Use of Filters and UV Rays for a Dual-Filtering System During Disasters

The Golden Carp

Shibuya Senior High School Shibuya

Japan

Nanako Asakura, Mone Muroi, Yuino Senta

ishihara@shibushibu.jp

Abstract

The 3.11 earthquake showed us the reality that Japan was unprepared for such a large-scale disaster. Especially in large cities, due to the large population, the demand for water during disasters is high, creating a situation in which there may not be enough water for all. It is typically said that people can only survive without water for three days and therefore, our group concluded that we need to create a system which allows people to have access to safe water. We intend to achieve this through a dual-filtering system that uses filters and ultraviolet (UV) rays to purify fresh water from local sources such as fountain water and rainwater. The collected water first goes through a filter composed of pebbles, activated charcoal, and then gauze removes the remaining contaminants, converting the fresh water to hyaline water. Once this is processed, UV rays are used to sterilize the water which may be contaminated out of dangerous bacteria. Since UV rays are absorbed by black, we will create the machine with a black plastic box and a glass lid designed to collect UVB (a type of UV ray) to sterilize. Thus, realizing the dream to create enough safe water for all.

Keywords

1. safe water 2. sterilization 3. purification 4. UV Rays (UVB) 5. disaster

The Purpose of the Research

The Great Hanshin-Awaji Earthquake in 1995, the Great East Japan Earthquake in 2011, and the Kumamoto Earthquake in 2016 made us realize how crucial water is during disasters.

After each earthquake, cities surveyed temporarily displaced people to see what difficulties they faced in the shelters. The availability of water was constantly mentioned in all surveys. People cannot live without water for more than five days. This is because about 60~65% for adults of our bodies are made of water and once that amount of water starts to decline, dehydration symptoms occur. Losing more than 20% of water leads to death. Additionally, not having enough water accelerates secondary health damage, such as the Deep Vein Thrombosis. This is a syndrome where blood clots are created deep within the legs, potentially causing death. During the Kumamoto Earthquake, about 11 people died from these secondary effects which could have been ameliorated with some water.

These data clearly show how water is essential to the human race and our group concluded that everyone, no matter the situation, should have access to potable water. Normally, Japan has clean, purified water and therefore we decided to create a system which would supply people with water in times of disasters.

Method of the experiment

The idea of our main focus-the ultraviolet ray water purification system-came from the organization, Solvatten. This organization created a machine which used ultraviolet rays and heat from the sun to sterilize contaminated water to make it potable. According to the organization, this machine is designed for developing countries with a warm climate, such as countries in Africa, but also works in countries with four seasons, although it isn't as effective. Therefore, we contacted Solvatten and asked some questions about their product. Consulting the information given to us, we decided to make a UV ray/heat using sterilizing machine.

Experiment on the Simple Filter

As a result of consulting prior research and organizations which have developed purification technology, we reached a conclusion that we need to create a dual filtration system using a simple filter and a sterilization system using ultraviolet and heat rays.

To be more specific, for our simple filter, we decided to layer materials such as activated carbon, gauze, and granite pebbles (especially the granite from Gifu prefecture due to

the fact that one of our group member has a family there who works with granite). Activated carbon works to absorb toxic substances with the Van der Waals force, playing an essential role in making the fresh water safe. Also, the gauze keeps the larger impurities from going down the filter with the purified water. Additionally, granite pebbles are well known to have a water purification effect which helps to create safe, potable water. Since the particles that compose the rock are larger than other similar rocks, granite pebbles are able to be used for refining water.

Experiment on Whether E.coli Exist in the Water Around Us

From our research, we found out that the amount of E.coli included in the water is used as a standard for water quality. Thus, we decided to make E.coli as our standard for our sterilizing system as well.

In order for our system to function, there was a need for us to experiment to see if E.coli exists in the water around us. Therefore, we collected some water from the school fountain, the Yoyogi park fountain, and the leftover of snow, which are available water resources in the urban areas in terms of disasters.

We bought an experiment kit which uses β- glucuronidase and experimented to see whether E.coli exists in the fountain water (β- glucuronidase is an enzyme which attacks glycosidic linkages in natural and synthetic glucuronides). We injected 1 milliliter of both fountain waters in to the test tube which has liquid containing β-glucuronidase inside and cultivated this liquid for 24 hours in an incubation room.

Effectiveness of Sun Heat for Sterilization

This system allows the water to be sterilized by the UV rays from the sun, but it also heats the water with the sunlight as well. Therefore we decided to experiment about the effects the water receives from heat.

We first used tap water to see how high the water temperature would go up when we left the water in three different places around the school: the 9th floor, 6th floor, and the entrance. Later, we checked whether or not heat itself has any effectiveness in sterilizing water by using β-glucuronidase.

Experiment on the Effectiveness of Ultraviolet Rays and Sun Heat for Sterilization

From our prior research, ultraviolet rays are easily absorbed by the color black and are easily reflected by aluminum foil. Therefore, we conducted three experiments to test the credibility of these information and to test whether these materials help to sterilize the contaminated water. In order to perform this experiment, we bought two translucent boxes (270mm×170mm×130mm), thick black paper, aluminum foil, and some black plastic tape. Each container contained 1.75 liters; half the amount of water from “ Effectiveness of Sun Heat for Sterilization”, a thermometer taped to one side of the box, a simple lid made from a plastic wrap in order to prevent water from evaporating, and a triangular shaped rock to tilt the box towards the sun. The three experiments are the following:

・ Taped the thick black paper with the black plastic tape on all sides except for the top and bottom to see how effective the sun heat is to sterilizing water.

・Covered the box with aluminum foil to test whether the idea of making the ultraviolet rays reflect would be effective.

・Combine the first and second experiment together to see if combining these would help to make sterilizing water more effective.

From these three boxes (the black plastic box covered with aluminum foil on the inside, the black plastic box, and the transparent box with aluminium covers), we chose the one that worked out better in the experiments for the actual system.

Colony Formation for the Number Comparison of E.coli

In addition to our β- glucuronidase experiment (see “Experiment on Whether E.coli Exist in the Water Around

Us”), we decided perform an experiment of colony formation on E.coli in order to collect data on whether our sterilizing system is working to decrease the number of E.coli in the fountain water. According to the Ministry of Health, Labour and Welfare, the amount of E.coli accepted in tap water is “none”. Therefore, in order to create potable water with the resources around us, we must set our goal in completely eradicating this bacteria.

In order to count the number of E.coli in the water, we created a fixed medium from scratch. We used two sticks of LB AGAR powder (Figure 1), dissolved it into 200 milliliters of water, and sterilized the liquid with an autoclave. After the autoclave, we sterilized all the materials (a petri plate, surgical tape, scissors, marker, bacteria spreader, and micro pipette) we needed to make 10 plain mediums. Once the mediums are solidified, we applied 1 microliters to the plain medium and spread it with a bacteria spreader. When the liquid is completely stretched out, we sealed the petri plate with surgical tape and placed it in the incubation room and waited for it to culture.

Figure 1: The agar powder we used for making a medium for cultivating E.coli

filter container due to the fact that bottles are relatively easy to get even in the evacuation shelter.

Also, while consulting prior research we found data which proves that both activated charcoal and bamboo carbon have the same effectiveness for water purification. Since bamboo carbon is easier to obtain in times of emergencies, we decided to use this as an alternative. The first time we used the plastic bottle as our container, we were not able to make the water transparent and litter free because of the small particles from the decomposed rocks and bamboo charcoal that came trickling down with the water(Figure 2&3). We lightly rinsed the materials to remove the particles. However, this did not work and we had to find another way to keep the water clean and free from the small grains. Additionally, the cotton that we applied on the last part of our filter kept coming off and so we decided to find a way to keep the particles within the filter and the cotton to stay in place.

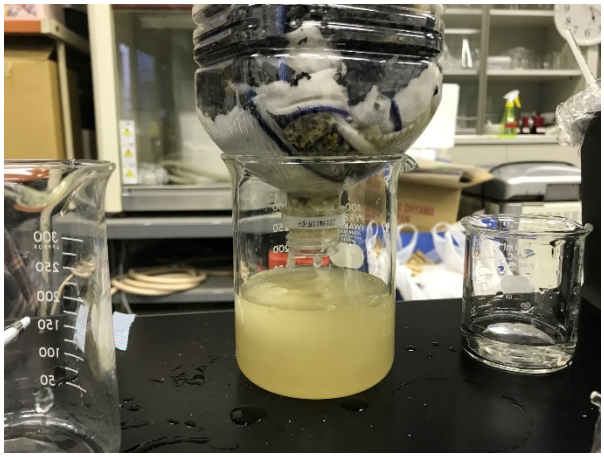

Figure 2: The results of attempting to filter tap water with the first filter we made

Results of the experiment

Experiment on the Simple Filter

Our first filtering container was completely handmade rolling a plastic board and gluing on a funnel. Keeping in mind the fact that we plan on using this system in times of disasters, we decided to use a 2 liter plastic bottle as our

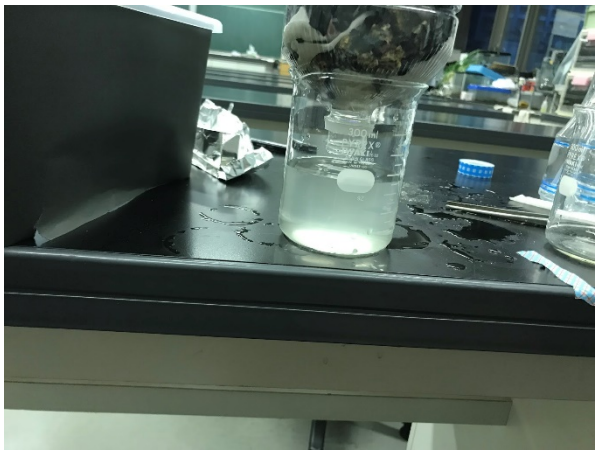

Figure 3: The result of filtering water twice with the first filter

This is when we realized the possibility of using tea bags as a filter for the decomposed granites and bamboo charcoal. Although tea bags let water through, it prevents the small particles from trickling down with the liquid and therefore, we decided to test its' efficiency. We made another filter container using the same method, except the decomposed granite and the bamboo charcoals were each contained in independent tea bags.

From experimenting the new filter a couple times with tap water, we found that the new filters with the tea bags work perfectly in ceasing the particles from mixing with the filtered water and making the two materials stay in place. We also tried this tea bag filter with the water from our school fountain to see whether the water would become any clearer because as in Figure 6 the water is cloudy. From filtering we found out that it improves the water color and transparency.

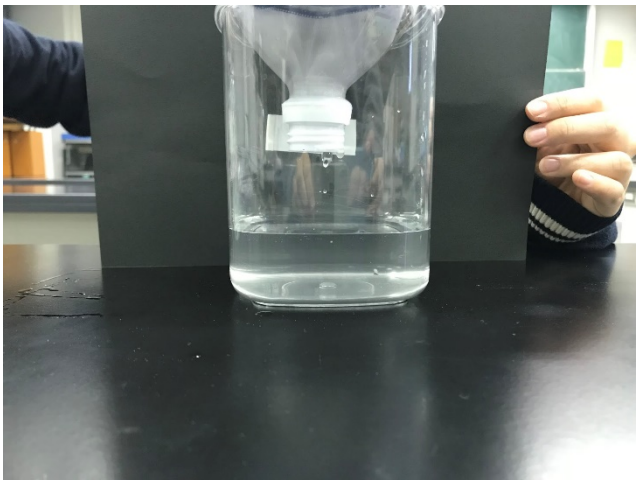

Figure 4: The result of filtering tap water using the filter made by tea bags

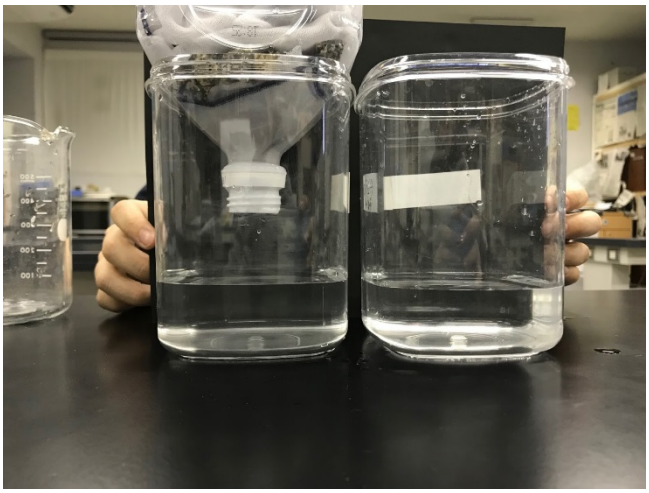

Figure 5: Comparing the filtered water with tap water (filtered water to the left, and tap water to the right)

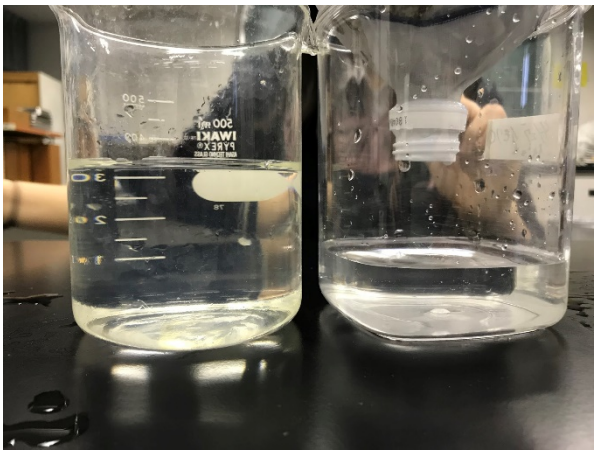

Figure 6: Comparing water from our school fountain and the same water that want through filtering (unfiltered water to the left and filtered water to the right)

Experiment on Whether E.coli Exist in the Water Around Us

After 24 hours of cultivating the liquid in the incubation room, we illuminated a black light on the test tube to check the presence of E.coli in each of the sample water. If the β-glucuronidase with the water emits light, this shows that

E.coli do exist within the water and if not, the water is free from E.coli.

As a result of cultivation, the test tube with the school fountain water emitted light when illuminated under black light (Figure 7), which is solid proof that E.coli exists in the water.

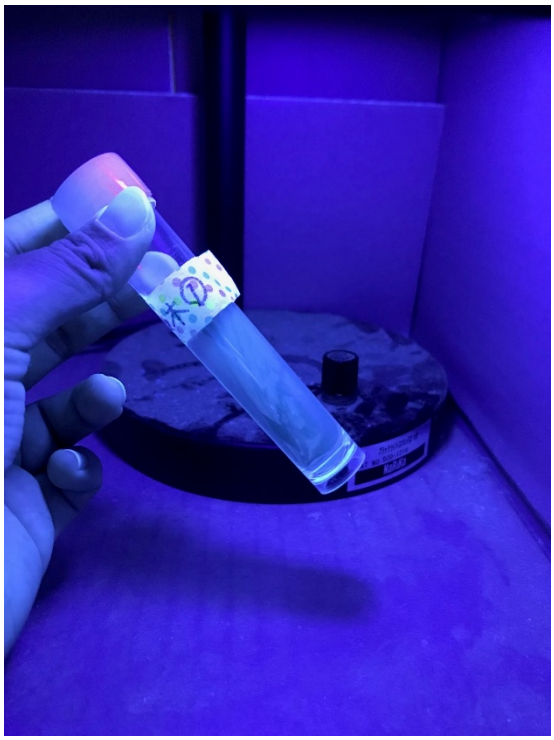

Figure 7: Yoyogi park fountain water

However, the Yoyogi park fountain water emitted less light when illuminated under black light (Figure 8) and therefore, we are not completely sure about whether E.coli exists within the fountain water and we plan to do additional research on this.

Figure 8: School fountain water

Also, when we experimented with the water from melted snow, the result completely differed depending on where the snow came from. While the snow from Tama-ku in Kanagawa was relatively clean and had less E.coli, the snow from Saitama city had a large amount of E.coli. Though this remains conjectural, we think that the bacteria which potentially exists on people's shoes had spread to the snow and increased in number, from the fact that the snow from Saitama city had been stepped on many times after the snow storm. Although most of the snow has melted, if possible, we would like to do some further research about this.

Effectiveness of Sun Heat for Sterilization

We placed 3.5 liters of water in the places we listed earlier, the 9th floor, 6th floor, and the entrance. We performed this experiment on February 14th, which was a sunny day with the highest temperature rising up to 10.6°C and the lowest at 0.0°C. The water we used was taken from the same tap in the same room, and at the start of the experiment, which was around 8:00 AM, the water was 16 °C. However, by noon and the afternoon, the water temperature had dropped greatly in all three places (see table 1).

Table1: The effect of the sunlight heat

	08:00 (at the start)	12:15	15:15
Entrance	17□	5□	8□
6F	17□	12□	11□
9F	17□	10□	11□

From these results, we concluded that on winter days, even with the sun out, the water temperature does not go above 25 □. Therefore, during this time of the year, we cannot expect much heat sterilization. Additionally, from the experiment that we conducted earlier on the school fountain ("Experiment on Whether E.coli Exist in the Water Around Us"), the water was proven to be contaminated with E.coli although the fountain is outside: constantly basking under the UV rays and heat from the sun. From this, it is clear that the water temperature is not affected by sunlight on winter days and that there is almost no effect of heat sterilization while exposing water to sunlight on cold, winter days. After submitting the research paper, we do plan to test the same experiment during the summer.

Experiment on the Effectiveness of Ultraviolet Rays and Sun Heat for Sterilization

To put this experiment into action, we bought a translucent plastic box (Figure 9), aluminum foil, and some thick black paper.

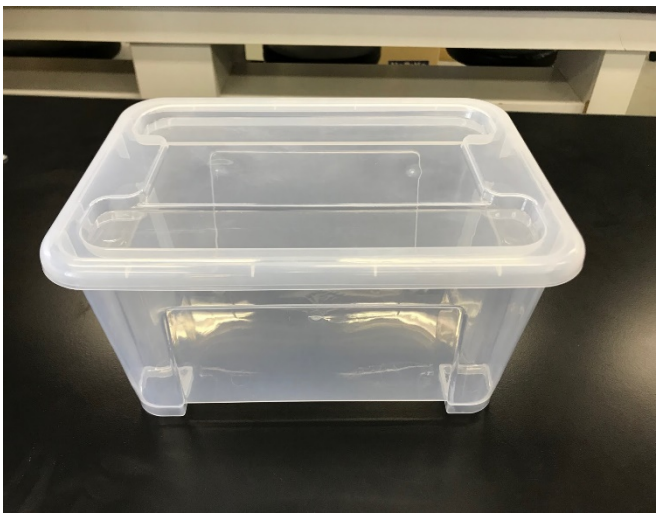

Figure 9: Plastic box

First Sterilizing Test

On our first try, we decided to combine all the materials (the plastic box, aluminum foil, and the black paper) together (Figure 10 & 11); which is our ideal form of the machine according to our hypothesis.

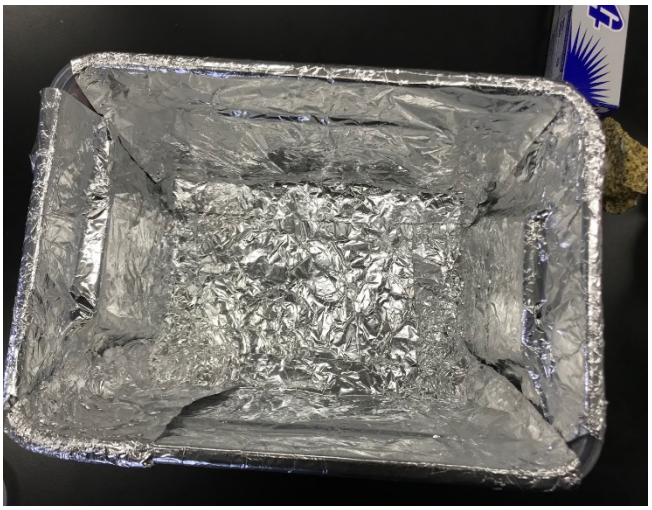

Figure 10: Inside the box

Figure 11: Outside the box

For this experiment, we placed 1.75 liters (half the water used in “Effectiveness of Sun Heat for Sterilization”) of the school fountain water and placed it on the 6th floor balcony. The day was February 17th, a sunny day with a high temperature of 12.3□ and a low of 0.6□. Then again, like in “Effectiveness of Sun Heat for Sterilization”, we took note of the water temperature at around 8:00 AM, 12:00 PM, and 2:30 PM.

Table 2: First sterilizing test for school fountain water

	08:00 (at the start)	12:15	14:30
6F	7□	18□	12□

Once this experiment was performed, we took 1 millimeter of the tested water and dispensed it into the β-glucuronidase to see if the water had been sterilized. 24 hours later, we placed it under a black light and unfortunately, the water sample emitted light, showing us that the experiment had failed to sterilize the water. Although in this experiment, we failed to sterilize the water, it made us wonder if our experiment had decreased the number of E.coli in the water. Therefore, we decided to do an additional experiment of colony formation to observe the number of E.coli and compare the data with the water before and after the experiments (see “Colony Formation for the Number Comparison of E.coli”).

Second Sterilizing Test

On February 27, 2018 we conducted the sterilizing experiment for the second time. Only for this experiment, we did not combine the Aluminum Foil and the Black Paper, but instead we only taped the black paper around the plastic box to see whether this would bring about some better results than the first one. Also, learning from our last experiment, we made a slight difference in where we placed our box to a place where the sun shone a little more and we also slightly moved the boxes so that it would be facing the sun more. This day had almost the same condition as the 17th with the highest temperature being 12.8□ and the lowest being 3.9□. These were the results:

Table 3: Second sterilizing test for school fountain water

	08:10	12:20	16:10
6F	8□	20□	18□

As a result, the water temperature rose to a point that we did not expect from the result we got from the first sterilizing test. Then again, we took 1 milliliter of the tested water and conducted the same process as “First Sterilizing Test” to find out the existence of E.coli in the tested water. This time, unlike the “First Sterilization Test”, we were able to affirm the extinction of E.coli in this water from the fact that the test tube did not emit light when it was placed under the black light (see Figure 12).

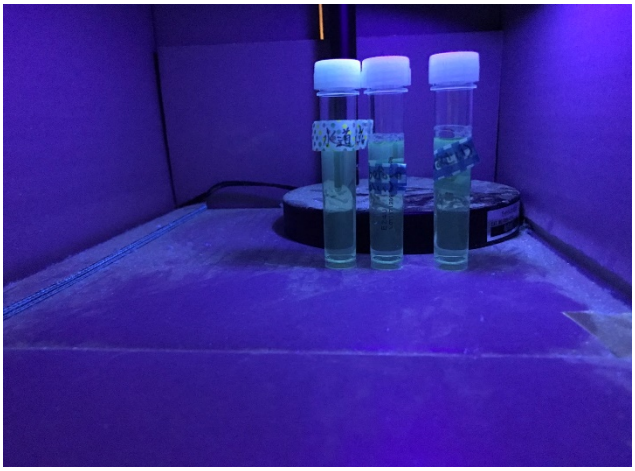

Figure 12: the result of inspecting the water we sterilized using the machine we made, compared with the original water which is not sterilized

Third Sterilizing Test

On February 28, 2018 we conducted another experiment similar to that of the “First Sterilizing Test” and the “Second Sterilizing Test”. However, for this experiment as well, we made slight differences; for this plastic box, we simply taped aluminum foil on the inside. Other than this change, the sterilizing process is the same as the experiments before and we performed this experiment on a day with a similar temperature condition as the other two days. The highest temperature being 14.7□ and the lowest being 3.3□. This was our result:

Table 4: Third Sterilizing Test for School Fountain Water

	8:15	12:30	15:20
6F	8℃	17℃	17℃

Colony Formation for the Number Comparison of E.coli

As a result of examination, in the plain medium with bacteria from both the original and sterilized fountain water, we were not able to find any colonies in the original water but many colonies in the water that we had attempted to sterilize. However we were not able to see any light emit from the experiment kit we used to examine the amount of E.coli. From these two contradicting results, we could not get a clear vision of what is going on inside our sterilizing machine and therefore we are planning to repeat the same experiments until we get a clear conclusion.

Conclusion

When we performed the above experiments, it was during the winter season and thus the amount of ultraviolet rays and the heat from the sun decreased to one-fifth of that in summer, giving us less choices for the variety of experiments that we could conduct. For these reasons, the results were not convincing enough and we could not reach a clear conclusion about the effectiveness of our sterilizing machine using ultraviolet rays and heat from the sunlight. Since the seasons in Japan will soon shift to spring and summer, we are planning on doing further experiments. Also the repeated experiments proved how the water quality in the fountain are very unstable and therefore very hard to deal with just a simple system. However, in order to realize the use of this machine during disasters, there is a need for it to be functional even in the coldest days and by the filthiest waters because we created this dual filtering system so that the people in evacuation would be able to use this as a life-line until the water distribution cars arrive. Therefore, once our experiment succeeds during the spring / summer season and we are able to prove the efficiency of our sterilizing machine, we would like to do some further research on how to make it as effective during those periods.

Additionally, we were able to confirm that the layered filter clearly had the ability to remove debris that were visible. Therefore we are assuming that the filter will work out nice enough for our original purpose, though we still think that we are able to improve the filter so that it can purify the water to a new extent.

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