Solar Water Disinfection Device

Final Report

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The following is a final report of the progress of the solar water disinfection device, from the early design stages through prototyping, as well as a description of future plans, including further testing and implementation. The report has been broken down into various section so as to provide a narrative of the project's chronological development in as concise and clear a fashion as possible.

BACKGROUND

Current Needs

Water is an essential element for life, both in quantity and quality. However nowadays we face the threat that one-sixth of the world's population, 1.1 billion people (WHO, 2002), lacks access to an improved water supply, and two-fifths, 2.4 billion people, lack access to improved sanitation. In many developing countries this problem has lead to a high risk of water-borne diseases such as diarrhea, cholera, typhoid fever, hepatitis A, amoebic and bacillary dysentery, etc, that causes illness and and/or death of millions of people, especially children.

The 2.2 million deaths every year from waterborne diseases, nine out of ten who are children, could be avoided through improved water supply, water quality and sanitation. Most of these people live in Asia and Africa, where less than half of Asians have access to improved sanitation, and three-fifths of all Africans lack to an improved water supply. These numbers, however, are for urban areas; rural areas are even farther from the goal of universal access to a safe and plentiful supply of drinking water and appropriate sanitation.

Current Solutions

Currently, many methods for treating water exist, but for various reasons, they have not been successful in stemming the tide against the spread of waterborne diseases. Below, we hope to address these different methods, highlighting their shortcomings, and thus explaining why a plastic bag design is better.

A common approach for water disinfection is chlorination. While it is a cheap method of disinfecting water, say a few cents to process a whole bucket of water, anyone who has had to drink chlorinated water can tell you that the taste and smell are not pleasant. While variable amounts of chlorine can be added to reduce such a strong taste, there is an obvious risk in not killing all of the bacteria in the water. This problem also is extended, in that you require some sort of measuring device to be dispensed, and the knowledge of what ratio of chlorine corresponds to what ratio of water. Also, the problem with chlorination is that it requires a well-stocked inventory, which means populations living in remote areas are dependent on deliveries of chlorine.

The most logical alternative would be to boil water of poor quality. However, in many communities of need, it is already difficult to gather sufficient fuel, particularly firewood, in order to be able to boil water. This system is not sustainable, considering the environmental repercussions associated with deforestation in order to satisfy firewood fuel demands, which can be seen in Haiti, several sub-Saharan countries, and other poverty stricken areas. The process also requires a large time input, though unlike solar water disinfection, a boiling pot of water requires your attention. For this reason, it is an unattractive option, even when the community knows that boiling water is good. Likewise, it occupies another container in the household while it cools, and in the process of doing so, it often faces the threat of being re-contaminated.

Possible Solution

One potential solution is a solar water disinfection device. Current solar water disinfection devices are either too expensive for households in developing countries or inefficient in terms of transportability and disinfection time. Our goal is to design an inexpensive solar disinfection device that is easily transported in bulk to distribution sites, quick to disinfect water, and easy to use and maintain in the areas of need. This device will have to be rugged enough in order to survive constant exposure to the sun, while at the same time being functional enough to be handled by a single individual.

The most comparable to our project, is the SODIS PET bottle. This system utilizes a bottle identical to that of a two-liter soda bottle, which is filled with water, and left in the sunlight for a set number of hours. This system has the advantage of being able to be placed between the spaces of corrugated metal roofs common in lower-income dwellings across the world, as well as sharing the intuitive operation of any other bottle. The big advantage over other systems is that once disinfected, this water can be directly poured out and utilized by the household.

There are, however, some serious shortcomings compared to our system. The same small opening that makes the SODIS bottle ideal for household pouring also makes it difficult to fill, especially if the water source is a common borehole that sends water gushing out in large spurts. In terms of disinfection efficiency, the bottle takes longer to disinfect the same volume of water. For one, the depth of the water is constant, whereas a bag can expand to decrease the depth, and thus decrease the hours of direct sunlight exposure required to disinfect the water. Secondly, the bottle is thicker than a bag design, which also reduces UV transmission, and likewise increases the amount of sunlight exposure required to disinfect the water. Additionally, the specific bottles required for this system are not readily available in many parts of the world that have the most need to have treated water. Often times, there are glass bottles, or plastic bottles much thicker than those used by SODIS. If one plans to ship out the SODIS bottles, then one encounters a second problem with the bottle itself, and while the bottle is light, it occupied a large volume. A stack of collapsible bags take up the same space as a single bottle, thus making it more attractive to choose the latter.

Using our strong ties with reliable community partners in Zambia, we will also develop a device that is marketable to our population of users, and generate different marketing plans to maximize the dissemination of our product. Inspired by Paul Pollack's inexpensive and mass produced drip irrigation kit, we hope to create a similar easy-to-produce product that can also be traded in for credit toward the purchase of the next device, so as to ensure that waste accumulation does not become a problem that plagues even the most remote of areas representing a large share of our ideal market.

One of our team members has worked with the small community of Mwape in rural Zambia before that currently must endure the negative externalities associated with utilizing a poor water supply from a nearby river. Because of the time involved, and the material input required to boil the water, villagers seldom boil river water, despite knowing clearly the effectiveness of such a method. Other villagers utilize boreholes as their water source. Even while the village's two boreholes have water of good quality (after conducting field testing in January 2005), contamination still occurs in the water supply. This is largely as a result of having to transport water from the centralized dispensing site to individual households.

Both of these problems could be solved by utilizing a solar water disinfection device. Our design would reduce the need for a fuel source, which is required for boiling water. It would utilize Zambia's abundant sunlight to disinfect water by taking advantage of UV rays' property that alters the DNA of bacteria so as to prevent them from reproducing. This device would also be designed to be as functional as a conventional water dispensing container, and thus can be utilized as the final dispensing device for water, and therefore prevent further recontamination by eliminating the need to move the water from device to device. This would mean that one could disinfect the water gathered at the source in this device, and then use it in the household as a conventional water dispensing device.

This solution would benefit the community at large, considering that the whole population is dependent on water from contaminated sources. However, fulfilling this need for the community has broader implications. This community is representative of many villages across the world, faced with the hardships of utilizing poor water sources. Thus, if we are able to fulfill the need for Mwape, we will be well on our way to identifying a model that can be replicated and applied in other parts of the globe. And given the millions of people affected worldwide by waterborne diseases annually, this solution could potential make an important impact from a health care standpoint.

PROBLEM STATEMENT

Current solar water disinfection devices are either too expensive for households in developing countries or inefficient in terms of transportability and disinfection time. Our goal is to design an inexpensive solar disinfection device that is easily transported in bulk to distribution sites, quick to disinfect water, and easy to use and maintain in the areas of need.

DESIGN SPECIFICATIONS

Summary of Specifications

1. **Inexpensive for the user:** $1.2/family/year
2. **Low Lifetime Cost:** 0.016 cents/ L disinfected
3. **Quick to disinfect water:** ideally 20L/day
4. **Easy to transport:** implied characteristic simply by using plastic bags
5. **Easy to use:** 1 min/fill, 10 kg max weight (full), 0.5m max length when carrying
6. **Optimal Thickness:** UV transmission vs. durability
7. **Easy to maintain:** No loose parts
8. **Environmentally friendly:** Long-lasting (1-year), other uses

Detailed Descriptions of Specifications

1. **Inexpensive** for the **user**
    - **Purchase price**
        - **($/family)**
        - **$1.2/device**

This is based on the current cost of chlorine treatment (10 cents/month/household), an alternative to our system; therefore, this amount should act as our maximum, assuming that the device lasts for a year. We could extend the lifetime of the product, but we would like to keep initial cost relatively low.

2. **Low Lifetime Cost**
    - **0.016 cents per L disinfected**

This is assessed by calculating the total expenditure involving the product (capped cost of purchase + upkeep) and dividing it by the total number of liters processed over the lifetime if the product. A household is estimated to use 20 L per day = 7300 L/yr.

3. **Quick** to **disinfect** water (on the scale of a single day)

- **Minimum of 0.42 L/hr, or 10 L/day, for drinking**
- **0.83 L/hr, or 20 L/day, if need includes washing dishes, etc.**

This relates to day usage. Ideally, we would like the device to be used in a single day to maximize functionality. People ideally need 2L per person per day (at 5 people per family); 15-20L once you expand past personal usage, to include cooking or cleaning food.

4. **Easily transportable** from **manufacture** sites to **distribution centers**
    - **Rough estimate (analogy to zip-loc bags):**
        - **100 1-gallon bags take about 5 cm x 5 cm x 30 cm when bought at Star in cardboard box**
        - **translates to about 7.5 cc/bag**
    - **Try to beat this density if possible. The real benchmark will be cost.**

We want to ensure that in transporting this device, we get our money's worth for the capacity and the magnitude at which it performs.

5. **Easy** to **use** (simple operation design)
    - **Easy to fill**
        - **1 minute per fill**

It is practical not to have to spend a lot of time filling the device. Most likely this will mean a broader spout/entry for the device.

- **Easy to carry**
    - **Is not dropped more than once in 20 water "trips"**
    - **Is tolerably comfortable to carry (pain below 2 on scale of 1-10)**
    - **10 kg ABSOLUTE MAXIMUM**

Derived from the fact that water weighs 1 kg/1L. Larger devices will be difficult to handle and empty. Also, we must take into consideration weight if we hope for the system to be flexible enough to be placed in different locations to dispense water once brought indoors.

- **Maximum Dimensions**
    - **Maximum Length in a single direction when filled**
        - **.5m**

We do not want the device to be bulky or difficult to handle. This consideration factors in that children are often responsible for bringing water back to the household.

6. **Optimal thickness**
    - **Maximum Thickness (6 mil)**
        - **thickness must provide sufficient UV transmission**
        - **thickness must likewise provide sufficient structural support**

We are trying to reduce thickness in order to increase efficiency of device.

7. **Easy** to **maintain** or **easily replaceable**
    - **Duration Exposed to Sunlight**
        - 1 year
    - **Locally accessible parts**
        - OK to have 1-time import of a very simple machine (e.g. heat sealer, shears) that has small maintenance cost
        - OK to have to import rolls of plastic sheet material between long intervals
    - **Drop Test**
        - 5 foot drop test
    - **Puncture Test**
        - drag full container along a board with bumps or nails

We acknowledge that our product is not indestructible, but at the same time, we want the product to be something local users will seriously consider in investing. Therefore, it should have a sufficiently long usage life so as to make up for its cost. Because most communities of need are largely impoverished, we understand that even an "inexpensive" bag of 20 cents, can be a financial burden.

8. **Environmentally friendly**
    - **Minimize waste during manufacture**
        - throw out no more than 25% of plastic sheet or other raw materials
        - energy-efficient and environmentally friendly equipment (e.g. disposable battery-operated sealer would be bad, but car battery heat sealer would work well)
    - **Minimize littering**
        - when torn, can be mended & re-used or used for other purposes
        - long-lasting to minimize turnaround

Ideally, we would like to have a similar set up to Paul Pollack's drip irrigation system, whereby you can trade in your old system and receive credit toward the purchase of your next one, so as to reduce the amount of waste generated, and entice users to continue utilizing this product.

<u>Additional Features</u>

These are features, if achieved without sacrificing our original design specifications, would be incorporate into the design.

- **Inexpensive** in **production** and **distribution**
- Capable of heating water at temperatures of **50° C** or above for at least one hour a day
- The **same** the **device** used to **collect** water and **disinfect** it
- Capable of operating in both **rural <u>and</u> urban** areas

DESIGN ALTERNATIVES

Over the course of the semester, our team produced nearly two dozen different prototypes of bags. Different designs were abandoned for different reasons; however, user-friendliness and user-acceptability were two main criteria the eliminated many of these designs. For example, the "water vest", which theoretically sounds like a good idea because it combines a large volume of water that can easily be carried by individuals of all sizes and can be laid flat, does look rather strange since it does not resemble any conventional water carrying devices. The two-valve "chicken", which was designed while conducting solar radiation tests, effectively combined the two valve system and did not require additional materials to make; it however, was difficult to fill and handle, though its conical pouring spout made emptying significantly easier. An early "heart chamber" prototype proved effective in keeping water in compartmentalized sections of a bag, thus making it better to stand upright, but because it did not have clear spout or cap, there was a fear of recontamination. A "folding" bag, the next generation of the vest, had an integrated handle, but this process significantly reduced the carrying capacity of the bag, and proved to add weak points to the bag where they would be hard to repair. In any event, these prototypes helped in the process of moving toward a better product. Characteristics which were positive in each of these, were identified, and later applied to the next generation prototypes. All prototypes, past and present, have utilized the heat sealer to shape and seal the plastic, because of the simplicity of this process and effectiveness.

FINAL DESIGN CHOICE

We managed to rule out a number of designs simply by using them in the lab during our water quality testing sessions. However, even after this process, we still had two schools of thought for the design: one to use additional material to create an external handle for the bag, and another to have the plastic bag serve as a bladder. After considerable deliberation among the members of our team, we came to the conclusion that the best approach to take for the remainder of the semester would be to have two competing prototypes. One featured a conventional design, with an intuitive spout and screw cap, as well as an external handle to carry it. The other was a plastic bladder with two valves, sewn into a piece of dark cloth. The two designs were quite different from each other, but neither was clearly superior to the other. Where one had simplicity, the other had cost effectiveness, and so on. We determined that the ultimate design selection would come from more extensive field testing, and more importantly, from getting direct user feedback in Zambia this summer.

DESCRIPTION OF PROTOTYPES

Screw Cap Design

The screw cap design features an external handle and an intuitive spout with a screw cap. The external handle currently consists of a chopstick, some rope, and a piece of PVC. The chopstick can be replaced by any type of thin stick-like piece, since it is only meant for added support. Chopsticks are inexpensive and durable, and hence they were chosen, but a similar shaped-piece will also serve the same purpose without having to be wood. The rope we employed forms the handle that slips under the chopstick. Rope of any sort, especially hemp, is readily available and can be used in the design. It is also inexpensive, and thus appropriate for the design. Another similar prototype featured a piece of wire, but we figured rope is more economically feasible for mass production. The piece of PVC pipe gives the bag a comfortable grip. Having to carry these bags a long distance is a reality we have to face, and we figured it would be best to have a comfortable grip for the bag. PVC is rather inexpensive and easily accessible. As with the chopstick and the rope, a similarly shaped piece would give the bag the same functionality. (See Appendix for figures)

Cloth Design

The cloth design has two components: a plastic bladder and a cloth cover. The plastic bladder does not require additional parts, thus making it extremely affordable. Instead of having a conventional spout, the bladder has two valves, one wide-mouthed for filling, and a narrower one for emptying. The valves are sealed by folding over the openings and slipping over pieces of the same bag (cut to fit exactly). This is a design feature borrowed from the drip irrigation kit utilized by Paul Pollack's IDE. The cloth component of this design serves several purposes. For one, it adds added durability and strength, since it is the cloth and not the bare plastic that is being exposed to potential dangers while transporting it between the household and exposure site. The dark nature of the fabric also helps heat the water up, which helps speed up the process of disinfection. Additionally, the cloth factor allows the user or retailer to adapt the look and usability to local customs and traditions. For example, one can make a bag from the cloth that carries the bladders like a conventional handbag, while a slight modification to the design can create a “wearable” backpack. The presence of cloth also creates the possibility of having job generation, whereby an enterprise could sew (or alternatively attack) the bladders to these cloth sacks, bags, or backpacks, etc. (See Appendix for figures)

LESSONS LEARNED

On-going Design

We learned lessons about practical design and testing. Early on in the prototyping phase of our project, we saw the importance of making models and testing ideas. While we liked an earlier design with built-in handles and a fold in the bag, after making a physical model of the idea we discovered several flaws with this method. We also learned about the tradeoff between finding a perfect solution and finding a practical workable solution. With our project, it was very easy to make different prototypes. While this ease was appreciated so that we could keep improving our ideas, in reality the practical solution was to move forward with a model that worked. Likewise, we learned about practical testing techniques.

Testing

While there was an abundance of tests we wanted to conduct on the material, design, and use of the bags, performing all the tests would create a huge drain on our time and resources. We realized that it was most important to identify and perform the critical tests. Also, we learned that certain tests we wanted to conduct would have amounted to 'reinventing the wheel,' answering questions that have already been solved by other scientists. For example, it is not necessary to test dozens of bags in the sun at one-hour intervals initially. Instead, it is best to have 2-3 hour intervals to determine the initial range of water disinfection, and then proceed to move in with more finely calibrated time intervals.

Issues Related to Community Partners

We learned the difficulty of finding an appropriate community partner for our technology. This process can be riddled with disappointments, and starting off with a partnership that does not work out can have a profound impact on design choices that then cease to become appropriate. It seems that the whole point of spending such a long time phrasing a problem statement and making design specifications is to ensure that the product meets the unique needs of the community partner. It seems like this semester was mainly preparing us to gather a "real" set of design specifications from the field and then re-design out product accordingly. It's all a learning experience!

CRITIQUE OF PROTOTYPES

Screw Cap Design

We currently have two prototypes. One of them, involving a screw cap spout and external rope handle, has the benefit of a sturdy handle and an intuitive spout design. A threaded screw cap nozzle has a proven ease-of-use, having been used in products around the world, including products available in Zambia. The design does have some problems, however. First of all, the screw cap and handle might make the product cost up to twice as much (~$0.25 to $0.12) as an all-polyethylene design. Depending on the price sensitivity of people in the target communities, this price could cause the product to fail. Also, the design has a "loose part," the screw cap that could get lost and make the product useless to the user. However, given the prevalence of screw caps in bottles and jars used daily around the world, we believe that this will not be a common problem. Finally, we currently have a somewhat awkward method of attaching the screw cap to the bag. Using our current heat sealer and this method, we have some difficulty mass-producing the screw cap bags. However, we believe that with a different screw cap part or different sealing method, we can overcome this problem in future prototypes.

Cloth Design

Our other design involves an all-polyethylene bladder with built-in valves and a cloth layer sewn onto the bladder. The benefit of this design is that a monolithic design of the bladder keeps the cost of both the materials and the labor low. Additionally, the cloth piece adds a protective layer to the bag which can add durability. Finally, the cloth part could be designed and sewn by local merchants, which would likely make the design more suitable to local tastes. Although the local merchant could help promote the product and ensure maintenance and sustainability, the need for merchants in every village could present an unreasonable workload as far as dissemination of the product, and could create a problem if trying to ensure universal quality as compared to a centralized manufacturing site.

The main problem with this design is the questionable usability of the valve design. While the valves are effective in containing water, they are less intuitive to use. The extent of this problem depends on the sensitivity of users to ease-of-use. Also, the valves involve narrow points in the plastic that are more likely to tear. In terms of the cloth parts, the cloth protecting the bladders may be a form of "feature creep," adding costs and labor without notable benefit. Finally, the simplistic look of the bags may prevent people from trusting their effectiveness; the local users may want a product that looks more "western" and expensive.

Summary of Critiques

Overall, while our two prototypes have the problems noted, we are happy with our final designs for several reasons. Firstly, we believe that the two models are capable of solving our original problem. That is, we believe that both have the potential to be effective in the host communities and improve the health of the people living there. Also, as mentioned earlier, we understand that our solution may not be the perfect solution, but trying to find a flawless design would be impractical for our purposes.

Furthermore, we recognize that improvements will likely be made to the designs, or perhaps features from the two prototypes will be combined. However, at this point, we should be looking to what our end users would prefer; to this end, we look forward to seeing how people from Zambia respond when we bring the bags to then over the summer.

NEXT STEPS

Our most critical next step is to take the prototypes to Zambia for community feedback. If our design specifications started off as fairly representative, this would allow us to focus our subsequent efforts on the more appropriate of our two prototypes. However, we still have some basic questions, such as whether people would prefer to use our bags to carry water from the source, or whether the bags will only serve as a disinfection container at the point of use. Information like this may result in a significant change in our design specifications and hence a re-design of our product.

Field Tests and User Feedback

During this summer, we also plan to conduct field tests in Zambia to verify the effectiveness of our bags in disinfecting water. We would like to collect data on the performance of bags under different conditions, most importantly under different amounts of UV radiation and temperature. With this information, we hope to determine the optimal times needed for disinfection and provide this information to the users. We are in the process of designing a questionnaire to be taken into the field so that it may answer our most fundamental questions about the product and its reception by the people of the Chiefdom of Mwape. We also plan to take several different unfinished prototypes highlighting specific features (i.e. screw caps, handles, etc.) to allow the users to choose what they prefer. We will wait to show them finished prototypes so as to get a better feeling for what the community wants. It may turn out that a hybrid model is desired. If this is the case, this data will be invaluable, so that when we go back to the drawing board, we can integrate all of these features. This may be at MIT or in Lusaka. (See Appendix for questionnaire)

Next Generation Prototype

There are still issues to pursue apart from community feedback, however. Durability testing thus far has given poor results, with leakage possible after just a 2-foot drop, and the burst of a major seam guaranteed at 5 feet. Putting multiple seals across a seam does not help, because the tear occurs through a layer of plastic that has been weakened by sealing, rather than between the sealed sheets.

Possible approaches to this problem could involve changing the heating element used to heat seal the plastic, or switching to a yet more durable plastic. It is also possible to have the valves or screw cap to pop out if dropped. In the long run, it is better if you lose 5L of water when you drop the bag rather than having no bag because it breaks along a seam. If the bags were to be utilized in close proximity to the manufacture site, it might be possible to simply re-seal these bags, but because we are planning to distribute these bags widely (and we are not sure how quickly or widespread a support network can be established fro them), it would make sense for the bag to be a stand-alone system until a new bag has to be purchased months later.

Possible Business Model

Through community feedback, we also hope to find out if our proposed business model for the cloth prototype is feasible. First, we would have to find out if most families have spare cloths that they are willing to use to cover the bags. At the same time, we would also need to locate a local merchant who is interested in pursuing the business of sewing the bags onto the cloth and selling the bags to the villagers. We believe that this information would help us define our business model more clearly.

Co-Creation and Local Collaboration

While in the capital of Lusaka, one of our team members will integrate the goals of this project with another ongoing project there that is focused around high school students engineering creative solutions to their communities' needs. Because the students have identified infected water as a major problem that they would like to tackle, there is ample room to introduce solar disinfection. We plan to take a heat sealer and a number of bags to Zambia, and have the kids make different prototypes as well. In a process of co-creation, we hope to emerge with a product that is better suited to the local environment than anything we could design in an isolated lab at MIT. We will pass on knowledge of various challenges that will undoubtedly be encountered by these students in making bags, but we will not limit them in their designs.

Besides giving the students valuable hands-on experience for international development education, this project has the potential of having a long-term impact, whereby we foster a strong community partnership. In doing so, we could have on-the-ground designers working on the bags, thus reducing the amount of time it would take to create a prototype in the lab and its field testing or implementation in any of the many communities of need.

Long Term Manufacture and Distribution

Though it may be too early as of now to write proposals to USAID or other NGOs to request grants to go forth and distribute this technology, we do not believe it is too soon to begin to research the possibility of mass-production. It is already clear that a plastic bag design gives us flexibility in being able to choose between on-site manufacture or centralized mass production and transportation. The main reason is that the materials utilized, namely plastics (polyethylene, polypropylene, etc.) are readily available in most capitals of developing countries, and because of their small bulk, can be transported easily to the periphery in trucks, cars, motorcycles, bicycles, beasts of burden, or even on foot. Likewise, the method to make the bags requires an electric heat sealer, which is not a complex machine to operate or find, and can run off a car battery if needed for production in remote areas. Additional modification could even lead to a pedal-powered heat sealer or one powered by a car battery, though we are currently satisfied with the flexibility offered by the heat sealer as it exists.

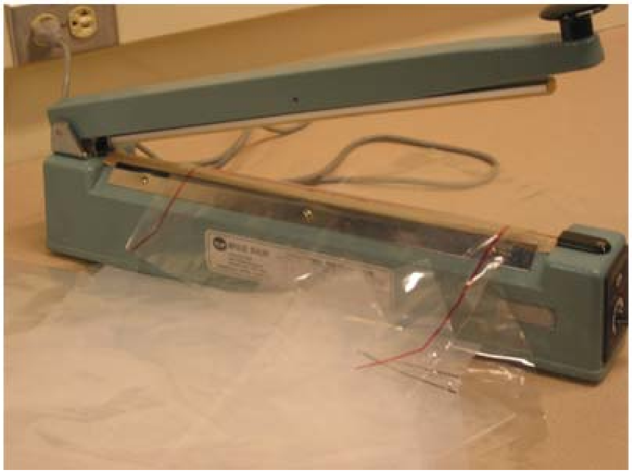
However, simply because we *can* offer local manufacture, it does not mean that we require the product to be locally manufactured. The cheap materials and production methods utilized can also be used by labor-intensive, well-established manufacturing sites. Already in our own experience, we have seen that the plastic, the heat sealers, and any number of components (screw caps, chopsticks, etc.) are readily and cheaply available in China. This comes as good news, though it is still not clear if we would like to have centralized production. In the centralized model, the distance to the final destination would not be as large a factor, namely because plastic bags are easy to transport in bulk quantities due to their collapsible nature and because they weigh a few ounces. And as stated before, whether it is transporting the finished bag or the raw materials, existing transportation and distribution networks can be utilized, and thus our product could reach even the most remote villages. Thus unlike SODIS bottles, which cannot be manufactured locally, our bags could potentially generate jobs and vendors as their distribution spreads. An economically viable product is often more likely to survive and make a difference in the long-run, than one that requires highly specialized production, and whose manufacturing centers cannot move around the world readily.

APPENDIX

Screw Cap Design

Cloth Design


Heat Sealer



Questionnaire used in Tibet. Similar questions will be utilized in Zambia. In addition, we plan to incorporate part-specific questions i.e. "which screw cap do you prefer…small, medium, or large?"

Questions about Tibet for Arthur from Solar Water Disinfection D-Lab team

Alfinio Flores
Eunmee Yang
Edward Hsieh
Anna Bershteyn

- Are PET bottles available to people? (Spinoff questions: Approx. how many per captia? How are they currently being recycled? How frequent are tractor runs to towns? Would people be willing to take up precious space in the trucks for PET bottles, or would they prefer a product that's more compact to ship?)

- What do people currently use to transport/store water (including all containers from lake/river to the drinker's mouth)? Pictures would be helpful

- What is the approximate cost of shipping from a manufacturing site (must have electricity: so likely a township) to local villages for distribution? (Spinoff questions: Cost of gas? Mileage of truck? Distance from electrified township to surrounding villages?)

- How difficult would it be to find a manufacturing site with electricity (to plug in a simple device like a heat sealer)? Please take some photos and get contact info if you see some potential manufacturing sites!

- What manufacturing capabilities already exists for products like plastic bags or bottles? (factories, companies) Plastic bottle caps or other plastic parts (probably injection molding machines)?

- What is the average water use per person, OR average water use per household and average size of household? (We had assumed 20 liters per household her day, including both drinking and dishwashing.)

- How frequently could we get a new bag to a family whose bag is dysfunctional? (I.e., minimum bag lifetime)

- How far do people walk for water, on average? Would they want a product that replaces the container they use to transport water, or only to replace their in-home water storage container?

- Do people have an aversion to the taste of chlorine?

- What are the typical problems with the water that people drink (turbidity, bacteria, etc)? What is the turbidity of typical water sources? (Please collect samples as late in your trip as you can.)

-Would it be possible for Arthur to talk to the local clinic to find out the extent of water-borne diseases in the local area? How is the clinic currently dealing with the problem of water-borne disease? Would the doctors and staff at the clinic be willing to help educate and promote the use of solar water disinfection? (Also, more information about clinic's capacity would be helpful)

- Is sedimentation already in practice by the villagers? Do they practice any other water treatment practices currently?

- How many villages is the NGO working with? How many families are in each village and how far apart is each household? Do the villages hold community or town meetings? (If yes, would the community leaders be interested in helping out with the implementation.)

- What is the potential market size for this device, if the device cost US$1 and lasted a) 6 months, b) 1 year, c) 2 years, d) 5 years
- What is the breakdown of this market? (distance from manufacturing centers,

typical population of cities, villages, townships)

- What business plan would a potential entrepreneur use to distribute/sell a product like this?

-Where do the villagers dispose their wastes/trash? Once the bag becomes dysfunctional, where would they put it? (we should think of ways to recycle.)

-How do the villagers currently get rid of large pieces of materials present in the water (e.g. insects, leaves, other floating objects). Or do they get rid of those large pieces at all?