

Liquid Life

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ABSTRACT

In our world today many countries occupied with human life experience clean water scarcity. Engineers from all around try to find a solution to this epidemic before it can be inhabitable. Liquid Life is a project team consisting of two architectural engineers and one mechanical engineer, all juniors, currently attending Worcester Polytechnic Institute. This report entails the water crisis at hand, the research we conducted on engineers whose projects were implemented and are currently operating, as well as engineers and their projects that have failed for one reason or another. With this compiled information we constructed a report and a pamphlet with guidelines for, but not restricted to, engineers who are interested in implementing water sanitation systems or any projects of the same assisting nature.

ACKNOWLEDGMENTS

Liquid Life would like to acknowledge our project advisor Aaron Sakulich who gave us the guidance and random yet accurate knowledge that helped us complete our project report.

Next, we would like to thank Worcester Polytechnic Institute's Chapter of Engineers Without Borders, who let us interview a couple of their members who have first hand experience implementing water filtration systems.

We also would like to acknowledge a WPI professor who teaches a "Great Problems Seminar" class, which focuses on problems that are of current global importance. The professor provided great insight and other factors to consider when interviewing.

Last, but definitely not least, Liquid Life would like to acknowledge all the humans suffering through the global water crisis. A project like this was put together to guide engineers who are new to implementation to help better your life (the clients). We realize that water can be the new gold if nature's balance scales are tipped more by humans. When demand goes up and supply drops, that means the cost of water, "liquid life," will increase.

AUTHORSHIP PAGE

Corrado Addonisio, Kory Girouard and Cesar Rodriguez take 100% authorization of this report equally.

EXECUTIVE SUMMARY

The issue of water scarcity is not new to the engineering world, in fact many technologies have already been developed to combat this crisis. So, why does a water crisis still exist throughout the world? The answer comes with complications that arise when implemented technologies are not suited for the specific needs and conditions of the affected areas. In order to make a stand against the global water crisis, we will compile information on water filters and water filtration systems in order to make the information as publicly available as possible. Simplicity will be the key to making a universally understandable guideline capable of providing solutions to all who have hopes of helping

an impoverished community. Our plan, through the collaboration of local and distant advocates of the cause, is to bridge the gap between engineers and those affected to better



Can you think of a better way to turn hard labor into a little bit of joy and play for Kids? By wiseclerk,

understand, evaluate, and prescribe solutions to water issues around the world.

Filtering and purifying water has come a long way from the introduction of the first slow sand filters to the United States in 1870.¹ In today's day and age, filters with many varying characteristics can be used to purify water around the world. There are three main

¹ "History of Water Filters," **The Water Exchange**, 2014. (© 2014 By The Water Exchange), <http://www.thewaterexchange.net/water-filters.htm>, p. 01.

categories of water filters to consider when looking for the one best suited to your needs: chemical, physical, and radiation. How each individual filter performs in different areas around the world is limited by the area's economic, environmental, and social aspects as well as the capabilities of the filter itself. When implemented in the correct conditions, even the simplest of filters can make all the difference when it comes to saving lives throughout developing countries.

With all of the miraculous water filtration devices and systems available in today's market, it is astonishing to find that so much of the world remains without clean, potable drinking water. Countless water scarcity projects have spawned all over the globe, each aimed at combating the crisis head-on with the help of society's latest and greatest technologies. Two crucial questions raised by this seemingly brilliant effort being made by so many are: "Why does water scarcity still persist in our world today?" and "What is happening to the innumerable projects that are currently in place?". In order to understand what overwhelming force is preventing people around the world from gaining access to clean water we first examined prior sanitation projects, how they were conducted, and what resulted from their ventures. Only then, after analysing the work completed by previous groups, can we begin to establish a definitive direction in which to lead future endeavors.

In many instances of modern day filtration systems, the project's success or failure was largely dependent on the indigenous people's involvement in the implementation and eventual acceptance of the system as well as the accountability that comes with it. Yes, there are many attributes of filtration systems (contaminants, cost, technology, environment, etc.) that can directly affect the outcome of said system, but in the end it's

the indigenous people who ultimately decide what is best for *their* community, *their* financial situation, and *their* personal needs. What is needed, as stated by Marla Smith-Nilson in her “Humanosphere” article are “standards and accountability... Estimates are that less than 5% of organizations follow-up on their projects post-construction [and] an estimated 35-50% of water projects fail within 2-5 years after they are constructed.”² Chilling data when you consider the number of project attempts that have been made and the amount of them still in place, providing no more than a glimpse at what could have been. Our group went about our in-depth research in a similar manner to that of Vestergaard’s; collecting information on all possible variables pertaining to the filtration system while holding the human variable above all else throughout the process.

The interviews that we conducted allowed us to hear first-hand accounts of how the crisis affects each community of concern, what can be done to improve upon, if not fix, the situation, and to come to a better understanding of the necessary balance between the needs and means within the community with the current availability of water filtration technologies. After gathering information on the topic at hand, we compiled a complete report on how to properly implement a water sanitation system into an afflicted community suffering from the water crisis. This helps bridge the gap between engineers and the suffering communities, so that filtration systems can be easily be matched and operated by the client, who will be educated on the system to ensure that the system runs at its prime efficiency with respect to its environment.

² Smith-Nilson, Martha. “Guest Op-Ed: Water projects everywhere, but little accountability”, **Humanosphere**. (Copyright 2014 Humanosphere.org), <http://www.humanosphere.org/basics/2013/08/guest-op-ed-water-projects-still-lacking-accountability/>.

Throughout our investigations into filters, previous sanitation projects, and the conducted interviews it became apparent that the real issue at hand concerning the water crisis is not a lack of technology but that of education and sustainability. Today's available water filtration technology and its effectiveness in cleaning any type of contaminated water coupled with the inter-connectivity of the modern world would make it appear as if the water crisis has already been solved. Although the technology and means of implementing filtration systems are out there, there is yet to be a standardized method to sustaining the project over time. What we have found is that education, involvement, and accountability are the major factors that, when performed well, are the key to a filtration system's success. It is our greatest desire that with the step-by-step guide we've constructed to help aid the implementation of projects in developing regions that more can be done to aid in the eradication of the world's water crisis.

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INTRODUCTION

The issue of water scarcity is not new to the engineering world, in fact many technologies have already been developed to combat this crisis. So, why does a water crisis still exist throughout the world? The answer comes with complications that arise when implemented technologies are not suited for the specific needs and conditions of the affected areas. In order to make a stand against the global water crisis, we will compile information on water filters and water filtration systems in order to make the info as publicly available as possible. Simplicity will be the key to making a universally understandable guideline capable of providing solutions to all in need. Our plan, through the collaboration of local and distant advocates of the cause, is to bridge the gap between engineers and those affected to better understand, evaluate, and prescribe solutions to water issues around the world.

BACKGROUND

Given that 70% of the world is water, it is astonishing to find that only 2.5% of that water is fresh, potable drinking water. Of that small fraction of freshwater contained in the world only .007% is readily accessible to humans due to the containment of water in glaciers and snowfields.³ In the world today, 780 million people(1 in 9 individuals) are without access to clean drinking water, and 2.5 billion lack improved sanitation.⁴ As a team we decided to research what type of filtration systems are available to the lives of

³ “Freshwater Crisis”, **National Geographic**, (© 1996-2014 National Geographic Society), <http://environment.nationalgeographic.com/environment/freshwater/freshwater-crisis/>, p. 01.

⁴ “Sanitation and drinking water at the heart of human health and development”, **Progress on Drinking Water and Sanitation 2012 Update**, (© UNICEF and World Health Organization 2012), www.unicef.org/media/files/JMPReport2012.pdf, p. 02.

people that need them most. Certain water filtration systems perform better when under specific circumstances such as the energy, climate, and financing in a given location. Also, any hardships concerning the selected individuals, their local community, and the terrain surrounding them will play a key role in the success or failure of any implemented system. These systems have been close to being implemented in numerous areas around the world where the water is constantly contaminated by natural disasters, human fecal matter, virus' from carriers, excessive amounts of minerals, and the mere fact that standing water tends to grow sickly bacteria called "Blooms" more quickly. Still today, there is no single filtration system that can completely fix the worlds' water contamination problem; however there is a lot that can be done to enhance the number of water filtration systems in under-developed countries. More important is the need to further communications between engineers designing water filtration systems and the locally-affected, so as to reach a solution that not only solves the contamination issue but is tailored to those individuals using it.

There are two different categories to water scarcity; physical scarcity and economic scarcity. We can assume that the drier areas have much higher levels of water scarcity which is not necessarily true. More than 75% of all river flows are withdrawn for agriculture, industry, and domestic purposes. This ultimately leads to physical water scarcity which is primarily concentrated in Central America and in most countries of the Middle East. For economic water scarcity human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands.

Less than 25% of water from rivers are withdrawn for human purposes.⁵ It's also a matter of how much of that accessible water is actually safe for human consumption. There are areas where the government does not support water sanitation programs which would provide clean water to the locals but only do so for those who can afford to pay for the sanitation service. This can be seen in many third world countries like those in Africa where it's up to the people themselves to search for possible bodies of water, the better portion of which probably won't be safe to drink. This then leads to the atrocious problem of the loss of human lives; not just from dehydration due to water scarcity, but from water contamination which can inherit symptoms like diarrhea (which at the end of one's life dehydrates the victim to death).

Numerous factors lead to water contamination ranging from those where the victims can do little to prevent against an illness because of difficulty detecting the contaminants to contamination that is caused by natural disasters. Other contaminants can be avoided if a well-planned water sanitation system was implemented cleansing the water from human fecal matter, viruses and excessive amounts of minerals. Detection of viruses is quite difficult considering the numerous carriers that have the capability of contaminating a body of water. In most cases viruses make their way into water sources through carriers like mosquitoes and birds who drink water off the water sources. Lack of proper sanitation systems unlike the United States which has certain guidelines they need to follow to ensure that the water they provide is consumable, such as, Dasani, Aquafina, and the tap. These corporations have to run their water through certain filtration systems

⁵ "Areas of Physical and Economic Water Scarcity" **Comprehensive Assessment of Water Management in Agriculture**, 2007. <http://www.fao.org/nr/water/art/2007/scarcity.html>.

following guidelines and standards set by the Safe Drinking Water Act. We would like the filtration systems being implemented in third world countries to meet the same standards the United States has set through the Safe Drinking Water Act but on a smaller and less expensive scale.

LITERATURE REVIEW

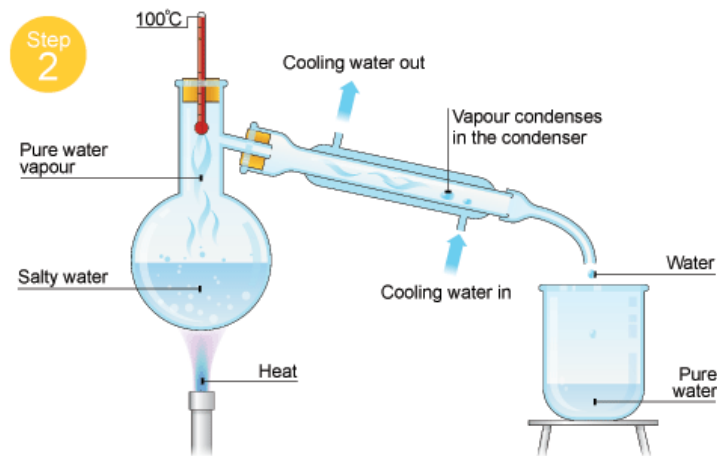
Filtering and purifying water has come a long way from the introduction of the first slow sand filters to the United States in 1870.⁶ In today's day and age, filters with many varying characteristics can be used to purify water around the world. There are three main categories of filters to consider when looking for the one best suited to your needs: chemical, physical, and radiation. How each filter performs in distinct areas around the world is limited by the area's economic, environmental, and social aspects as well as the capabilities of the filter itself. When implemented in the correct conditions, even the simplest of filters can make all the difference when it comes to saving lives throughout developing countries.

Distillation

The oldest, but in no way least effective, form of water filtration techniques is the process of distillation. Distillation of water, as stated by Bruce Kucera in "Water Distillation: *New technology meets cost challenges for bottled water industry*" is "the only process that replicates the hydrological cycle... It is a simple evaporation-condensation-

⁶ "History of Water Filters," **The Water Exchange**, 2014. (© 2014 By The Water Exchange), <http://www.thewaterexchange.net/water-filters.htm>, p. 01.

precipitation system.”⁷ Water distillation requires little more material than a source of energy (electric, gas, solar) to boil the water thoroughly, a simple system to transfer flowing steam away from the boiling water, and a cooler catch basin to collect the condensed water. When done properly, the method of distillation has the ability to kill off any microbiological contaminants found in the water source while simultaneously ridding the water of any minerals and providing up to six gallons of water for every gallon of waste water produced.⁸ Many factors directly affect the output of the distillation process including access to electricity, or sunlight as a substitute, the location of the water source, and the means and understanding of the individual operating the distiller. Although the distillation process appears to be the solution to all of the world’s water issues, it is only as good as the conditions in which it is operating.



KS3 Bitesize. “Separation a liquid from a solution,”

If the inexpensive method is chosen, then the system would best thrive in a country’s dry season that averages a temperature of roughly 85 degrees F or higher. The lowest Temperature the dry season should experience is 70 degrees F. This aids to the fact that bacteria is eradicated from water between the temperatures of 70-100 degrees F. If the

⁷Kucera, Bruce. “Water Distillation: *New technology meets cost challenges for bottled water industry,*” **Water Quality Products.** (© Scranton Gillette Communications,) <http://www.wqpmag.com/water-distillation>, p. 01.

⁸ KS3 Bitesize. “Separation a liquid from a solution,” **Compounds and mixtures.** (BBC © 2014) http://www.bbc.co.uk/bitesize/ks3/science/chemical_material_behaviour/compounds_mixtures/revision/9/

lowest the temperature will be 70, then the system will have more than enough energy to kill the bacteria and evaporate the water to be condensed separately. If there is not enough solar energy to evaporate the water, then the total pressure of the evaporation station can be lowered to decrease the boiling point of water. Granted if there is lots of solar energy, such as $T > 80F$, then decreasing the boiling point will increase the speed of the distillation process. Keep in mind that bacteria will not evaporate when water evaporates. Bacteria's evaporation point can never be reached due to death, therefore the water leaves the bacteria behind in the evaporation station. This means the sanitation system would have to be cleaned more frequently than if it killed the bacteria. As said by Subject A in the interview on page 36 question number two, a back flush system attached would be nice to clean the system and if there is a biosand filter attached the "backwash" helps build a thin layer of "good" bacteria on top of the biosand that will rid the "bad" bacteria. Distillation as a filtration process has proven itself time and time again as an easily applicable system that can greatly improve upon the current water crisis, granted the conditions are correct.

Chemical Reactions

On the tenth of December, 1813, English chemist Sir Humphry Davy published his discovery of a new substance having similar characteristics to chlorine, which he called "iodine". Up until Jean Lugol's discovery that bonding iodine to a mineral granted it solubility in water, the medicinal benefits of iodine as a method of sanitization had yet to be realized.⁹ Both chlorine and iodine are used to kill off pathogens commonly found in

⁹ "The History of Iodine", **International Wellness Directory**, 2013. (© Copyright 2013 Minnesota Wellness Publications, Inc.), <http://www.mnwelldir.org/docs/history/iodine.htm>, p. 01.

water (bacteria, fungi, yeasts, viruses) but only iodine is capable of killing all classes of pathogens; it does so through a simple chemical reaction between certain amino acids (tyrosine and histidine) that denatures the proteins found in pathogens, expunging them from the water.¹⁰ There are however strict guidelines you must follow when sanitizing water with the use of chlorine or iodine as stated by British Columbia's Centre for Disease Control:

"Bleach works best when added to warm water that is about 20°C (68°F). To treat your water, add 2 drops (0.1 mL) of unscented household bleach (about 5.25% chlorine) to 1 litre of warm water...Iodine works best when added to warm water that is about 20°C (68°F). To treat warm water, add 5 drops (0.25 mL) of 2% Tincture of Iodine to 1 litre of warm water. Mix the [active ingredient] and water together. Cover it and let it stand for at least 30 minutes before drinking."¹¹

If not followed correctly, these chemicals can have an adverse effect on the human body and in some instances cause illness or even death. Amounts as small as 2g pure iodine or 30 ml of iodine in an alcoholic solution are fatal to most humans.¹² Additionally, being that it is only a chemical, iodine is incapable of removing any physical particulates from the water and it also leaves behind a foul taste. Further filters with the means of filtering physical contaminants must therefore be used in conjunction with chlorine or iodine to ensure complete water purification.

¹⁰ Dr. Mark Sircus, "Iodine and Antibiotics", **DR. SIRCUS - INTERNATIONAL MEDICAL VERITAS ASSOCIATION**, 15 November, 2009. <http://drsircus.com/medicine/cancer/the-end-of-antibiotics>, p. 01.

¹¹ "Disinfecting Drinking Water", **HealthLinkBC**, January 2014. (Copyright © 2013, Province of British Columbia), <http://www.healthlinkbc.ca/healthfiles/pdf/hfile49b.pdf>, pp. 1-2.

¹² "Iodine in Water: *What are the health effects of iodine in water?*", **Lenntech Water Treatment Solutions**. (Copyright © 1998-2014 Lenntech B.V), <http://www.lenntech.com/periodic/water/iodine/iodine-and-water.htm#ixzz3G2CXnIot>, p. 01.

Another chemical that is able to purge water while turning into water is hydrogen peroxide (H₂O₂). This chemical is used to disinfect bacteria on bodily wounds and now in water. For about 20 years now H₂O₂ has been used in water treatment plants as a pre-oxidant chemical due to its lower disinfectant micro-bacterial properties compared to harsh chemicals like iodine, chlorine and bleach.¹³ It also reacts specifically with hydrogen sulfide and iron (Fe²⁺ ions which occurs naturally in groundwater sources).¹⁴ A common reaction is the H₂O₂ with iron, which produces Ferric Hydroxide precipitate that can be filtered out of the water. Iodine, chlorine and bleach leave a nasty after-taste in the water after treatment, and can be more work to purge the water of the chemicals after. Since H₂O₂ is not a stable compound at atmospheric pressure, it breaks down into water, diatomic-oxygen (oxygen found readily in nature) and floating hydroxide ions. These hydroxide ions are the key component to its antibacterial properties, while also diminishing taste and odor from the water. Once the chemical reaction has reached approximately 100% yield, the final products are water, oxygen and ferric hydroxide precipitate, with a pH of roughly 7. To make sure the H₂O₂ has broken down completely

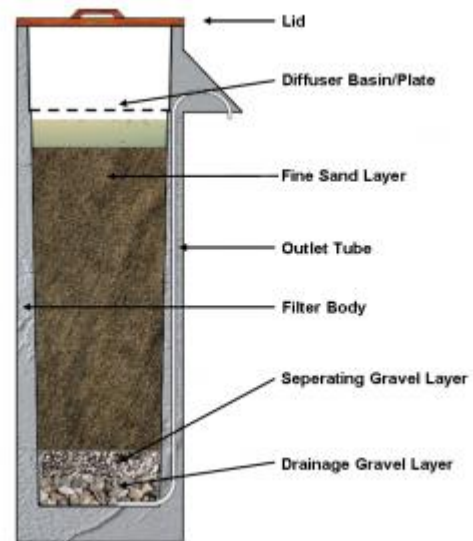
¹³ "Municipal Drinking Water Treatment with Hydrogen Peroxide" **U.S. Peroxide.**
<http://www.h2o2.com/municipal-applications/drinking-water-treatment.aspx?pid=145&name=Municipal-Drinking-Water-Treatment>

¹⁴ "Iron and Metals Removal with Hydrogen Peroxide" **U.S. Peroxide.**
<http://www.h2o2.com/industrial/applications.aspx?pid=102&name=Iron-Metals-Removal-with-Hydrogen-Peroxide>

into water, either increase the solutions temperature or shake the solution to help break the oxygens off the H₂O₂, thus increasing the entropy within the water. ¹⁵

Biosand

One of the first filters aimed at removing physical particulates from water is very simplistic and can be made with an assortment of materials. Most common biosand filter systems contain two parts: the filter itself is constructed from a plastic or concrete container which is filled with layers of washed sand and gravel, and a disinfected container to catch the clean water as it flows out of the filter. Biosand filters utilize the water molecules' extremely small size in comparison to contaminants present within the solution so as to allow water to pass while simultaneously trapping all unwanted materials. There are many advantages to having such a simplistic system: it is relatively inexpensive to own and operate, it has a high removal rate of turbidity and pathogens, flow rates can exceed 30 liters per hour, and all



Dangol, Bipin and Dorothee Spuhler. "Biosand Filter", Sustainable Sanitation and Water Management.

materials necessary to construct this filter can be found in most areas around the world. Biosand does however have a low rate of virus inactivation and can also become

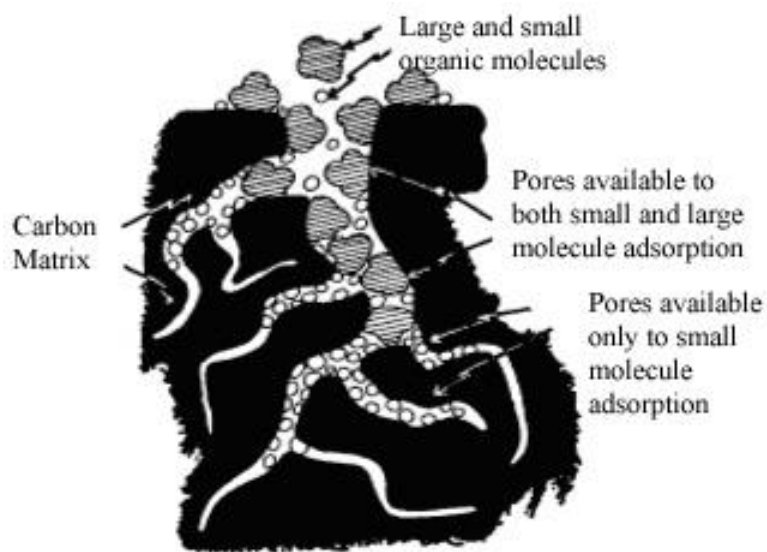
¹⁵ Dangol, Bipin and Dorothee Spuhler. "Biosand Filter", **Sustainable Sanitation and Water Management**. <http://www.sswm.info/category/implementation-tools/water-purification/hardware/point-use-water-treatment/bio-sand-filtrat>.

congested quickly in high-turbidity water, creating more maintenance and a possibility of infection. As with other water filters, biosand is aimed exclusively towards one type of contaminant and demands the use of additional filters to purify completely.

Activated Carbon¹⁶

Similar to the Biosand filter in its form and functionality, activated carbon has become a major source for water filtration around the world.

You can find activated carbon filters in many households nowadays; whether it be inside a handheld water purifier or within a refrigerator's water dispensing system. There are many materials that activated



AURO Carbon & Chemicals. "Pore Structure of Activated Carbon", *About Activated Carbon*.

carbon is made from as Jason P. Pope describes in his article on remediating groundwater pollution; "wood (at 130,000 tons/year) is by far the most common source of activated carbon, followed closely by coal (100,000 tons); coconut shell (35,000 tons) and peat (35,000 tons)."¹⁷ Once processed, the remaining activated carbon product contains either an intricate crystalline or orderly network of constricted pores that occupy an

¹⁶AURO Carbon & Chemicals. "Pore Structure of Activated Carbon", **About Activated Carbon**. <http://www.aurocarbon.com/activatedCarbon.html>

¹⁷ Pope, Jason Philip. "Raw Materials Used in the Production of Activated Carbon", **Activated Carbon and Some Applications for the Remediation of Soil and Groundwater Pollution**. (Copyright 1998 Naraine Persaud Last Modified: January 1, 1999), http://www.webapps.cee.vt.edu/ewr/environmental/teach/gwprimer/group23/acraw_materials.html.

extensive amount of surface area; engineers utilize the micropores in filters which have the ability to cleanse tainted drinking water of copious harmful contaminants. The cleansing process, not to be confused with 'absorption', is called 'adsorption' which is defined by Merriam Webster as "the adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact."¹⁸ In the instance of activated carbon filters, most microbiological, organic(Aromatics, Ethers, Ketones, Glycols, Halogenates, Esters, Aldehydes, Amines, PCB, Chlordane, Kepone, Toluene, Dimethylphenol) and inorganic(Cadmium, Chromium, Zinc, Lead, Mercury, Copper, Cyanide) substances' molecules are attracted through electric forces (Van Der Waal's forces) to the surface area within the filter itself, leaving behind purified drinking water.¹⁹Now there are many factors to consider when using activated carbon filters for purifying contaminated water. Some of the factors that can considerably limit a carbon filter's efficiency include: the system's temperature, the pressure inside the system, and the impurity concentration(s) within the water to be filtered. Even the slightest variation in how a filtration system operates or its surrounding conditions can mean the difference between life and death when it comes to particular water-borne pathogens found in many developing countries. Overall, activated carbon is a relatively inexhaustible resource that, when used in filters, can provide versatile water filtration systems that are easy to maintain, extremely efficient, and due to their simplistic design, have very little learning curve for those involved in the operation.

¹⁸ Webster, Merriam. **Merriam Webster, An Encyclopedia Britannica Company**. (© Merriam Webster, Incorporated), <http://www.merriam-webster.com/dictionary/adsorption>, p. 01.

¹⁹"Adsorption/ Adsorbents/ Granular Activated Carbon", **Granular Activated Carbon (GAC) Selection**. (© 2014 TIGG Corporation), <http://www.tigg.com/granular-activated-carbon.html#Anchor-Sinc-32871>.

Ceramic

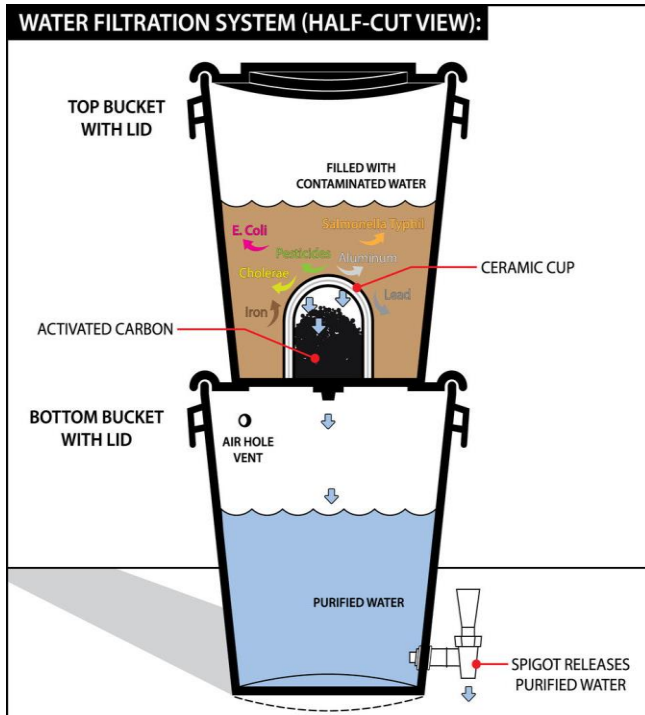
A third approach to physically filtering contaminated water is that of the ceramic filter. Much like activated carbon, ceramic filters take advantage of naturally small pore sizes and Van der Waals forces to attract and remove unwanted particulate from the water source. The filter itself is made up of little more than a mixture containing clay, an organic 'burn-out' material that is interwoven and ignited so as to leave channels through which the water can flow, and occasionally the pure element silver which acts as a biocide to inactivate bacteria and viruses.²⁰ Albeit, ceramic filters permeated with pure silver do offer a significant health advantage over many other filtration systems in its ability to not only inactivate bacteria passing through the filter but also prevent against the generation of bacteria within the filter over time. When dirty, contaminated water passes through a ceramic filter the water is reliably purged of many illness-causing pathogens that include cholera, typhus, cryptosporidium, amoebic dysentery, e-coli, colibacillose or bilharzia, and anthrax spores among others.²¹ Ceramic filters, alike their carbon-counterpart, are proficient in removing microbiological and organic waste but cannot however filter inorganic materials or chemical toxins from the water. One precaution that must be accounted for when dealing with ceramic filters, just like in any other physical filter, is the

²⁰ Hagan, Judy, Harley, Nick, Pointing, David, Sampson, Mickey, SAOM, Vanna, Smith, Kathryn. "How the Ceramic Filter Works", **Resource Development International-Cambodia Ceramic Water Filter Handbook**. (Copyright © Resource Development International - Cambodia, Engineers Without Borders Australia, 2009), <https://www.engineeringforchange.org/static/content/Water/S00067/Ceramic%20filter%20manual%20no-appendices.pdf>, p. 08.

²¹"Ceramics, a natural water filter - Sterasyl micro-filter", **Doulton Water Filter Ceramic Candle & Cartridge Technologies, taking the mysteries out of the drinking water filtration**. (Copyright 1996-2014 DoultonUSA - a unit of Eco Systems International LLC), <http://doultonusa.com/HTML%20pages/technology.htm>.

congestion of waste materials in and among the pores of the filter. A good cleaning is all that is required in order to remedy this dilemma that only gets worse with time. These

filters are extremely versatile and are often adapted to work in association with other filters as part of a system that outputs completely purified water. Despite the contention from other water filters, activated carbon in particular, ceramic filtration devices offer a unique health aspect that makes it a vital component in many potable-water movements around the world.



“Ceramics, a natural water filter - Sterasyl micro-filter”, Doulton Water Filter Ceramic Candle & Cartridge Technologies, taking the mysteries out of the drinking water filtration. (Copyright 1996-2014 DoultonUSA - a unit of Eco Systems International LLC

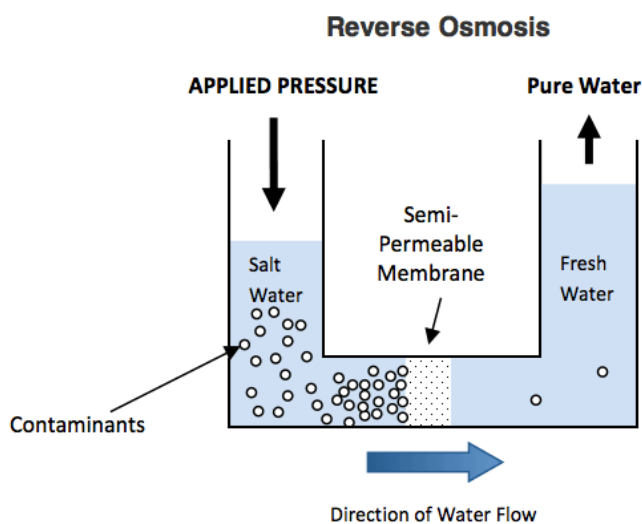
Reverse Osmosis

When water is passed through the semipermeable membrane of a reverse

osmosis water filtration system, those particles exceeding the size of the membrane’s pores are withheld as smaller water molecules pass through. The naturally occurring osmosis process is described as “a process where a weaker saline solution will tend to migrate to a strong saline solution.”²² The exact opposite is true for reverse osmosis processes; a semipermeable membrane still separates the strong and weak saline solutions, but in this case a pressure is applied to the stronger solution side of the membrane to negate the naturally-occurring osmotic pressure and grant safe passage to

²² “Osmosis”, **What is Reverse Osmosis?** (© 2012-2014 Puretec Industrial Water), <http://puretecwater.com/what-is-reverse-osmosis.html>.

clean water while removing all contaminants too large to proceed. Membrane pore sizes implemented among reverse osmosis filtration systems are typically around 0.0001 microns in size, far smaller in comparison to the pore sizes found in activated carbon and ceramic filters. This allows for the filtration of not only the majority of all microbiological, organic, and inorganic materials from the water, but also many of the healthy minerals contained in the water too. Further treatment beyond the filtration process (passing through a magnesium and calcium bed) is necessary in order to achieve drinking water that is pure and also contains the healthy minerals commonly found in water.²³ A filtration system involving reverse osmosis can be extremely efficient, but it comes with the cost



“What do these three processes remove?”, Ultrafiltration, Nanofiltration and Reverse Osmosis. (Copyright © 2009 Safe Drinking Water Foundation)

of materials and maintenance. Special care and consideration must be taken when constructing and implementing reverse osmosis filtration systems to those in need; there must be enough finances available in the affected community to ensure the extra care necessary for supporting and maintaining the expensive equipment that is easily damaged by excess contaminants or the incorrect

system pressure.²⁴ The true success of reverse osmosis as a feasible solution to the

²³ “What do these three processes remove?”, **Ultrafiltration, Nanofiltration and Reverse Osmosis.** (Copyright © 2009 Safe Drinking Water Foundation),

http://www.safewater.org/PDFS/resourcesknowthefacts/Ultrafiltration_Nano_ReverseOsm.pdf, p. 04.

²⁴“The Drawbacks of Reverse Osmosis”, **Understanding Reverse Osmosis Systems.** (© 2001-2008 Everpure, LLC), <https://www.everpure.com/products/Pages/UnderstandingROS.aspx>.

water scarcity issue, as with any filtration system, depends tremendously on the conditions pertaining to each of the locally affected areas and the people inhabiting them.

Prior Water Sanitation Efforts

With all of the miraculous water filtration devices and systems available in today's market, it is astonishing to find that so much of the world remains without clean, potable drinking water. Countless water scarcity projects have spawned all over the globe, each aimed at combating the crisis head-on with the help of society's latest and greatest technologies. Two crucial questions raised by this seemingly brilliant effort being made by so many are: "Why does water scarcity still persist in our world today?" and "What is happening to the innumerable projects that are currently in place?". In order to understand what overwhelming force is preventing people around the world from gaining access to clean water we must first look at prior projects, how they were conducted, and what resulted from their ventures. Only then, after analysing the work completed by previous groups, can we begin to establish a definitive direction in which to focus our efforts.

PlayPump International

One example of a truly ingenious project that promised to eliminate impoverished communities' woes is the PlayPump. The PlayPump was designed as a children's merry-go-round that, when in use, would pump water from the earth to a storage container above ground where



Figure 1 Vandendriessche, Marie. "The Story of PlayPumps: Merry-go-rounds, Water, and Failures in Development Aid", *United Explanations*. <http://unitedexplanations.org/english/2012/03/22/the-story-of-playpumps-merry-go-rounds-water-and-failures-in-development-aid>

it would be kept as village water source. According to Vandendriessche in her 2012 article on the PlayPump, initial claims stated that "three problems were to be solved simultaneously: women having to work hard every day to pump water, girls staying away from school to help their mothers fetch water, and children having no playground"²⁵ In theory the plan was foolproof; the storage tank even had advertising availability on its sides to help pay for the system, but in practice... not so much. What the creator of PlayPumps quickly discovered was that the implemented systems were not being used by children at all (due to claims of child labour) but by women who would painstakingly turn the device acquire water. Furthermore, in 2009 the Guardian calculated that the

²⁵ Vandendriessche, Marie. "The Story of PlayPumps: Merry-go-rounds, Water, and Failures in Development Aid", **United Explanations**. <http://unitedexplanations.org/english/2012/03/22/the-story-of-playpumps-merry-go-rounds-water-and-failures-in-development-aid/>.

children would have to play on the PlayPump non-stop for over twenty-four hours each day in order to meet the recommended minimum of fifteen liters per day.¹⁸ Beside all the technical faults with the system, its creator also disregarded the essential aspect of community involvement and adoption of the new mechanism. Had the PlayPump been introduced in a more thorough, informative manner rather than being handed to a village that has no prior knowledge or involvement of the system or the components involved, the outcome and success of the project might have been a little more prosperous for all involved.

LifeStraw

On the other hand, projects such as the LifeStraw have been finding their place amongst the top filtration systems used globally. It is because of their outlook on the situation at hand. Vestergaard, unlike many of the other organizations that are trying to solve the water scarcity issue, is focused on the human element and what it entails for each hazardous situation. Vestergaard goes further than simply shipping supplies to those in need; in their 'about us' page, Vestergaard goes on to say that "the company's intimate knowledge of [local] markets and its network of strategically located warehouse facilities help program



"Facts", LifeStraw by Vestergaard. (© Copyright 2013 Vestergaard)

implementers distribute products affordably and efficiently.”²⁶ Since its introduction in 2005, the LifeStraw has been Vestergaard’s way of fulfilling their claims through its use in immediate natural disaster relief efforts like during the Haiti earthquakes in 2010.²⁷ LifeStraw has revolutionized the way in which water purification for those in desperate need is handled by developing the cigar-sized personal filter to treat 1,000 litres of water for turbidity, bacteria, and parasites while remaining free of any chemicals or energy consumption. What Vestergaard has managed to do so well is captivate the particular circumstances and requirements for each distressed location and employ the best suited technology in a personal way that introduces and establishes a social system which revolves around the overall output and maintenance of the system involved.

Our Take on it All

In both examples of modern day filtration systems, the project’s success or failure was largely dependent on the indigenous people’s involvement in the implementation and eventual acceptance of the system as well as the accountability that comes with it. Yes, there are many attributes of filtration systems (contaminants, cost, technology, environment, etc.) that can directly affect the outcome of said system, but in the end its the people who ultimately decide what is best for *their* community, *their* financial situation, and *their* personal needs. What is needed, as stated by Marla Smith-Nilson in her “Humanosphere” article are “standards and accountability... Estimates are that less than 5% of organizations follow-up on their projects post-construction [and] an estimated 35-

²⁶ “High-Impact Partnerships”, **About Us**. (© Copyright 2013 Vestergaard), <http://www.vestergaard.com/about-us>.

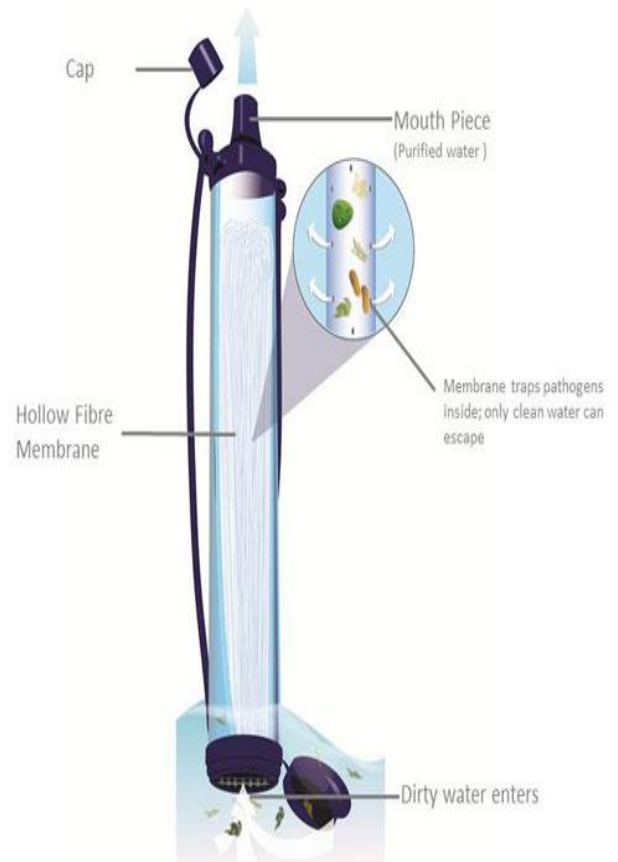
²⁷ “Facts”, **LifeStraw by Vestergaard**. (© Copyright 2013 Vestergaard), <http://www.vestergaard.com/index.php/lifestraw-personal>.

50% of water projects fail within 2-5 years after they are constructed.”²⁸ Chilling data when you consider the number of project attempts that have been made and the amount of them still in place, providing no more than a glimpse at what could have been. Our group will be going about our in-depth research in a similar manner to that of Vestergaard’s; collecting information on all possible variables pertaining to the filtration system while holding the human variable above all else throughout the process.

METHODOLOGY

Our primary objective is to evaluate the current water crisis in developing countries based on factors which include the economic, social, and physical limitations unique to each location, and work to better all aspects of living with a limited water supply. In order to do so, we will first categorize the different types of filters and filtration processes that are applicable to each

community. In doing so, we will have collected all information pertinent to determining a clear and concise methodology for combatting any type of water crisis. Also, in order to develop a true understanding of those afflicted and their battle with the water crisis, we



Smith-Nilson, Martha. "Guest Op-Ed: Water projects everywhere, but little accountability", *Humanosphere*. (Copyright 2014 Humanosphere.org),

²⁸ Smith-Nilson, Martha. "Guest Op-Ed: Water projects everywhere, but little accountability", **Humanosphere**. (Copyright 2014 Humanosphere.org), <http://www.humanosphere.org/basics/2013/08/guest-op-ed-water-projects-still-lacking-accountability/>.

plan to interview local inhabitants of varying social positions. The interviews will allow us to hear first-hand accounts of how the crisis is affecting the community, what could be done to improve upon, if not fix, the situation, and to come to a better understanding of the necessary balance between the needs and means within the community with the availability of water filtration technologies. After gathering information on the topic at hand, we will compile a complete report on how to properly implement a water sanitation system into an afflicted community suffering from the water crisis. This will bridge the gap between engineers and the suffering communities, so that filtration systems can be easily be matched and operated by the client, who will be educated on the system, so that the system can be at its prime efficiency with respect to its environment.

Making interviews will be the most useful piece of information going towards our overall categorization of the filters and systems. We will collect first-hand testimonies of the direct and indirect effects of the various aspects pertaining to the community including the physical to social characteristics of the overall population. We can specifically focus our interviews on individuals who get to experience those effects on various different social groups to provide us with a much more broad analysis of the systems. In these interviews we will be asking questions that are geared to learning about how the Engineer(s) of design and implementation handled and viewed their influential aspects to their design process. Enough information to construct a pamphlet/guide for, not restricted to, Engineers who are interested in saving lives. Money and fame are fine, but the client always comes first.

INTERVIEWS

Subject J:

Background: Subject J has their post doctorate focusing on chemical and environmental engineering, while working with the Chemical Engineering Department of University of Massachusetts Amherst conducting research.

1) What projects have you worked on that deal with developing countries or water filtration systems in general?

Before she started as a faculty member at the institute she did a post-doctoral position with a faculty member who made filtration polymer based membranes for water purification. In the design process she and her team designed a new membrane that had a better structure for water filtration. The membrane decreases the energy required to separate water solutions. The membrane is *patented* and in production by a company.

It does not allow toxic ions to pass through during filtration.

Many of her colleagues wanted to establish their systems in countries like Indonesia rather than a small scale purification. They talked to many communities vendors about their water purification systems and revisited old systems that were set up to try to figure out how they were being used and how can they improve their usage.

2) In your opinion what is the main factor that prohibits their use?

Cultural, some villagers did not want to use the membrane. In other countries like Indonesia water is a commodity, there were women selling water for profit which empowered them and provided job opportunities. They used membranes just like the membranes Subject D created to clean water.

At some point the membrane became old, dirty, no longer useful, and they had to be cleaned or replaced. These women were given the option to either use their profits to clean the membrane or buy new membranes.

3) What option did the women go about?

They continued selling the membranes that were dirty due to unknown reason or because they weren't able to afford to buy new ones. They were perfectly aware that they

should be cleaning and replacing the membranes, which many may interpret this issue as an educational barrier. In this case they were provided the job and education to ultimately function as the boss of a large team; they are in charge of all the clean water to the community. It's a very well regarded, much high respected goal for the distribution of such membrane. They let their community down and turned many villagers against foreign teams attempting to establish a filtration system in their community due to lost of trust the many villagers had for the team.

4) How many people were involved in your project?

There were five members in her patent.

5) Was there any funding involved?

Her team developed the membrane for an organization called The Membrane XPrize. There wasn't any money involved. Once the membrane was patented, her team got a "token" in return once it was actually in usage.

6) How was the target area selected?

It was selected in terms of verbal ease of the language barrier and long standing relationship with the community/country and people there. Other factors that lead to the selection were previous technologies used to develop their previous relationship with the area.

7) How was communication established between the engineer and the client in the developing country?

The director who led the project in Indonesia got in touch with 3 different universities and about 25 local communities. The director provided the communities with 50 handheld computers which were funded by a grant of her own. This gave her the opportunity to maintain communication with many volunteers given the computer. This whole study took two years to set up. The study consisted of calling several people and working up connections.

8) How did the community reaction/behavior during the system's installation and over time?

The team member in charge of the installation was for the most part loved by the community since she first employed many community members who were primarily in

charge of the communication and installation. They would update her on the system's operating status. This way they were able to determine what changes were necessary, which went pretty well compared to other instances where outsiders were trying to come into the community to make a change in the system.

9) How critical was the social acceptance to the project and whose expectations were trying to be met?

The community's social acceptance was 100% critical. The communities' expectations were the team's goal to meet. Their goal was to decrease disease, which would be the expectation for community members in spending money on these membranes in order to decrease occurrences of diarrhea and other diseases that are caused by toxic water that are not as common in the American population.

10) What major social aspects or concerns helped guide your team in the design process?

Always bearing in mind that there has to be a very simple educational plan in place alongside whatever you're implementing. One should provide simple guidelines to teach people how to operate the system as well as how it operates, explain how and where to wash your hands, and how to prevent any contamination.

11) What were some of the questions you asked your client during the design process? Was there further communication between you and your clients as the system was being installed in addition to those asked during the design process?

More questions were asked as the system was being installed. Questions were more in line with hopes of educating the people that were purchasing their membrane.

Some questions included:

How many times do you wash your hands a day? Do you wash your hands with the same water you use to cook with?

They asked question that would not affect the design of the product but to demonstrate how the product should be used.

12)What would you attribute to being the cause of most water filtration failures in terms of implementation?

Not knowing/respecting the community where the system is being implemented. Not understanding the fact that people want to have clean water but there might be some cultural, educational, or traditional barriers to that.

In some occasions engineers make fantastic filtration system which they leave in the designated area, which then becomes very difficult for the client to operate and maintain the water filtration system.

Not realizing that they can't just walk over to a water faucet and collect water but have to transport their water, in many cases, even ten miles from where they live.

13) In terms of the failures of water filtration systems, what is the best course of action, in your opinion, to avoid such catastrophes like that?

Continually talking and listening to the community, more listening than talking.

14) What other technologies were used in your project besides the membrane?

They also used gravity operated filtration systems where water would pass through granule soil/granule particles.

There was no electricity consumed in purifying water using the gravity operated purification with the membrane.

Subject D:

Background: Subject D works as a professor who teaches a class called, “Great Problems Seminar” to Worcester Polytechnic Institute students which focuses on problems that are of current global importance.

1. What projects concerning water filtration design have you worked on?

Subject A teaches the *The World’s Water* where students have done several projects on filtration systems. Some technologies used include sun rays and nanotechnology to break down biological organisms.

2. Are you familiar with using hydrogen peroxide or iodine to clean water?

Especially in drinking water, it works as a disinfectant as well as an oxidator. Its very inexpensive and simple to apply.

Iodine is a similar disinfectant which can be easily controlled by changing the pH level.

It does not take much iodine to fully disinfect water but not measuring the dosage can potentially kill the consumer.

3. What other minerals do you know of which are used to purify water?

Silver is used as a coat for metals. It functions as a bath for metals during the strengthening process. Unfortunately it is only useful for an extended amount of time.

4. How important is understanding how people think/value towards a filtration system?

Example: In Haiti there are some religious beliefs on water. They don’t believe in filtering water; a little dirt in water may be seen as a blessing and appreciation for what this world has to offer us.

Engineers have to understand how and where they get their water which may relate to their religious/cultural belief.

5. How would you establish communication between you and the client in developing countries?

During abroad projects, IQP students would communicate with the people. Best way to start a good relationship is getting to know the people and gaining their trust so they can open themselves to us hence we get to truly understand their problems.

6. Do you feel that some engineers are closed minded towards cultural factors that may conflict with the implementation of their system?

Engineers don't really worry about implementing cultural aspects...social aspects necessarily into their engineering practice, that's just not the norm. Some engineers do, who use a particular system to implement social aspects in their practice by first knowing what the user really needs and how the user will go about operating the system. Some engineers are more worried about building their system rather than whether it's going to be used or not; the goal with filtration systems in the eye of an engineer is whether the system filters water or not.

7. Do you think engineers should take social science classes in order to understand how to communicate with the client and to understand how people behave to new technology introduced to their lives?

It is essential to take into account many perspectives and understanding which are the most important perspectives to be incorporating into the design process. Understanding the people can be obtained through systems like surveys and feedbacks. Understanding different lifestyles that make up the people like commuters, government organizations to create rules and laws. Affiliating with nonprofit organizations who have worked with the community will facilitate the relationship between the engineer and the people. These affiliations will help to understand the people's need and their perspective on clean water provided by a foreign group of people "engineers/team".

8. Do you think that greed in terms of making money can cause a failure within the water filtration system?

Money is always an issue. Greed is not the issue that has to be addressed as much, more so that people are going to do what it takes to get as much resources. Maintaining the technology has to be considered into the design. Maintenance issues may be that the person in charge just didn't know how or didn't really trust the person that was telling them how...how do they know if the water is clean or not? If they didn't

have the money to maintain it, so they invested in the technology, to keep using it rather than replacing it and cleaning it. That money is going to be a pressure.

9. Trust is a major issue, especially for engineering teams who try to establish their system in a community that has already experienced a purification project conducted by an engineering team.

That's part of the social science part side that needs to be understood; the context in which you will apply the technology. All communities may have different norms or customs, policies, and procedures that have to be used to implement this technology. It depends on whose responsibility it is. Sometimes gender plays a role, women have certain roles and men have other roles. Trying to understand that your technology may be implemented differently and even in different places. Understanding "Well how much maintenance is needed?", in one place maybe that's not a big deal, maybe maintenance is not very normal or common. There's roles for people who do that. Its pretty clear, you implement the technology, you tell them how much maintenance will be needed. In other places that won't work at all. This is one of the cases where, for whatever reason some kind of social, political, and economic reason it wasn't maintained.

One rule of thumb is to create a technology that's least expensive and low maintenance.

10. Do you think this topic is new to the engineering field?

It's not necessarily new, per say, and not a top priority. Partly because you're not going to be making money making low cost filters that can be not implemented in developing areas. That's not why most people work on these things, they work on this for a more personal interest in doing good for the world and doing something positive for people who are struggling people in those communities at most disadvantage that need the most help in things like purifying water, which is in this country it all falls under the government.

11. Going back to the Play Pump International, the individuals who invested into the project seemed to not even care to see if this will even be sustainable by the community. There was some lack of communication from the investors to the community to assure that the system would actually work and be socially acceptable by the people. Do you believe that this form of neglecting still happens today?

The governments that were receiving the playpump didn't really put any money into it, so to them it wasn't too much of a big deal the fact that the system failed. No matter how good or not the system worked they were getting something out of it. Donors just wanted to see something happen. There was not a lot of testing done prior to the system's establishment. They didn't take in mind much of the social context. They didn't really invest in advertising their product. They didn't leave anyone in charge to make sure it was frequently operated *properly*.

12. Do you think foreign government officials are accepting to American teams intending to implement a water cleansing system in a community they overlook? Do they fund or help out with the project?

It all depends, most funds usually come from nonprofit organizations rather than directly from our government. In many occasions, partnerships are formed between the government and nonprofit organizations since there are certain things that nonprofit organizations can do and that our government can't. Sometimes there are ulterior motives our government gets involved with ultimately for national security.

13. Do you find it necessary to provide an incentive to the clients to have them maintain the system?

There was one situation where in one project a villager was left in charge for a pump's maintenance. The researchers and organization left the site for a couple of months. When they came back to the site/village, they found her wandering outside the village on her own because the water pump broke, which was her responsibility but she didn't know how to fix it. It's important to know who's responsible as much as understanding how that responsibility is going to be fulfilled, how are they going to fix it, where are the parts going to come from and are the parts accessible.

You should first get to know the person you're leaving in charge. Make sure he/she knows the languages spoken in the areas the project will be affecting.

14. In your opinion, what's the best course of action to avoid such catastrophe in water purification projects?

Managing time, it's not very efficient rushing a major project that will have a significant effect in one's life. Really take the time to communicate with the community in which you're implementing the technology to better understand how they live and what their relationship is to water.

Doing some research and testing in various environments and situations that the technology may experience while in operation. Making prototypes.
Getting feedback from the community: How is it working? How is it not working?

Subject K:

Background: Subject K works among a group of Worcester Polytechnic Institute students in the schools chapter of Engineers Without Borders. Subject K also has been to Guatemala to study the community and to implement water filtration systems.

1. Have you ever been to Guatemala?

Subject K responded with “Yes I have been there twice.” Last year, two weeks in January and two weeks in May.

2. What was your role for the EWB team?

Primarily, Subject K was interviewing the community members of implementation, while also experiencing other roles. It was a really interesting process because they do not speak Spanish, instead they speak a dialect from their community. Because of that they hired people to translate to and from Spanish and the dialect of the community. This translator also knew a good amount of English which really helped out.

3. What were some of the questions you asked the community members during the interviews?

Subject K began to communicate to them on the personal level, asking how the family situation is. Other questions were,

- How far do you have to travel to collect water?”
- How many times a day do you collect water?
- How many family members are there?
- What are their names and ages?
- How long have they lived in the community?
- What job does their husband do?
- What job does the wife do?

It was a semi-structured interview, which is asking a leading question and then continuing with conversation after. Each leading question listed above always leads to a

deeper conversation. They communicated about the politics of the town and the people (rumors). It was interesting to hear everyone's perspective of their life and environment.

4. Do you think the interviews were key in terms of getting to know and understand them?

"Absolutely," it is important for "us" as engineers to understand who the beneficiaries are; to know and understand them so we know that the Rainwater Harvesting System (RHS) being implemented is the right solution for them.

5. What do you think would have happened if you and your team did not try to understand the social aspect of the community?

Hard to say for sure, because there are so many factors they play into the situation. But, there are a lot of projects of implementation that fail and our project would have failed if the clients of the community did not know how to operate or maintain RHS. Because our team invested time and effort to understand them and get to know them, in return the people of the community invested the time and effort to learn how to maintain and operate the implemented water system - in this case, it's a Rainwater Harvesting System. Our team spent a lot of time on education programs and materials for the community members to try and reduce the likelihood of the water system failing due to the community members lacking the knowledge to operate and maintain the system.

Another outcome is the community members not choosing not to use it nor understand it.

The client could not care enough for their system, therefore, they are likely to sell pieces of their system to gain money which is important to them given the situation they are in. That is a source of failure.

We put a lot of effort in making sure the design meets the clients' needs, but not over design them. We make sure that the client has enough tanks filled to supply water for the dry season. We do not supply more tanks than they need.

Having an NGO, Non-Governmental Organization, is helpful because they know the people in the community well and they holds the clients of the community accountable for the water system being implemented. This is done by requiring families to pay 5% of the material cost, which gives them ownership but not an excessive amount of roughly 80\$. They pay this off on a payment plan, which is basically a loan.

6. What are your team's future goals of education for the community?

The idea is to educate the children of the community because they can have an influence on the older generation's perspective of "water security." It is the same reason why the United States has an education system for children; it's to plan for the long term. So that they will have the knowledge and resources to either leave their community to live a better life or stay and help the community and country grow as a whole. Getting the children to have the confidence and knowledge for solving real world problems is an important outcome.

7. During your time spent there how much communication was done between you and the clients?

Because our team has a relationship with each family we go to their house and do a two stage assessment. During stage one we get information and data about the house and family to build the RHS specifically designed for the home. After we go home plug in the data into our excel spreadsheet, which takes into account rain data from the past 30 years in Guatemala, the roof area, amount of proposed storage tanks, the number of family members and an estimated water consumption of 12 liters per person a day. It takes these values and gives a graph representing the timeline of the year and shows when the clean water in the tank(s) will become empty. This allows us to figure out how many tanks will be needed for the family. Any other additions that need to be made to house were communicated to the client of the house beforehand. For instance, "based on the slope of your roof we think gutters should be attached to your house here and this amount tanks should be over here." If the client has an idea or some type of input they will tell us then.

Sometimes houses change within the community and they need to be re-assessed for the RHS.

8. Were there any setbacks during the time you spent there?

Time works differently in Guatemala. Here in the U.S. every moment is booked with an event and punctuality is definitely preferred. They're meeting up and getting work done at 2pm will end up being 4pm. So our schedule ended up being pushed back, which is alright, but it is definitely a setback. We decided it's better to adjust our schedule to accommodate them and this helps us understand that for our next trip if we plan for a meeting during a certain, take into account 5 hours+ might be wasted.

A setback was materials because during our earlier implementations we had planned for what the design will be but once we got there the design ended up changing because calculations made not always worked when implemented and because of that

extra materials ended up not being used. On top of that we needed new materials that we did not have.

In the community there is a man who has a complete inventory of all the materials and tools needed to implement a system for a house, this is not a setback. It actually helps save money by using unwanted materials from past years.

9. Where did your funds come from?

Last year in May our funding mainly came from Engineers Without Borders USA and other companies like Fidelity. This coming May funder will be completely funded by The Rotary Foundation.

10. What are your goals for this upcoming trip?

This will be another assessment trip. We need to figure out logistics for materials, that is one of our primary goals. Where are we going to get the materials for 20+ RHS? How are we going to transport them to the community? Who will be in charge of that? How do we incorporate new people?

We are going to confirm the design plans with the clients of the home and make sure that everyone is "on the same page." Make sure they are aware of the contract entails in terms of responsibilities. We will also be meeting up with the Mayor of the municipal district, he is very supportive of our project. We do not work closely with them because of factors that arise in Guatemala, but in the past they have provided transportation for us and materials - it's good to have that contact.

11. Why does your implemented project seem to last?

We have taken a lot of time to get to know the community members. Made sure we designed systems that are what people want and need. We have a very dedicated team. This is a priority and a passion.

We also have an equally committed NGO, which is critical. We also have university student who works with the NGO and goes to the implemented houses to check up on the families and their RHS every couple of weeks. He is very helpful. The main reason why this project has not failed is because the people who are helping the community and even the community members are committed.

Subject A:

Background: Subject A works among a group of Worcester Polytechnic Institute students in the schools chapter of Engineers Without Borders. Subject A also has been to Guatemala to study the community and to implement water filtration systems.

1. What projects concerning water filtration design have you worked on?

Biosand filter use and implementation into a rainwater filtration system.

2. Does the filter Prototype from Question 1 include a backwashing system?

The filter's natural, anti-bacterial biofilm eliminates contaminants in water but must be regenerated after backwashing by running water freely through the filter. Only once the biofilm regenerates can the output be considered safe for consumption. The EWB also rake the top layer of the biofilm to stir, and help promote growth of the biofilm.

One disadvantage of the biosand filter is the slow flow rate which requires the use of a water collection system for immediate use.

The biosand filter used in their project is generic. Other engineers of course, have used these filters in their filtration systems, however the EWB were able to successfully implement the filter in their unique filtration system design.

There are many variations of the biosand filter in terms of the filter's construction materials, the size of the filter, the environment surrounding the and how. These variables which is influenced by the engineers, the clients, the local culture and social context, as well as the location and climate.

3. How much energy is used by the Prototype System?

No energy is required to operate this system, it all relies on gravity to move water through the filter.

Any new filters must be implemented to all subjects within a confined area so as not to cause feelings of abandonment or resentment among those who would otherwise be missing out on the opportunity for cleaner water.

Subject A roughly stated that "the biosand filter wasn't actually implemented in a country... it wasn't something we were able to work into our system, because we didn't implement it into too many homes. And you can't; you'd have back implement everyone

in order to make sure that everyone has the same system, and if you're talking about the 'social' issues of it if, you'd start implementing a better system on one and you can't go back to the first one...there's going to be all sorts of controversy."

Analysis of quote: Subject A wishes to forewarn us that the implementation of a new filtration system among only selective individuals in a community will cause not only an imbalance amidst neighbors but "all sorts of controversy" according to Subject A if not remediated in a timely manner. Whatever this controversy may be, it's better not to deal with it and make sure that the clients' living standards are met and/or exceeded. A controversy can cause a delay time which can cause a loss of money.

Taking time to understand the community is different than delaying a project because the engineer and "implementer" implemented the systems incorrectly because they did not empathize well enough for all the clients.

In our opinion, abandonment may cause a human who is deprived of general technology, which industrialized countries may take for granted, to steal or dismember other clients new water filtration systems that are being implemented in spite of their own. Remember that the clients can be civilized or uncivilized, as the engineer: try to be respectful and completely understanding to their way of life. The engineer should not expect them to conform so easily. Patience and a translator to the clients' language is key to starting off well at implementing a water filtration system in developing countries.

4. What filter(s) are currently being implemented at your EWB site in Guatemala?

At the moment, the EWB uses a small wafer-like paper that comes right out of the tap from the tank that is acquired via their supplier. This paper wafer filters the contaminants that surpasses the "first flush" of the rainwater filtration system. The "first flush" is essentially a removable container that collects any debris or larger contaminants that may have been washed off the roof, into the gutters, and towards the primary filter itself. Although discrepancies do exist between each house's respective filtration system that suit their personal needs, all filtration systems implemented Guatemala and overseen by the EWB are outfitted with this "first flush" technology which consists of little more than pvc piping, a water-flow control valve, and a buoyant object whose purpose is to seal off the "first flush" debris container for later disposal. Surface areas of each individual roof were calculated, and adjusted if need be, in order to use a "first flush" container that had the correct dimensions for the application. This initial removal of major contaminants in the water makes a dramatic difference in the filter's efficiency as well as the longevity of the system as a whole.

Tilted gutters catch rain fall and leave no water stagnant. The water flows from the gutters to a PVC pipe to the tank, but before it reaches the tank it officially reaches the “first flush”. The “first flush” system being applied to a standard home consists of a 2” pipe going to a downspout which reaches a 2” T-shaped pipe, which connects down to a 2”-4” reducer which attaches to a 4” pipe, back down to a 2” pipe then to a ball valve. Within the 4” pipe there is a water bottle with a bottle cap. As the 4” pipe fills up with dirty water from the roof, the water bottle clogs the 2” to 4” reducer, allowing clean rain fall to flow over the cap through the 2” T and be saved and/or used. The dirty rain water can be drained through the spout after the 2” ball valve. This allows the system to clean itself before being used by people.

In their next trip to Guatemala, subject A and the team are going to do more water quality testing between the first flush (clean) to the tank (contaminated roof water).

However, the water they had been testing when they built it was remarkably clean. In our opinion, this system suits Guatemala because of its heavy rainfall season which occurs from mid-May to October or November (<http://www.climate-zone.com/climate/guatemala/>). During these months the “first flush” system is most effective. During the summer season temperatures do not get high enough and the air is dryer because it is also located in the mountains (<http://www.climate-zone.com/climate/guatemala/>).

5. How was the system initially introduced to the people in need of water?

The people already had some experience with rain water harvesting systems, because their government had “dropped” it on them before. The quality of the job done and the maintenance thereafter was poor. The water tanks which had been implemented were open systems, leaving the consumers’ water open to roaches and other life forms that could contaminate the processed water. The design included an open tank with a spout at an angle that went through a hole in the top of the tank. The hole of course being too large for the spout and leaving a gap for any contaminants to fall through.

The residents are used to having roaches and other forms of life in their tank of rainwater. They did not know that the presence of life forms in their drinking water exposes them to a great deal of health risks.

The main social obstacle the EWB ran into when implementing their filtration systems was that they are giving the people a much more complex system over the residents’ previously used tanks. The residents were used to having the simple water tanks and they became like a commodity to many; being short on cash or wanting

something else of value was easily alleviated through the deconstruction and selling-off of the systems' parts.

If they go to a house that already has a lot of water with tanks, they will only revise the tank into a closed system and that will help improve the water quality. In Subjects As words, it is socially a little weird.”

Last year they gave the people contracts and they were all thrown off by it. The people were not used to contracts nor systems. They have grown comfort towards the tank. The people have to understand that the system being given IS NOT a commodity.

6. You wanted them to become comfortable with the new system you're implementing?

Yes, they are comfortable with the “stuff” meaning the system, but not the thought process behind it. Maintenance is hard for them.

If the system is to last in the targeted area the users must be comfortable with operating and maintaining the system. The engineers have to spend time educating the user on the system, making sure they understand it 100%. If the user does not understand how to operate and maintain the system it will end up failing unless the engineer can put in the time to maintain it at least twice a month.

7. How do you go about educating the people who receive the system?

When implementing a system it is mandatory that one of the family members, minimum, who is receiving it must help EWB construct it. Therefore they know how to build it and if it breaks they know how to fix it. They are also required to help everyone else build their systems close to their area. The people from the immediate previous trip are required to help the new people as well to help bring some back knowledge. Thus the people of the village can teach each other which is much better than us trying to teach them since, EWB would have to translate and that can cause confusion.

Educating the client is a very important part of implementing a water system. In an industrialized setting where projects are done for money. The engineer does not need to educate the client so much on how to maintain and operate the system being installed. The client will actually pay to have the system serviced and maintained every so often. However these clients in Guatemala cannot afford to pay someone to service and maintain their water system. Engineers do not want to be flying back and forth fixing it. The best thing to do is invest in educating the client when the client is not going

to be able to afford maintenance, like WPI's EWB did. In this situation it is not about the money it is about helping others in need.

8. How was Guatemala selected?

The way that the EWB works is when a group is formed, they apply to "nationals" asking for projects. Communities in Guatemala and around the world also apply to "nationals" in hopes of gaining a EWB team to help them with their troubles. The EWB team sees that Guatemala is an available project and apply by completing an application form. Nationals reviews the application and decides whether the club is a good fit based on, "how active is the group?", "how difficult is the project?", "where it is?", and grants the group access to those in need.

In our opinion, this system appropriately matches teams of engineers, and their abilities, to the specific problems faced by different communities. Nationals checks how active the EWB team is. If they are active and they have a good completion rate they will be considered for the project at hand. To have successfully completed water systems in a community means the team must have adapted to the social aspects of the community, making it easier for the community to accept them. Nationals also takes the project's location and difficulty into account when reviewing applications. Above all, nationals cares about the engineers' ability as a team to apply their knowledge to help those in need in a way that satisfies both the individuals involved and those supporting the work. Social aspects including the climate, beliefs, and lifestyle of the afflicted area have to be taken into account when considering the environment and location. If an organization uses this template to match engineers to projects it implies there are engineers that lack a certain set of qualities that hinder them from having successful project outcomes. These qualities begin with being able to give and not expect anything in return. Having patience and truly wanting to help the community is all the clients can ask for.

9. How was communication established between the engineers of design and the clients?

WPI EWB started off with a NGO, Non-Governmental Organization that gave them non-responsive country contact. They then came across a NGO, which happened to be a Museum that had contact with indigenous Mayan communities. Inside this NGO was a university student, whom EWB pays, to check the communities twice a month. He checks with each family on the status of their system and their well-being. Asking questions in terms of, "what is working?", "what is not working?" The student also speaks the dialect of the EWB's Guatemalan target area. He does not have a salary but gets paid enough to make it "worth it." He is also a volunteer at the NGO, so this is

what he wants to be doing. Subject A said he is “super dedicated” and that he is “...absolutely key to the whole thing.”

This coming trip, they are working on pre-trip design communication. Previously, they would go to their community, show each person in the community the design specifically made for their home. Once it is implemented the people of the community figure out how to optimize the system even better. Therefore, the plan is to show them our design and let them help with optimizing the design before it is officially implemented. So when it is implemented it will be running efficiently.

They ended up with a large excess of materials last time because certain dimensions did not suit their client’s house design. Subject A said “it would have been better to consult with them (client, people of the implementation) beforehand, so we didn’t order all the wrong materials.”

At this point the clients of the community are already educated on the system, so the goal is to get their feedback on the drawings to optimize the system. In our opinion, having good communication with the developing country is the very most important aspect to an implementation. The word communication is expanded to the “details” of itself.

Details:

Having a translator(s) that can speak the language of the engineers and clients. On top of that there should be a translator that can speak the most common language of the target country.

Monthly check up done by someone who understands how to take apart and build back the implemented system. Someone who can speak the language of the client.

Education will probably lead to the client being able to optimize the system above what was given to them. Include them in the design process. In return the client will appreciate your honesty.

10. Do you find that you needed to provide an incentive to the clients to have them maintain the system?

Subject A says that they will definitely fix the problem. He recalls a memory of how a family had to relocate their home and water system. The people of the community helped them move it and reconstruct their water system. He says, “They reconstructed it perfectly.” It is a huge indicator that the EWBs implemented education system had worked.

The people of the community hate to see water go to waste also. It is ingrained in their society.

EWB leaves the clients with education booklets that touch on things like, “separation of containers, such as if you are emptying the first flush in this bucket; don’t use that bucket for your clean water.” The booklet tells them that the first flush water can be used when cleaning their clothing. It gives them guidelines.

11. Was there any cultural or social resistance when you arrived?

The hardest thing was building a trust with the community. They experienced a community member trying to gain profits from the project, even though it is obvious it is not part of the program. So they naturally built a relationship with the people that showed that they are “open,” friendly and honest. They needed to show them that they are here to help them for the long haul, while not making a profit. Subject A says, “This was foreign to them.”

12. Why does WPI’s EWB water system last in their targeted area?

Subject A believes it’s the amount of time spent in Guatemala. WPI’s EWB has been working and monitoring their targeted site since 2009. The education part of it is important, which is why this coming trip they will begin to educate the children on water security. This will then lead the children to nag their parents to do the right thing when it comes to water security. They put lots of focus into the initial social aspect than the implementation.

Interview Analysis:

Subject J:

- Designed patented membranes to purify water.
- Target Area was selected as Indonesia because of verbal ease of the language barrier and a long standing relationship with the community/country and people there.
- Water is a commodity within Indonesia. Women who were put in charge of distribution ended up selling the filtered water for profit which empowered women and gave them jobs.

- Membrane became worn out and dirty but were never replaced by the women even though they gained profit from the water. However they decided to sell contaminated water and then the dirty membranes for profit.
- Subject J's team consisted of 5 members.
- Funded by XPrize
- The target area was contacted by the project director through communication with 3 different universities that led to 25 local communities. These communities were given in total 50 handheld computers which were funded. This gave the opportunity to maintain communication with the many volunteers that were given the computer.
- Community members loved the director because jobs were supplied.
- These volunteers whom were handed laptops kept the director and the team up to date on what changes are necessary to be made to the design of the sanitation system and its implementation procedure.
- Subject J decided that the community's social acceptance of the project was 100% critical.
- Subject J stated that there has to be a very simple educational plan in place alongside whatever is being implemented. One should provide simple guidelines to teach people to maintain and operate the system.
- Questions were frequently communicated to the client while the system was being installed. The questions were asked to not affect the design but to demonstrate how the product should be used.
- One of the biggest problems that lead to implementation failure is not knowing/respecting the community where the system is being implemented. Engineers must acknowledge that the client may be experiencing some cultural, educational and/or traditional barriers that can hinder the maintenance and operation of the system
- Subject J concluded that continually talking to the community/client would have helped the implementation process move further than it did.
- Finally no electricity was used to power the project, gravitational energy was used.

Subject D:

- Worked on technologies that include sun rays and nanotechnology to break down biological organisms.
- Especially in drinking water, hydrogen peroxide acts as a disinfectant as well as an oxidant. It is very inexpensive and simple to apply.

- Iodine is a similar disinfectant which can be easily controlled by changing the pH level. It does not take much iodine to fully disinfect water but not measuring the dosage can potentially kill the consumer.
- Engineers have to understand how and where they get their water which may relate to their religious/cultural belief.
 - Example: In Haiti there are some religious beliefs on water. They don't believe in filtering water; a little dirt in water may be seen as a blessing and appreciation for what this world has to offer us.
- The best way to get to know and fully understand the client is to spend time with them.
- Engineers are not used to implementing social science/aspects to their design and viewpoint. Their priority is whether the system filters water, not, the concern of it being used.

Subject K:

- Member of Engineers Without Borders chapter in Worcester Polytechnic Institute.
- Target area was a village in Guatemala.
- Subject K interviewed target area community members via a translator their family situation at a personal level. They emphasized their questions on the living situation of each family member.
- There are a lot of projects of implementation that fail and Subject K's project would have failed if the clients of the community did not know how to operate or maintain RHS. Because their team invested time and effort to understand them and get to know them, in return the people of the community invested the time and effort to learn how to maintain and operate the implemented water purification system. A lot of time was spent on education programs and materials for the community members to try and reduce the likelihood of the water system failing due to the community members lacking the knowledge to operate and maintain the system. Subject K focused in making sure the design met the client's needs, but not over design them.
- Having an NGO, Non-Governmental Organization, helped because they knew the community members well and they hold the clients of the community accountable for the water system being implemented. This is done by requiring families to pay 5% of the material cost (roughly \$80), which gave them ownership, acquired through a loan.
- The future goal is educating the children of the community since they can have an influence on the older generation's perspective of "water

security.” Getting the children to have the confidence and knowledge for solving real world problems is essential.

- There were two stages in communication done between the team and clients. During stage one they got information and data regarding the house and family to build the specific RHS design for each home. Subject K incorporated calculated data into an excel spreadsheet, which takes into account rain data in Guatemala for the past 30 years, the roof surface area, amount of proposed storage tanks, the number of family members and an estimated water consumption of 12 liters per person a day. It took those values and created a graph representing the timeline of the year as well as when the clean water in the tank(s) no longer occupying the tank. This allowed them to figure out how many tanks will be needed for the family of interest. Any other additions that need to be made to the house were addressed with the homeowner beforehand.
- Due to how time works in Guatemala their schedules had to get pushed back numerous times. Another setback were materials because during their earlier implementations they had planned for what the design will be but once they got there the design ended up changing since calculations made did not always work when implemented and because a lot of extra materials were not used. On top of that they needed new materials that the team did not have.
- Most funding was provided by Engineers Without Borders USA and other companies like Fidelity. When handling design plans, Subject K would first confirmed with the clients (homeowners) and made sure that everyone was “on the same page.” They made sure they were aware of the contract entails in terms of responsibilities. They’ll also had to meet with the Mayor of the municipal district, he was a very supportive to their project. Subject K do not work closely due to factors that arise in Guatemala, but in the past they have provided transportation for us and materials - its good to have that contact.
- Their project seemed to last because they had dedicated a lot of time to get to know the community members. They made sure they designed systems that are what people want and need. Their team was very committed with an equally committed NGO, which is critical. They had university students who worked with the NGO and went to the implemented houses to check up on the families and their RHS every couple of weeks.
- The main reason why this project has not failed is due to the intense communication and collaboration between the team and community members.

Subject A:

- Member of Engineers Without Borders chapter in Worcester Polytechnic Institute.
- Target area is a village in Guatemala.
- Spent time with the community built trust with them. Came to conclusion that their schedule is based off of the clients.
- Established a mediator from their NGO to check up on the clientele about every month.
- Setup translators to help the engineers communicate with the clients effectively and also to help communication between the country's main language and the target areas dialect.
- Helped develop a Rain Harvesting System (RHS) based on the target areas geography. Their filter of choice is a Bio-sand filter with a back-washing attachment.
 - The RHS is most efficient during the target areas precipitation season, which happens to be rainfall.
- Educated the clientele to be able to construct, fix and maintain their RHS. This was done by creating a pamphlet with pictures that explain water sanitation levels, setting up the system, constructing and operating it.
- Mediator kept track of the RHS to help the client and keep the engineers of implementation and design up to date.
- Visits the target area before their implementation of their re-design to get feedback from their now educated clients. Educating their clients made their future problems less stressful.
- Updated their re-design and intends to implement it.

EWB Failure Report 2011:

Mismatched time scales²⁹

In 2010, Boris Martin had intentions of working with the Alliance for a Green Revolution in Africa (AGRA) to implement a prototype agricultural design his team had been working on over the past year to help raise \$800,000 for EWB. Unfortunately though, AGRA works by going through funding proposals for six months to a year and then starting the partnership proposal process with the selected applicants; which for Martin and his team, took more than a year to complete. False assumptions made by Martin on AGRA's time scale cost him the immediate funding he was looking for as well as the momentum his team had acquired.³⁰

Communication

Alix Krahn stresses the importance of knowledge management and communication within her chapter of the EWB after missing out on productive conversations with Peter Goldring, a member of parliament. While Krahn was attempting to make contact with Mr. Goldring she was unaware that the EWB already had an established relationship with him, making the time she spent with him explaining the EWB's mission and some sample projects wasted.

²⁹ "Failure Report", **Failure Report 2011**. 2011 ©EWB-ISF
Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.ht>

³⁰ "Failure Report", **Failure Report 2011**. 2011 ©EWB-ISF
Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.html>

Insight Before Influence

Mike Klassen, while working in Ghana was given time to explore and absorb the local environment and societal ways so as to gain a better understanding of the ways in which their agricultural product would affect and hopefully improve the locals lives. Mike did not. Instead he shifted his focus and dedication from staff capacity-building to managing the strategy for the inputs and equipment sector of the project. By jumping at the opportunity to work with the first-hand implementation of the equipment and abandoning the leadership role that he had originally held, Mike missed out on the local background information that was so vital to the appropriate implementation of their project.

Language Barrier³¹

During the 2010 unveiling of the EWB's failure report where there were over 800 people in attendance, Kyle Baptista (Creative Director for Canada EWB) recounts the simple mistake that cost them big time. On the cover of every report given away at the end of the presentation that day was a slightly misspelled title that had been poorly translated into french. The misleading title meant the recipients would not be able to as easily accept the EWB as a legitimate organization.

³¹ "Failure Report", **Failure Report 2011**. 2011 ©EWB-ISF
Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.ht>

Transparency

James Hagra, the Director of Advocacy for the EWB Canada division spent 2010-2011 helped bring about the signing of the International Aid Transparency Initiative in order to help bring transparency to the aid they were receiving from Canada. Through his work, Hagra began the process of formally publishing data the EWB had collected in the field in a manner that satisfied the IATI standards. This brought the EWB into the mainlight where they could be both more easily recognisable as well as scrutinizable. The EWB is still working on what Hagra started, managing information and publishing it in the easiest and most efficient manner.

Creating an Organized Urgency Among the Community

In 2011, George Roter expected great things to come of his EWB Canada team; an estimated 50% growth rate was possible with the given team of people they had. Unfortunately though Roter and his team of 30 person leadership team kept the information regarding the need for change and the new directions they were looking to take from their constituents. This resulted in, as Roter puts it; “the losses of trust between people in EWB, burnout as leaders struggled to anticipate change, an overall slower pace, and [a] lower sense of unified purpose”, (EWB Canada).

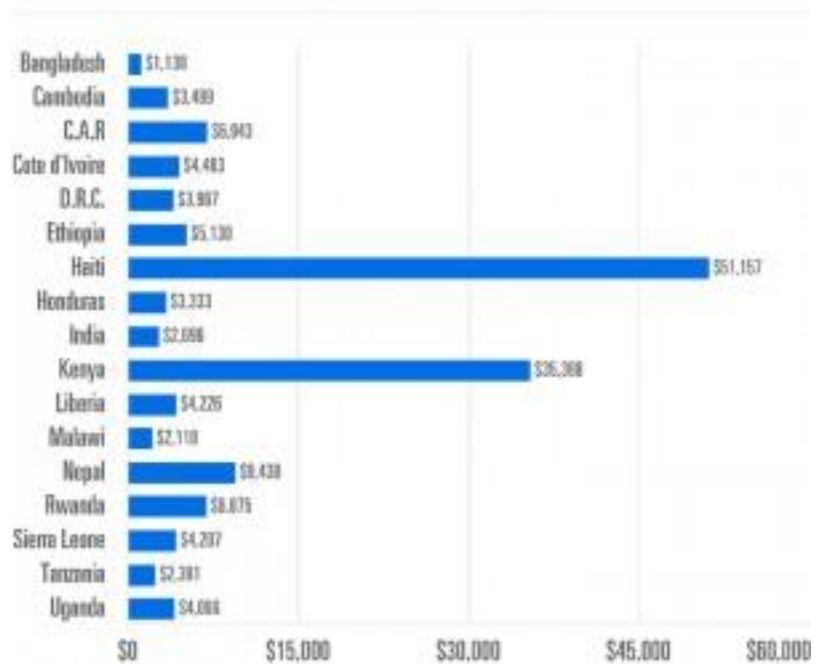
Breaking Down \$20 for 20 Years³²

Mo Scarpelli, the multimedia producer for the foundation Charity:Water decided to retract the long standing claim she had made about her product. As Scarpelli puts it; “We’ve always known that \$20 per person covers the implementation of the water project on the ground. But we became unclear about the cost to maintain our water projects over time³³” The \$20 investment/donation

is enough to cover the basic implementation of the water sanitation project but the group had not had the foresight to predict the necessity of maintenance over time. Since the 20 year claim has been revoked Scarpelli and her team have worked on including a maintenance regiment in each of their projects. The maintenance process varies with type of filtration method used as Scarpelli says in her report; “in some countries, we form and support local Water Committees to look after the projects. In others, we fund training for individual families to learn how to maintain their projects or set up a scheme where the village pays an available repair team to help.” This shift in focus for Scarpelli

average cost to implement a charity: water project

These average costs include installation (i.e. toilets, handwashing stations), hygiene education and support of maintenance programs.



“Breaking Down \$20 for 20 Years”, Admitting Failure. © Copyright 2015 Engineers Without Borders Canada.

³² “Failure Report”, **Failure Report 2011**. 2011 ©EWB-ISF Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.ht>

³³ “Breaking Down \$20 for 20 Years”, **Admitting Failure**. © Copyright 2015 Engineers Without Borders Canada. <https://www.admittingfailure.org/failure/mo-scarpelli/>

and her team has brought about a change in the groups way of going about project implementation; instead of getting as many filtration systems out there to as many people as possible they have now directed their attention to ensuring the longevity of each project through maintenance and accountability.

Katadyn Water Filter³⁴

On a more personal level, in 2002 Kelly Anderson donated a \$700 Katadyn water filter to a village in Haiti. For this being a personal endeavor, it meant that Anderson had to make sure the filter was used correctly and shared among the village on her own. This also meant that the long term success of the filter would be ultimately up to the people of the community. As it turned out, the moment Anderson left Haiti the expensive device was put in a closet under lock and key and never used in order to protect the piece of equipment that was too far above the people's perception of technology to become a viable tool. Later, the locked closet was broken into and the filter was stolen; presumably it was sold off for its' relatively immense value. Kelly Anderson's story proves that it takes more than one person to solve the water crisis and that expensive solutions aren't always necessarily the best.³⁵

³⁴ "Failure Report", **Failure Report 2011**. 2011 ©EWB-ISF

Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.ht>

³⁵ "High Tech Water Filter Donation", **Admitting Failure**. © Copyright 2015 Engineers Without Borders Canada. <https://www.admittingfailure.org/failure/kelly-anderson/>

Finding Room for Error³⁶

In Ecuador, Mary Fifield hoped to revolutionize the structure of project aid by allowing communities to propose projects they had designed to Fifield and her team instead of dropping a project on them. In theory it was perfect; communities, after given a background information and some guidance, would propose a project that they feel would work best in their community and the winning project would be awarded a grant as well as a year of intensive project management training in order to keep the public both educated and involved. One proposed project that had won the approval of Fifield and the Amazon Partnerships Foundation (APF) had shown troubling signs that other communities had exhibited before so Fifield, “Having learned from previous failures, we’d developed tools to alleviate these problems, but they didn’t work this time. As we suspected when our board approved their proposal, the community wasn’t sufficiently organized or committed to the project.”³⁷ Under normal circumstances the project would have been dropped due to the overwhelming amount of noncompliance but in this case Fifield and her team had received funding from an outside source that had only been interested in the implementation of 57 rainwater catch systems, not the overall success of the project in the community over time. In the end Fifield was successful in installing the 57 filtration systems but she was deeply upset that she was unable to teach the community to design and implement their own projects. Fifield’s case is the perfect example of an individual driven to change the project implementation framework but

³⁶ “Failure Report”, **Failure Report 2011**. 2011 ©EWB-ISF
Canada <http://legacy.ewb.ca/en/whoweare/accountable/failure.ht>

³⁷ “Finding Room for Error”, **Admitting Failure**. © Copyright 2015 Engineers Without Borders Canada.
<https://www.admittingfailure.org/failure/mary-fifield/>

being held back by those who have more influence over the project because of their financial involvement.

Conclusions:

The problem does not solely lie in the technology being put to use, whereas the real issue at hand is engineers are having trouble analyzing geographical/social aspects within the environment and human culture, respectively. Through the interviews, we were able to understand where engineers failed or made progress and with the Engineers without Borders failure reports it made it that much clearer that “how engineers approach implementation and actively implement play a dependent role on the success rate.” Based off this data, our team has created a step-by-step guide compiled with the thought process and topics needed to effectively implement a system, specifically being water sanitation, in developing countries.

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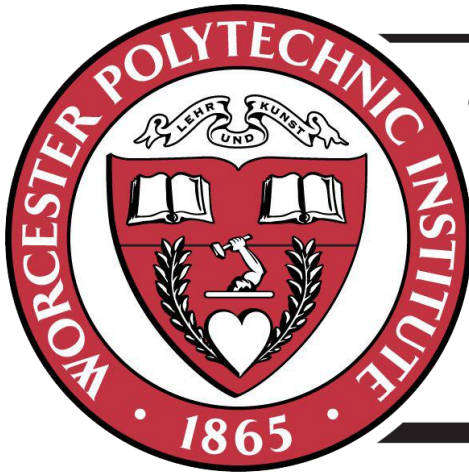
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Appendix



WPI

PROJECT GUIDE FOR SYSTEM IMPLEMENTATION



"The Trouble with Distilled Water" By Rock and filed under Water Storage, <http://www.efoodsdirect.com/blog/the-trouble-with-distilled-water/>

Interdisciplinary Qualifying Project

Kory Girouard, Corrado Addoniso, Cesar Rodriguez

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- a. Examination prior to implementation
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- c. Educate the occupants in the target area on how to operate the system

1. Sustainability

- a. Establish maintenance routines/schedules and material connections
- b. Institute a way of direct communication between the client and help
- c. Assign responsibilities to individuals of authority
- d. Mediator should have fixed meetings with the client (weekly, bi-weekly, or monthly)
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 - c. Variables
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 - ii. Dependent
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 - 3. Clientele family Interaction with the system
 - 4. Government and their past/present/future influences on the system

Water Filtration Implementation

1. SETTING UP A TEAM

The team should consist of a **Social Science Specialist, Translator(s), Engineers** and a **Mediator** (a translator and mediator can be included part of the first step if an NGO and Target Area has been pre-selected already.)

- a. **Social Science Specialist:** An individual who studies sociology, psychology, anthropology, economics, political science, and history.
- b. **Translator(s):** Individual(s) that can fluently speak the target groups language and the country's main language.
- c. **Engineers:** Depends on the system. A good team of engineers, if well-funded, should consist of a chemical engineer, mechanical engineer, and an electrical engineer.
- d. **Scientist:** Biologist
- e. **Mediator:** Hire a well-educated student who is fluent with the language and dialect target area to keep in contact, through monthly visits, with occupants of the target area to make sure that the system is operating efficiently and maintained properly.

2.) Find an NGO to sponsor the project

- a. Set up an annual plan/budget
- b. Define Goals
- c. Outsource

3.) Find a Target Group

- a. Who is going to be directly affected by your system?
- b. What other groups will be involved in the project?

- c. Accessibility to the community in concern
- d. Is there a willingness to adopt a water filtration system?

4.) Gain an understanding of the target group

- a. Learn their way of life
 - i. Daily Routine
 - ii. Relationship with sanitation
 - iii. Possible hierarchies in the community
 - iv. Any forms of segregation among the community
 - v. Communications with the outside world
- b. Build a sense of trust with the client
 - i. Let the people know that they won't be abandoned
- c. The better the understanding is of the community, the better the product can be molded to their needs and interests

5.) Product Design

Factors to Consider when Designing a Water Filtration System:

- a. Geography- The target area's geography can be divided into three categories containing human, physical and climate characteristics. The first of which consists of matters concerning the population as a whole; the ways in which the people conduct themselves and treat each other greatly affects the project's success. One should be understanding and respectful of the client's way of life at all times so as not to draw any negativity towards you nor the product itself. The latter of the geographical aspects deals with understanding the terrain to benefit your design. If, as an engineer, you have already had a design without selecting a targeted area beforehand, we suggest that you start all over and begin with selecting a targeted area.
 - i. Human
 - 1. Population
 - 2. Societal standing

3. Social/Political standing
4. Possible Class Structure
- ii. Physical
 1. Water availability
 2. Altitude
 3. Terrain
 4. Material availability
- i. Climate- The target areas climate is divided into the subdivisions below. Each of these characteristics can be used to power, filter, or even destroy your design
 1. Sunlight
 2. Precipitation(rain, snow, humidity)
 3. Wind
 4. Seasonal/Temperature Patterns
- a. Dimensional/Visual
 1. Make sure the visual design is not intimidating to the average community member.
 2. Families in third world countries, in many cases, rely on children to collect water for the family, hence design a user friendly systems operational by children as well.
 3. To make the system much more acceptable by community you can possibly make the color scheme an interactive design with the community from the target area.
- a. Clientele Characteristics-The system's success directly depends on the client's understanding and trust of the projects' purpose. Become familiar with any beliefs/values the population has with the visual quality of minerals (water in particular). You have to gain their trust before implementing your design. Make your implementation process interactive with the population of the target area. Many successful projects have provided jobs prior and during the implementation process. Plan ahead throughout your design and implementation process. Schedule your system "opening" to be during the period where your system would operate at its best, this may include the season which brings along physical factors which amplifies the output of your system. Familiarize yourself to who your client

really is. Keep in consideration the individuals who will be directly affected by the system.

- i. Religion/Beliefs
 - ii. Trust
 - iii. Routine/Schedule
 - iv. Perception of water
 - v. Education
 - vi. Hygiene
- b. Financial Terms
- i. Who's financing?
 - ii. Product's material/production costs
 - iii. Input vs. Output
 - iv. Is the project for profit or nonprofit?
- d. Prototypes
- i. Exposed to physical factors expected to experience in target area.
 - ii. Test it with various communities, examine how various community members react to the system.

6.) Implementation

1. Before starting implementation of any project, examine the surroundings of the target area for the possibility of any major physical phenomenon such as earthquakes, heat waves, floods, droughts, animal behavior, etc.
2. Create a community-wide incentive to back the project and its' success
3. Educate the occupants in the target area on how to operate and maintain the system

Sustainability

1. Establish maintenance routines/schedules and material connections
2. Institute a way of direct communication between the client and help
3. Assign responsibilities to individuals, creating authority

4. Mediator should have periodic meetings with the client (weekly, bi-weekly, or monthly). Communicating with the client may include having to speak with the community members, hence, the mediator being fluent, he/she can also update the team on the social status of the target area since the community members are the individuals who will be directly affected by the system. The mediator should be in charge of creating a database with the recordings of the following systems' status within a given period:
 - a. Condition
 - i. Operational
 - ii. Maintenance
 - b. Closed system
 - i. Check if internal pressure meets design standards
 1. Any pressure different from design standards may be caused by leaks, which may result in contamination.
 - c. Variables
 - i. Independent
 1. Time, natural manifestations
 - ii. Dependent
 1. Any factor affecting the quality and quantity.

The mediator will more than likely be the only team member who will witness societal interaction within the target area. Any conflicts between groups (families', clans, neighborhoods "if applicable", religions, etc.) may affect the system's efficiency or even destroy the system due to the following possible factors:

- a. Destruction of surrounding environment
- b. Neglecting system maintenance
- c. Corruption

There are two different sizes the system can be incorporated into depending on the size, output and effectiveness factors (will it work better indoors or outdoors?)... The system can either be large enough to provide clean water for a large number of community members or small enough to be distributed to families or individual clients. In the case of smaller systems, the mediator would have to become familiar with the living conditions of

the family. Living conditions can change any given time without forebode, the mediator has to be up to date on the living conditions of the families the system systems were distributed to (e.g.: loss of family member, unemployment, property damage, etc.). There are living conditions which could stray the family's attention towards solving another issue affecting their family rather than dedicating attention and time in maintaining the system at its state of highest possible effectiveness and stable operation.

Government affiliation for projects could range from zero affiliation to total control. Zero affiliation means the government does not overlook the entire process of implementing your system into the target area they control, this means they will not fund your project what's so ever. As an engineer, you have to understand the government's role in influencing your system whether it means having to follow policies, licensing procedures, and contract documents set forth with the government before, during, and/or after implementation, executive decisions by the government, and, worst case, corruption. It's always best to give the government the option to, at any time, have access to data regarding the systems operation to prevent any doubts or trust issues. You have to be aware of as many possible government influences in the past, present, and future to be prepared for anything that way harm or hinder your system. It's up to the engineer to identify what will benefit/obstruct their system.

Evaluate how the social aspects (religion, traditions, economic class structure) influence the system

- a. Consider the physical attributes required to operate the system
- b. Costs of materials necessary to construct, install and maintain the system
- c. Prototypes: different environments (simulations or actual "better results") within the target area, during different season

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³⁸ The Board of Trustees 1987. The Mission & Goals, “The Mission of WPI.”
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