THE CANADIAN SCIENCE FAIR JOURNAL

ARTICLE

SODIS Water Bottle Holder

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Poor water quality is a significant issue in our world. According to the Global Burden of Disease study, which is a global study on many common causes of deaths, poor water quality was responsible for 1.2 million deaths in 2017 (Ritchie & Roser, 2021). Therefore, it is critical to ensure adequate disinfection to reduce the death toll from poor water quality. When one thinks of a way to disinfect water, boiling is usually the first idea to come to mind; however, one may not realize that there are those who may not have easy access to electricity or fire to boil the water. After all, in a study from 2016, approximately 13% of the world population, or 940 million people, were shown to not have easy access to electricity (Ritchie & Roser, 2020).

Due to this reason, I have decided to investigate and develop upon one method of efficiently disinfecting water without having to rely on electricity, known as solar disinfection (SODIS). SODIS is a cheap way to disinfect water, where the ultraviolet (UV) rays from the sun inactivate pathogens (CDC, 2022). It has been proven to have a strong effect against bacteria (more than 99% of bacteria are inactivated) and a fair effect against viruses (more than 80% are inactivated) (CAWST, n.d.); however, it takes much longer to achieve this level of effectiveness on days without much sunlight. Thus, I wanted to build on this method and create a water bottle holder that utilizes the focal point of a reflective surface, such as aluminum, to reflect UV light that passes through the water to allow SODIS to be effective in disinfecting bacteria, even on days without much sunlight. Using a light cardboard frame as a prototype, as shown in Figure 1 below, I created said device by placing aluminum foil below where the water bottle will be held in a parabolic manner, with the focal point of the parabola set onto where the water will be so that any UV rays that hit the aluminum foil will reflect back into the water to disinfect it in a more efficient manner.

My hypothesis was that using aluminum foil in this parabolic manner as a reflective surface will increase the efficiency of SODIS, meaning that the amount of bacteria in the trials influenced by my device will be less than the amount in the controlled trials. To assess whether my hypothesis is correct, two water bottles contaminated with bacteria, one influenced by my device and another as a control, were placed outside in sunlight for two days before incubating the resulting bacteria on agar plates. After two days of incubation, the amount of the agar plates covered by bacteria in each trial was measured for comparison.

MATERIALS AND METHODS:

To begin, 100 mL of distilled water was poured into each of two plastic water bottles. Then, a pill of Acidophilus bifidus was opened and poured into each water bottle. Subsequently, one of the plastic water bottles was placed and secured into my device at a flat 180-degree angle, as shown in Figure 1.

After two days of exposure to some sunlight outside, both bottles were retrieved, and six open agar plates were prepared on a flat table. Using a pipette, 250 microliters of the liquid from the influenced water bottle was transferred into an agar plate. Using a cell spreader, the liquid was spread to fully cover the entire surface of the agar plate. This process was done two more times to create three gels containing the bacteria from the bottle influenced by my SODIS device (influenced trials). Similarly, 250 microliters of the liquid from the controlled water bottle was transferred into an agar plate. Using a cell spreader, the liquid was spread to fully cover the entire surface the agar plate. This process was done two more times as well to create three gels containing the bacteria from the control bottle (controlled trials). The pipette tip was disposed of after each use. The agar plates were closed with their lids and then placed into an incubator. After two days of incubation at a temperature of 37 degrees Celsius, photos of the

Figure 1: SODIS Water Bottle Holder Device Under the Sun. Prototype of the SODIS device that has aluminum foil in a parabolic shape to reflect UV rays onto the water. A plastic water bottle was placed and secured into the SODIS device at a flat 180-degree angle.

agar plates were taken from the same height using a ring stand, which are shown below in Figures 2 and 3. These images were put onto a grid in a photo editing software for analysis, where I divided the number of grid squares occupied by the bacterial colonies by the total number of grid squares that the agar plate occupied.

While bacterial growth was observed in all trials, there was a clear difference between the influenced and controlled trials, both quantitatively and qualitatively. For instance, as shown in Figures 2 and 3, the bacteria spread more in the influenced trials when compared to the controlled trials after incubation. The percentages of the agar plates covered by bacteria in the influenced trials were around 89%, 92%, and 88%, while the percentages of the agar plates covered by bacteria in the controlled trials were around 80%, 82%, and 81%. Essentially, for the influenced trials, the agar plates were covered on average around 90% by bacteria, while for the controlled trials, the agar plates were covered on average around 81% by bacteria. One must note that this 9% difference is more significant than it seems when one accounts for the relative difference between them. The agar plates of the controlled trials had almost double the amount of space not covered by bacteria when compared to the agar plates of the influenced trials (10% vs 19%). However, certain qualitative observations could also be made. While the influenced trials only had colonies of small bacteria, the controlled trials contained both these small bacteria colonies and colonies of bacteria that were much larger in size when compared to the ones found in the influenced trials. The large bacteria colonies more than doubled the size of the smaller bacteria colonies found in the influenced trials. The difference in size between these larger and smaller colonies can be observed in Figure 6 below.

DISCUSSION

It was hypothesized that there would be fewer bacterial colonies on the agar plates of the influenced trials when compared to the controlled trials; however, the results did not support this hypothesis. Instead, as described in the Results section, there were more bacterial colonies on the agar plates of the influenced trials when compared to the controlled trials. This may be explained by the competition between different bacterial strains, as the bacteria I used, Acidophilus bifidus, is a multi-strain formula, meaning there are many different bacteria to be found (Webber Naturals, n.d.). As discussed by Hibbing et al., bacterial strains can impair or kill competition in the battle for survival (Hibbing et al., 2009). If the larger bacteria strains were inactivated in my influenced trials, the smaller ones would be able to prosper and produce more colonies. In contrast, in the controlled trials, the smaller bacteria would be competing with and being suppressed by the larger bacteria colonies. This may explain why more of the agar plates were covered up by bacteria in the influenced trials when compared to the controlled trials. Therefore, it is plausible that my device was able to inactivate certain bacterial strains, in this case the larger bacteria, allowing other bacterial strains to thrive instead. This is supported by the result that the influenced trials had only small bacteria colonies, while the controlled trials had both the small bacteria colonies and much larger ones. Furthermore, a possible explanation as to why all the bacteria were not inactivated may relate to the fact that the experiments were done on days without much sunlight, meaning that the bacteria may not have had the necessary exposure to UV rays to be inactivated. Thus, additional experiments should investigate the impact of regular SODIS and my new device on days with ample sunlight, to compare the results with the ones gathered in this experiment to see whether

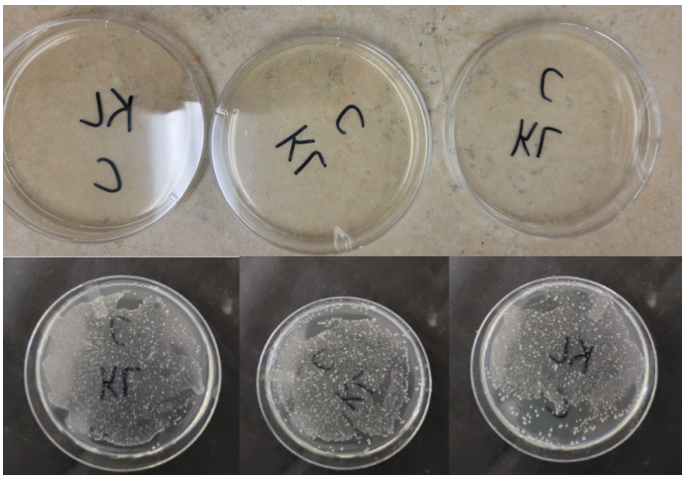

Figure 2: Agar Plates of the Controlled Trials. Three agar plates covered by bacteria from the controlled trials, before (top row) and after (bottom row) incubation.

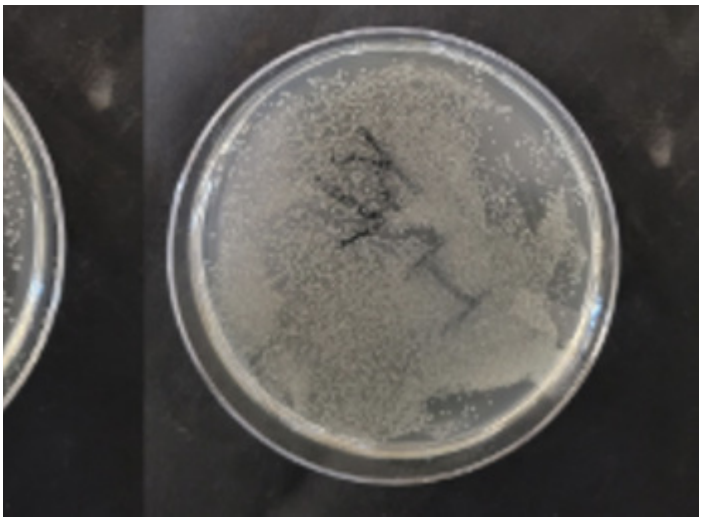

Figure 3: Agar Plates of the Influenced Trials. Three agar plates covered by bacteria from the SODIS device, before (top row) and after (bottom row) incubation.

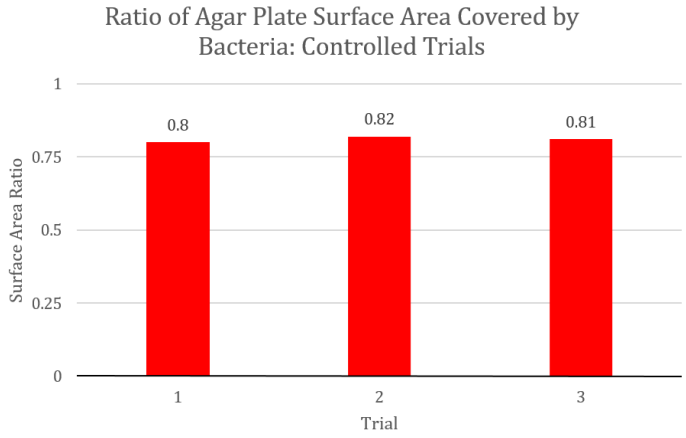

Figure 4: Bacteria in Controlled Trials. Graph showing the ratio of agar plate covered by bacteria of three controlled trials

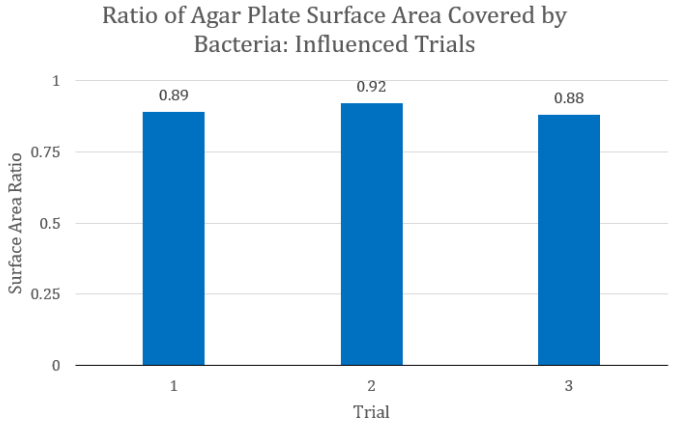

Figure 5: Bacteria in Trials Influenced by Device. Graph showing the ratio of agar plate covered by bacteria of three trials influenced by the device

my device is more effective on days with more sunlight. In addition, these experiments could explore the effects on different single-strain instead of multi-strain formulas, for that would give more comprehensive and conclusive results on the true impact on bacterial growth.

Overall, while no definitive evidence could be gathered on whether or not my device makes SODIS more effective, my results did indicate that despite the weather not being as sunny as desired, reflecting UV rays into the water with a reflective surface like aluminum foil with my created device was able to inactivate bacterial colonies that the normal SODIS method could not, despite this potentially leading to a greater amount of bacterial colonies and spread due to the competitive nature of bacteria.

CONCLUSION

Disinfecting water is critical for our society. Millions of people suffer and die from poor water quality each year. Therefore, it is essential to expand our understanding of affordable methods to disinfect water, like SODIS, and to keep on developing these methods to be as efficient and effective as possible. To that effect, in this study, I developed a novel device to improve the delivery of UV light during SODIS and carried out preliminary tests to evaluate the system's ability. There were promising results regarding disinfection of certain colonies, and further testing will be conducted to improve the system in the future. As our understanding of SODIS increases, we may be able to develop an affordable, reliable, and rapid method to disinfect water without having to use electricity, saving many lives all around the world.

ACKNOWLEDGMENTS

I would like to acknowledge my parents, Mr. Daniel Osborne, Ms. Erin Dallin, Dr. Ian Crandall, and Dr. David Dubins for helping me formulate an initial idea and always supporting me on this project.

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My name is Jonghoon (Kevin) Lim, and I will be in grade 11 in the 2022-2023 school year at Glenlyon Norfolk School in Victoria, BC. Having lived in three different countries, I have grown accustomed to a variety of diverse cultures that shape the person that I am today. My favourite subjects include science, math, and economics, while my favourite hobbies and activities include reading fantasy books, playing sports, coding, and especially playing the cello. I hope to continue my scientific endeavours with the Canadian Science Fair Journal to help make the world a better place.