Refrigeration and Water Filtration
Jill Kanney
CRP 4900
Professor Kim Burton

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The Problem

Currently, Ghana is struggling with many power outages and water-borne illnesses. Also, lack of effective refrigeration techniques to preserve food has been an issue for many years; oftentimes, there is an ample amount of fresh produce, but it spoils and goes to waste before reaching consumers. In 2013, a survey was conducted in the markets in the Offinso North District (OND) in which all participants stated that they were interested in food preservation methods. Furthermore, six out of seven participants said that if effective methods were available, they would pay money to preserve their produce. This supports the fact that there is a need for preservation methods in the homes and markets.

Furthermore, Ghana has also struggled with water-borne illnesses for many years. It is statistically proven that dirty water kills more children than war, malaria, HIV/AIDS, and traffic accidents combined. Residents in Sub-Saharan Africa only use about 2-5 gallons a day. This small volume of water could easily be produced by a small in-home water filter, and thus supports the fact that there is a need for a cost-effective and simple technique to provide clean water in the homes.

The Solution:

My plan is to build a combined refrigeration and water filtration system that does not require electricity. I have done much research on the topic, and have come up with two initial designs that will accomplish this task.

The first design is based on the WindChill Food Preservation Unit. The Windchill unit uses cooling mechanisms that different animals use to regulate their internal body temperature. This new idea for cooling was recently developed by a group of students from the University of Calgary in Canada (Jorge Zapote, Mitchell Weber, Xi Cheng, Michelle Zhou). Although the design has been proven to work in Canada, it has yet to be tested in countries that have extreme heat, such as Africa. The cooling unit consists of a funnel, tubing that is made from recycled aluminum cans, copper tubing, recycled glass or clear plastic, and a styrofoam cooler. I have incorporated a built-in water filter into the design that uses the biosand technique. This way, food will be preserved and clean drinking water will be provided...without the use of electricity! Theoretically, the device will be able to keep food cold by using only ambient air.

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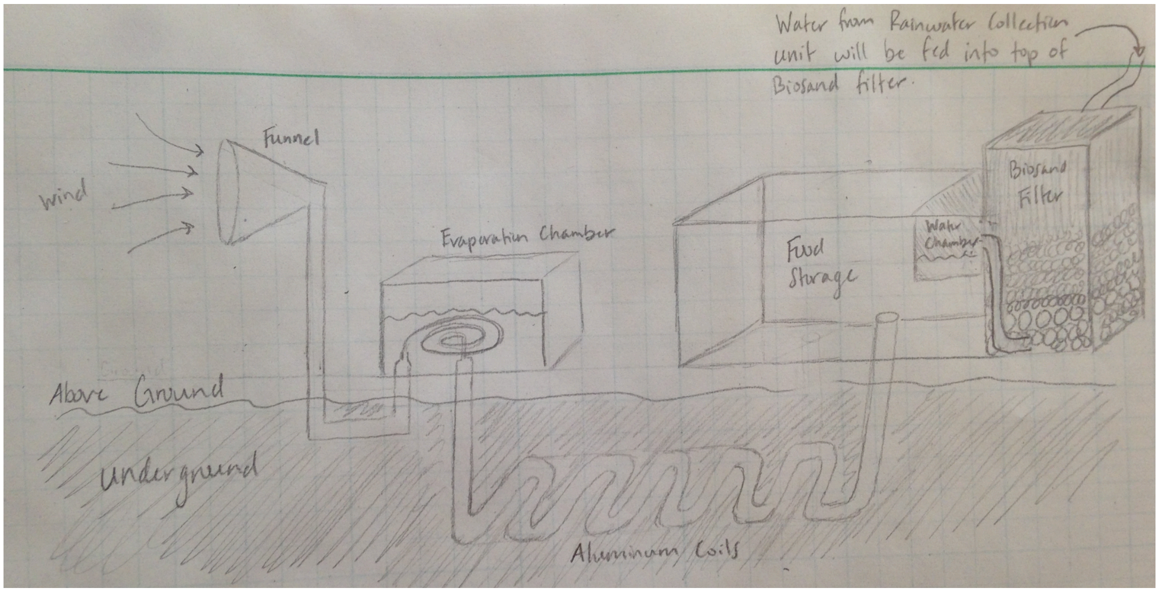

Figure 1: Brainstorming draft of Windchill with built-in water filter

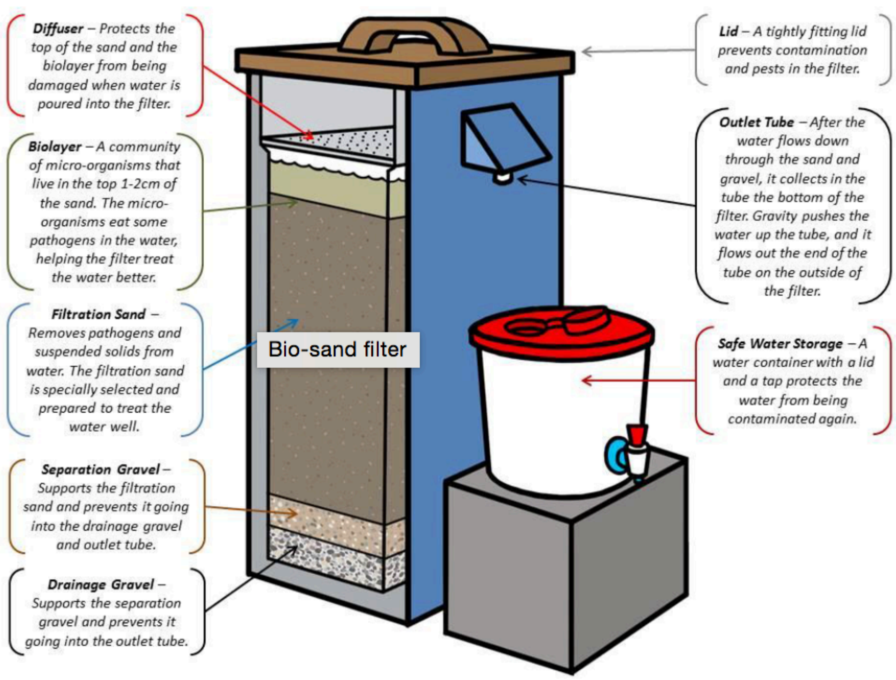

Figure 2: Biosand Water Filter

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If the Windchill unit doesn't work out as planned in Ghana's climate, the back-up design is an Evaporative-Refrigerator with a built-in water filter. The Evaporative-Refrigeration Technique consists of an inner metal cylinder and an outer plastic cylinder that has holes drilled into the side. The gap between the inner and outer cylinders will be filled with sand. Rainwater will be collected and diffused over the gap layer of sand. As the rainwater travels through the sand, the water will evaporate off, thus cooling the inner cylinder. The excess water that doesn't evaporate will continue traveling to the bottom of the unit and, by way of gravity, will be forced up a tube into a collection chamber in order to store the cold, filtered water.

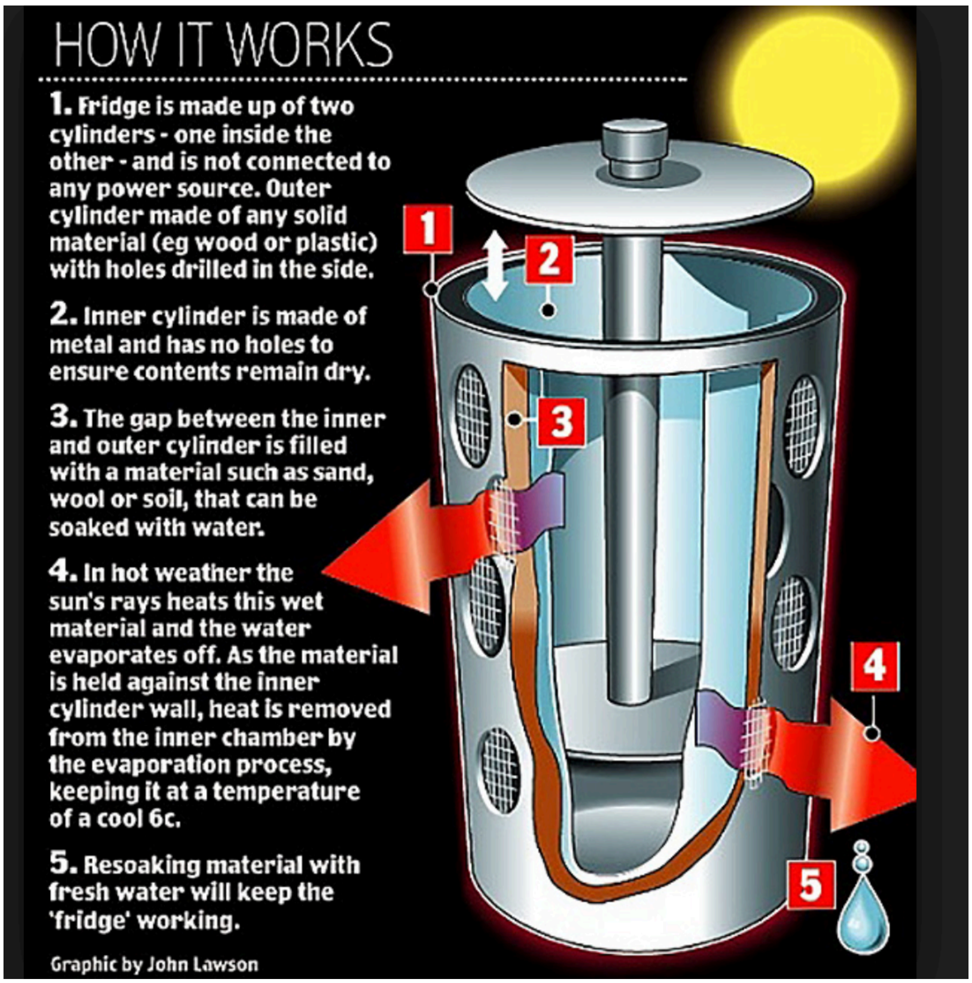

Figure 3: Evaporative-Refrigeration Technique

Previous Projects:

In 2013, a group tried to build a "Pot-in-Pot" unit in the Offinso North District. The Pot-in-Pot consisted of two clay pots of different sizes, sand, and water. One pot was placed inside the other, with sand in-between. The sand was saturated with water, and when the water evaporated, it cooled the inside of the inner pot. However, too much time was spent locating materials, and there wasn't enough time left to build, effectively test, and educate the people of OND about the project. Therefore, there is not much information about the effectiveness of the Pot-in-Pot design.

After conducting some research, the biggest downfall I found with the Pot-in-Pot is that due to the extremely humid climate of OND (most days ~95% humidity), the water will have a hard time evaporating away from the sand. Therefore, the Windchill unit is my primary design for the project, and the evaporative-refrigeration technique is my back-up design. The back-up design is basically a modified Pot-in-Pot. Modifications to the Pot-in-Pot design include: the inner cylinder is metal instead of clay, the outer cylinder is cardboard or plastic instead of clay, and holes are drilled into the outer cylinder. All of these modifications will aid in the evaporation process. Furthermore, the modified design will also collect the excess filtered water that reaches the bottom of the cylinder (the water that doesn't evaporate) and store the filtered water for drinking purposes.

<u>Cost:</u>

Most materials that make up the Windchill unit are recycled materials that can be found in a junkyard: funnel, aluminum cans (for tubing), copper tubing, clear glass or plastic, and a styrofoam container. However, even if these items aren't found in a junkyard, all of the items can be purchased for less than $50. Therefore, the maximum cost for each Windchill unit was estimated to be $50.

However, it was discovered that in Ghana, it is highly unlikely to find anything of value in a junkyard. As soon as something of little value is thrown away, it is immediately recycled and used by somebody in the village. Furthermore, there are no set prices in Ghana. You must haggle with storeowners in order to obtain a reasonable price for the items you wish to buy. Thus, the cost breakdown of one Windchill unit in Ghana was as follows (USD):

Copper coil…………………………………………………$13.98
11x14 in styrene sheet (6 sheets at $4.38 each)……………$26.28
Aluminum Tubing……………………………………….…$28.95
Styrofoam Cooler……………………………………….…...$4.00
Funnel……………………………………………………..$1.00
Epoxy……………………………………….….…...……..$5.25
Welder……………………………………………………..$185.00

As can be seen, even though the supplies weren't found in a junkyard, they were still purchased for relatively cheap ($79.46 USD). However, the labor for building the project was very expensive, as the welder charged $185.00 USD for his work. The next section explains that welding was not the preferred method for making the coils, and therefore, the cost of labor will be greatly decreased when the next Windchill unit is built.

The Evaporative-Refrigeration technique is also made from recycled materials. Again, if the materials are not found in a junkyard, it is estimated that they can all be purchased for less than $20.

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Pre-Trip Activities:

The initial ideas were communicated with Offinso Executive Director and District Leaders Kojo Appiah Kubi and Andy Bediako. Andy and Kojo both said that the project ideas were really good and that they will help their communities to a large extent. Andy also said that all materials needed would be available in Ghana. This was a relief to know that there was no need to bring materials from the United States.

I also asked Kojo if he knew of somebody from the Offinso North District who was willing to test out the initial design in their home, school, business, market, etc. Kojo said that there would be plenty of opportunities and not to worry.

After communicating the ideas with Kojo, the communication began with the students from Canada who developed the initial Windchill design. By way of phone calls and email, I learned about the initial aspects about the Windchill design. I incorporated a water-filtration system into the design and then built a prototype.

Figure 4: Prototype of Windchill

In-country Activities:

I quickly learned that building something in Ghana is completely different than building something in the United States. It only took one afternoon in the United States to buy all of the supplies from Home Depot, build the refrigerator, and place the refrigerator in ground for testing.

In Ghana, on the other hand, I first had to explain the supplies that I needed to a translator. Then, for each item that I needed, I had to walk around different markets in order to find a market that sold what was needed. Once I found an item I needed, the translator had to haggle with the shopkeeper in order to get the item for a reasonable price.

After finally gathering all of the supplies, I explained to the translator that I needed a metal works person who could bend the aluminum tubing into thick coils. Instead of bringing the aluminum tubing to someone who would heat the tubing and bend it, the aluminum tubing was brought to a welder who cut the aluminum tubing into pieces and then welded the pieces together by hand in order to form coils. Although the welder did a fantastic job with the project, it was very time consuming and very hard work for the welder. Because it was so difficult to weld by hand, it was an expensive process. Furthermore, there is a chance that the coils are leaking some of the cold air since they were welded instead of bent.

We only had four days in OND to work on our projects. Because we only had four workdays, I only had time to build a Windchill unit without the attached biosand water filter, and I didn't have time to make modifications to the design. On the first day, I purchased all of the supplies. After gathering the supplies, it took 2 1/2 days for the welder to make the coils. Therefore, on the afternoon of the 4th workday, the refrigeration unit was placed in the ground for testing. Although cool air was definitely coming from the pipe, the styrofoam cooler that was used failed to contain the air. This was partially due to the fact that the cooler was very thin-walled and contained a few small holes where the cool air was able to escape. Furthermore, the extreme heat in Ghana was most likely a second contributing factor. In order to combat these issues, it is suggested that a stronger insulator is used to capture the air, and the insulator is placed underground, preferably in a shaded area. Ideally, after the Windchill design is perfected, the funnel and evaporation chamber will be located outside of a home where wind will enter the funnel and the sun's heat will evaporate water from the copper coils. The aluminum coils will then carry the cool air underneath the walls of a house and into the insulator, which will be located underground inside the home. Because we had to present our projects and leave OND shortly after testing the initial project, I did not have time to implement any of these ideas for improvement. However, the government officials were very excited about the project and I am currently communicating with a few people from the Offinso North District Assembly (ONDA) who are going to continue work on the project.

Figure 5: Translating to welder how to build the Windchill unit

Figure 6: Drawing in the sand in an effort to explain to the welder how to make the aluminum coils

Figure 7: Digging a hole 3 feet deep for the Windchill

Figure 8: Windchill before putting it in the ground

Figure 9: Windchill in ground (before covering with dirt)

Figure 10: Completed Windchill

Figure 11: Testing the Windchill

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Suggestions for Improvement:

While building the refrigerator in Ghana and experiencing their culture and climate, I thought of additional ideas that will improve the design and help to further cool the air before it enters the insulator. A summary of all of my ideas for improvement is as follows:

- Use a better insulator
- Put insulator underground
- Build aluminum coils deeper in ground (Right now the coils are 2 ½ feet underground. In Ghana, the ground is still hot 2 ½ feet underground. It is estimated that the coils must be 6+ feet underground in order for the ground to provide effective cooling.)
- Place insulator is in a shaded area
- Build Windchill in a more rural area (maybe on a farm?) where there is more wind
- Use a bigger funnel in order to collect more air (have welder build a funnel instead of using a plastic funnel)
- Find a metal works person to bend the pipes instead of weld the pipes (this will be much cheaper and take less time!)
- Use PVC pipe instead of metal pipe (PVC will be cheaper than metal, and ONDA knew of a person who could bend PVC pipe into the coils needed)
- Build the funnel and evaporation chamber outside of a house, and use the aluminum coils to carry the air underneath the wall of the house and into the insulator that is located inside the house.
- Add a biosand water filter to the design

Sustainability:

After building and testing the initial design in Ghana, the unit was presented to the Offinso North District Leader in hopes that engineers in the district will make the changes suggested for improving the design and will add a small water filtration system to the design. This way, the design will be approved to be mass-produced. If the design is mass-produced, many people will be able to use the refrigeration unit in their homes, at the market, and in schools. I gave ONDA detailed documents about the components of the design, how to build the design, the scientific theory behind the design, and suggestions for improving the design. Over the next couple of months, I will continue to communicate with the government officials about the progress and sustainability of the project. I will also communicate any new ideas for the design with ONDA. The design was well received by ONDA, so I am confident that they will continue to pursue the project.

Note to Reader:

If you would like to see the Solidworks drawing plans for the project, or a separate report that breaks down the components of the Windchill design and explains the science behind the design, please email me at kanney.21@osu.edu