Can You Drink a River? An Evaluation of Solar Disinfection Efficiency in the Inactivation of *E.coli* and *Coliform* Bacteria at a Northern Latitude

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I. Description of Research

Every year, 1.8 million people die from diarrheal diseases (World Health Organization [WHO], 2007). The leading cause of diarrheal disease is lack of a clean drinking water source. Around the world, 1.1 billion people lack an "'improved' drinking water supply" (WHO, 2007). Especially in rural areas, municipal water treatment facilities are not available and residents must take responsibility to disinfect their water individually.

One newer method of water disinfection in tropical areas is solar disinfection (SODIS), a method in which water in clear plastic bottles is exposed to sunlight for 4-6 hours on a clear day and the sunlight works to kill pathogens. Solar disinfection relies on the ultra-violet-A (UVA) rays of the sun and heat to deactivate the pathogens in the water by altering the nucleic acids of the organism and altering their metabolism. On an overcast day in warm climates, SODIS is effective if the water is left out for two consecutive days. In tropical countries, SODIS is a reliable method for reducing bacteria, viruses and protozoa, is easy, and virtually free of cost. (National Academy of Sciences, 2008).

Based on expansive review of the literature surrounding water disinfection summarized above, the author was inspired to join the global challenge of providing clean water to all. Solar disinfection has already been implemented in many developing countries worldwide, but is most commonly used in tropical climates. Also, many studies have been conducted in the laboratory in optimal conditions with artificial UV light. With this project, the author aimed to determine if solar disinfection could be used effectively at a northern latitude during non-optimal conditions (lower solar altitude and cooler temperatures). The author hypothesized that in water evaluated after exposure to UV from the sun in non-optimal conditions, the *E.*coli and General Coliform counts would be reduced to undetectable levels because even during times of low solar altitude and cooler temperatures, enough UV will still effectively interfere with the bacteria's DNA, inhibiting it from proper gene expression and further replication. In this way, if solar disinfection was found to be effective, developed nations could use solar disinfection during the first response of emergencies and developing countries in the northern hemisphere could also begin to apply this low-cost method of disinfection in their communities.

This experiment was conducted using water obtained from the Snoqualmie River to simulate realistic water sources. Testing occurred from January 27, 2011 through January 29, 2011 to achieve a low solar altitude, cooler temperatures, and semi-optimal conditions. The outside temperature, solar altitude, and environmental conditions were recorded on each day of sampling. After collection, the river water was distributed into 72 half liter PET bottles. Half of the bottles were laid on their sides on a corrugated metal surface raised about three feet of the ground in a field with adequate exposure to sunlight at Northwest University. This was meant to simulate the roof's surface of a typical home in a developing country. Half of the bottles were set in a cardboard box underneath a table to create a control group which would have the same environmental conditions, but no exposure to sunlight. At each sample time, eight bottles were retrieved, four from the group on the table, and four from the control group. Sample times were 9:30 a.m. (initial), 10:45 a.m., 11:30 a.m., 12:15 p.m., 1:15 p.m., and 2:30 p.m. On the second

day, sample times were 10:00 am, 12:00 pm, and 2:00 pm. At each sample, water was sampled from each bottle and the membrane filter technique was used to isolate *E.coli* and *Coliform* bacteria through incubation. After incubation, *E.coli* and *Coliform* colonies were counted from each bottle at each of the different sample times. The average number of *E.coli* and *Coliform* In this way, solar disinfection's efficiency as a disinfectant could be measured over 12.8 hours of daylight time.

The environmental conditions were recorded on each day of testing. On both days, the weather was overcast with some breaks and slight rain throughout the day. The outside temperature never rose above 12.22°C, not a significant temperature to create warm enough conditions for the inactivation of bacteria due to heat changes. The solar altitude was 24° compared to a solar altitude of 65.8° predicted for the summer solstice of June 21, 2011. These conditions were hypothesized to be non-optimal for solar disinfection's efficiency.

To analyze the inactivation of *E.coli* and general *Coliforms* over time by SODIS, the results from each group were separated into sub groups based on whether they were exposed to UV, and by how many daylight hours they were outside before being sampled, with group 1 having 0 daylight hours and group 9 having 12.8 daylight hours. The mean of viable bacterial cell counts for *E.coli* and general *Coliform* for the four bottles of each subgroup was calculated and recorded under the amount of daylight hours the bottles received. In regards to the inactivation of *E.coli*, after 12.8 hours, the UV group resulted in complete 100% inactivation of the mean viable cell counts while the group kept in the dark's mean viable cell count was reduced by only 11%. A two-sample t-test compared the mean *E.coli* viable cell count of the first UV group and the mean *E.coli* viable cell count of group exposed to 12.8 hours of UV. The difference between these two means was found to be statistically significant based on a p-value of 0.0004 and an alpha level of 0.05. A similar test compared the mean *E.coli* viable cell count of the first dark group and the mean *E.coli* viable cell count of the group kept in the dark for 12.8 hours. The difference between these two means was found not to be statistically significant based on a p-value of 0.594. This indicates that UV was an effective force in reducing *E.coli* even in non-optimal conditions. In regards to general *Coliform*, over 12.8 hours, *Coliform* was reduced by 88% in UV groups and by 55% in dark groups. The difference between the mean *Coliform* viable cell count of the first UV group and the group exposed to 12.8 hours of UV was found to be statistically significant with a p-value of 0.0003. A similar test compared the mean *Coliform* viable cell count of the first dark group and the mean of the group kept in the dark for 12.8 hours. The difference between these two means was found to not be statistically significant based on a p-value of 0.552. Although each group decreased noticeable, the UV group's percent decrease is considerably higher than the dark groups, again indicating that SODIS was a significant source of General *Coliform* inactivation.

This experiment was conducted to evaluate solar disinfection's efficiency in the inactivation of *E.coli* and *Coliform* bacteria to disinfect drinking water obtained from a river at a northern latitude during periods of low solar altitudes and cooler temperatures. It was hypothesized that if water obtained for drinking from a river at a northern latitude was exposed to UV rays from the sun, that *E.coli* and Coliform would be reduced to undetectable levels after exposure even during non-optimal condition (temperatures below 12°C, heavy cloud cover, and a low solar altitude).This hypothesis was not supported, as *Coliform* was not completely inactivated after exposure. It can be concluded that solar disinfection is not an effective method for disinfecting water obtained for drinking when conditions are non-optimal at a northern

latitude, although it does play an effective role in reducing bacteria significantly. In the future, a long term experiment investigating how the solar altitude affects solar disinfection's effectiveness would be beneficial to determine whether time of year has a major effect on solar disinfection's performance.

Reference: World Health Organization. (2007). *Combating waterborne disease at the household level: part 1*. Retrieved from http://www.who.int/water_sanitation_health/publications/combating_diseasepart1lowres.pdf