope to break even in two years, with an expected annual return of 9%. There will be repatriation of profits over a three-year period for three years and USAFInternational will buy out the VC in four years.

![Figure 30. Financial projections](image-url)
IMPLEMENTATION, CONTROLS, & EVALUATION

Measures of Performance: Meeting Triple Bottom Lines

USAFI East Africa is dedicated to meeting our triple bottom line, which is defined by our social, environmental, and financial impacts. In addition to delivering a robust product capable of addressing the water quality issues at hand, we seek to encourage people to adopt viable solutions. WaziMaji provides both short and long-term health benefits, functional benefits, and emotional benefits. Additionally, we aim to have a broader impact on the surrounding communities’ opportunities for income by focusing on women’s development.

In terms of ecological impact, WaziMaji is sustainable throughout its life cycle. Materials are locally sourced and manufactured to decrease our environmental impact of transportation and production. By offering a water treatment method that eliminates the need for firewood as fuel, WaziMaji also alleviates the growing deforestation problem and concerns related to climate change.

In conjunction with these positive societal and environmental impacts, USAFI East Africa will maintain a profit, which allows for the continued success of our venture. We have only one request: an upfront investment of 44,000 USD. This is all that is needed to develop the mold and to complete the first phase of the project. Once we are in operation, the project will support itself fully, breakeven within two years, and then earn a profit of 10,000 USD for every 0.01% of the population of East Africa that we serve. Additional income will also be generated by the maintenance of the product, but it is not a significant amount. Most of those earnings will be earned by the women entrepreneurs and be used by them to support their families and to bolster the local economy.

Monitoring and Evaluating Performance on Multiple Dimensions

Our success will be measured by our ability to meet the triple bottom line in terms of people, profit, and planet, as outlined previously. First and foremost, we must provide education and increase awareness of the water quality issues and their potential health effects. This will be achieved through a multi-phase implementation plan, which targets primary schools and health clinics in the first stage to ensure a widespread educational effect. Second, we will be tackling the lack of awareness of waterborne illnesses and fluoride contamination by using our four-tiered marketing strategy that incorporates women sales agents, telephone support, a mobile platform, and radio ads.
Utilizing these different players and our local partnerships in Tanzania, we can perform successive interviews to assess whether or not and how many people acquire and retain this knowledge. More importantly, increased awareness of the issues, health effects, and our efforts to address these problems will, in itself, promote WaziMaji, which will lead to increased sales. This ties our societal impact into our monitoring and evaluation of profit.

We will track the number and type of units sold to gauge the number of people directly impacted by WaziMaji. We will also look at the broader health impact of WaziMaji by analyzing statistics on diarrhea and other waterborne illnesses in the area. Our partnerships established with the local health clinics in the pilot phase are extremely advantageous in this aspect, because the recording and monitoring of diarrheal and some other waterborne illnesses is already performed by many health clinics.

Monitoring the fluorosis will prove to be more difficult, because the adverse effects occur more slowly and are not reversible. Observing and analyzing trends in the primary schools will be key to evaluating success in this aspect.

Aside from monitoring and evaluating product sales and direct health effects, user feedback will be critical for future product developments and improvements. Again, each of the four players in our promotional strategy and local partners will greatly aid in our acquiring this type of feedback. Some of the questions that can be used to gauge educational changes, product adoption, and customer satisfaction are as follows:

- How clean and safe is the water that you drink?
- How clean and safe is the water that your children drink?
- How necessary is boiling your water?
- How necessary is adding WaterGuard (chlorine) to your water?
- How necessary is filtering your water?
- Have you learned about these things before?
- What would you like to learn more about?
- What components of WaziMaji are you using?
- What do you like about WaziMaji?
- What do you not like about WaziMaji?
- Would you add anything to WaziMaji?
- Would you change anything?
- How often do you replace the bone char?
- How often do you replace the ceramic filters (if applicable)?
- If you are not replacing the media, what is preventing you from doing so?
Finally, we must ensure that USAFI East Africa is financially self-sustainable in order to succeed. In May 2014, we will begin negotiations with the Tanzania Women’s Bank to help provide financial oversight of the project. The bank does not have branches; instead, it operates through regional women providing training and services. They would be our partners in ensuring the funds are managed appropriately and professionally.
Tanzania Field Work Interviews and Notes

17 February 2014

**Home Visit, Mjimwema village source**

Interviewees: E, F, G, K, P, M

Source has a pipeline closer to homes, but starts with a spring box with a filter from a slow source

Hiked up to spring box – hard to access and not collection point

Sampled at church source (tap)

Sampled tap at **school in Ngarenyuki** (school with weaver birds in the slave market and external kitchen facing Mt. Meru)

E – teacher at Ngarenyukischool (B.A. In education, Swahili language)

Teach pupils that they should wash their hands after the toilet → tell them they should tell their parents. They keep a bucket and soap outside the toilet (5L bucket with a small side tap), and tell them they should find a bucket and do the same at home.

**Drinking water?**

At school, water is boiled. They have weekly lessons where they remind children of how to boil so they know how to teach boiling to their parents.

Kids were getting water at the tap for washing hands or porridge cups (not boiled). Occasionally a student drinks the water but is stopped by a teacher if that's noticed. All the students from Std 3-7 have the knowledge and teach their parents.

**How did you know to boil your water?**

They don't trust it and want to protect the pupils. The know livestock and people pass around the open source. The have a filter at the source, but don't know what kind. Informed that if it's cleaned or filter is changed because the water is unavailable then. There's service every 2-3 months. They get notification 1-2 days before and fill a 500L tank for reserve use.

**Are there any other problems?**
Only bacteria and fluoride. They believe that boiling the water reduces the fluoride, “probably we should have more” fluoride treatment. They have more concern for the pupils.

The water is boiled in a kitchen building and use firewood as a fuel source. It’s an Oikos built kitchen with low firewood use. They also cook porridge for the children (beans and corn).

Unsure of the stove in students' homes, but most families use firewood to cook. Has seen stoves in some homes.

Children get sick during the rainy season, usually 1-2 or 2-3 people during the season.

Boiling the water at school is done by the school cook and sometimes supervised by the teachers. The water is stored in 20L buckets in office with school cups specifically for water and is dipped out for the students. Six buckets total. Have water before or after porridge or when they get thirsty during the day. Water is boiled for 30-40 minutes (takes 30 minutes to heat and ~10 minutes of boiling).

Radio ad for Kilimanjaro water?

Trusts the Tanzania Bureau of Water (has standards on water)

“Kilimanjaro water. Safe water/Clean water”

Who taught you that boiling your water reduces fluoride?

Taught during Oikos workshop. Also, SOTIS/SODIS (??) you can water in the sun for 6-8 hours to reduce fluoride. Put in bottles (capped) in the sun.

No awareness of other education efforts. There's also household level issues with traditions and taboos. They also don't like the taste change after boiling, but they're not aware of alternative technology or methods.

Malula Primary School

E: health education coordinator

H: education coordinator

school water: brought in from another district. 20L bucket for all students (600 students) refilled from a large 200L/day (water is delivered). 15,000 shillings for 500L. (Maybe 500L/week, amounts were unclear)

Local source is a bucket for student drinking. The 500L tanks are treated before delivery, but are boiled again if the water is for drinking. About 40L is boiled/day for the drinking buckets. The students have their own containers to take water to drink. The buckets are cleaned each day with soap and hot water.
She believes the water is safe to drink, there are no complaints or stomach problems. The water is boiled on firewood for 30 minutes, now reported as 100L/day.

S – teacher we interviewed

400 out of 600 students eat lunch at the school, and usually only those students drink the water, the others leave early and go home. There from 8-11am.

The use water from kitchen storage for hand washing. They also have a rain water harvesting system. Reported as 50kL tank, but it's probably 5kL. The tank was installed by a group which used to clean it but haven't come in a year. Now hasn't been cleaned since February 2013. The rain water is used only for cleaning. They stopped cleaning it since there's been a drought and there's no incentive for the school. They're not preparing to clean it. There's a lid to get in, but they need other treatment like Cl+ or WaterGuard. She learned about the water treatment from the science books she uses for teaching.

**Student interviews: J, N, G, M, I**

1 of 5 brings water from home. Nancy knows water is boiled and put into clean containers, filter water

Janet: boil water, put in a clean place

Why do you boil the water?

To destroy destructive insects (Janet). Bacteria which stay in the water (Nancy). Only diseases on the water (Gibson). Rust in the water (Mason).

If they don't take the insects out, they'll have stomach problems: birhazia (?), cholera + other diseases with bacteria (like cholera and typhoid).

Why do people get diarrhea?

Collecting dead food, eating dirty food. Mangoes (fruits and vegetables) they're dirty if not washed. Food prepared in dirty places. Should wash fruit using clean water.

Why do people have brown teeth?

Sweets and sugar, biscuits, brushing teeth – not brushing or not using toothpaste. They learned by observing people who did this. Distinguishing brown vs cavities due to bacteria. Not the same. They start getting brown teeth around 2 ½ years old.

Does anyone help cook beans at home?

All yes.

How do you make beans?
Put on fire, put water on fire, put in beans, later put salt, when beans are done, remove from stove and cook something else to eat with the beans. Boil the water out of the beans.

Do you flavor or soften the beans?

Use magadi or salt. N's family uses a pressure cooker, not magadi.

Cook 2 kg of beans to feed 16-20 people (about 10 in family). 7 in Janet's family uses 203 kg of beans. Use 1 teaspoon magadi, 1 tablespoon of salt.

“If I (Lauren) tell them something, will they believe anything I say?”

Depends, they'd have to check. The younger ones probably yes.

“How about him [Tanzanian professor]?”

Have to check

“What about the teachers?”

Have to check on what they said.

“How do you check?”

“No one knows everything, even the teachers”

Any tooth/bone pains?

1 had a cavity.

Do you know anyone who has? → No.

When was the last time you were sick?

• Stomach problems, went to the hospital to visit the doctor. Took medicine after, her parents said she had typhoid. Experienced stomach pains and headache.
• Last September with malaria (doctor told her), went to hospital and came home. Had fever and headache.
• Last year with eye pain (both eyes), couldn't see properly. Went to hospital for appointment, doesn't know cause.
• Last week, with a headache. Went to hospital for appointment, said it was caused by noise from uncle's music system and sun.
• Last year with a headache, at hospital said it was from too much sun, now he tries to stay out of the sun.

Parents don't report bone pain.

Water at home?
Boil and filter with clean white cloth under the water

Mother and sister filter, using white cloth, knows other families don't filter

Why white? So they can see when it gets dirty

Use WaterGuard at the hostel.

What's the water you like best: At home, they're sure it's safe, “confident”

Prefers taste of boiled water

**Village Committee/Council Interviews – Malula (2/18)**

M – village chairman

They serve five year terms

K – water committee

A – health committee

Committee membership: appointed by village government, serve two years, selected based on their commitment to activities

Day of the chairman:

Wakes up and takes care of private business until 10am. Supervises trench being dug for new water system. Sometimes goes into office for meetings and committee issues. Leader meetings where they discuss health, development and education issues. They're building a village office (the current major project), which is funded from organizations, companies and members of the village (give 10k shillings each). Meetings are coordinated between villages because reports are sent to the district level and are discussed before sending.

K: starts work at ~9am, volunteering for water system and committee meetings (promotes volunteering for work on the system)

Health committee – A

Morning: cleaning home, at 11am she check homes and holes for rubbish burning, make sure it's not burned at the wrong place. Location is determined by distance from the house (10+ meters). Other committee issues: hygiene and sanitation issues – establishing and using toilets, hand washing. Follow up is hard, she's not sure how, mostly she does promotion.

Do the committees work together? Not currently, but in the future on water.

Promoting issues:
to people's homes as an official, no enforcement authority but influence.

There's an Oikos committee and an official government committee. She can report to the official committee who has legal powers.

What are the permanent committees? Oikos committee is temporary. The government committees stay but the members change.

Communication with the village: explain issues when people come to volunteer, or at town meetings. They use any gathering.

The new water system: 14 villages, water for drinking, washing, livestock and cleaning. Treatment: currently no plans, they're told the water will be safe. The source is spring(s) on Mount Meru (gravity fed) and bore hole. There are 3 sources from Meru (there were 2 before Oikos), all are springs. Water is combined for the 14 villages. Oikos is combining and developing the 3rd spring for the 14 villages. Also bore hole through a university study to supplement (but only for two of the villages).

How is this system being paid for?
Investment: village contributes in labor. The services (to extend the system) are paid by the villages (individuals in the villages). There's a community management body that needs to be paid

How are you getting water now?
Taste: not good = not safe (heavy, salty, magadi)
After boiling it's safe
Clean water is taste

What about chemical treatment? Use WaterGuard, especially in water (village leader)
The committee members use water from a well that the owner treats with WaterGuard. How to use? Pumps into storage tanks and adds it so he knows how much to use.

What's in the water that's unsafe? They want to use clean containers.

Why is the water unsafe before it's boiled? There's dirt from travel and the pipes have rust. Bacteria is a particular concern for rainwater. It also brings worms, but there are not other worries.

What about fluoride? Magadi and salt = fluoride, they can taste it. There's nothing you can do to remove it. Water with magadi is okay for cooking but not drinking. Use that water to cook certain foods, it also uses a lot of soap for washing.
Is it a taste issue or a health issue? To most of the community, it's just taste. The village leader has been told it can cause health problems. What about dental fluorosis? Noticed his teeth versus Kupaza's. Village concern is majority taste.

**It's more important to just have water than worry about it. They don't have a choice.**

What is the biggest concern? Fluoride is the priority because he can boil to remove bacteria.

19 February 2014

Mkuru Training Camp

J - Maasai

Can you describe what you did yesterday?

Got up ~5am (farming season) and goes to farm. Around 11am, he goes back to let the livestock out and takes a bath. A child goes out with the livestock (someone 10-20 years old). After the bath, he follows after the child and livestock, but may do repairs around the house first. At the field with the livestock he counts the # of animals. He supervises taking the livestock back and finding any lost animals.

He has cows, goats, donkeys, sheep. It can be rude to ask how many, since it's inquiring about wealth. He said he didn't mind us asking, has 50 goats, 20 sheep, 5 cows, 1 donkey. Has males and females of animals. The bucks and does are keep separate because they won't breed seasonally (don't want them to be bred when there isn't enough food for the nursing does). Cows will breed seasonally.

Brings back the livestock, wife takes over the livestock. He goes to rest and waits for the evening meal.

He has only one wife and is planning for more

Using water during the day?
It's a woman's job to collect water, comes in 20-30L. Water is used for drinking, washing clothes (they are washed at the source), utensils, bathing.

Drinking – a max of 1L a person each day. It's the same for most Masai, although they drink more with dry foods. They also drink milk, soft porridge with milk. Milk: after milking, the milk is boiled and kept to cool. He doesn't like unboiled milk (it used to make him vomit as a child). Most Masai drink the milk right after milking. The milk is traditionally not sold, it has to stay in the house (it's drunk and made into yogurt).

There's no treatment on the water.
The livestock are taken to the source to drink, except for very young calves the can't make it to the source.

The water is kept in plastic buckets with lids inside the house (100L black tanks).

They drink any water they find when herding, even if it's used by the livestock.

**Drinking water:** Is there anything he dislikes?

The only thing is that the water they're drinking now doesn't satisfy thirst, drinking it leaves you thirsty.

Are you worried about the same water as the livestock?

The sources found while herding are collected rainwater, you'll get malaria from it. They have started to use taps.

Do you like the way the water tastes?

The water still has some magadi “feel” but less than the previous source they drank from.

What was the previous source?

Kuiatoi, but they'll still use it if there are issues with the current source. The current source is a bore hole (built by Oikos). The pump broke down last year. There is also a dam but they only use it if there with livestock.

Is there treatment done at the home?

No, just drink it.

Do you think your family experiences health issues from drinking the water?

Doesn't think so now, but he knows Kuiatoi had minerals that destroyed their teeth. It could hurt their bones, but he didn't see that. It also had worms that caused stomach problems.

Worms?
You can see them in the water. They attach to the animals mouths and suck blood. You can treat them with a mix of tobacco and magadi. The worms can also go into the stomach.

(Aside with translator) What happened to the source that was broken?

It's a bore hole powered by solar panels. It needs 32, but 18 were stolen. Since there's less power to the pump, less water is drawn. The water shortage is a big problem during the dry season and people go back to other sources.

During a water shortage, the animals get water first.

Has he ever learned about how to remove worms or minerals from the water?

With the old source they used lime (like whitewash) where the animals used to drink. You can buy it at the village market. When he was young, his parents did that, doesn't know how they learned but they did it to kill the insects. It was a different source for livestock. Treatment was done once a year. They pour a bag into the source, some settles. Done in June when the rainwater storage dries up.

For people, they use a cloth to filter.

The old source was a spring

The bone and teeth problems only affect people, not the animals. They have not affected him, there are some teeth problems in his family. They have to spend money on a doctor. The problems have increased recently, his parents didn't have them. It's caused by the food they eat now. They used to only eat milk, meat, blood and traditional medicine. Now they eat bananas, porridge, fruits, vegetables, beans, and all these things are recent additions to their diets. They used to only drink water mixed with herbs (when they have to eat a lot of meat to help tenderize the meat in their stomachs).

What herbs? Orkrien, oltughai

20 February 2014

Health Clinic Visit

B at Melula Dispensary
Services are treatment and care of mother, father, children. They provide daily health education, after have general problems and getting treatment. Work with pregnant women, children's health, STDs, HIV testing, malaria, weigh and immunize kids.

Dispensary: treat if they're able. If it's too expensive or needs admission, that requires a hospital.

Health center: Treatment, lab investigation, up to three days admission

District hospital

Lab work: HIV, malaria, syphilis at the dispensary

Seasonal complaints, and treatment according to the season

Rainy: cough, pain → give medication

Dry: diarrhea

What do you teach them?

Diarrhea, pneumonia, typhoid: signs and symptoms, treatment, complications

Just talking, nothing to show them

If I came in with head and stomach aches, what then?

Rule out stomach problems and food poisoning. Ask about associated factors and duration to rule out some diseases for diagnosis. Malaria test if affordable, otherwise parasitum.

What did you treat yesterday? Pneumonia, burns, cut wounds

All pregnant women and kids under five years old get a mosquito net, malaria has decreased.

Pregnant women must come with apartner. They get HIV counseling, malaria prevention with net, health education: know your risk factors, prep for delivery, family planning (decide right after deliver)

Infants don't drink water until 6 months. Don't have immunity, must be breast fed.

Offer education on food prep, spoons, water for the baby.

First meeting is longer, 2-4th need more of reminders...do you remember...? just remind me ... review if necessary

Teach according to village. Buying water is difficult. Boil until completely boiling, cool and pour through clean cloth (towel, clothes, whatever is available) to remove particles. It's usually bore hole water. Need to use a clean cloth.

“First you have to know what they know.”
Do you consult? There are also two nurses that help with the mother and child work, but there hasn't been a need for consulting. Are there public awareness programs? Not for water.

The most common signs and symptoms are headache, vomiting, diarrhea, abdominal pain, joint pain (due to typhoid and malaria).

There are posters around the clinic. Do people use the posters?

Some people read them, but others only see the pictures. They don't ask about them because they don't know their rights.

Only about 10 out of 100 know how to boil water. They don't boil tap water, they believe it won't cause them any harm.

If all 100 knew about water; how many would still come to the clinic? The number of cases would decrease with education, about 30 out of 100 come due to water related issues.

Education: sometimes classes (5-10 clients), then treatment. If they're alone, you educate according to the problem. The health officers check homes, lack of toilet, etc. They give instructions on hand washing. People know, but get reminders at education. People don't because they need a shortcut and want to save time and water.

---

20 February 2014

**E – Meru home visit**

She doesn't use magadi, she was told not to during her pregnancy with lots of vomiting.

Buys her water from Kia → 300R/20L, uses 20L for a day. Delivery is at varied times during the day, probably the morning. She gets her water from neighbors with bore holes if there's no delivery, or she doesn't have the money (about 1.5 km away)

Carries on her head in 20L buckets, boils it in another bucket. She always boils her water. All her water is boiled, not just drinking water, if it's not to Kia. She doesn't boil her water from Kia, believes it's safe and it also tastes better.

The bore hole water contains germs and microbes, and is hard → the hardness stays after boiling.

About 5 out of 20L is for drinking. She filters before drinking bore hole water with filters that are sold.

Sends water with the kids (two older) to school. Boiled water in Kilimanjaro water bottles.

---

21 February 2014
Defluoridation Research Station at Arusha University

GM – station chief

MGM - assistant

About 70% of available sources are over 1.5 mg/mL, government standards were changed to 4 mg/mL to keep sources from being shut down.

Fluoride is highly variable, readings change within meters.

Mission is to target the simplest possible solution

- absorption methods are the priority here
- mix lime and aluminum sulfate to get pH and flocculation, but the alkalinity varies and requires custom ratios
- now working on bone char filters – developed in the US in 1920s, ended in 1951 when last factory was closed
- they use exclusively cow bones for mass usage (no pigs for Muslims, etc.)

° Charring system is a furnace where they can control and determine the charring temperature
° 500-600 degrees for gray bone char. The best char is at 400 degrees, but the organic matter isn't all destroyed and leaves smell, taste, color in the treated water
° They crush and wash the char and pack into a column
° There is a collection center for the bones – they want them as clean as possible. There is a mental perception about the bones not being clean.
° They are currently only in Arushatown, but are looking to expand
  - bone Ca$_{10}$(PO$_4$_6)OH

How much bone char do you sell?

About 500 kg/month. Once established, it will be turned over to the private sector.

Cows are sold by weight (as meat), need to give value to the bones to have the carcasses deboned.

Existing filters are via Oikos, paid half by Oikos and half by the villages, done in 2007-2009. Now they are leaking and not working well.

Filter fab: issues with leaking and installation, joins between components

Exhaustion of fluoride, inlet/outlet arrangement

Absorption is w/in five minutes
With upward flow, need to restrict the flow rate into the filter module. If you increase pressure, the
filter bed expands. A flow switch is expensive, so they restrict the flow with the size of the orifice.

Takes 2.5-3 hours to filter 20L. Uses a propylene column and buckets, although the tested a design with
PVC

3-8 mg/g absorption of bone char

Charring – 1 kg of wood used to start it then bones burn on their own. Requires careful control of air
supply.

The effect of fluoride on the body varies with ambient temperature

Use waterguard before the bone char filter. Too much forms chloramines. Aluminum sulfate drops the
pH and may become soluble (won't precipitate)

21 February 2014

ANEPO visit

Start with the environment, it affects health. People's habits are changing- diet, food, water, and these
are all becoming contaminated.

Women are blamed for children's lack of attendance at school, costs of the household, sickness. Blame
should be distributed equally.

Current project is the biosand filter. Needs 24 hours to set cement, 7 days to cure. The perception is that
the sharp sand kills bacteria, the water is fresh like spring water. Needs 25 kg of sand, 5 kg of 6 mm
gravel, 5 kg of 12 mm gravel. There is an initial flush of 60L water, 2 weeks of bacteria “starvation”

Better than the cost of fuel (time and money) to boil water. A bag of charcoal is 28k shillings, costs 6000
shillings to boil 20L

Can filter 200L a day. Filter cost is water and labor to clean the gravel/sand

Some users are selling their water to neighbors after it's filter
### Concept Testing

#### Table 12. Concept Testing Results

<table>
<thead>
<tr>
<th>ISSUE</th>
<th>QUESTION</th>
<th>RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dirty Water (Before news on contamination at household level)</td>
<td>How clean and safe is the water that your children drink?</td>
<td>Jacob: Clean and safe water from KIA, Betty: Clean and safe water from KIA, Jane: Clean and safe water from KIA, Elizabeth: Clean and safe water from KIA</td>
</tr>
<tr>
<td></td>
<td>How clean and safe is the water that you drink?</td>
<td>Jacob: Clean and safe from KIA, Betty: Clean and safe from KIA, Jane: Clean and safe from KIA, Elizabeth: Clean and safe from KIA</td>
</tr>
<tr>
<td></td>
<td>How good does your water taste?</td>
<td>Jacob: Taste is good, Betty: Taste is good, Jane: Taste is good, Elizabeth: Taste is good</td>
</tr>
<tr>
<td></td>
<td>How necessary is adding Water Guard (chlorine) to your water?</td>
<td>Jacob: Necessary for water harvested from rain, Betty: Necessary for water harvested from rain, Jane: Not necessary, Elizabeth: Not necessary</td>
</tr>
<tr>
<td></td>
<td>How necessary is boiling water?</td>
<td>Jacob: Necessary for water harvested from rain, Betty: Necessary for water harvested from rain, Jane: Necessary but firewood is expensive, Elizabeth: Necessary</td>
</tr>
<tr>
<td></td>
<td>How necessary is filtering your water?</td>
<td>Jacob: I don’t have knowledge on filtering of water, Betty: I use sieve used for tea to filter water, Jane: Necessary, Elizabeth: Necessary</td>
</tr>
<tr>
<td>Dirty Water (After news on contamination at household level)</td>
<td>How necessary is adding Water Guard (chlorine) to your water?</td>
<td>Jacob: I need more knowledge on how to keep the water in the home safe, Betty: Only for water harvested from rain, Jane: Water Guard is added in KIA water before we buy, Elizabeth: Not necessary</td>
</tr>
<tr>
<td></td>
<td>How necessary is boiling water?</td>
<td>Jacob: Firewood is expensive, Betty: Firewood is expensive, Jane: It is necessary, Elizabeth: It is necessary</td>
</tr>
<tr>
<td></td>
<td>How necessary is filtering your water?</td>
<td>Jacob: I need more knowledge on this, Betty: I filter using sieve for tea, Jane: I don’t have equipment for filtering, Elizabeth: Not necessary</td>
</tr>
<tr>
<td>Fluoride (After communicating fluoride issues on the slide)</td>
<td>Is any of this information new to you?</td>
<td>Jacob: I know fluoride water has bad taste, Betty: I know fluoride water is salty and doesn’t quench thirst, Jane: I know fluoride causes legs to become painful and cripples especially children, Elizabeth: I know fluoride is salty</td>
</tr>
<tr>
<td></td>
<td>What would you like to learn more about?</td>
<td>Jacob: More about other effects of fluoride on people, Betty: More about other effects of fluoride on people, Jane: We have enough knowledge, Elizabeth: Effects of fluoride on health</td>
</tr>
<tr>
<td>Summary and Tends</td>
<td>What do you have to say about the trends cannot dispute the trends because I am not conversant with the problem</td>
<td>Jacob: I agree accept what experts say, Betty: I agree because I don’t know, Jane: It can happen if you don’t wash water buckets with soap</td>
</tr>
<tr>
<td>Actions to Take after communicating the proposed actions and issues on the</td>
<td>What do you have to say about the proposed action will try my best to find money and time to implement the actions because it is important for my family</td>
<td>Jacob: Water is life. It should be safe, Betty: am strict about use of water in my house. I teach my children how not to contaminate, Jane: It is difficult because sometimes you have no access to safe water because of</td>
</tr>
<tr>
<td>Subsistence Marketplaces Initiative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Affordability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>How much would you be willing to pay for the basic bucket/lid/spigot?</strong></td>
<td>Ths 7,000/= Or USD 5.00</td>
<td>I will negotiate</td>
</tr>
<tr>
<td><strong>How much will you be able to pay for the other filter options?</strong></td>
<td>I will negotiate when I see the product</td>
<td>I will negotiate</td>
</tr>
<tr>
<td><strong>Would you want to build it yourself?</strong></td>
<td>Someone competent to build it</td>
<td>I would like to do it myself</td>
</tr>
<tr>
<td><strong>Would you want to purchase a complete unit?</strong></td>
<td>If I can afford it</td>
<td>Depends on cost</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What do you like?</strong></td>
<td>The initiative to educate people</td>
<td>Education about effects of unsafe water</td>
</tr>
<tr>
<td><strong>What do you not like?</strong></td>
<td>Does not reach many people</td>
<td>Nothing</td>
</tr>
<tr>
<td><strong>What would you like us to add?</strong></td>
<td>Use of methodologies that will enable many people to acquire the knowledge</td>
<td>More knowledge on safe water</td>
</tr>
<tr>
<td><strong>What would you like us to do differently?</strong></td>
<td>Include more details for people to understand the water issues better</td>
<td>To reach more people</td>
</tr>
</tbody>
</table>
### Determination of Technical Specifications

**Table 13. Constants, input parameters, and output parameters for the bone char filter design**

<table>
<thead>
<tr>
<th>CONSTANTS</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>porosity</td>
<td>0.47 calculated from 2013 CEE 449 lab data</td>
</tr>
<tr>
<td>bulk density (g/L)</td>
<td>790 calculated from 2014 CEE 449 lab data</td>
</tr>
<tr>
<td>capacity (mg F/L BC)</td>
<td>1266.27 assumes a capacity of 1 mg F/g BC</td>
</tr>
<tr>
<td>ka (L/mg/hr)</td>
<td>2.13E-02 least squares regression using 2014 lab data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>flow rate (cm³/min)</td>
<td>133 6-8 L/hr used in filter design at Ngurdoto Defluoridation Center (d=15, l=55)</td>
</tr>
<tr>
<td>column diameter (cm)</td>
<td>15 must fit inside 20L bucket inner diameter ~26 cm, ceramic filter diameter 6 cm</td>
</tr>
<tr>
<td>column height (cm)</td>
<td>56 must fit inside 20L bucket-height ~37.5 cm</td>
</tr>
<tr>
<td>hours/day filter runs</td>
<td>2.51 column volume/flow rate</td>
</tr>
<tr>
<td>Cin (mg/L F)</td>
<td>15 influent concentration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OUTPUT</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>height of funnel (cm)</td>
<td>34.93 approximate additional height of CYLINDRICAL funnel required to hold 5 L untreated water</td>
</tr>
<tr>
<td>total height (cm)</td>
<td>91.93 total height of product</td>
</tr>
<tr>
<td>void volume in filter (L)</td>
<td>4.61 space in column not occupied bone char</td>
</tr>
<tr>
<td>volume of filter (L)</td>
<td>9.90 volume actual filter occupies</td>
</tr>
<tr>
<td>mass of bone char (g)</td>
<td>7.8</td>
</tr>
<tr>
<td>retention time (min)</td>
<td>34.67 this value must be greater than 30 minutes</td>
</tr>
<tr>
<td>linear velocity through column (cm/hr)</td>
<td>45.16 flow rate/cross-sectional area</td>
</tr>
<tr>
<td>breakthrough (days)</td>
<td>87 when bone char needs to be replaced</td>
</tr>
<tr>
<td>volume after filter (L)</td>
<td>19.84 volume to be chlorinated/storage space</td>
</tr>
<tr>
<td>chlorine conc. (mg/L Cl₂)</td>
<td>2.18 chlorine concentration after adding 1 WaterGuard tablet</td>
</tr>
</tbody>
</table>

These input and output values lead to the following breakthrough curve for fluoride using a bone char filter. After 87 days of filtering 20 L/day, the bone char can no longer produce water that
meets the WHO guideline of 1.5 mg/L F. More details on the technical aspects of the design including the breakthrough modeling can be found in the CEE 449 Tanzania 2014 Report.

Figure 31. Breakthrough curve for bone char filter predicted using Bohart-Adams model
REFERENCES


IstitutoOikos (2011) THE MOUNT MERU CHALLENGE Integrating conservation and development in Northern Tanzania. AncoraLibri, Milano (Italy).


