THE MICROBIOLOGY OF SOLAR WATER PASTEURIZATION WITH APPLICATIONS IN KENYA AND TANZANIA

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THE MICROBIOLOGY OF SOLAR WATER PASTEURIZATION, WITH APPLICATIONS IN KENYA AND TANZANIA

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ABSTRACT

The purpose of this work is to establish the microbiological parameters for solar water pasteurization, and to present methods that enable point source water testing in remote areas. Heating contaminated water to 65°C will pasteurize water and make it safe to drink, in a manner similar to milk pasteurization. A reusable, wax-based Water Pasteurization Indicator (WAPI) verifies that 65°C has been reached. The simple Cookit solar cooker is being used in the Nyakach area, Nyanza Province, Kenya, both to cook food and to pasteurize contaminated water from shallow wells. As a result, solar cooks who also pasteurize their water report a dramatic decrease in diarrheal diseases. Accurate microbiology tests of local water sources can be performed using the Colilert MPN test and the *E. coli* count Petrifilm test. The package of water testing, Cookit, and WAPI addresses two fundamental problems in developing countries – contaminated water and fuelwood scarcity.

1. INTRODUCTION

Worldwide 1.1 billion people do not have access to safe water. This annually leads to approximately 2 million deaths and 1.5 billion bouts of diarrhea, particularly affecting children.

When health officials make recommendations about treating contaminated water to make it safe to drink, the most common recommendation is that the water should be boiled. Boiling will kill all pathogenic microbes in water, but this level of heat is far in excess of what is required. What has been missing in discussions about unsafe water is the inclusion of the concept of pasteurization, which has been accepted within the food industry for over a century. Pasteurization is the use of moderate heat to kill pathogenic microbes. It is different from sterilization, in which all microbes, potential pathogens as well as non-pathogens, are killed. To pasteurize milk in a continuous flow operation, only 15 seconds at 71.7°C is required. This heat treatment would also pasteurize water.

2. MICROBIOLOGY

2.1 Heat Inactivation of Pathogens

What conditions are required to pasteurize contaminated water? To answer this question, one must determine the inactivation rates of water pathogens at various temperatures. Borrowing again from food microbiology, there are extensive published studies on inactivation rates of microbes in foods, buffers, or water. The inactivation rates are expressed as "D-values," the time to cause a decimal reduction in viable cells or spores. One D reduction is equal to 90% inactivation, or a one-log inactivation. A 5D reduction would kill 99.999% of microbes, and be a five-log reduction in viable cells.

The temperatures required to cause at least a one D reduction of common water-borne pathogens within one minute are: 55°C (131°F) for worms and cysts of the protozoa *Giardia, Cryptosporidium*, and *Entamoeba*; 60°C (140°F) for the bacteria *Vibrio cholerae*, Enterotoxigenic *Escherichia coli*, *Shigella sp., Salmonella typhi)* and for

rotavirus; and 65°C (149°F) for Hepatitis A virus. As the temperature rises above 55°C for protozoa, or 60°C for bacteria and rotavirus, the D value, or time required for a one log inactivation, decreases significantly. For example, the D value for these bacteria at 65°C is less than 12 seconds, which translates into >5D reduction in just one minute.

Using published D value data and and our experimental results for water-borne pathogens, we established that heating contaminated water to 65°C will pasteurize the water and make it safe to drink (1). The total lethality will be the sum of the D reductions as the water heats from 55°C to 65°C, and then cools down below 55°C, when D values for bacteria are >2 minutes. As batch heating of water will have water temperatures from 60-65° for several minutes, cumulative D reductions for the water pathogens will by >10 D, reducing whatever level of pathogens to zero.

2.2 Water Pasteurization Indicator

In order to verify that water reaches 65°C, volunteers for Solar Cookers International, Sacramento, CA, developed a reusable water pasteurization indicator (WAPI). The WAPI is a clear polycarbonate tube, partially filled with a wax which melts at 65°C, and sealed at both ends. The WAPI is placed at the bottom of a container, which is heated. If the WAPI wax melts and falls to the bottom of the tube, it indicates that pasteurization conditions have been achieved (2).

2.3 Solar Water Pasteurization

With the realization that 65°C is sufficient to pasteurize water, several solar water pasteurization products have been developed, including the Sol Saver (Safe Water Systems, Honolulu, HI), and the AquaPak (Solar Solutions, San Diego, CA). I have focused on using the simple Cookit solar cooker, developed by Solar Cookers International. The Cookit is made from cardboard and aluminum foil. To cook, dark, covered pots are placed inside a clear plastic bag, which is placed in the Cookit facing the sun. To pasteurize water, the clear plastic bag is not needed, and a WAPI is added to the container. With full sunshine, it takes about 2 hours to pasteurize 2 liters of water, and about 3 hours to pasteurize 4 liters.

2.4 Point Source Water Testing

Although contaminated water is known to be a major source of illness in developing countries, it is rarely tested because standard methods are inefficient, cumbersome, and require materials and facilities that are rarely available in a country as a whole. These facilities are almost certainly never in rural areas where water sources are most likely to be heavily contaminated. Thus, although water contamination is the likely source of much illness, local health officials are helpless to test various water sources in their area.

The best indicator of fecal contamination of water by people and animals is the bacterium *Escherichia coli*, which is present in human feces at a level of about one hundred million *E. coli* per gram. The presence of *E. coli* always indicates a public health threat, and water containing one *E. coli* per milliliter is considered heavily contaminated.

In order to do excellent microbiology in developing countries where there is no lab, I have used two complementary tests extensively in Tanzania and Kenya since 2000. The Colilert MPN test (IDEXX Laboratories, Westbrook, ME) is a presence/absence test, which is inoculated with 10 ml of water. The *E. coli* Count Petrifilm (3M Microbiology Products, St. Paul, MN) is used extensively in the U.S. food industry, and it gives a quantitative count from a 1 ml sample. Combined with sterile plastic pipettes and sterile plastic sampling bags, these tests enable serious microbiology to be conducted even in the most remote areas, with clear results present in 12-18 hours.

In my workshops on point source water testing and solar water pasteurization in Tanzania and Kenya, local water sources from shallow wells or open water sources have been heavily contaminated, often with >10 *E. coli*/ml. By sampling water before, and after heating in a Cookit to melt the WAPI wax, dramatic results are evident the following day – many *E. coli*/ml before heating, no bacteria after heating.

2.5 Solar Water Pasteurization Project in Kenya

Solar water pasteurization with a Cookit and WAPI is being included in the Sunny Solutions project, which Solar Cookers International started in 2003 in the Nyakach region, Nyanza Province, western Kenya, near Lake Victoria. In this area there is a high incidence of typhoid fever, bacterial and amoebic dysentery. In July, 2003, I led water testing/solar water pasteurization workshops for community leaders and women chosen to be the first solar cooker representatives in Nyakach. They performed the Colilert and Petrifilm tests which showed that their shallow wells were heavily contaminated with *E. coli*, and we demonstrated how to pasteurize contaminated water using a Cookit. Visits to the homes of 16 solar cooker representatives in July, 2004, found that each woman was heating water in a Cookit when she was not cooking, and was pasteurizing 5-10 liters/day. The women reported significant decreases in diarrheal diseases since solar pasteurizing water.

3. SUMMARY

The Millennium Development Goals (MDGs) include reducing by half the number of people without sustainable access to safe drinking water and basic sanitation by 2015. Even if these ambitious goals are achieved, there still will be about 600 million people without access to safe water in 2015. These are likely to be the poorest of the poor, in places like Nyakach, Kenya.

It is vital that the poorest people in the world learn how to use the only energy source they often have in abundance, sunshine, for basic human needs. Most of the 1.1 billion people who now do not have access to safe water are among the 2.4 billion people who cannot afford modern fuels for cooking, and use wood, crop residues, charcoal or dung in a non-sustainable manner. Surprisingly, the MDGs do not mention the extreme urgency for poor people to find a sustainable alternative to fire for cooking. Solar cookers can address both fundamental problems of unsafe water and fuelwood scarcity. Solar water pasteurization, using the innovative point source water testing methods and a WAPI, could provide new opportunities to introduce low-cost solar applications worldwide in a significant way.

4. REFERENCES

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