2.500 Desalination and Water Purification
Spring 2009

A Proposal and Analysis of Water Desalination Systems for the Villages of Phaeton and Paulette in Haiti

2.500: Water Desalination and Purification Technologies

Class Project

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1. Introduction

This paper proposes and analyzes multiple water desalination systems, to provide a drinkable water source for two villages in Haiti. After presenting the background and motivation for our work, we will proceed to establishing the assessment framework we will use to compare the different water desalination systems proposed. Following that we will analyze the systems proposed by the authors using the established framework. At the end of the paper, we will also propose multiple short term solutions that can be used to provide cheaper fresh water until a longer term solution is implemented. Finally conclusions and recommendations for solving this problem are presented.

Paulette and Phaeton are two poor villages in Haiti whose inhabitants live on less than $1 a day. People living in those villages have no local drinking water infrastructure. For their daily supply of fresh water, they depend on water from a nearby town called Ti Kampeche, which is pumped by means of a diesel-driven pump to two stations; each station is a few kilometers from its respective town. Residents of both villages have to pay a price of $0.024 for a bucket of this water, equivalent to a price of $0.0048 per gallon. It is estimated that each family consumes five to seven buckets of this water. Water from this water that reaches Phaeton has TDS of 650ppm, while that of Paulette has TDS of 450ppm. We are uncertain whether this water is always safe (free of bacteria, not too brackish for small children or in the long run…) and if the health problems are only caused by drinking water from the other community well, or if this pumped water is also a health hazard. It is estimated that there are 500 and 350 families in Phaeton and Paulette respectively.

Given that people are very poor in those villages not everyone is able to afford water from Ti Kampeche and instead, some people drink unsafe water from hand dug wells and community wells which have been contaminated with sea water. It is highly probable that these wells are unsafe because they are not sealed properly. They might have been contaminated with bacteria and other types of biological microbes. In addition they have salinity above 600 ppm, all of these are reasons for negatively affecting the health of the villagers. The community wells used to use a hand pump, which has been broken for a while and instead residents have to use buckets to draw water from these wells. The salinity of the wells currently in use is estimated to be around 4,000ppm. People also use water from these local wells for non drinking purposes.

The cost of drinking water represents a large portion of the villagers’ income, and the cheaper alternatives for water present significant health risks for the local population. Consequently, if a cheaper and more reliable source of fresh water is available for the inhabitants of Phaeton and Paulette it will greatly increase their living standard by saving them a large amount of their income and reducing their health risks. Having presented the background and motivation for this paper we will not proceed not presenting the assessment framework we will use to compare the different systems.

2. Assessment Framework

Since we are proposing multiple systems to accomplish the same task in this paper, and we are concerned with building one of those systems at some point of the future, it is important to establish a framework so that the multiple systems can be compared together. Different factors used in this framework can lead to a different choice of system so we will clearly present the factors we have chosen and the reasons behind our choice.

2.1 Cost

Since we are dealing with a very poor population and since one of the main motivation behind our work is to increase the net income of villagers through the supply of a cheaper water source, the cost of the system being proposed is one of the most important factors. Since all water desalination systems in our context will be creating the same product (drinking water), systems that can achieve this goal at a lower cost than others present a strong advantage. To ensure that the chosen system will not have any reliability problems and that it will not cause different problems that the ones the authors of this paper embarked to solve, we will have to consider other factors.

2.2 Robustness and reliability

Since our goal is to help the local villagers gain access to cheaper fresh water than what is currently available, we must ensure that the system is reliable in practice and not just in theory. Since our setting is in a poor village with limited resources, practice and theory could be two very different worlds. Consequently we must ensure that the systems presented can be utilized by the villagers and that the system will be able to deliver fresh water in this rough environment. Thus, the effort and skill required to accomplish the regular maintenance of the system is a very important factor in our analysis. In addition, the skill required to fix any of the components that fail in the system or the relative easiness to replace them is also important.

Perhaps even more important is the quality of the treated water that we obtain with our system. We must be able to assess the risk on people health associated with those systems.

3.3 External Problems

Although we have set out to solve problems of living standard and access to fresh water, it is important to ensure that the system proposed does not cause new problems while solving the ones of interest to us. Thus, we closely consider if the systems proposed might cause problems different from the ones we are trying to solve, so that the system we choose will have as little negative impact as possible.

Having establishing the framework we will use to analyze the water desalination systems, we will now focus our attention to evaluating four different systems proposed by the author that can solve the problems of interest to us. The systems we will analyze are Reverse Osmosis membrane, Single Effect Evaporation, Solar Still and short term solutions.

3. Design Considerations

The first approach we used to solve is problem is a large scale centralized water desalination system for the village that would provide all the villagers' water consumption. For Phaeton alone this would require a total of 12,500 gallons of fresh water per day. We found it would be very challenging to provide the high flow rate of water required by a centralized system that would generate this large amount of water. For example, the large amounts of electricity required to drive an RO system of this capacity or the equivalent mechanical power required to drive a pump that operates and RO system of this capacity would not be possible to generate locally.

Consequently, we decided to focus on designing decentralized water desalination systems, each of which could be share by a family or a group of families. Thus our goal was to design a system that could easily operate using smaller energy resources that would be available to individual villagers. A few examples are small amounts of human power, sunlight, and small amounts of fuel.

In addition, we decided to design a system that would provide a fresh water supply for the drinking water requirements of the villagers. Consequently we think it is very important that the villagers become educated about uses of different types of water qualities. Villagers should only be using the water supply generated from the water desalination system for drinking and other purposes that require a high quality water source. Currently, it seems that no-one make a distinction between drinking water and other domestic use of water. For instance, people who purchase water from the diesel powered pump, takes an average of five gallons per person per day. This is obviously much larger than their drinking requirements of two liters per person per day. As a result, we recommend that villagers use water from the community and hand dug wells for purposes that do no not require high quality water such as washing clothes or showering. This very simple measure would lead to an economy of 90% in water expenses (i.e. instead of buying 19L of fresh water per person per day, we recommend that they buy only the 2L/person/day, and take the other 17L from free community well). Part of this 90% of economy will go into the building of the desalination system, to have even cleaner water than the 600ppm sweet water, and part of it will be spare by the people!

To accomplish this goal, and to sensibilize the population to the importance of sanitary conditions, we have also created a flyer in the spoken language of the villagers (French) in order to educate them about water usage.

4. RO Membrane

The first system we are proposing for this project is a new concept that was pioneered by our team. This system uses the well developed Reverse Osmosis (RO) membrane technology to desalinate water. What is innovative about this system is that instead of using electricity to achieve the high operating pressures required by RO membranes, it uses a traditional bicycle pump. This is a great advantage since the use of electricity is a rare and limited commodity in Paulette and Phaeton. Moreover, our system is designed for small scale individual use and uses other bicycle components, readily available in these villages, to make up the rest of the system.

In addition to the RO membrane, this system is made up of a bicycle rim, two bicycle tubes and a bicycle tire. Our design, one of the bicycle tubes is inflated with air by means of a hand pump. The other tube is filled with saline water and is closed by two valves. In the second tube, one valve is used to fill the tube with saline water and the other valve is equipped with the RO membrane.

Figures 1 and 2 below show how the system is assembled and how it operates. In fact, after inserting a membrane and a permeate spacer inside one of the tubes, the user has to fill this tube with unsafe water and seal it by the means of the clamp system shows hereafter. Putting back this modified water-filled tube and a conventional air-filled tube into a bike wheel, he has to pump air inside the second tube to pressurize the system.

This system can produce one liter per cycle of operation. It takes an average of 30 minutes to complete one cycle, which includes filling the system with saline water, providing pressure through the manual pump and removing the saline water from the system. This is not the time needed to provide continuous pumping power. After the system operator provided the first mechanical pressure to the tubing by means of the pump, they should watch the level of inflation of the tube, as it decreases at a very slow rate. Once it begins to decrease significantly mechanical pressure through the pump should be applied another time. It is estimated that this process of applying pressure at a non continuous pace will take an average of 10 minutes. Consequently the system can provide two liters of fresh water every hour. This system can be share in a family, where each family member can use the system for an hour every day to generate their own drinking water.

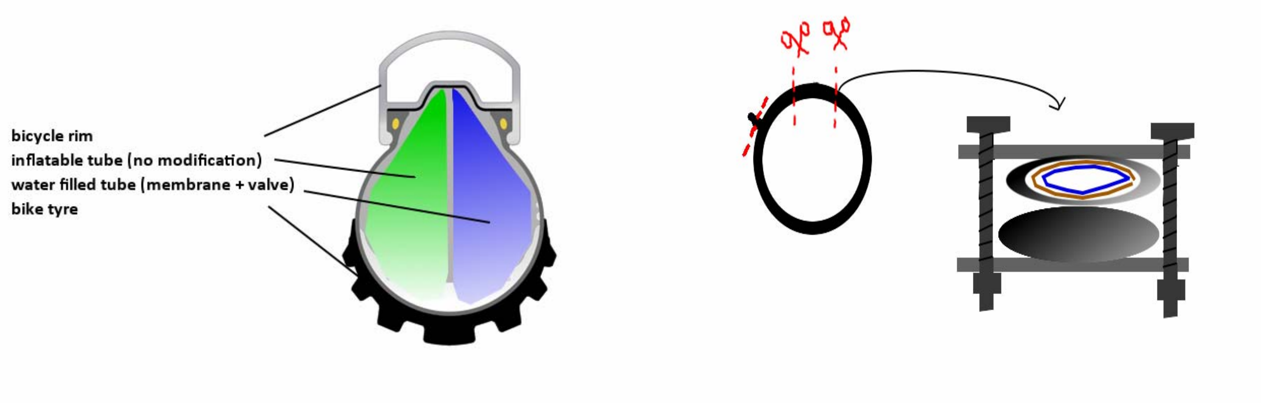
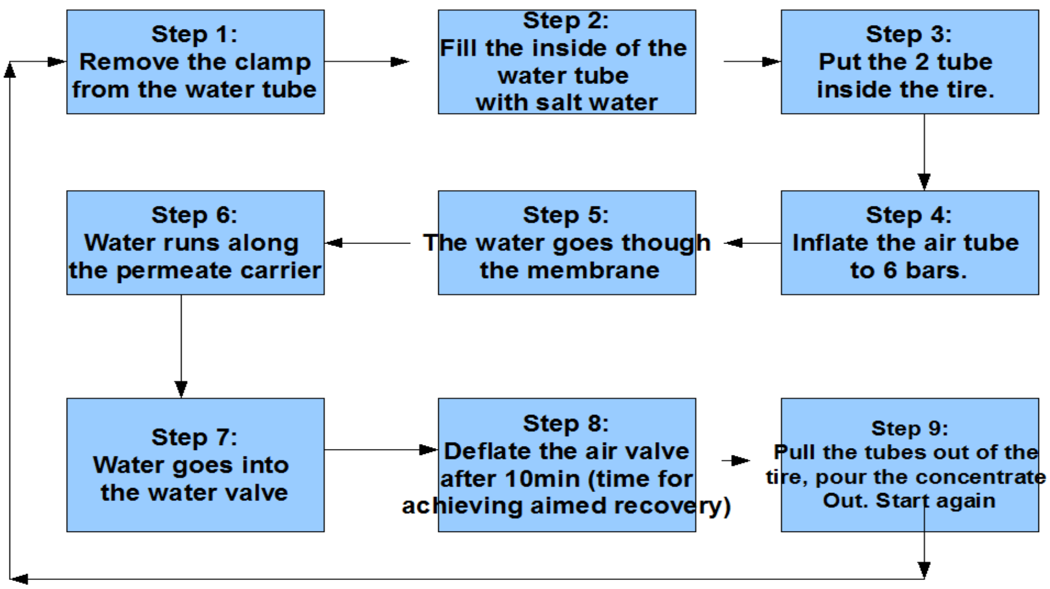


Figure 1: Operation of RO Membrane system



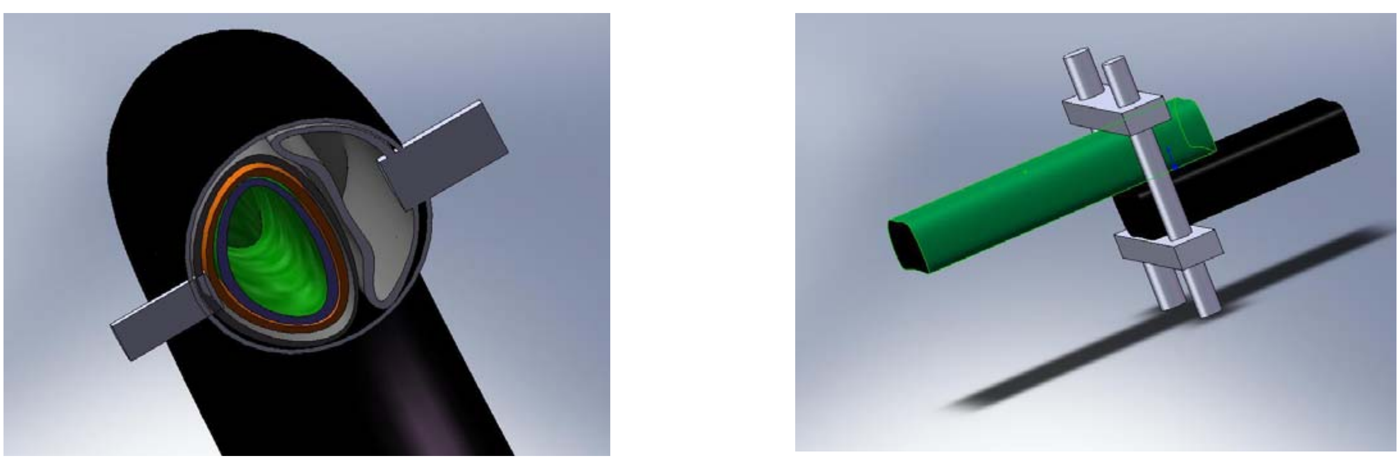


Figure 2: Operation of RO Membrane System

4.2 Cost

When analyzing all the proposed technologies, we are going to benchmark their cost against the cost of currently available water from the diesel generator pump. Currently, unsafe drinking water from this source costs $0.0025 per person for the daily consumption of two liters or 0.53 gallons of water. This results in a cost of $0.012 per family per day, assuming an average of 5 people in a family and a total cost of $5 per family per year. But in fact, the family usually buy all the water for domestic use at the pump, and does not make a difference between drinking water, cooking water, and water that is used for cleaning and washing. As a result, the real price of water rises at 45$/year/family, as mention on the Amy's slides.

The capital cost of this system is estimated to $10. We estimate that the RO membranes will have short life of one year instead of the three to eight years lifetime they manufacturer advertised when the maintenance operation is respected. A detailed discussion of this assumption is provided in the annexe. If we think only in terms of cost, it would take a little bit less than a year for this system to break even for its capital cost and would save a total of 3% for the family. It would cost $5 to replace the membrane every year. This results in a total of 86% annual savings on the combined expenditure on drinking water for the two families. In addition it also gives a safer source of water. Instead of desalinating water from the community well, we can also desalinate water from the pumped system. This would provide much higher quality water, and as we reduce bio-fouling risk on the membrane, we could reduce the frequency at which we have to change the membrane

4.3 Reliability

Although this system leverage the proven RO technology while reducing the need for electricity usually needed by RO system, it is still in the concept stage. To determine how reliable the system is, it has to be used for at least a few months at the water production rates required to determine the real lifetime of the membrane under these conditions. Moreover, this system has a great advantage of using locally available materials for the rest of the system components. Bike tubes, tires, rims and pumps are all locally available and have well established repair and replacement services in this region. However, it is worth noting that without further studies, this system is associated with a high risk, because if the membranes fail earlier than expected the cost of water to the villagers would increase.

4.4 External Problems

This system does not seem to cause any external problems such as environmental concerns. However, there are two unresolved issues that we have not discussed above. The first is the procurement and payment for the RO membranes. Some entity or organization will have to order, import and pay for the RO membranes from the US. In addition the entity will have to divide the RO membranes in the smaller size required by the system; hold a training program to the community on how to assemble and use this system, and finally distribute the system.

Any new system is going to have an additional training and distribution component. Thus, the only additional need that this system requires of the entity that will take responsibility for executing this project is the procurement and upfront payment of the RO membranes. Furthermore, we have to make sure to provide membrane to the population.

5. Single Effect Evaporation (SEE)

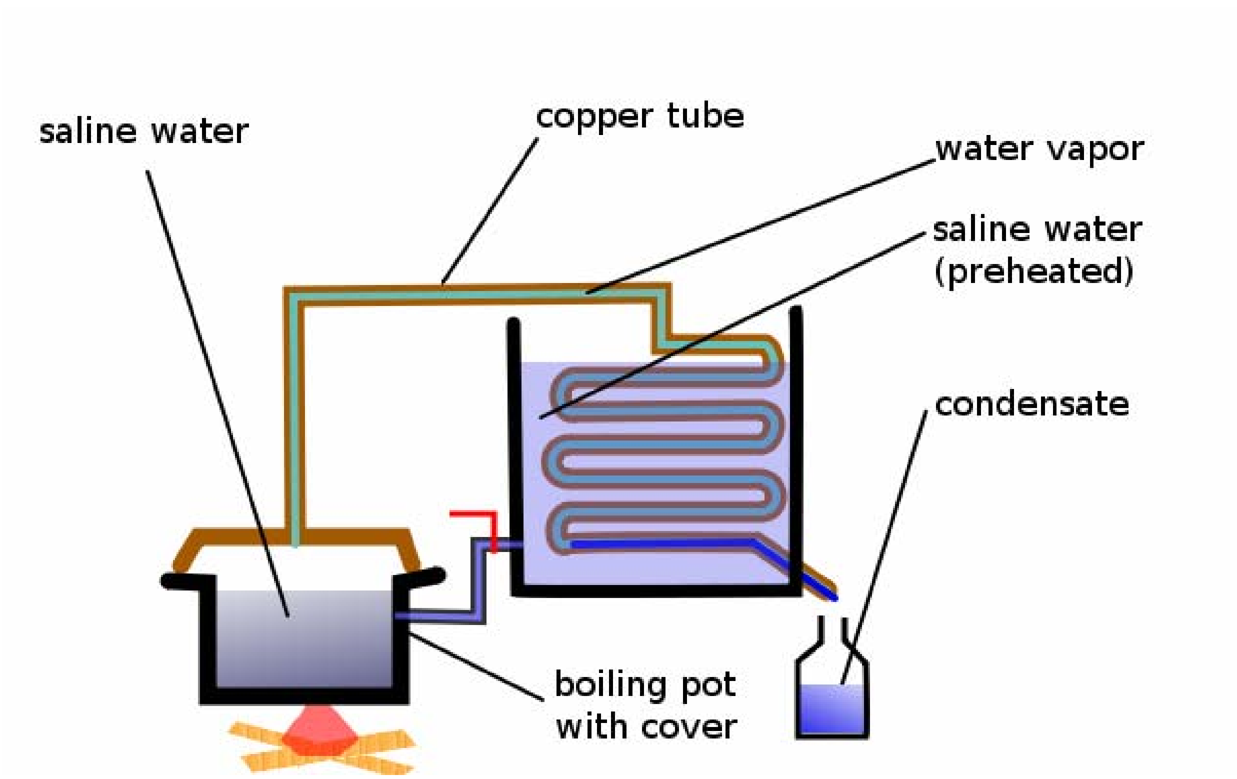


Figure 3: Single Effect Evaporation System

In this design, pots made from cast iron or aluminum are filled with saline water and covered with a lid. A hole is made in the lid and a black copper pipe is inserted through the hole as seen in the figure above. A source of cheap fuel such as wood is then used to evaporate the water. Water vapor leaves the pot through the copper pipe. During the assembly of the system the pipe is inserted into another container containing saline water. This allows us to use the vaporization heat to preheat this saline water in the second container, after which it will be transferred to the first container to vaporize the water. After the copper pipe leaves the second container the condensed water is poured into the distillate container. The result is pure drinking water with no contamination. To avoid scaling and corrosion in the boiling pot, the salt residue must be regularly flushed. Each family will have one of those systems constituting of a 10 liter sized boiling pot. Villagers can use wood from the surroundings of the village to burn in this system or some form of biomass, or the charcoal pioneered by Amy Smith. If there is no agriculture crops in those specific villages, agricultural waste to make biomass can be procured from nearby villages.

5.2 Cost

To produce the required 10 liters of water daily for each family, 1.7kg of wood should be burnt. Since the system will cost $30, assuming a life time of 5 years for the system, gives a total cost of $0.0016 per liter of fresh water produced. This is less than the cost of water from the solar still and the diesel powered pump. Though, if we include a cost for the wood instead of using Sugarcane charcoal or wood from the surroundings, this systems turns out to be the most expensive of the 3 systems proposed.

5.3 Reliability

Since all the components of this system are locally available and easy to handle, it is very reliable. Water distillation for every day’s use could be done the night before, however, operation of this system is not restricted to a certain time of the day like solar energy, so it can be operated at any time. In conclusion, since the skill and components required to build and operate this system are all locally available and time of operation is not restricted to a certain time of day or type of weather, it is a very reliable system.

5.4 External Problems

Although this system has excellent ratings for cost, and reliability it might cause a big environmental problem depending on the type of fuel used. For instance, if only wood is used to provide all the drinking water needs of the village then almost a ton of wood would be burnt daily to produce the required fresh water. This can threaten the local supply of wood, forests, in addition to causing pollution and soil erosion as a result of cutting down more trees. On the other hand the system can still be used if an alternative set of fuel is investigated. For instance some form of biomass could be used as fuel. If the local villages are not rich in agriculture or vegetation, perhaps the wasted organic material from agricultural grounds in nearby villages can be procured and used as biomass. This would need its own logistics and so to make sure the system does not cause new problems more ground work needs to be done on the possibility of using biomass as fuel.

6.1 Solar Still

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Please see slide 21 in Foster, Robert, and Sharon Eby-Martin. "Solar Water Purification for the Border: Solar Distillation." http://www.epsea.org/pdf/borderpact.pdf

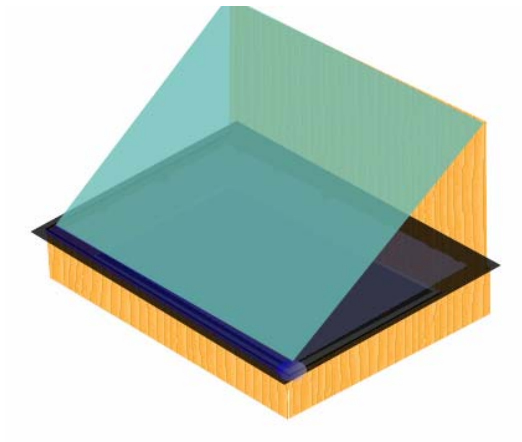


Figure 4: Solar still made from wood and local material

The third idea we are proposing is a conventional solar still. During times of sunshine, salty water is left in a glass covered basin that is airtight and has a black base to absorb radiation. This causes the water to evaporate, and since the system is airtight, the air inside the unit becomes saturated with water vapor, and consequently condensation occurs on the coolest the glass surface which covers the black basin at a tiled angle. The glass is set at a tilted angle of about 25 degrees as seen in Figure 4 above so that the condensing water flows down, rather than forming droplets and falling back into the basin. As a result of this angle design, the water can be collected at the lower edge of the glass and can be lead into storage tanks. After all the water has been distilled by the solar still, the salt in the bottom should be removed. 4.26 meters square solar still can generate 10 liters per day of pure water to provide requirements of one family.

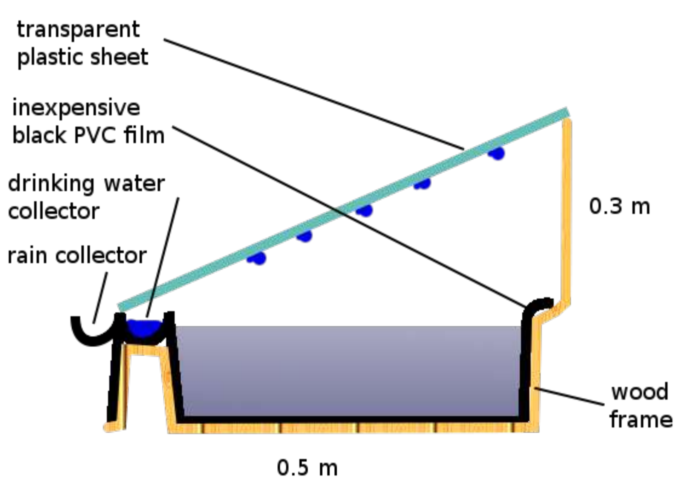


Figure 5: Section view of a solar still

6.2 Cost

The cost of one solar still used by a family that will provide 10 liters of pure fresh water per day is evaluated to $65. Solar still systems of this design have been used in Botswana in Mexico, developing countries, and have shown a lifetime of 10 years. Consequently this solar still can provide fresh water at a cost of **$0.00175 per liter** as opposed to the $0.00127 per liter from the diesel generated pump. Once again, the gain in term of cost is not obvious. What is more obvious is the improvement in water quality.

5.3 Maintenance

This design uses locally available materials, which are very easy to work with and maintain. With training, these systems can be easily built in Haiti so there are no issues involved with regards to lack of know-how for fixing this system as in the case of more complex systems like reverse osmosis. For this system we think it is better to go with a design that is simple at some expense of efficiency so that it can use local materials and require little or no maintenance costs.

6.4 External Problems

Since there are no components imported for this system and since the only fuel it uses is the sun, there are no external problems involved here as we have seen in other designs. However, we know that this system will only operate in the morning and in sunny conditions, so on rainy or very cloudy days the villagers will have to rely on a different source of water.

7. Short Term & Other Solutions

Since at least six months to one year is required before a new water desalination system can be deployed on a large scale in those two villages, we have developed a number of short term solutions that can be used to supply fresh water for the whole village until the new systems are in place. The reason it would take at least six months to a year for the new systems to be deployed includes: testing multiple systems and collecting technical data on which system performs best; observing villagers use systems; training villagers to build systems; establishing the necessary supply chains for the various components of the system; and raising the necessary capital to pay for the upfront cost of the system.

7.1 Donation

It costs $10.9 per day to provide all the daily drinking water required for the 4,200 villagers. Although this is a large cost of the villagers' income it is a very small price in an American setting. Consequently, this money can be raised from US donors to purchase drinking water from the diesel power pump of Ti Kampeche to ensure that everyone in the villages has access to low salinity drinking water that will not cause them health problems. Thus each person could get a coupon, distributed by the local NGO that will take responsibility for this, for 2L of water per day. This solution can be use for the year that is required to bring about the deployment of new desalination systems. $3,923 would be required to bring fresh water to all the people in both villages during that year.

7.2 Water Transportation Logistics

Since diesel is an expensive fuel in Haiti, the use of diesel powered pumps to transport water to Paulette and Phaeton results in around a $5.4 per day cost for each town. An alternative short term solution is the use of a donkey cart that collects water from the water station in Ti Kampeche and transports it back to the village. Each village can have its own donkey cart and this can reduce the cost of water of one village to $2.6 per day, more than a 50% decrease in cost. The real question here is do we want to go back to less advance solution for water transportation.

7.3 Water well

A final solution that we want to include in our main analysis but did not hear back from the necessary suppliers in time, revolves around digging a new community well in each town. Since the water from Ti Kampeche is close to 500 ppm and Ti Kampeche is a few kilometers away from Phaeton and Paulette, it is very likely to find a ground water source in those two villages with similar salinity that would not require further desalination. Consequently, it is worth looking into the costs of building such a well and comparing it to the costs mentioned above. We have located a company specializing in digging such wells in Haiti yet we have not heard back from them. Therefore, we recommend that one of the local organizations interested in this problem, to contact this contractor and inquire about the related costs of drilling such a well. The contact information is given below:

HAITI FORATECH
Gerald Jean Baptiste,
Varreux 1 Route National #1
Port au Prince, 6140
Phone: 509 5107434
Fax: 509 2509490

8. Conclusions & Recommendations

In conclusion, we have seen how the three technologies proposed can provide clean drinking water to the villagers at a cost less cost and a higher quality than water from the currently available diesel powered pump. The RO system is a new concept that has not been commercialized and therefore it is the most risky of all three technologies and thus the least preferred. Solar stills have been used in many developing countries around the world and have demonstrated a low risk characteristic with regards to their performance. However, if this becomes the predominant method of supplying fresh water then the water supply would be disrupted on rainy and very cloudy days. Finally, we have seen that the SEE system used with sugarcane charcoal (http://web.mit.edu/d-lab/resources/nciia_files/charcoal.pdf) provides the lowest cost of clean water production out of all three systems. However, this system might cause some environmental problems to the villages of wood is used on a large scale as the fuel for this system.

To reduce the negative impact of the disadvantages of the SEE and solar still systems, we recommend that both of these systems be used in each village in the following way. One of two neighboring families will have an SEE system and the other neighbor will have a solar still. This will reduce any environmental impact on the village as a result of burning fuel by 50% compared to the case if only SEE systems were used. Furthermore, if the village experiences a number of consecutive cloudy days, owners of the solar still can use fuel to generate fresh water from their neighbor's SEE system. Consequently the supply of fresh water will not be interrupted on cloudy days for villagers that use solar stills.

We recommend the establishment of a nonprofit mechanic shop in each village that will assemble the solar still and SEE systems. Workers in this mechanic shop will be trained to design and erect these systems, procure all the necessary materials and fix or replace any of the system components. In addition, a microfinance fund should be established to help the villagers pay the initial capital cost of the water desalination system.

We also recommend that an educational program is put in place to educate the villagers about characteristics and used of pure water. Villagers should not drink water from the community, hand dug or diesel pumped wells because they have high salinity and are at a higher risk of bacterial contamination. Instead, villagers should drink water provided by their new water desalination systems and only use water from the other wells for non-drinking purposes.

Since it might take at least six months to one year in order to establish the required training and the necessary environment for the large scale deployment of the new water desalination systems, we have proposed a couple of basic solutions to improve the living standard of the villagers in the short term. Since a large number of the villagers cannot afford to buy water from the diesel powered pump and instead drink very unhealthy water; this money can be raised from the US in the short term since it only costs $10.9 per day to provide water for 4,200 villagers. Finally we also recommend for the local NGO that will assume responsibility for the implementation of this task, to investigate the cost, with the local company mentioned above, of building a new ground water well that has a salinity similar to the well used with the diesel powered pump, and comparing it to the costs of the SEE and solar still systems.

9. References

- **http://www.htiwater.com/main.html**
- **Solar Power desalination- a case for Botswana, (Dr. Yates)**
- **Solar Water Purification for the border: Solar distillation (Robert Foster, SWTDI - New Mexico State University)**
- **http://www.desalination.ucla.edu/**
- **http://www.membranes4less.com**
- **http://www.vestergaard-frandsen.com/lifestraw.htm**
- **http://www.eau-rhin-meuse.fr/**

10. Appendices

10.1 Flyer

10.2 Technical Analysis RO membrane

10.3 SEE Costs Analysis

10.4 Solar Still Costs Analysis

Desalination project.
Annexe A

Specification of our system of RO.

We have lead the first studies on this system, to see if the theory was convincing or not. It is presented hereafter.

Hypothesis:

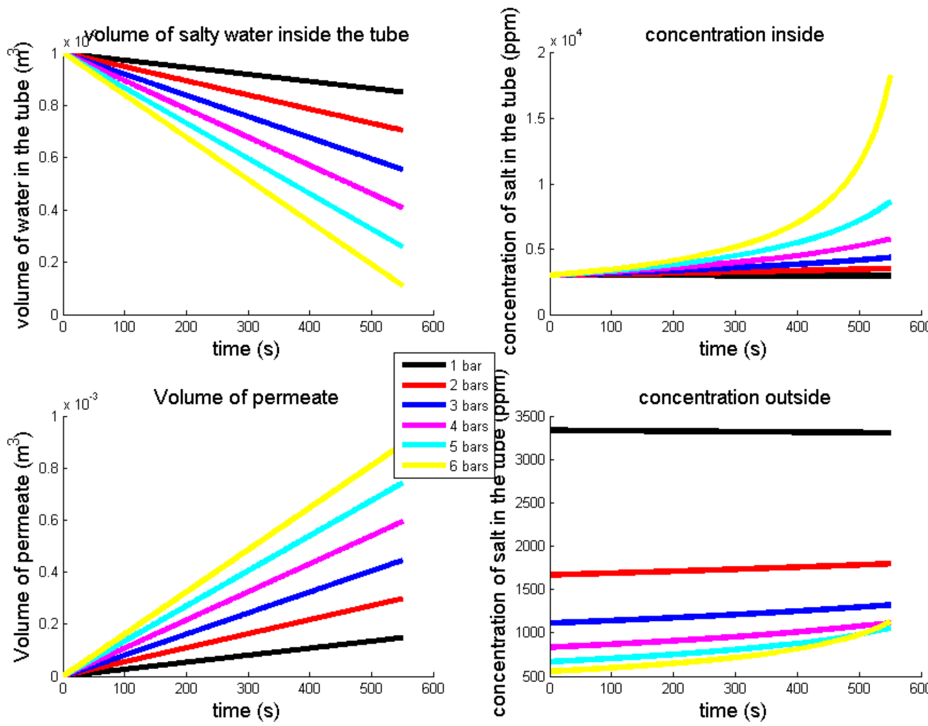
Pressure: up to 6 bars.	Ratings allow to pressurize cycle tube up to 120psi= 8bars. Even though the performance of the membrane in this range of pressure is not great, RO does make sens as it is also removing every bacteria/viruses... Those membrane are usually running at 60 bars, and the advertised 98% of rejection is calculated in this range of pressure. Here, the rejection is a modest 40 to 80%, as it is shown on the Matlab simulation hereafter.
Area of the membrane: $0.15\, m^2$	The size of the active membrane is determined by the internal area of the tube we are using. If we use small tube (more resistant to high presure) $A_{max} = Pi * 23\text{mm} * Pi * 700\, mm = 1.5 * 10^5\, mm^2 = 0.15\, m^2$. Someone is pumping during the 15 min of filtration, to maintain the pressure constant.
Total volume of water: 1L	The volume of the tube is $V_{tube} = \pi \frac{(23\text{mm})^2}{4} * 700\text{mm} * \pi = 1\, L$

Results:

Time of filtration: 10min for .6L.	We have taken the salt and water permeability from the Dow XLE-BW membrane, provided by prof Hoek (UCLA WaTeR center). The concentration in the initial stream was taken 3000ppm. In term of quality of the water produce, we know that no virus, protozoa or bacteria will pass the membrane. We have to worry about the salt permeation. Especially, this system is not a cross flow system, but a dead-end system. To do so, we have to solve the equations of the salt passage and water passage through the membrane. It should be noted that the concentration polarization was not taken into account. This would be a very bad approximation in a 60 bars system, but in our system, the flux of water are 10 times smaller, and the salt removal is relatively small. As a result, we expect the gradient polarization to have a much smaller effect. $\frac{dm_{salt}}{dt} = -\phi_{salt}$ $\frac{dV_{in}}{dt} = -\phi_{water}$ $c_{in}(t) = \frac{m_{salt}(t)}{V(t)}$ $\phi_{salt} = B \times \Delta c \times S$

$$\phi_{water} = A \times P \times S$$

A Matlab simulation have been run to try and asses the time of filtration and the salt removal that we could expect. We have also tested the sensitivity of this permeation devide to the pressure applied. The result is that we need only 10 min to filter 1L



Chlorination or no chlorination:

Biofouling is for sure the Achille heel of the system. We know that biofouling is very dependant on the quality of the feed water. So it is impossible for us to asses how sensitive we are to the formation of biofilm. We have 4 possibilities.

- The first one is to choose membrane chlorine tolerant (Toray inc. produces such cellulose acetate RO membrane). They seems to accept level of 10s ppm. But those type of membrane are not commercially available, but they are used industrialy. An agreement needs to be found with the manufacturer.
- The second solution is to have a chlorination-dechlorination technique. It seems to us that the precision required in dosing the chemical is not compatible with the use we make of our membrane.
- The third solution is to have a sacrificial use of the membrane. Dow membrane can sustain a concentration of free chlorine of 1mg/L for 200 to 1,000H. This represents 1200 to 6000 cycles of 10 min, or 1200-6000 L of permeate. Which is approximately one year of drinking water consumption for a family (3650L/year/family).
- The last solution would be to let the system without any chlorination. How crazy

this solution can seems, we know that Hydration Technology Innovations produces an hydration bag that can filtrate water by forward osmosis for up to one month. http://www.htiwater.com/hti.html. They do not use any chlorination in their bag, and are able to desalinate very muddy water, which could have a much higher concentration in biological agent than the water we want to desalinate.

Suggested Water solutions for Phaeton and Paulette

A) Short term solution

1- Donnation (no desalination)

Total number of people	4200		
Total amount of drinking water	8400	L/day	
	2270.3	Gallon/day	
	454.1	buckets/day	
cost of water	0.02	$/bucket	
Cost of drinking water	**10.9**	$/day	0.001 $/L
	326.9	$/month	
	3923.0	$/year	If it can be donated?

Each family get a monthly coupon to obtain 2 (L/day person) from the existing water source

2- Trucking water

1 man for each village works on a donkey driven farm cart to bring water from the neighboring town and sell it

Cost of water from the neighboring town	5.4	$/day	
(assume less by 50%)			
cost of donkey + cart + tank	2000	$	
assume 5 years life time	1.1	$/day	
cost of doneky food	0.5	$/day	
wage of the man	1	$/day	http://www.missiontohaiti.org/index.html
Total water cost	**8.0**	$/day	http://www.wellowner.com
			http://www.wellowner.**com**

Benefits:
job offering
drinking water is delivered to houses directly
no water contamination from pipes or water leakage

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B) Long term investment

1- Drilling new water-well

The water source in the two towns is from a sweet well in a nearby town
the water source is drinkable with 600 ppm
There is a probability that the two towns share the same water aquifer that the nearby sweet water well sucks wa
So the solution may be drilling a water well at the same depth (or deeper) the nearby sweet well is

Cost of drilling a new water well	**4500**	$	Source of the well cost
include drilling+casing+hand pump+disinfection			A water-well contractor in Haiti trie
			information about water-wells type

Benefits:
People from the two towns community can be hired to save and operate the well
The well will be owned by the community itself

C) Point-of-use solutions

1- Single effect Evaporation

Idea
Using wood or cooking fuel to evaporate brackish or seawater then condense it as pure water
Fires are lit at night in
households, so an attempt may be made to introduce stills that
consisted of a modified pot with a hole
drilled in its lid, and a blackened copper pipe connected to it to
act as a condenser. Cooling is to be provided by inserting the copper pipe in the plastic bucket and make a hole
to get the condensed water from it

Cost of 10 L pot	10	$	Used cast iron or aluminium pots	
Cost of 2 m copper tube of 1" diam	20	$	source:	http://www.pexsupply.com
Total cost of the system	**30**	$		
Estimation of wood cost				
wood cord volume	128	ft3	source:	http://www.woodheat.com
average wood density	40	lb/ft3	source:	http://www.engineering.com
cost of wood cord	337.5	$	source:	http://www.woodheat.com
specific wood cost	0.07	$/lb		
specific wood cost	0.13	$/kg		
Wood heating value	14500	kJ/kg		
water latent heat	2300	kJ/kg		
Water produced from 1 lb of wood	6.30	kg_water/kg_wood		
Cost of water produced	0.02	$/L_water		
Total cost of water	0.04	$/L_water		
(assuming 5 years life time of system)				
Total drinking water cost for the whole village	**313.74**	$/day	very very very bad idea with bad e	

Wood as fuel in Haiti

http://planetark.org/enviro-news/item/52655	nice photo for a boy carrying wood
https://www.entrepreneur.com/tradejournals/article/12722415_5.html	article about wood fuel in Haiti

2- Solar stills
Idea
Train each family to build their own solar still system and put it on the roof of their house
the solar still can be built from wood, transparent plastic sheet, black plastic sheet, PVC pipe and silicon rubber f

Estimation water production

Solar isolatuion	5	kWh/m2 day	Source
	18000	kJ/m2 day	
solar still efficiecny	0.3	(this is the minimum solar still efficiency but it can	
total amount of energy collected	5400	kJ/m2 day	
water latent heat	2300	kJ/kg	
amount of water produced	2.35	L/m2 day	(1 kg = 1 L of water)
amount of drinking water needed per family	10	L/family	
(assuming family is 5 members)			
Surface area needed	4.26	m2/family	(i.e. we need to design a solar stil

Estimated cost of the proposed solar still (see figure)