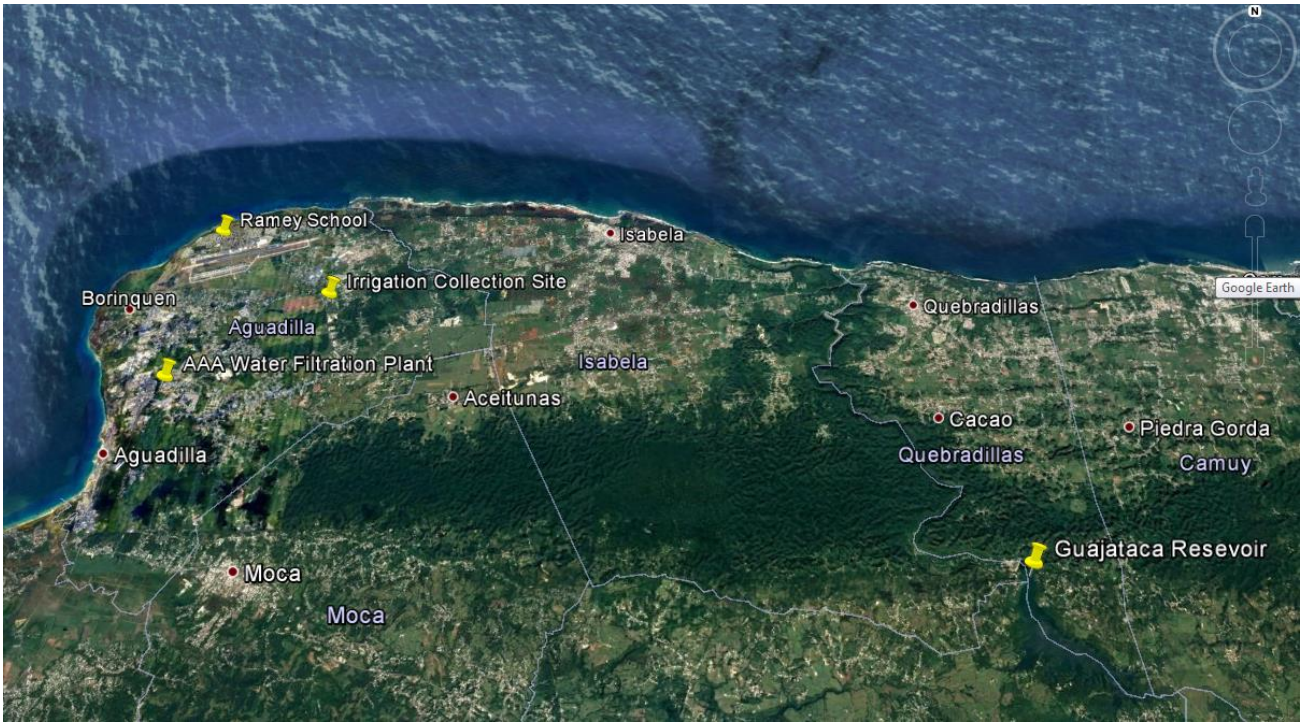
The Waterbenders: Evaluating Bacteria Levels in Filtered Water after Hurricane Maria Devastated Puerto Rico



By The Waterbenders:

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GLOBE Abstract

The Waterbenders are three high school students from Ramey School in Aguadilla, Puerto Rico. After Hurricane Maria, Puerto Rico was left in an island-wide water and power outage. The water company was devastated as well as the rest of the island. The public was left to find their own safe drinking water. Water filters became a necessity in people's lives; however, the filters weren't guaranteed to remove all of the bacteria.

This led our team to our research question: How can we verify that the water being filtered is safe for consumption?

Our team began testing tap and irrigation water with four different types of filters that relief groups were donating to the community. Due to the fact that no one was treating water after Hurricane Maria, we used water from the irrigation canal from the Guajataca reservoir to represent untreated water after the hurricane. We collaborated with the Surfrider Rincon Foundation to test for bacterial levels in the water samples (enterococci, E.coli, and total coliform). Through these tests, our team was able to compare the levels of bacteria that could impact the safety and quality of the water.

The bacterial test results showed that unfiltered irrigation water bacteria counts were extremely high. After filtering irrigation water with the Sawyer Filter and three AquaCera Filters, the bacterial count showed zero or low bacteria counts. The bacterial levels for filtered and unfiltered tap water tests were as well, zero or very low due to the fact that the water authorities are now properly treating the water supply with chlorine.

Feedback from the Surfrider Foundation suggests possible contact contamination resulted in low bacterial levels when there should have been zero. We discovered the need to practice proper sanitary sampling procedures when testing tap and irrigation water in the future.

We highly recommend using these water filters in the future for safe water when none is available.

Aqua Cera: Dome

Aqua Cera: Long

Aqua Cera: Cylinder

Sawyer

GLOBE Research Questions

Our team analyzed the problem that was occurring around us: the lack of knowledge about water quality after Hurricane Maria devastated the island. The people in Puerto Rico were desperate to find a water source that they could utilize for bathing and drinking. However, most did not know if the water was potable enough for use. This caused major chaos in the hospitals because many Puerto Ricans were using unsanitary water for drinking and cooking purposes. If these individuals obtained a safe water filter in their homes, the amount of fatalities could have been minimized to a certain extent. This problem led our team to our primary research question: How can we verify that the water being filtered was safe enough for consumption?

This is an important health matter because if an individual drinks contaminated water, they could become sick or even die. We took safe drinking water for granted; however, once the taps ran dry, it became very apparent that access to clean water was a critical necessity. There are no GLOBE protocols for bacterial level testing in water so our team had to look for other scientific techniques to answer our focus question.

From there we collaborated with our school science teacher, Herald Roettger, who conducts salt water bacterial tests for the Surfrider Rincon Foundation at Ramey School. He put our team in contact with Steve Tamar of Surfrider Rincon Foundation. Mr. Tamar set us up with the techniques and supplies to conduct fresh water bacterial testing. Our team also collaborated with the middle school group, Aquarico, who were building their own water filters. We travelled to the Rincon Foundation lab to learn the bacterial level protocols and test for them in our samples. Our team performed tests of the unfiltered and filtered water from the irrigation canal in Guajataca Reservoir and the tap water from Autoridad de Acueductos y Alcantarillados (Aqueduct and Sewer Authority) to verify that the water being consumed after the hurricane was safe to use.

We proceeded to answer our focus question by testing filtered and unfiltered irrigation and tap water with four different filters provided by the Water Filters for Puerto Rico non-profit organization; which then provoked a new question: Which of the filters is most effective in cleansing the water?

GLOBE Research Methods

Our team hypothesized: if the water coming from the irrigation canal (post Hurricane Maria untreated tap water) was tested, then the levels of bacteria within the water would be higher than that of the pre-Maria tap water. The devastation throughout the island after Hurricane Maria left all systems on the island inoperable. This led our team to assume that the water running through the taps was unchlorinated and that the bacterial levels were high. After Hurricane Maria it took several weeks and months before our tap water was properly treated. The need for filtering water was essential and the filters were highly valuable for the communities on the island.

Our team tried four water filters (Aqua Cera: dome, cylinder, and long and the Sawyer) to test their safety and reliability. Driven by our research question, we designed a test for two types of water (tap and irrigation) that would be filtered and unfiltered for the bacterial levels. Our team also used probes to test water quality such as dissolved oxygen, pH, and conductivity. While filtering the water, we noticed that the flow rates of the filters were different and decided to measure it.

We used the probes to ensure that the levels of the water were stable and safe enough to drink. Our team also wanted to ensure that we were using some GLOBE protocols during our testing due to the fact that they did not have protocols for bacterial testing. We used Vernier Software and Technology to record and analyze the levels of dissolved oxygen, pH, and conductivity.

The sampling irrigation water was collected from the irrigation canal that connects to the Guajataca reservoir to the Aguadilla water treatment plant. Our team chose to test this water because it represented the untreated water after the hurricane. The sampling tap water came from our school's sinks. Our team tested both water samples for enterococci, E.coli, and total coliforms at the Surfrider Rincon Foundation lab on February 1, 2018. When testing the water with Steve Tamar at Surfrider Rincon Foundation, he smelt chlorine in the tap water. He said, "If you can smell the chlorine in the tap water, it is too much to be consumed." The bacteria tests were prepared at the Rincon Lab and Steve Tamar read and sent us the results the next day. We ran the bacterium tests again a second time on February 26, 2018 at our own lab at Ramey School.

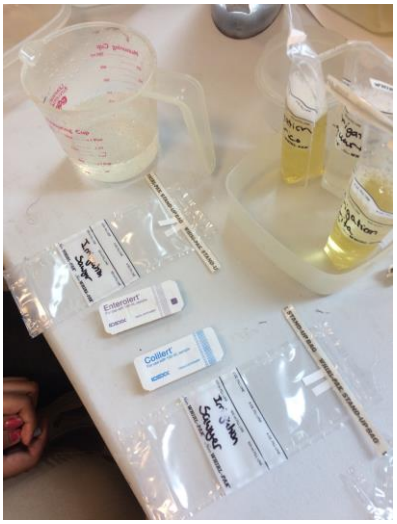
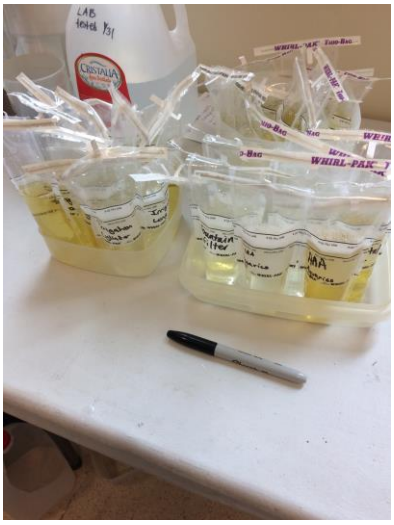
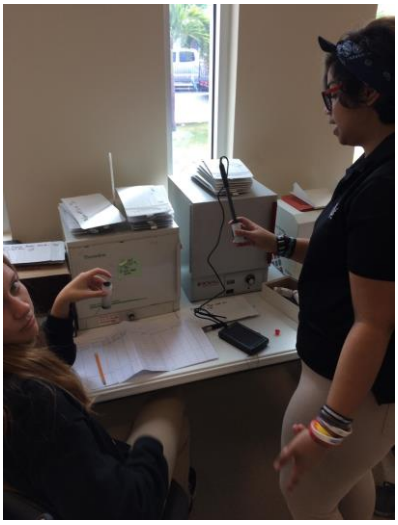
We completed these bacteria tests by separating the two types of water (irrigation and tap water) from the unfiltered and four filters into two 100 mL bags and added the Colibert and Enterolert test. After shaking to dissolve the Colibert and Enterolert power, we poured the solution into a Quanti-Tray/2000 to be sealed. We placed the water samples in two incubators at different temperatures overnight and read the results the next day. The Colibert incubated at 35°C±0.5°C for 24 hours and the Enterolert incubated at 41°C ± 0.5°C for 24 hours.

To read the results for enterococci, our team placed the samples under a black light. If the samples illuminated, then it was positive for the enterococcus bacteria. When it came to the E.coli and total coliform tests, the sample would turn yellow if it were positive for coliforms and

if it would iridescence, then it would be positive for E.coli. In total, there were ten tests for enterococci and ten tests for E.coli and total coliforms conducted on February 1 and February 26.

Our team had prior experience with bacterial salt water quality testing (Enterolert) through our science courses before the hurricane. This knowledge was useful while doing our fresh water testing (Colilert) because we already knew how to handle the Enterolert bacteria test (enterococci). Thanks to donations to the Rincon Surfrider Foundation, they started conducting fresh water bacteria testing with Colilert bacteria tests (E.coli, and total coliforms) and were able to provide us with the testing materials.

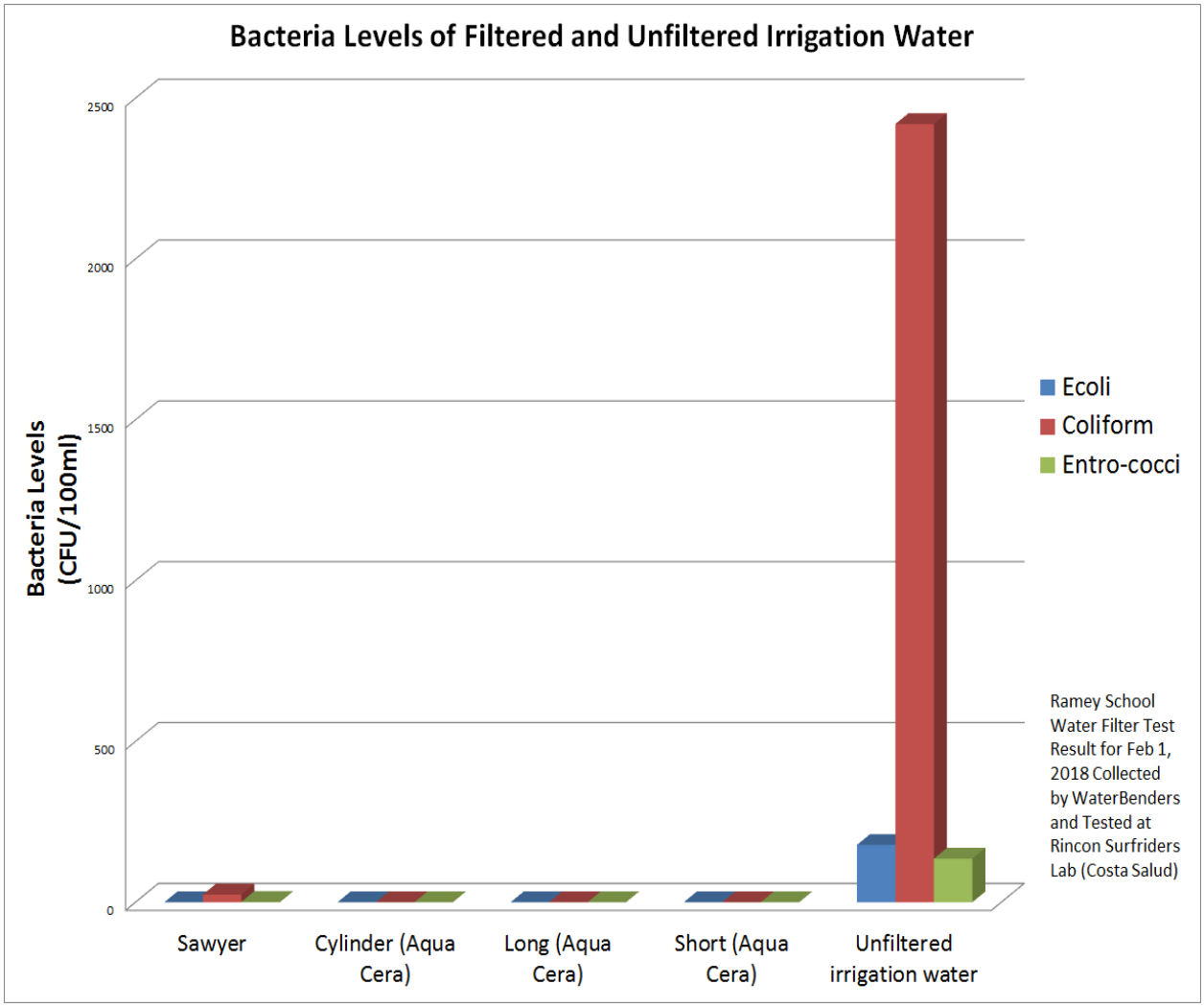


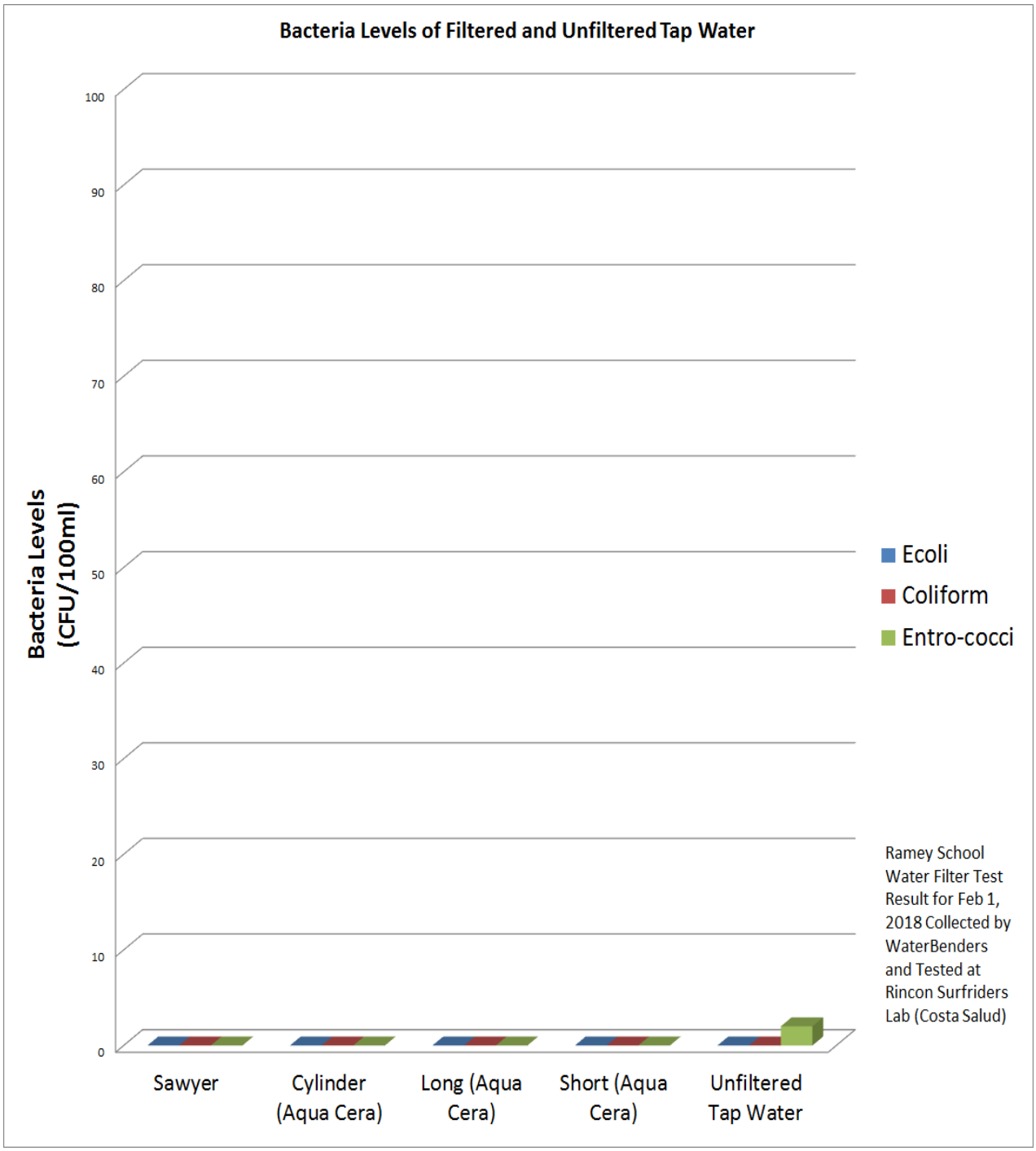

GLOBE Results

Results from February 1, 2018 testing at the Rincon Surfriders Lab (Costa Salud) are shown in the two graphs below:

Our team's results were able to answer our research question(s). The graphs of the bacterial levels clearly show that the unfiltered irrigation water had high levels of total coliform (>2419.4 CFU/100 ml), E. coli (178.2 CFU/100 ml), and enterococci (135.4 FU/100 ml); which supports our hypothesis that the drinking water after Hurricane Maria was presumably not safe to drink. The filtered samples of irrigation water had little to no bacterial count which shows that there was a need for communities to filter their water. The Sawyer filter showed some presence of coliform bacteria (23.8 CFU/100 ml) which was most likely due to accidental contact contamination during sampling/testing.

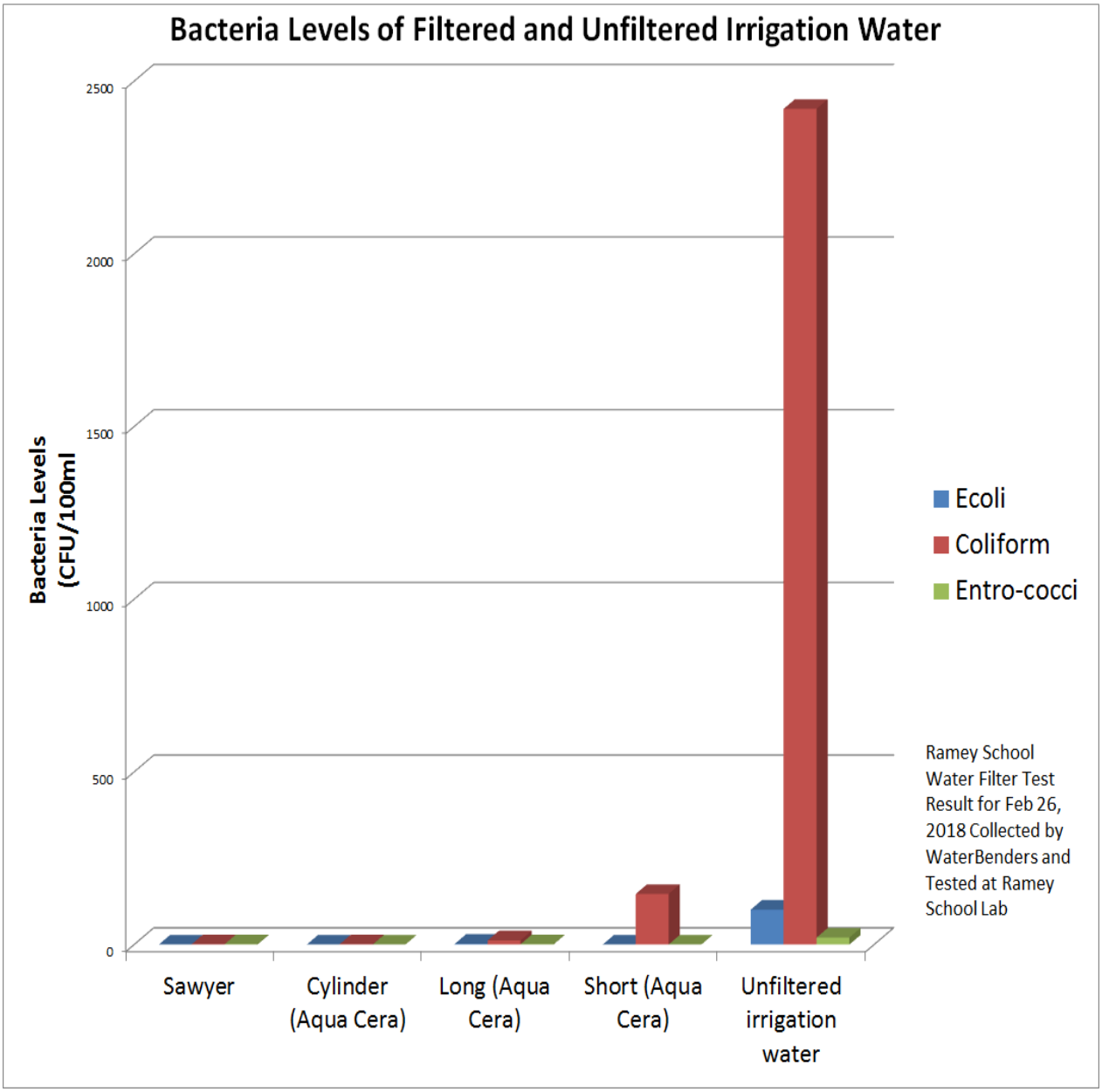


The tap water results show no bacteria except for the unfiltered sample, enterococci (2 CFU/100 ml) which is most likely due to contact contamination. The strong smell of chlorine from the tap water should have resulted in no bacterial presence due to the treatment process.

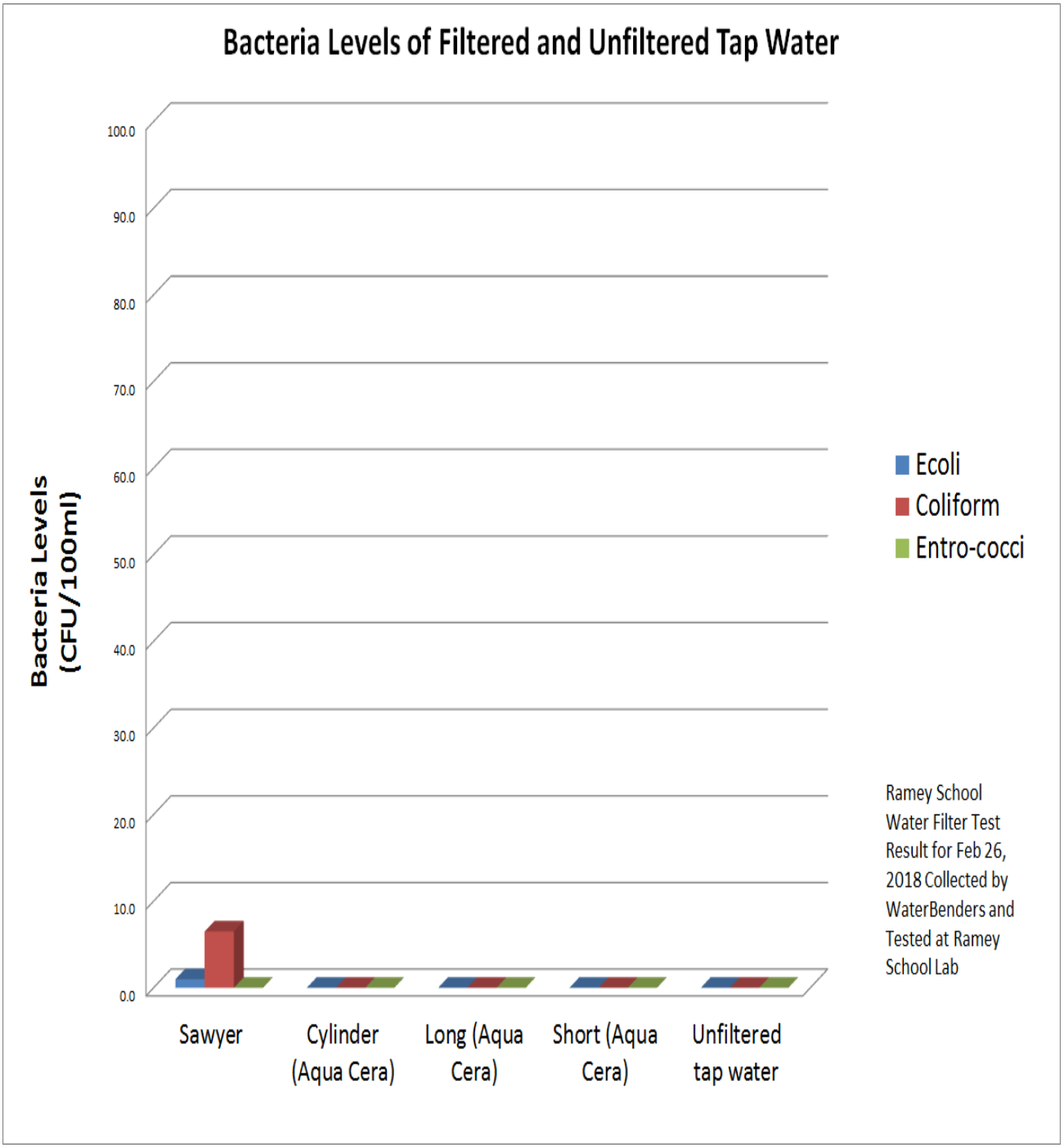


The results from the February 26, 2018 testing at Ramey School Lab are shown in the following two graphs:

After collaborating with the Surfrider Rincon Foundation, we re-tested the bacterial levels due to the possible contact contamination in the original testing. Our results were similar to the tests on February 1, 2018 but had more possible contact contamination. Again, the unfiltered irrigation water had high levels of total coliform (>2419.4 CFU/100 ml), E. coli (101 CFU/100 ml), and enterococci (20.1 CFU/100 ml). The filtered water again showed little to no bacterial levels, except Short (Aqua Cera) total coliform (146.2 CFU/100 ml) which was probably also due to contact contamination.

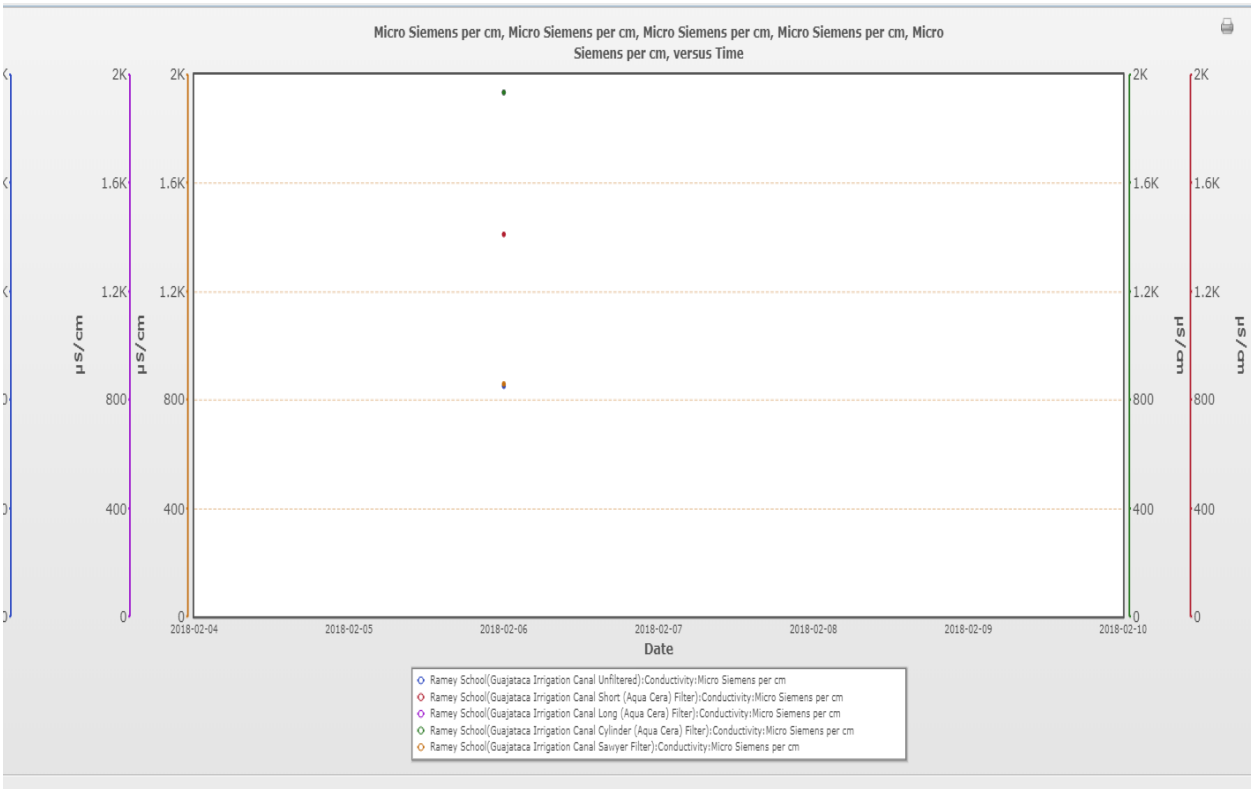


The tap water results show no bacteria except for the Sawyer filter sample, total coliform(6.5 CFU/100 ml), E. coli (1 CFU/100 ml) which is most likely due to contact contamination. Both tests showed very similar results: unfiltered water showed high total coliform bacteria and the filtered water no or very small levels of bacteria.



GLOBE Water Quality Comparison

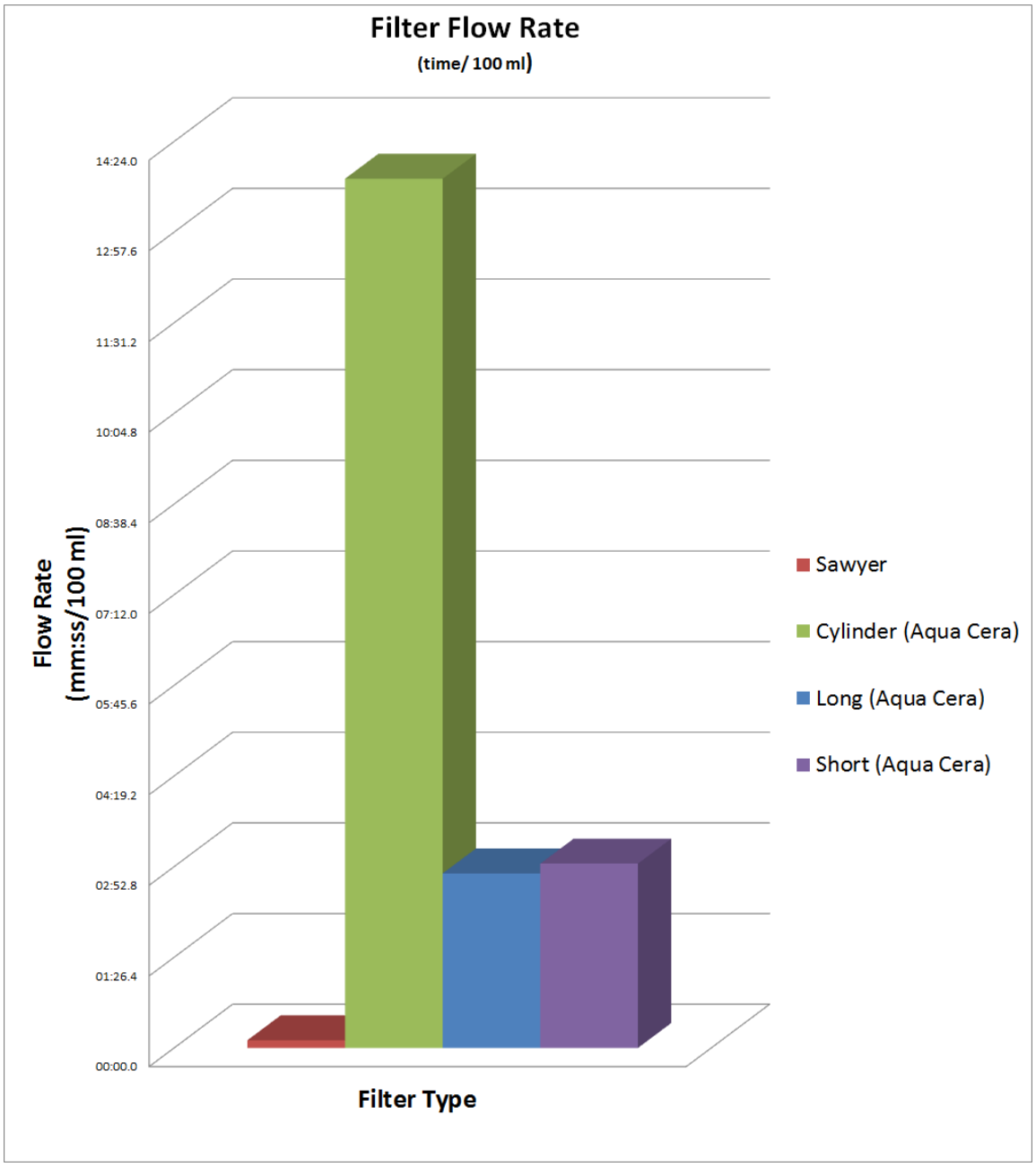
The following three graphs compare the irrigation water and filtered using the four filters for Conductivity, Dissolved Oxygen and Ph.



The data table below includes other data collected using Vernier probes and the flow rates data for each filter.

	Dissolved Oxygen Probe (mg/L)	Conductivity Probe (µS/cm)	ORP Sensor (mV) Not Calibrated	pH Sensor	Temper-ature (C°)	Flow Rate (time/ 100 ml)	Flow Rate (time/ Liter)	Notes
Filter Type Irrigation						mm:ss.s	h:mm:ss	
Sawyer	7.8	858	236.8	7.12	22.3	00:07.3	0:01:13	Fast flow rate
Cylinder (Aqua Cera)	6.2	1934	203.2	7.05	21.8	13:48.5	2:18:05	Very Slow flow rate
Long (Aqua Cera)	7.5	1934	222.1	6.63	21.4	02:46.4	0:24:04	Slow flow rate
Short (Aqua Cera)	5.6	1410	222.2	7.28	21.8	02:55.7	0:29:17	Slow flow rate

When we measured the flow rate and found that the Aqua Cera Cylinder filter was very slow (2 hour 18 minutes for 1 liter of water). The other two Agua Cera Long and Short filters took about 24 minutes and 29 minutes per liter respectively. The Sawyer water filter was fastest at 1 minute 13 seconds per liter.



GLOBE Conclusion

After five months of researching water quality, probes, bacteria, and the efficiency of our four filters, we had finally acquired the answers we were searching for. By filtering both our irrigation water and our tap water, we could greatly regulate if not fully cleanse the bacteria from our water sources. Although all four of our filters gave impressive results, the Sawyer and the Aqua Cera Cylinder filters functioned and gave the best result.

While both filters achieved an equal bacterial count, the Sawyer filter performed the fastest; therefore, we concluded that this filter was the most efficient way to filter our water.

Our findings impacted the community by making it easier for people to identify which filter would be most effective. Based on the findings, our team was able to spread awareness to others about the bacterial contamination in their water.

One of the errors we made while conducting some of the bacterial tests was that one of the team members possibly contaminated some of the water due to a lack of gloves, which then resulted in our data being altered. Therefore, in future trials we will take careful precautions when conducting tests to ensure that each of our tests is accurate and uncontaminated.

Throughout this journey we were guided by our Globe teacher, Richard Roettger. When we learned about the bacteria found in the unfiltered irrigation water we were all personally affected; this was the water we consumed after the hurricane. Mr. Roettger then went out of his way to find ways that we could expand our research and gain a greater understanding of this topic. In the end we had not only grown closer as a team but we had also learned new ways to help our community in these harsh times.

As we prepare to enter hurricane season again, these findings will help the people of Puerto Rico to access clean and safe water should we face another hurricane or natural disaster.

GLOBE Badges

Collaboration Badge:

Our team is made up of two ninth grade students: Elisa Torres-Yeckley and Kaymarie Jimenez; and one tenth grader: Giovanishka Gonzalez. We divided our tasks and responsibilities based on our strengths. Elisa wrote down our data and was in charge of creating spreadsheets while Kaymarie prepared the probes and Giovanishka conducted each test. Kaymarie and Giovanishka conducted each test and prepared for the upcoming ones while Elisa would record each result into our datasheet, this way time was used efficiently and everyone had a task.

Community Impact:

After Hurricane Maria, all of the inhabitants of Puerto Rico were left without water or power. The communication lines were down, cutting us off from the outside world. Many people were on the first flight out of Puerto Rico and many others came to help. A non-profit organization named Water Filters for Puerto Rico donated over 1,000 water filters to the island. Mr and Mrs McFarland two of Ramey School's teachers donated three of their filters for our project. Our team was then able to perform our test and evaluations for the bacterial count. In the end, our team was able to spread awareness about the levels of contamination that were found within the water samples. This in return helped the community, in particular those who still did not have access to a safe and sanitary water source.

Connecting to a STEM Professional:

When beginning our project, our team partnered with the Surfrider Rincon Foundation to test the filtered and irrigation water for enterococci, E.coli, and total coliforms. The individual who contributed to our project was Steve Tamar. Mr. Tamar has been part of this organization for a few years and was a major help during our project. He expanded our view on how water filtering companies tend to use chlorine to filter out bacteria but also how that chlorine can also affect the individual who is consuming the water. Mr. Tamar also gave us insight on how to detect forms of bacteria in water. Overall, he helped our group improve our data results and their precision. After meeting with Mr. Tamar, we conducted a second bacterial test and sent the results to verify if they were accurate. By the third test, our team had already mastered how to conduct a bacterial test, all thanks to Mr. Steve Tamar.

Resources

Fundación Surfrider Rincón
https://rincon.surfrider.org/

Water Filters for Puerto Rico
https://waterfiltersforpr.com/

Waves4water
http://www.wavesforwater.org

EPA **National Primary Drinking Water Regulations**
https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

The Entrolert and Coliert product service sites:
https://www.idexx.com/en/water/water-products-services/enterolert/

https://www.idexx.com/en/water/water-products-services/colilert/

Costa Salud Community Health Centers
http://www.costasalud.com/

Mr Steve Tamar and the Ramey School's Waterbenders and Aquarico Teams at the Costa Salud Community Health Centers (Temporary Rincón Surfrider Foundation Lab)