Improving the Drinking Water Quality after Hurricane Maria Using Natural Resources

Aguarico

Kailey Aponte, Janeliz Guzman, Bria Roettger

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Abstract

On September 20, 2017, Hurricane Maria, a nearly Category 5 storm, devastated Puerto Rico. Millions of people were left without potable water or electricity. As a result, people drank hazardous water that led to bacteria-related diseases.

Our research questions were: (1) How can we prevent bacteria-related diseases from water contamination during the aftermath of Hurricane Maria? (2) If we filter contaminated water using a modified solar water distiller and secondary filtration system, will the output water quality be safe for consumption? This problem developed into our hypothesis: If we filter contaminated water using a modified solar water distiller and secondary filtration system, then the output water quality will be potable. Therefore, the objectives were to (1) create a prototype to filter water using natural resources along with utilizing steam collected from a solar water distiller and (2) produce potable drinking water after a natural disaster.

A prototype was created using natural resources and tested to verify that pathogens in the water were reduced after filtration. In addition, this product was compared against five filtration systems used during the relief effort. The methods used to test our prototype and compare it with others included probes, sensors, and bacteria tests. The results were listed and organized on a spreadsheet.

In conclusion, our team, Aguarico, created an effective prototype that distilled and filtered water using local materials and natural resources. Although city water (AAA) resulted in zero contaminants, the first results from the irrigation water had contaminants. Finally, our last trial resulted in zero bacterial pathogens from the filtered irrigation water. We hope to empower community members in Puerto Rico to rely on natural resources to filter drinking water through our website and brochures created in both English and Spanish.

Research Questions

- ***How can we prevent bacteria-related diseases from water contamination during the aftermath of Hurricane Maria?***
- ***If we filter contaminated water using a modified solar water distiller and secondary filtration system, will the output water quality be safe for consumption?***

Hypothesis

If we filter contaminated water using a modified solar water distiller and secondary filtration system, then the output water quality would be potable.

Introduction

Hurricane Maria left residents of Puerto Rico without clean drinking water. According to the CNN website, “The aftermath of this storm affected millions of Puerto Ricans” and left the entire island without potable water or electricity. Without electricity, the water purification system did not function properly leading many to drink hazardous water. Based on the Natural Resources Defense Council (NRDC) website, “ More than 2.3 million Puerto Ricans used water that had positive testing for E.coli and coliforms”. Water became increasingly infected with coliforms and spread of bacteria-related diseases such as Leptospirosis, a dangerous disease caused by animal urine. According to the Centers for Disease Control and Prevention, “ Leptospirosis can lead to kidney damage, meningitis, liver failure, and even death”. Due to the lack of proper medical facilities, this became a major crisis in Puerto Rico.

Based on these events, Aguarico confirmed the urgency of this problem to formulate a problem statement: “How can we prevent bacteria-related diseases from water contamination during the aftermath of Hurricane Maria?” We worked directly with STEM experts and interviewed local residents. We also read many articles that were about the current water situation in Puerto Rico since Hurricane Maria. This led us to hypothesize: ”If we filter contaminated water using a modified solar water distiller and secondary filtration system, then the output water quality will be potable.”

Since relief supplies were limited, it was crucial to depend on available, local materials. Therefore, our solution utilizing steam collected from solar hot water systems and directing water to a secondary filtration system using natural resources may provide a reliable source of drinking water during a disaster and everyday use.

Research Methods

The methods used to test our prototype and compare it with other water filtration systems used in Puerto Rico included probes, sensors, and bacteria tests. The results were listed and organized on an excel chart. We analyzed our data based on our research questions: (1) How can we prevent bacteria-related diseases from water contamination during the aftermath of Hurricane Maria? (2) If we filter contaminated water using a modified solar water distiller and secondary filtration system, will the output water quality be safe for consumption?

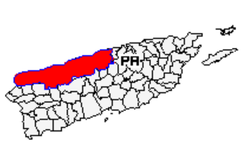
Data was collected and evaluated based on the amount of total coliforms, enterococci, and E.coli bacteria present in the water samples collected. The protocols followed to collect data are the same used by the Environmental Protection Agency (EPA) to determine if our drinking water is free of bacteria and contaminants. In addition, we collected data such as PH level, conductivity, turbidity, temperature, and ORP Sensor.

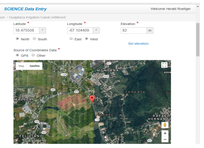
We compared our data collected on February 1, 2018, February 20, 2018 , February 27, 2018, and February 28, 2018. Over the course of these tests, our filter’s performance improved. Originally, it did not eliminate all of the bacteria necessary to be effective. This data supported our idea to improve the overall performance of our filter. We could do this by following stricter sanitary procedures, testing new materials, changing our design, or creating a more efficient primary solar water distiller. On the last test, completed on February 28, 2018, zero coliforms, enterococci bacteria, or E.coli bacteria were present for one of our tests. This was significant because our prototype successfully sterilized contaminated water for the purpose of drinking. The improved effectiveness of our filter supported our hypothesis:

If we filter contaminated water using a modified solar water distiller and secondary filtration system, then the output water quality will be potable.

Study Site

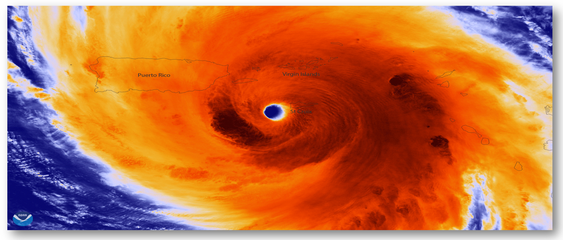
Guajataca Water Shed, Puerto Rico





GLOBE Badges

- **Four Star Research Badge**
- **Collaboration**
- **Community Impact**
- **Engineering Solution**



Hurricane Maria devastated Puerto Rico and its infrastructure on September 20, 2017.
Image by NASA

Results

In order to analyze data from our trials, we organized it on a spreadsheet to compare it with other filtration devices. Using this spreadsheet, we placed our data in a scatterplot to observe how much our filter changed. Using this scatterplot, we could apply a trendline (or line of best fit/ regression line) to predict how well our filter will do in the future if it continued to improve. Also, in order to keep our trials constant, we needed to keep our times and numbers constant as well. This means that we had to boil or bleach our materials for the same amount of time before every trial. It also meant that we needed to measure exactly how much charcoal, sand, and husks we were placing in our filter, and keep the same measurements for every setup.

This would rule out irregularities in our data that could come from different boiling times, because not all of the bacteria may be killed. It could also rule out the possibility of different filtration times due to inconsistent measurements, meaning water could soak more in the filter during the first trial than the second if the measurements are inconsistent.

The data presented was sufficient to answer the research questions and support our hypothesis because it confirmed our devise to be an effective filtration system to eliminate all coliforms and bacteria from a contaminated water sample. Our data also supported the conclusion that it was possible to create an effective decontamination and filtration device using natural and local materials. With future improvements, our filtration prototype may become something useful to all Puerto Ricans.

Aguarico tested the coliform, enterococcus, and E.coli bacteria levels for all our prototype water samples. In addition, we tested the dissolved oxygen, conductivity, pH, and temperature of our final prototype water sample. We compared our results to the EPA safe drinking levels as shown below:

The results of our first test included running tap water **(AAA)** and **irrigation water** from the Guajataca watershed through our prototype which is shown below:

Aguarico Filter Test from Feb 1

Sample Source	Enterococcus CFU/100ml	tot. coliform CFU/100ml	E. coli CFU/100ml
AAA			
Raw	2	0	0
Aguarico	2419.6	>2419.6	0
Irrigation			
Raw	135.4	>2419.6	178.2
Aguarico (student)	4.1	>2419.6	110

Our second prototype included sterilizing all of our filtration materials and transferring filtration materials to one five-gallon plastic bucket. The results are shown below:

Aguarico filter test results from Feb 20

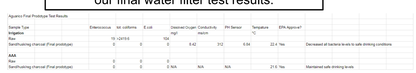
Sample Source			
Irrigation			
raw	19	>2419.6	104
Aguarico old irrigation water	2	0	0
Aguarico new irrigation water	24.5	1986.3	67
AAA			
raw	0	0	0
Aguarico (no other ID)	0	0	0
AAA from hot water filter	0	244	0

Our final test was conducted by testing four different filters, as shown below. According to the table, the sand/husk/regular charcoal proves to filter the water most effectively, and maintains EPA safe drinking levels.

Aguarico Filter Test Results from Feb 27

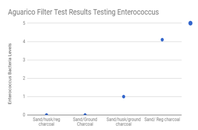
Sample Source			
Irrigation			
Sand/husk/reg charcoal	0	0	0
Sand/Ground Charcoal	0	30.7	43.5
Sand/husk/ground charcoal	1	49.6	30.1
Sand/ Reg charcoal	4.1	33.3	52

This final chart demonstrates the results for our final water filter test results:

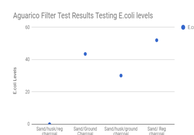


Final Test Charts Comparing the Four Different Filters

The table below shows that the sand/husk/regular charcoal and the sand/ground charcoal were the only two whose results met the EPA standards for safe drinking water for Enterococcus.



The table below shows that the sand/husk/regular charcoal was the only filter that passed the EPA levels for safe drinking water.



The following chart shows the total coliform levels for all filter types. According to the table, the sand/husk, regular charcoal, is the only filter that passes the EPA standards for safe drinking water.

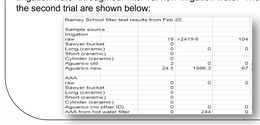
Discussion

According to our results, we managed to improve our prototype with each trial and succeed in eliminating all coliforms from both city (AAA) and contaminated irrigation water samples. Aguarico faced many challenges during the research process, yet we continued with our work. Our results support that we were able to embrace challenges and continue working and refining. The results from our final trial were the best and most significant. We reached our goal and supported our hypothesis of developing an effective filtration and decontamination device using local materials that could be used during the aftermath of Hurricane Maria.

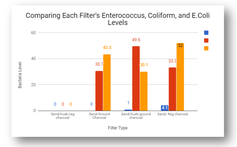
Comparison with Similar Studies

Our team compared filtration system to several other commercial filters that were distributed throughout Puerto Rico during the aftermath of Hurricane Maria. These included: Sawyer, Agua Cera (Long), Agua Cera (Short), Agua Cera (Cylinder), and Brita.

During the second trial, we sterilized our filtration materials more thoroughly, and had precise safety measures. The AAA from the solar hot water filter labeled on the graph shows the results from our steam collecting device that we attached this heater. The Aguarico old shows results from passing old irrigation water through our filter vs. new irrigation water The results from the second trial are shown below:



Comparing Each Prototype Tested



- The above graph represents the effectiveness of the different filters tested for enterococcus, coliform, and E.coli levels.
- This supports that the **sand/husk/regular charcoal filter** performs the best in filtering out the contaminants.

Conclusion

Aguarico developed an operational distillation and filtration prototype. Our results demonstrate improvement through each trial. We connected with scientists such as Steve Tamar, who helped us perform almost all tests. We spent hours completing research, whether it was online, from books, or interviews. We worked almost every day and made sure we did everything to our highest potential.

Aguarico experienced the struggle of living on an island with no electricity, water, or true infrastructure. Our struggles and the struggles of others are what drew us to this particular idea. Our prototype works effectively, and we are proud of our accomplishments.

We plan to improve our prototype by implementing ceramic infused with colloidal silver, which is used in many commercial filters to eliminate bacteria. We could also expand our use of resources, or improve the sterilization methods of the device. Everything completed so far, however, meets our objectives and answers our research questions.

Our team later transferred all information into a user friendly website which includes the steps on how one could create our prototype. We also created and brochure which could be easily distributed through the residents of Puerto Rico who did not have access to the internet.

Our team’s project mentor has also been an inspiration to us. Mrs. Rapatz-Roettger helped us to keep on task, gave us meaningful advice on what we should complete and when, and scheduled research trips and meeting dates. Without her, we may never have known where to start with such a large task. She always encouraged us, and made sure we would be able to submit. Working with a project mentor improved our morale and helped us find our strengths and interests.

Through the help from STEM professionals, tons of research, late nights and early mornings, and our project mentor, we were able to develop an efficient and effective filtration device that could be used to help community members in Puerto Rico during the aftermath of the devastating effects of Hurricane Maria.

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Acknowledgements

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Globe Testing Materials:

- Conductivity Probe
- Dissolved Oxygen
- pH Probe
- Water Temperature

Other Testing Materials Used:

- E.coli, Coliform and Enterococcus bacteria tests