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Design of a Small Scale Power Loss Tolerant Water Treatment System in Nepal

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by

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Abstract

The Kevin Rohan Memorial Eco Foundation (KRMEF) is a non-profit in Kathmandu Valley, Nepal dedicated to a variety of methods of helping its surrounding community. To achieve these goals, the foundation works extensively with volunteers from other countries, who often come to stay at the foundation. In the kitchen, tap water is used to cook and clean vegetables. While cooking kills many of the bacteria, sometimes food is not cooked hot enough, or simply was not cooked in the case of the raw vegetables they serve, to kill said bacteria. While the incidence of water borne disease is very low in the area of the village; non-treated water has plenty of bacteria in it to make the unaccustomed volunteers sick. There is a small UV sterilizer in the kitchen, but frequent blackouts when people are actually cooking means the UV sterilizer often lacks electricity. A new system was designed, and built, to solve this problem. The filtration method was simple, a biosand filter combined with UV sterilization. After the biosand filter, there was a reservoir to collect the filtered water. When it is predicted that the power will be on for long enough, the UV sterilizer will be turned on, the water from the biosand reservoir will flow throw the UV sterilizer. There are two tanks at the end of the UV sterilizer for the water to go into. The water in the end tanks should be used within two days, to prevent any new growth of bacteria or algae, since there is no continuing disinfectant in the water. One reservoir can be completely emptied, while the other is filled, to ensure that no water is in the tanks for more than two days. The sterilized water tanks are then directly connected to the kitchen tap water.

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Acknowledgements

I would like to thank the staff of KRMEF, especially Krishna, Santosh, and Lela, for all of their help. Additionally I would like to thank the plumber, electrician and carpenter who work with KRMEF and were crucial in the completion of the project. I regret that I can no longer remember their names. I would also like to thank Professor Doug Daley for all of his advice and the Rosen Fellowship for funding me and making this project possible.

About the Kevin Rohan Memorial Eco Foundation (KRMEF)

The NGO, Kevin Rohan Memorial Eco Foundation (KRMEF), was founded in 2008 in the Kathmandu Valley, Nepal. The foundation was founded to create a healthy, sustainable environment that embodies eco-friendly practices for the well being of local communities. To meet this goal, the foundation tackles a multitude of smaller problems including more sustainable farming, kindergarten education, reusing materials for cheaper and more sustainable building, alternative fuel sources, and empowering women. In their methods of meeting these goals, and to view them through a holistic lens, the foundation was inspired by many of Rudolf Steiner's teachings, particularly his method of education and farming.

Farming at KRMEF is done in the biodynamic method. This method has many different components, which to get into would be going beyond the scope of this paper. The most important aspect of farming is that it is meant to replenish the soil's nutrients, instead of depleting the soil and having to user fertilizer to be able to continue farming as is true with the conventional methods of farming that are common across Nepal. KRMEF shares this method of farming by traveling across Nepal and giving small seminars to local farmers. KRMEF also hosts large training sessions twice a year that are led by a volunteer from New Zealand who's an expert on biodynamic farming.

KRMEF also strives to help its local community through a small clinic which is open once a week. There are no other nearby clinics, so this proves to be a valuable source for many people living in the area. The clinic and medicine is free to all of those who cannot afford it. Those who can afford to pay half price for the medicine.

For those who have children, KRMEF has a Waldorf inspired kindergarten that provides a home cooked lunch to the children every day. There are now two years of classes and the hope is that the school will be able to grow and open a new classroom each year, with the current children, eventually expanding up to fifth grade.

The actual building of the school is also part of KRMEF's outreach. Its main support structure is reclaimed glass bottles (Figure 1). The bottles provide stability to the mud and clay solution by which they are surrounded. This eliminates the need for expensive bricks, thus enabling people to afford a building they would otherwise be unable to build. This style also has the benefit of being resistant to earthquakes. With help from KRMEF, this technology has already been used outside of the foundation, including at a women's center and several orphanages in nearby towns. All of these glass bottles are recycled from the American Embassy and the surrounding area.

Figure 1: KRMEF's kindergarten

KRMEF also recycles shredded paper donated by the embassy by mixing it with water, sawdust and cow manure to make bio-briquettes which are burned for cooking. This is supposed to be a more sustainable option. It is also hoped that it gives off less air pollution so the cook breathes cleaner air.

Figure 2: Jewelry made by women at KRMEF

The final products of the foundation are handicrafts, such as jewelry. Some of this jewelry is made out of soapnuts, whose casing is also used to make soap (Figure 2). The jewelry making provides jobs to women in the community, thus helping to empower them by providing a source of income. Some of the women also go to a weekly market where the handicrafts are sold.

Present State

The foundation is not connected to any municipal supply. Drinking water, whose label boasted of being treated by ozonation, is trucked in and delivered in water cooler jugs. Tap water, which was used for everything else (cooking, clothes washing etc.), is untreated and attained from three different sources: a community stream, a tank filled from spring water, and a well. When these three sources prove to be insufficient, a tanker is paid to supply water.

Figure 3: Water Tanks on the roof

The well was not a current source of water while I was there because the pump needed for the well was being used to pump water up to the roof (Figure 3). Water is stored on the roof so that during the many rolling blackouts in Nepal, gravity supplies KRMEF's water. These rolling blackouts are due to the country simply not producing enough power for everyone to use electricity at the same time, so they are scheduled for different areas at different times.

These power outages also affect the small UV filter in the kitchen (Figure 4). However, according to Krishna (KRMEF's founder), it is extremely rare for the foundation's clinic to see anyone who is sick from drinking the water, despite it being untreated. There isn't anything deadly in the water and they are accustomed to the local bacteria. Volunteers stomachs are not used to the same bacteria, so the untreated water, particularly in use in the kitchen, from cleaning vegetables or cooking, often causes volunteers to get sick, which prevents them from doing what they came to do, actually volunteering. The number of people at KRMEF, which includes volunteers and Krishna's family, ranges from 3 to over 50.

Figure 4: UV system in the kitchen

Project Description

As mentioned in the Present State section, volunteers often got sick due to the untreated kitchen water. As such Krishna, Lela (Krishna's wife) and I decided that my skills would be best put to use creating a filtration system, tolerant of power outages, for the kitchen water.

In addition to having the constraint of being tolerant of power outages, there were several other constraints and objectives for this project.

Objectives/Constraints

1. The design had to align with the mission of KRMEF, meaning it had to be eco-friendly.
2. The design had to have simple and easy maintenance and operation because once I left there would be no engineer to continue working on the project.
3. The design also had to be cheap, as it was entirely funded by the grant I received through the Rosen Fellowship.
4. Since I was there for a fairly short time frame (10 weeks), which became shorter in terms of active working time for various reasons, discussed in further detail in the Level of Preparation section, it had to be quick to build and design.
5. The materials had be possible to obtain, which due in part to the short time frame, meant they had be available from the town KRMEF was in or Kathmandu.

Potential Treatment Options

There were several different treatment options considered for this project. The table below contains each system considered and the main reason(s) it was rejected.

Table 1: Treatment Methods Considered

System	Reason for rejection
Chlorination System	• Doesn't align with the mission of KRMEF (not "green") • Requires Monitoring/semi-complicated operation
Activated Carbon	• Couldn't get the materials to build this system
Ozone	• Too complicated • Too expensive • Couldn't get materials • Require Monitoring/Complicated operation
UV	• Ineffective if water is turbid, thus is a risk if water becomes turbid
Biosand Filter	• Incomplete treatment • Period after maintenance where it is ineffective
Combination Biosand filter and UV	• NA

Final Design

A combination treatment of a biosand filter and UV sterilization was decided on for the final system (See Figure 5 for a picture of the final design). The treatment train started with a trickling biosand filter, which is connected to the water stored on the roof. Flow into the biosand filter is controlled by a floating valve. Water trickling out of the biosand filter feeds into a temporary storage vessel throughout the day. The vessel connects to a UV tube with a

Figure 5: The water system final design

valve in between them. The UV can be turned on, when the blackout schedule predicts there will be power, and the valve will be turned to let water run through the tube. Thus the UV bulb will only need to be on for about ½ hour per day. The UV system connects to two different reservoirs, which reservoir it is feeding at the time can be changed by two more valves. Having two reservoirs allows one reservoir to be fully emptied, and still have treated water in the other reservoir. Since there is no continuing treatment left in the water, unlike a chlorination system, fully emptying the reservoirs on a regular basis will prevent anything, such as bacteria, that gets into the water post-treatment from having time to grow.

The directions for building the biosand filter can be found in Appendix A. The instructions for maintenance on the biosand filter can be found in Appendix B. The directions for building the UV can be found in Appendix C. The maintenance and operation instructions for the UV filter can be found in Appendix D. The design of the biosand filter was based off of the Centre for Affordable Water and Sanitation Technology (CAWST) *Biosand Filter Manual: Design, Construction, Installation, Operation and Maintenance* report published in 2009. The design for the UV system was based off of reports given to me by Doug Hollinger during a workshop run by SUNY ESF's chapter of Engineers without borders (Hollinger, UV-Tube Building Instructions).

Level of Preparation

This kitchen water project was not what I first thought I was going to do. As can be seen in my application for the Rosen Fellowship in Appendix E, I originally thought I was going to build one, or several, drinking water systems. I first met Krishna about a year before I started planning my trip, in December 2012. Over spring 2014, I talked to several other people involved in the foundation and also exchanged several phone calls with Krishna. This pre-trip communication is why I thought I knew what I was going to do when I arrived. I believed that Krishna and I were both prepared; that I could hit the ground running when I got there.

As it turned out, that is not the way things went. Instead there were time delays within the first two days of arriving. The day after I landed, two professors from Johnson and Wales University arrived to set up the final stages of an internship program between their school and KRMEF. Since they were there for a short period, they spent all of their time running around with Krishna. Thus, I didn't get to actually talk to Krishna during this time. The benefit was that I got to spend the time volunteering around the foundation and getting to know the community. I was sure that once I was settled and they had left I would still be able to get really going on the project. Instead, the very day they were leaving, an opportunity to go hiking in the Himalayas fell into my lap and I could not turn it down.

Thus, I immediately "lost" over two weeks of project time out of my 74 day stay in the country. I had arrived May 31, and on June 16, a couple of days after getting back, Krishna and I had our first preliminary meeting about the project. Instead of just fine tuning the details, we discussed possibilities for different projects. At this point, I still thought that drinking water seemed like it would be helpful to the foundation, since, as mentioned in the Present State section. There was one small project they came up with that I could definitely help with. Thus, I split my time between general volunteering, looking at treatment methods for drinking water, and this smaller project.

The project had to do with the water storage tanks on the roof, which were filled by manually turning on a pump, and then sending someone running to turn it off when the tanks overflowed and water dripped off the roof. The project was to figure out a way to get the pump to automatically turn off to reduce the water wasted. Some research revealed that a pressure control switch could do exactly this. After sharing the solution with Krishna, I reminded him that I did not know where in Nepal we could actually find it, so while it seemed like a great solution, the he would at least have to help me figure out where to purchase it. At different times during my stay I said I had a grant to cover the costs of my projects, but I do not think I emphasized that I was willing to spend grant money on the pressure control switch. The foundation did not have money to spare on this, and I think Krishna did not feel comfortable asking me if I could use the grant money. Thus, nothing ended up actually being done about the tanks overflowing while I was there.

Soon after this, on June 29th, Lela, Krishna's wife, came up with the project treating the kitchen water. Almost a month after arriving in Nepal, I started working on my main project.

Implementation Issues

I had my basic final design done on July 7, at which point we started working on finding and purchasing supplies. Certain supplies could be found in a small shop in town, but the plumber and electrician who worked with the foundation bought many supplies for me in Kathmandu, since they knew the shops far better. Neither of them could speak English, and I couldn't speak anything past very basic Nepali. I handed them a list of materials in English, and was assured by Santosh, Krishna's right hand man, that they could figure it out. They did amazingly well, but a couple of materials there was some confusion over, such as the UV bulb.

I went into Kathmandu to help find the UV bulb with the plumber. He directed us to a shop selling fully assembled filters. The shop keeper's English was decent, but not quite good enough to have the conversation we needed to have without some misunderstandings, in hindsight I think they believed I wanted a UV system, instead of just a UV bulb.

Since we were not really getting anywhere, they took me upstairs to the office of an Indian water engineer, who had capable English. He first praised my design as being excellent, but at one point seemed to suddenly change his mind and started telling me it was impossible, mainly because I wouldn't be able to find anything on my materials list. The only option was for him to come out and see the site himself to redesign it. He kindly offered the site visit to be free, but I'm sure the design and maintenance wouldn't have been, and neither KRMEF or my grant money could have afforded his time. Once I got over my shock at the sudden change, I asked him to look at the list and tell me which materials he was so such I couldn't find. Santosh happened to arrive shortly after this to pick me up to do something unrelated in the city. Since Santosh could speak with them in Nepali, everything got cleared up pretty fast. It turned out the shop had a UV bulb I could buy. At the time it was frustrating, but in hindsight I appreciate experiencing such situations as now I will be better prepared in the future.

Getting the container for the biosand filter was also plagued by communication setbacks. The original drum came from Rajesh, the driver of the school's van. He had used it for storing diesel, and when we first got the drum, it was still coated with oil. I was concerned that the oil may have leached into the plastic of the drum and would slowly seep from the plastic into the water the biosand filter would hold. The last thing a treatment should do is make the water more polluted. I explained my concerns to Santosh, but I'm not sure he fully understood them, or simply really did believe that we could wash it out. After a week of having the drum I convinced him to at least wash it with bleach instead of just soap. At this point it at least no longer smelled of oil, but I was still concerned there was still some that could ultimately leach into the water. Since they will ultimately be the users of the water, it is ultimately their decision about whether they are comfortable with taking the risk of oil leaching into their water. I explained the risks to Krishna so that he could make an educated decision, he was under the impression that the drum had only ever held cooking oil. When he checked with Santosh, but Santosh thought he was asking if that had been the drum's original purpose, which it had. Thus it was not until the next day when we saw the top, which was still lightly coated in diesel, that we agreed a new drum was necessary.

I was even there for the miscommunication, but was too worried about being perceived as over stepping my boundaries to speak up and explain how I thought they were miscommunicating. Luckily in this instance everything worked out, but in the future I need to be more careful about other people's communication in addition to my own and be more willing to speak up to clarify what I think others mean. Nevertheless, a new drum had to be found. I went around Kathmandu with a couple of other people, checking junkyards amongst other places to find a container that was tall enough. In the end we found a drum we were told used to contain shampoo. Since shampoo is designed to be water soluble, I determined that would be acceptable. Of course we do not know if that is the real history of the container, but sometimes semi-blind trusting was necessary.

My other main communication issue when working with the three tradesmen (the carpenter, plumber, and electrician) was that I was dependent on Santosh or other foundation members to translate for me. They spoke both languages excellently, but had no background is technical areas. I think my translators often did not fully understand what I wanted to say, and thus had trouble conveying my message. At one point the carpenter said he wished he could speak directly to me as he believed that would go far smoother. He also said he thought I was clever, which ended up being one of my most gratifying moments, that this man who can do all these things with wood that I cannot, and who must be getting frustrated with the complicated and odd directions I'm coming up with, still seemed to like me.

End Result

My last couple of days in Nepal were festival days, which I was unaware of until about a day before they started. The pipes needed special equipment to seal them together, equipment only the plumber had. When he came before the festival he set up most of the piping, but some of the valves were missing (due to miscommunication again). Additionally the biosand filter had not yet been connected to the water tanks on the roof. While the UV tube and the table it was mounted to were completed (thanks to the carpenter) the biosand filter needed more sand as I had underestimated how much sand had been cleaned. Though I left the volunteers who were staying with clear instructions on what needed to be done to get the system operatonal, they had their own projects and thus never managed to fix the water system. It remained as I left it for months. In March, I was contacted by a new volunteer at KRMEF who is trying to fix the system.

Conclusion

While two and a half months seems like plenty of time, it ultimately ended up feeling brief. This was due to time adjusting to the foundation, getting to know Nepal, determining KRMEF's needs, and normal project delays. My belief that I could dive into the project was an unrealistic expectation.

Many of these project delays and implementation issues were due to communication problems, many of which were language barrier based. Patience was the most important thing in overcoming these issues, along with someone who could serve as a good translator.

The final state of the project raised questions: Whether I choose the right project? Whether I failed to set them up properly so that they could finish the project when I left? I believed there were two main possibilities as to why the project did not end up being finished. Either it was because it was a project that did not truly need or value, or because they lacked the knowledge to finish it once I left. If I choose the wrong project it raised the questions of how one should choose a project. I spent a month getting to know the foundation and listening to them about their possible needs. As for not leaving them enough information, I encouraged them to contact me with any questions and left them with notes and all the materials they should need. This suggests that this was not the issue. Ultimately neither of these were probably the issue. Everyone at the foundation was so enthusiastic and KRMEF already has so many different focuses, with limited resources, in terms of everything from money to man power, that they were already stretched thin. This water project simply kept getting put on a back burner.

Overall I really enjoyed my experience and learned a lot in the process. I learned a lot about managing a project, especially about the importance of clear communication and making sure all parties are communicating well. I also learned a lot culturally. This was mainly about Nepali culture, but I learned a surprising amount about other cultures too. The foundation has people from around the world who come to volunteer. During different parts of my stay there were many Americans, several Swiss, an Israeli family, a British school teacher, two three-person groups of Chinese high schoolers, a German Masters students, two French in their twenties (who came separately), and an Indian 26 year old. I got to experience Nepali culture through traveling, participating in festivals, talking to people as well as through all the people at the foundation.

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Appendix A - Building a Biosand Filter

Materials used

- A drum approximately 1 m tall
    - The surface area will determine the rate of flow treated. It should be 400 $L/hr/m^2$ (CAWST, 2009). Surface area is Π*$radius^2$
- Coarse gravel (pieces between 12 mm and 6 mm)*
    - Volume=Surface Area *5cm
- Fine gravel (pieces smaller than 6 mm)*
    - Volume=Surface Area *3 cm
- Large grain size sand (pieces larger than 3mm)*
    - Volume= Surface Area *2 cm
- Sand (pieces smaller than 3mm)*
    - Volume= Surface Area *80 cm
- Small pieces of wood to be drilled into the container
- Silicone (to seal the pieces of wood to the container
- Diffuser plate (a plate, preferably made of stainless steel, with holes in it)

* Make sure these materials are properly sourced. They must be clean. The best source is directly from a quarry or gravel pit. If that is not possible, get the materials from a river bed source. This is not preferred because the river bed may be contaminated with animal feces or pesticides, which would be on the gravel/sand.

Tools used

- Expertise of carpenter and his tools

- Expertise of a plumber and his tools

Directions:

- Create a hole (3 cm from the bottom/ground) where a ½ in. connector was placed in such a way that it was water tight. This is the exit hole for the water.
- Connect piping to the connector such that there is an outlet 95 cm from the bottom of the drum. (See Figure 5: Biosand Filter)
- Sift out gravel so that you discarding all pieces larger than 12 mm (using a screen with an 12 mm hole size works well for this. Sift the gravel again, using a screen with 6 mm holes. You should now have two piles of gravel, one of the size 12mm-6mm and one of the size 6 mm or smaller.
- Plan to sort/clean the volume of gravel outlined under materials used.
- Clean the two piles of gravel using the bucket cleaning method. This method means put a small amount of the sand in gravel in a bucket and putting clean water in the bucket. Use your hand to swirl said water around the bucket. Pour the now muddy water out of the bucket, while being careful to not lose any of the gravel. Continue rinsing the gravel in this method until the water remains clear.
- Sieve the sand to separate the pieces larger than 1mm from the pieces smaller than 1 mm. You should have significantly more sand smaller than 1 mm. You want enough of the small sand to fill up the 2 cm of the drum. Clean both piles of sand using the same bucket method used to clean the gravel.
- Place the drum on its stand
- Fill about half of the drum with water.

- Put a long stick in the drum. Draw a line on said stick where it reaches the top of the drum.
- Slowly put the coarse gravel (between 6-12 mm) in the bottom of the drum. The water in the drum will help prevent air bubbles from being trapped. Use the stick to even out the gravel into a smooth layer. Put the stick on top of the gravel and use the difference between where the stick now lines up with the top of the drum, and the line previously made, to see how tall the gravel layer is. Add about 5 cm of the course gravel to the bottom of the drum.
- Next, using the same method, add the finer gravel (smaller than 6 mm) to the bottom of the drum until it adds another 3 cm in depth.
- Then add the course sand (larger than 1 mm) until it adds another 2 cm in depth. This will act as a buffer between the sand and the gravel to prevent it from falling through.
- Add the fine sand (smaller than 1 mm) until your total level is 90 cm and the level of just fine sand is 80 cm.
- Add the diffuser plate so that its mounted 97 cm from the bottom of the drum, which should be 2 cm from the top of the water level (which will be even with the top of the outlet pipe). See Figure 6: Diffuser Plate.
- You biosand filter is complete!

This design is based off of the designs found in the Centre for Affordable Water and Sanitation Technology's Biosand Filter Manual (see CAWST, 2009).

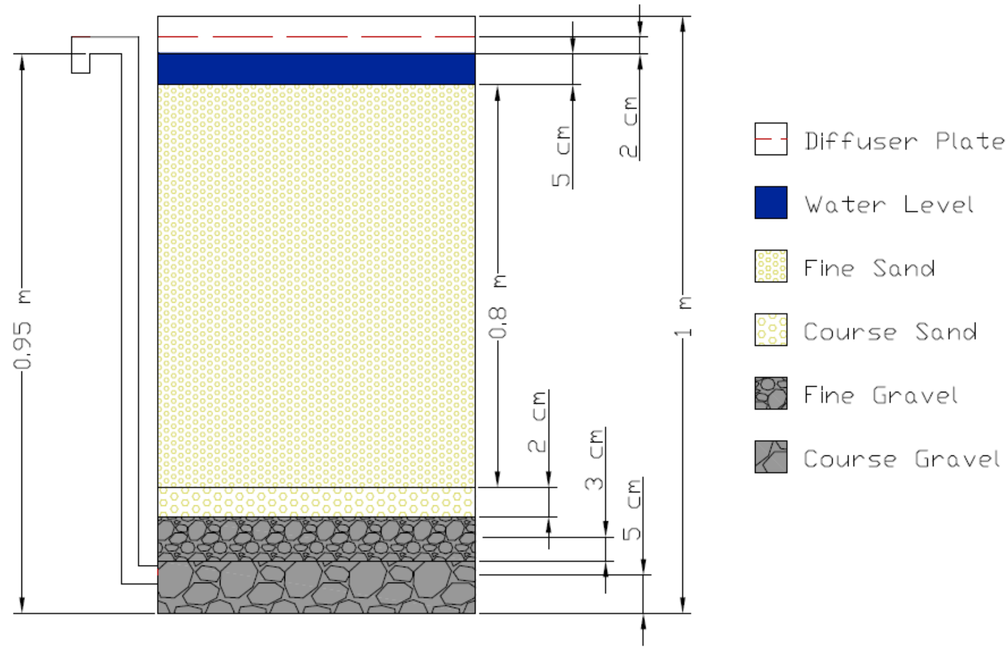

Figure 5: Biosand Filter

Figure 6: Diffuser Plate

Figure 7: Assembled Water System

Appendix B - Biosand Filter Maintenance

- It may take 30 days for the biolayer to form. While the filter can be used during this time, it will not be as effective at removing bacteria.
- The water level, when the biosand filter is not actively filtering water (meaning its reservoir is full), should be at least 20 mm below the diffuser plate and approximately 5 cm, above the sand level, to allow space for evaporation.
- As the suspended solids become deposited in the biosand filter, the filtration rate may be slower. This is fine for effective filtration purposes. Slower rates are actually more effective for filtration purposes.
- Once the filtration rate becomes too slow, or about every other year, the filter needs to be cleaned. To clean the filter, use the swirl and dump methods.
    - Remove the filter lid. If the water level is below the diffuser, add water until it is above the diffuser. Remove said diffuser. Lightly swirl the top of the sand (being careful not to mix the top layer of sand deeper into the sand layer). Scoop the now dirty water out with a small container and dispose of it into the garden or by some other method. Make sure the sand layer is smooth again. Replace the diffuser and the lid. Make sure to wash your hands after doing this
    - Keep in mind after this it will take approximately 30 days for the biolayer to reform as the cleaning process will have disturbed it.

This maintenance plan is based off the Centre for Affordable Water and Sanitation Technology's Biosand Filter Manual (see CAWST 2009).

Appendix C - Building the UV Tube

Materials used

- Stainless steel sheet (food grade) (45.5” by 17”)
- 3 plastic ½ in elbows with metal screw parts
- 3 metal ½ in couples with washer and two plastic washers
- One UV bulb (33”) with the ballast it comes with (original design had a bulb size of 42.7 cm)
- Two four inch endcaps
- Two pieces of bicycle tire, cut to 16” long and 2” wide (they are further cut down in the design)
- A 1 in elbow, 4 in long 1 in diameter PVC pipe
- Silicon
- A piece of glass cut to be 1” by 1”
- 4 5” hose clamps
- Piece of 4” PVC
- A 1 in plastic coupler
- Small hose barb

Tools used

- A drill, plumbers tools and abilities,

Instructions:

Preparing Materials

- In one of the ½ in elbows, create a hole in the side of it so that the wire that will feed the bulb can go through it and attach to the bulb in it.
- In two of the metal ½ in couplers, use silicon to make them water tight. Be careful not to cover the joints as they will still have to be used to attach to the elbows
- Place shiny side of the steel sheet down (the side facing down will become the inside of the tube
- draw a guideline 11.5 cm (about 4.5 in)from the bottom edge of the steel sheet with a pencil
- Measure all future marks along this guideline from the left edge (as if the sheet is not the exact same size, distance from the right edge will be different)
  - 4 in from the left edge make a mark labeled A (this will be where the inlet goes)
  - 6 in from the left edge make a mark labeled B (this is where the first elbow holding the UV will go)
  - 40" from the left side make a mark labeled C (this will be where the second elbow holding the UV will go)
    - note: this distance is based on the bulb being 33" and needing an extra ½ in of distance per elbow. It may vary depending on bulb size
  - 2.5" from mark C, make a mark labeled D (this is where the wire will be fed through

- At point A, B, and C create a hole that the metal couplers can fit in, file the hole so that the metal isn't too jagged.
- At point D create a hole that you can feed the wire through

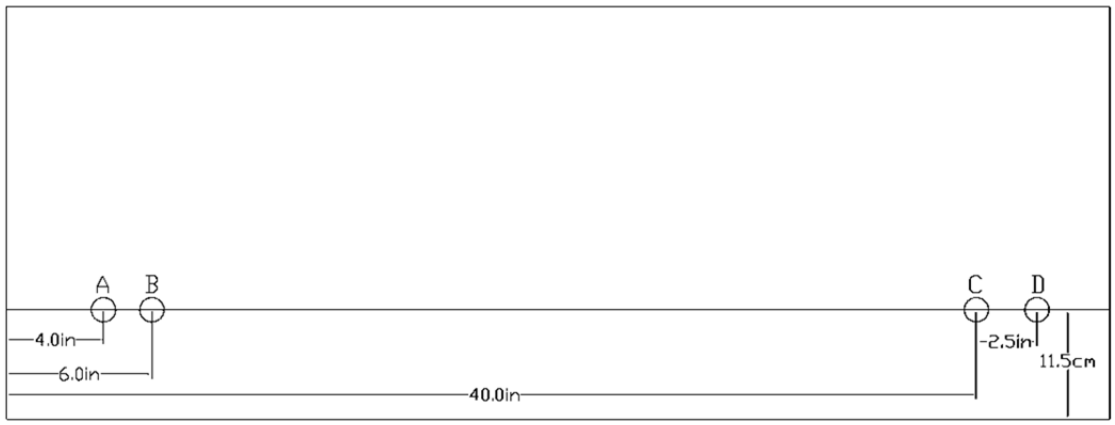

Figure 8: Layout of steel sheet that will become the UV tube

- Roll the sheet using a piece of 4" PVC as a guide to make. Put the endcaps on and the hoseclamps. Tighten to make sure the holes don't overlap. Take off the hoseclamps, the endcaps, and unroll the steel sheet
- In one of the 4" endcaps drill a hole of approximately ¾" diameter. Secure the glass piece to this hole with silicon to create a window.
    - Make sure there is open space not covered by the window, as if someone looks directly at a gap they will get eye damage from the UV bulb. The window will filter out the dangerous wavelengths and prevent eye damage.
- Cut a ½ piece off the coupler.

    - Put the ½ in piece of the coupler onto the end of the 1" PVC pipe (the rough (cut) edge should be facing the short end of the PVC pipe and the smooth manufactured end should be facing the
- Slightly off center in the other endcap, create a hole that the 1" PVC pipe can go through.
    - Create another hole that the small hose barb can go through. This hole should be below the larger one on the side where the hole is closest to the edge
- Put the 1" PVC pipe through the more centered hole in the endcap. The smooth/manufactured end of the coupler should go flush against the inside of the endcap
- Connect the 1" elbow to the end of the PVC pipe on the outside of the endcap. The elbow should face down toward the hole for the hose barb
- Put the hose barb through its hole

Assembly

- Put the metal connector without the silicon into hole A put the rubber washers on either side of the hole such that the hole is sealed. Attach one of the uncut ½ in elbows to the metal connector (on the inside steel sheet, the side without the) such that the outlet of the elbow is facing the shorter edge of the steel sheet where the closer endcap will be (away from the other holes)

- Put the one of the silicion metal connectors through hole B and attach the other ½ in elbow that isn't cut (also on the inside of the tube). This elbow should face the opposite way from the other way, toward the long end of the steel sheet.
- Feed the wire through hole D so that part that connects to the bulb is on the inside of the steel sheet)
- Put the wire through the back of the cut elbow.
- Connect the cut elbow with the last metal connector with silicon
- Attach the UV bulb to the wire so that both are sitting in the cut elbow
- Put the other side of the UV bulb into the elbow in hole B
- Put the connector through hole C and secure it so that the rubber washers are enclosing the hole
- Cut the bicycle tires down so that they fit the circumference of both end caps. Secure one each end cap (we used PVC cement to do so) so that the rubber goes all the way to the end of the end caps and will be between the steel sheet and the end caps.
- Roll the metal sheet so that the UV bulb an all the elbows are on the inside
- Put two hose clamps on the middle of the tube (we had to unattach them and re attach them directly on the tube as they could not slide over the metal connectors)
- Put the end cap with the window (and the rubber surrounding the endcap) onto the end of the rolled metal sheet that is closest to hole A. Make sure the window is on the top of the UV tube. The top of the UV tube is where all of the connectors are

sticking out. Slid a hose clamp over the end cap so that it can be tightened direct on the part of the steel sheet where the end cap is

- Put the other endcap onto the other end and slide a hose clamp on in the same way you did the other one. Make sure the elbow is pointed down (away from the metal connectors on the top). The hose barb should also be on the lowerside of the tube (again, opposite side from the metal connectors). The rubber from the bicycle tire should be between the end cap and the steel sheet
- Tighten all of the hose clamps

Congratulations, you now have the basics of the UV filter, now it just needs to mounted and connected into the system

The UV filter table:

The table the UV filter will be hung from was built by a carpenter employed by the foundation.

He added a piece of stainless steel to the top of the table to make it water proof, and one of the sides to prevent bounce off from the roof from hitting the UV filter.

The design for the UV system was based off of reports given to me by Doug Hollinger during a workshop run by SUNY ESF's chapter of Engineers without borders (Hollinger, UV-Tube Building Instructions).

Figure 9: Mounted UV System

Figure 10: Inside of the UV tube

Appendix D - UV Bulb & Tube Maintenance and Operation

UV bulb Operation

1. Try to make sure you will have electricity for at least an hour (or however long you generally keep the system on) before you turn the UV bulb on
    - if it gets turned off by a power cut, it will decrease the lifespan of the bulb/ decrease the effectiveness of the bulb faster
2. Turn the UV bulb on before running any water through the tube
    - check through the glass window to see if the bulb is working and on before opening the valve
3. make sure one of the exit valves is fully open.
    - This will make sure the water level stays low so that the water does not touch the bulb
4. Open the valve between the sand filter and the UV halfway (so it makes a 45º angle)
5. Keep the valve open until there is no, or very little water coming out or you have treated as much was as you want
6. Close the valve between the UV and sand filter (the same valve that was opened to the 45º angle)
    - Make sure to keep the UV bulb on until all water has run through the tube (check the window
7. Once all the water is through the tube, you can turn off the UV bulb

Note: Make sure to completely empty the end reservoir before refilling it. (This is why there are two end reservoirs.) Try to empty it every two days. If you are not using all of the water, close the valve sooner.

UV bulb Maintenance

- If the table is every tilted, make sure to get it flat again. A tilted table will mean the water runs through the UV bulb too fast for the water to be properly treated.
- NEVER look at the bulb directly. If you need to open the tube to replace the bulb or clean it, unplug the system first to make sure it is not on.
- Once a month, run a dilute solution of chlorine bleach through the UV
    - MAKE SURE THIS SOLUTION DOES NOT GET IN THE BIOSAND FILTER!!!
- Bulbs should be replaced once a year. For this system, it could probably be run once every other day if desired, which should expand the lifespan to two years. The bulb will continue to work past this time, but it will be less effective.
    - To replace the bulb, the tube must be taken down from the table and opened up. Make sure to unplug the system before doing this as if it is on and you look at it directly, it will damage your eyes

Please Contact Katja Fiertz (kfiertz@gmail.com) with any questions or concerns The Maintenance and Operation for the UV bulb was based off of reports given to me by Doug Hollinger during a workshop run by SUNY ESF's chapter of Engineers without borders (Hollinger, The Ultraviolet Water Purifer: A manual for use and operation)

Appendix E - Rosen Fellowship Application

I was in eighth grade when I first started appreciating how precious water can be. My family moved to New Delhi, India for my dad's job at the American embassy. It would have been hard to be oblivious to how differently water is viewed. No longer could I just turn on any tap to get a glass of water, or even brush my teeth. At home, we could use the distiller in our kitchen, which had the side effect of making the kitchen feel like an oven, even in winter. Anywhere else, we drank bottled water, something my family refused to buy at home. We were even told to be very careful about avoiding ice cubes when we were out because people often just froze tap water, so even the ice cubes could make you sick. My health teacher in school had gotten hepatitis A because she had forgotten this on a particularly sweltering day when she got a couple ice cubes in her coke. Even we, the lucky and sheltered embassy community, had to be careful about our water.

In addition to being concerned about water safety, I also become more concerned about water abundance. The water pipes in New Delhi often ran dry, so water trucks were a common sight on the street, and to our house. We had a cistern underneath the house that water trucks from the embassy would deliver water to when we called them. We ran out of water a couple of times before we got used to checking it. Since water was a fairly tight resource, especially for others, we started trying to save water in any way we could. Every time I wash my hands, even to this day, I turn off the sink while I'm soaping my hands. We stuck to the motto "if it's yellow let it mellow, if it's brown flush it down," and would generally turn off the showers when we weren't actively using the water, such as while we shampooed our hair. This was a particularly hard one to stick to during the winter since the bathrooms weren't heated, unlike the rest of the house.

Yet, despite all of the time we spent thinking about water, it was nothing compared to others. Poor people selling flowers, magazines, or just begging for a little money were at almost every intersection of the city. We were told by the embassy that the money generally just went into the pockets of their bosses who controlled who went on each intersection, so giving people money rarely actually helped those people. Thus, hard as it was, we always passed by without giving anything out. That changed the first summer we were there. As our car's a/c was broken, we always drove with our windows down, trying to catch a respite from the stifling heat that is synonymous with New Delhi. We were stopped at a traffic light close to home when an eight year old boy pulled himself onto the runner board and gasped out one word through the open window, Pānī, the Hindi word for water, This tired, red-faced sweaty kid wasn't asking for money, he wasn't even asking for much. He was hoping get enough water to live through another hot New Delhi day. We jumped into action, desperately searching the car for any water we might have to give him. But we failed. The light changed to green and we had to leave the kid, hoping that he would find another way to find water and make it through the day.

That was the last time we were caught so unprepared, we had finally found a way to try to help these kids, rather than trying to remain apathetic from within our car. We stopped throwing out our plastic bottles, choosing instead to bring them home and refill them from the distiller. As we constantly had to buy water when we were out, we always had at least a bottle a day to give out. We passed that same boy on the way to school every day, and would give him a bottle. His friend, a girl about his age, soon joined him in coming up to our car every time they saw it to get their water. If we passed by that intersection two time in a day, we would give them another bottle. They always wanted them. I have no idea how else they got their water, but I imagine at the very least it was not the same, clean water we gave out.

These kids were hardly the only ones for whom water was a precious resource. On Saturdays, my family would spend a couple hours at a jugi, also known as an informal settlement or slum, helping about twenty kids improve their English. The classroom was basically an old metal shipping container with two doors and windows put into it, and an aluminum roof that made it hard to hear when it rained. The rain was preferable to the heat though, even with both door open, the one fan barely created enough of a breeze to cool down the room, and that was when it worked, which it frequently did not. The desks were of an old style and were probably meant to fit a five year old. Somehow the kids found a way to sit, but all of us, teachers, had to sit on the end so we could stick our legs out. To get into the classroom we stepped over an open sewer.

Once inside, we would break off into groups, one teacher per group; I generally worked with a group of 5 girls who were 5-8 years old. The groups would then read a book together. The teachers sometimes read aloud, or had the kids read and helped them with their pronunciations, and tried to explain any words they did not know. This part was particularly hard since we read book donated to us by the embassy community, which often had things that though common in the US, these children had never seen. I remember my group read *If You Give a Pig a Pankcake* by Laura Numeroff. I'm not sure I managed to explain much of that book. There are the obvious culture differences, such as what a pancake and maple syrup one, but there was also one that caught me totally off guard. They had no idea what a bathtub was. I tried to explain it to them, but they just gave me the same confused looks and half smiles that they did when I tried to explain pancake. I think they eventually decided it just was not worth it and we kept reading. I'm not sure any more of the book was a success, but I did not think any more about the bath tub incident until months later during monsoon season. We were packing up for the day while chatting with the students when a teenage boy working with my mom asked if we were going to bathe when we got home. My mom pressed him to find out what he meant. He was asking because it was raining, and all of the students were going to go out in the rain and "bathe" in the rain. Water was too scarce to just use for bathing, especially when nature was providing water to clean them off.

After spending two years thinking of water as a precious resource, I had trouble adjusting to how dismissive some people are of it. Shortly after we returned I got annoyed with someone for leaving the sink running while they were doing something else. He simply responded that there is a plethora of water in the Northeast, and thus, there was no such thing as wasting water. This was hardly the only time, or place, I saw a lack of concern over water. The summer after freshman year at ESF, I studied abroad with SIT in Iceland to study Renewable Energy. While of course I learned a lot about renewable energy, I found the way they treated water equally fascinating. Iceland has such a large surplus of clean glacial water for its small population that they do not treat their drinking water or their wastewater. On a walk one day, I even found a dead sheep decomposing in a stream I was trying to cross. When I asked the trip organizers about it, they reassured me it was perfectly normal Icelandic practice to dispose of dead sheep in streams where they could decompose. Icelanders have so much water, they simply do not think of it as a precious resource.

Unlike Iceland, water treatment is extensive in the US. Last year, I attended two New York Water Environmental Association (NYWEA) chapter meetings; this year I am registered to attend NYWEA's annual meeting and exhibition in New York City. I also gained some hands on experience with wastewater treatment last summer when I interned at Smithsonian's National Zoological Park. The zoo had recently opened their new American trail section, which included their new pinniped (seals and sea lions) exhibits along with a new life support system (water treatment system) to keep the pinnipeds healthy. The new, state of the art, system used ozone, instead of chlorine, as a disinfectant because of concern over the animals' eyes. Industrial size sand filters are used to remove suspended solids from the water. The system also uses foam fractionators, which use bubbles to remove organic matter and other particulates from the water, in a process that mimics the foam, seen on beaches, created by the waves.

My internship was spent trying to learn why the exhibits had such a high prevalence of algae, compared to the past when the life support system used chlorine, and what could be done to safely reduce the amount of algae. To achieve this, I researched each component of the system, monitored water quality through regular water testing, and investigated potential solution to the problem, such as algaecides or flocculants. With each potential solution, my largest concern was whether it could hurt the animals or make the system less effective in any way. Second only to animal health, was the goal of keep the solution cheap, since the zoo is currently on a tight budget. I researched the potential cost of any solution I thought was feasible. This experience, combined with NYWEA, and the classes I am taking to complete my environmental resource engineering degree, especially the water pollution I am currently taking, has given me a background in US water treatment.

U.S. water treatment methods are often too expensive for developing countries to implement, especially on a small scale. Since India, I have been particularly interested in treatments that could work in these settings. My freshmen year I joined ESF's chapter of Engineers Without Borders (EWB) and attended the North-East regional conference at Columbia University in the fall. How to choose and ultimately implement a project was among the many things discussed. One point in particular was emphasized, you are there to help the community meet the needs they see as lacking in their community, not to try out a new technology because you want to. Any decision should only be made with community input; they know the community better than you do.

In the spring I participated in a small, hands-on workshop, organized by ESF's EWB. During the workshop, we assembled a pico-hydro system, that could used the water from a stream to create a small amount of electricity that could be used to charging cell-phones, a sand filter, and a basic UV filter, all of which are designed so that they can be built cheaply by people in developing countries. During the same semester, I took a class called Appropriate Technologies for Developing Countries. The class basically looked at different technologies being designed and implemented in developing countries. This included looking at water filtration and transpiration technologies, along with other important issues such as more efficient cooking stoves, and vertical gardens that can be used in cities where food and space are scarce.

Together, all of these experiences have made me realize that I want to help people in developing countries lift themselves out of poverty. I want to do this in a way that is not simply trying to emulate the lifestyle in the west. Instead, my goal is to help people set themselves on a new path. One which is sustainable, but where they do not have to worry about getting sick from dirty water, where their next meal is coming from, getting respiratory illness because of air pollution from a cooking fire, destroying their home as they have to cut down the few remaining forests so that they can cook their dinner, or hurt themselves or their homes in any other way just so that they can survive another day. I believe, like Maslow's hierarchy, that people must find a way to meet their basic needs before they can care how they are doing so. Though I would be happy to achieve this goal any way possible, my biggest concern is water supply and sanitation.

Thus, the project I am hoping the Rosen Fellowship will fund, will help people through providing water supply and sanitation. There is a small NGO, established in 2008, in the southwest of the Katmandu Valley, Nepal called Kevin Rohan Memorial Eco Foundation (KRMEF) which has created an ecovillage. They are constantly trying to improve and expand this village to better serve the community. Among the many things they do, are empower women, and the disabled. They teach women to build jewelry out of soapnuts that they can then sell. They are also trying to create a daycare so that mothers can work. They are trying to present alternative, sustainable fuels for cooking, such as bio-briquettes made from recycled paper, manure, and sawdust. The foundation is teaching people with leprosy to make these briquettes, and trying to create a market for them, so that they may have source of income. The ecovillage also has a model house that uses recycled glass bottles for structural support. They teach people to build this type of house so that they may afford a shelter that they otherwise could not afford the building materials for. They also practice biodynamic farming, a method of farming that is more sustainable as it does not use pesticides and is gentler on the soil. They invite villagers to stay in the ecovillage so that they may learn these practices and continue to spread them. They also hold seminars across Nepal for to teach people some of these methods, such as biodynamic farming. In addition to all of this, KRMEF is currently working to complete the building for an orphanage where they hope to give a home to 8-10 orphaned children of Nepal's low cast.

KRMEF works hard to help people by teaching them new skills they can use to lift themselves out of extreme poverty. One of things KRMEF is still missing is a water system. Their water currently comes from two springs. Currently all of their water comes from two springs. One is a small private spring piped to the house for Krishna, his family, and the volunteers staying with him. The other is a community stream piped in for use by the rest of the foundation. Currently all water used for cooking, washing, bathing and any other similar use, comes from these stream. They believe the streams are clean, but as they have not had a chance to do any water quality testing, they are not sure. All drinking water is purchased mineral water, which is expensive. This cost will only grow as the foundation gets bigger.

As KRMEF could use every penny it has to help people, it is important that they get a system for treating the water. Thus, I want to design and build a treatment system for KRMEF. As I have only been working on this project for a month and am still communicating with Krishna, one of KRMEF's founders, about the details what KRMEF would like, I do not yet know what filter will be used. This depends not only on the amount that needs to be filtered, but also how it needs to be filtered, how spread out the people are who need the water, whether we will try to train someone to build these filters in the future, and what the community wants. One of the major choices is the size of the filter. One option is to build several small or family size filters, or to build on large central filtering system. KRMEF currently uses 100 liters per day for drinking water, but they expect that to double as the foundation grows. This estimate only includes drinking water; preferably the filter will also be used to treat the cooking water, as it takes a long period of boiling to kill off pathogens.

I already have a few possible ideas for filters. These include having a family size biofilter where drinking water is needed (e.g. in the orphanage and Krishna's house), a combination sand and UV filter (which can be done with a light bulb in a fairly short time frame or the sun over a longer time frame), or have a settling period in the sun to settle out suspended solids and have the sun disinfect the water. There are some other options, such as ceramic filters, that are generally fairly expensive, need to be imported, can break fairly easily, and/or need to be replaced year or two. A chlorine treatment system is also an option, but not only is it not as sustainable as the aforementioned options (which would mean it is not aligned with the foundation's mission), it would also require a constant, albeit small, capital investment to buy chlorine tablets, and if the chlorine is mishandled the results could be quite adverse. If the technology is small and easy to make, such as biosand filters, the foundation may be able to train people to make them and care for them, which could allow people to build them for families in surrounding villages. Not only would this give a source of income to the person that is trained, it could give villagers clean water even if they cannot afford mineral water. In addition to actually building the filter, I would ideally like to the test the water in the streams to find out what pollutants it contains. I plan on continue to communicate with the community, as I design the filter over the course of the semester.

KRMEF is also interested in creating a system for rainwater harvesting. Not only will it help agriculture at KRMEF during the dry season, it will also act as an example for the community to implement. This will probably be a simple rainwater collection pond, or rainwater barrels, that collect water off of the roofs of the building at KRMEF. This will help prevent water shortages, as Nepal receives most of its rain during its monsoon season, but is fairly dry during the rest of the year. As this is an issue I have not examined in depth before, I will have to research it more extensively, particularly because I will want to be careful to avoid creating a still water breeding ground for mosquitoes. In my preliminary research I have seen no concern over this, but is still something I will take into consideration.

This project would last the entire summer. I plan on leaving for Nepal around May 30 and returning around August 15. I would be there for nine weeks, during which I plan on spending the entire time working on this project. The foundation requests that people staying longer than four weeks pay $15/day (if one stays less than four weeks they ask for $20/day). This covers the cost of staying at the foundation, and allows them to provide more outreach to the community. If I stayed exactly 9 weeks, this cost would end up being $945. Nepal has a $100 visa fee that one is required to pay when they enter the country. A flight to Nepal from Washington DC, my home, ranges from $1,500-2,000. The average biosand filter, the type of filter that may be used in this project, can treat 12-18 liters per hour, when water is being drawn from it, (this generally can serve a family of 8-10 people) and costs approximately $50. The cost of rainwater collection systems vary dramatically depending on whether gutters are already in place on the buildings, the type of rainwater collection system and the cost of supplies in the area. I am asking for $500 to cover the cost of the water filtration system, rainwater collection system, and purchasing water quality tests. I am asking for an additional $500 to pay for labor from the community. Labor may be necessary to speed up the building process, or to provide better building skills. While I have had some building experience, it has always been supervised. Many people in the community will be handling with tools as a necessity, and thus can help make this project more successful. The $500 may also cover the cost of paying someone to maintain the filters in the future and/or training them to build these filters and implement them in the community.

Since this project is exemplifies my current life ambitions, completing this project will allow me to validate these ambitions. Additionally, it will give me a chance to explore a new part of the world, and immerse myself in a new culture. I would also get to meet amazing people who have similar life ambitions in that they want to help people and make the world a better place by reducing the effects of poverty and making the world a little more sustainable. These people can act as mentors to me, as they have experience that I lack, and I can learn a lot from their experiences. I can hopefully learn from their experiences and avoid making the mistakes they made in the past, as well as create a clearer direction for my ambitions.

In addition to the worldly aspect, this will be my first time being lead, from start to finish, on a project that is actually going to be implemented. As students, we only have a semester to finish any project in class, thus we rarely experience full projects. It is also rare for a project student design to actually be implemented because of the time constraints of a semester, the complications of a true project, and people's lack of trust in students, not to mention the moral complications of having students do a project for free when one would otherwise have to hire a firm. This project will give me hands on experience to improve my skills in every stage of a project. This includes the design phase and working with the community to create the project that they want and need. In addition, it will give me experience designing a low-budget, water system within a given time frame. It will also allow me to face the challenges that arise with every project, and leave me better suited to face these challenges in the future. That being said, this would be a great time for me to face these challenges. I have a support network in the form of my professors at ESF, the members of KRMEF, and an engineer who is on KRMEF's board of directors, who can guide me through some of the challenges.

The Rosen fellowship can help make this project happen. With the Rosen fellowship, I will be able to go on this amazing trip without having to worry about having a tight budget next year. It will also increase the possibility that I can do trips like this in the future. Most importantly, it will allow me to have money for the project itself. Other than trying to find money from another fellowship, my only other option is for the foundation to fundraise money itself. This could take quite a while; it is fully possible that they would not receive the money until after I am gone. This would prevent the project from getting off the ground while I am there. It may even prevent the project from happening, as they would need someone who has the skills and the time to implement my design. Thus, the Rosen fellowship can be very instrumental in the success of this project.