

Briefing note

What are the hazards associated with heating and storing water?

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M Price



Headlines

- Boiling water removes many but not all waterborne pathogens;
- Heated, stagnant water can provide optimal conditions for their growth;
- Heating water can increase the concentration of arsenic, nitrates, and other dangerous substances that cannot be removed through boiling;
- Heating water also increases the risk of leaching, depending on the storage containers being used.

Introduction

In a quest to minimise the energy consumed in cooking food and heating water, we have had a number of proposals that suggest using the surplus energy from Solar Home Systems, or from Solar mini grids to 'pre-heat' water. The core idea has been that if the surplus midday energy was used to pre-heat and store water, the cooking processes could start with 'hot' water, and/or the heated water could be used for washing. While this idea perhaps has some merits from an energy point of view, it introduces some risks related to waterborne diseases and concentration of minerals.

This note lays out the core risks, and we would encourage all applicants who are suggesting 'pre-heating' water to explicitly explain why their system will either not allow standing water, and guarantee the water will be sufficiently boiled before drinking and not lead to boiling water multiple times.

Heating-related risks

Boiling provides a sufficient level of water treatment to mitigate against a wide range of waterborne diseases, which may take the form of bacteria (e.g. legionella, E. coli), viruses (e.g. norovirus, hepatitis A), or protozoa (e.g. giardia)¹. The World Health Organisation (WHO) report that heating water to pasteurisation temperatures (60°C-70°C) for ten minutes “will kill most waterborne pathogens”, and heating to 55°C for a number of hours “will dramatically reduce non-spore forming bacterial pathogens as well as many viruses and parasites (including giardia). In the appendix of this document, you will find a graph highlighting the various temperatures and storage time required for water to remain safe from various pathogens.



Figure 1 Inspecting stored water. Credit: Simply Creative Photography/Getty Images, via Stockholm Environment Institute (2019)

However, **heated water** can provide favourable conditions for the growth of harmful bacteria such as *Legionella* and *Escherichia (E. coli)*. *Legionella* develops at temperatures between 25°C - 43°C, and can survive between 55°C - 60°C², and it is therefore paramount that cold water is kept below 25°C and hot water remains above 60°C in order to remove the contamination risk. *E. coli* is removed from the water once it reaches boiling point. A rolling boil should be sustained for at least one minute, and for longer at high altitudes³.

In addition to the static temperature readings in the graph (see appendix), *fluctuations* in water temperature (e.g. heating and storing water at different times and temperatures) support not just the growth of *legionella*, but also *nontuberculous mycobacteria (NTM)*, *pseudomonas* and others⁴. From a health perspective, the use of surplus solar energy to *heat* water is not necessarily a substitute for boiling, and it may even increase the risk to health. This is important given that people can be reluctant to spend time and energy boiling water, and particularly if the perception is that the water is already safe for consumption⁵. It is also worth remembering that, when solar energy is being used to heat water, the health-related effects will be depend on the external environment:

¹ <https://worldwaterreserve.com/potable-water/common-waterborne-diseases/>

² <https://link.springer.com/article/10.1007/s42452-019-0533-1>

³ <https://www.freedrinkingwater.com/water-contamination/ecoli-bacteria-removal-water-page2.htm>

⁴ <https://www.cdc.gov/legionella/wmp/overview/growth-and-spread.html>

⁵ https://www.who.int/household_water/research/HWTS_impacts_on_weakened_immunity.pdf

“Solar energy can be used effectively for sterilising drinking water during clear and partially cloudy days. However, during mostly cloudy days the temperatures required may not be reached”

(Nimbkar and Rajvanshi, 2013⁶)

In addition, if water is being heated at two separate stages - for instance using surplus solar energy and again at the point of consumption - the risk to health can *increase*. Some toxic substances cannot be removed by boiling or heating water, and so the more the water evaporates through heating, the greater the concentration of these substances. Below are two examples of such substances:

- High levels of **nitrate**s, which can often be found in water sourced from wells, require water treatment processes such as ion exchange and distillation⁷;
- High levels of **arsenic** have been counteracted in Bangladesh through different mechanisms, including a shift in well selection and strict adherence to sanitary standards⁸.



Figure 2 Bangladesh has had a particular problem with arsenic in tube wells. Credit: Development Planning Unit, UCL (2005), (via Flickr)

⁶https://www.researchgate.net/publication/286542951_Simple_filtration_and_low-temperature_sterilization_of_drinking_water

⁷ <https://www.cdc.gov/healthywater/drinking/private/wells/disease/nitrate.html>

⁸ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3013257/>

Boiling or heating water multiple times can therefore increase the health risk for consumers. While the risks of double boiling have been exaggerated when it comes to water supplies with low nitrate levels, the risk is significant in areas where nitrate levels are much higher⁹. High nitrate concentrations are often caused by issues with well construction, over-use of chemical fertilisers, and improper disposal of waste¹⁰.

Given the importance of treating water at the point of consumption, the use of surplus energy to heat water is only efficient and safe if the water is boiled and consumed soon afterwards.



Figure 3 It is common to see stored water for cattle drinking in plastic tanks. Credit: Malaria Consortium (2017), (via Break Dengue)

Storage-related risks

When water stagnates, microorganisms grow and metals leach into the water, causing the supply to become unfit for consumption¹¹. This is true whether water is stored in pipes, filters, heaters or cooling towers, and a regular flushing/turnover of the supply is essential to prevent hazards arising.

In areas where mosquitoes pose a risk to health, stored water that is not sufficiently sealed can provide a fertile breeding ground for the insects¹². Malaria, dengue fever, and other such diseases can be spread by larvae laid in still water¹³. Boiling water is effective in theory, but parasites may be present in other daily activities, and recontamination post-boiling is also a risk (Dinkel et al, 2019¹⁴).

Studies have also shown that bottled water can become hazardous when left in warm environments for a prolonged period of time. At elevated temperatures, polyethylene terephthalate plastic releases two chemicals

⁹ <https://www.wellness.com/blog/13297562/is-reboiling-water-really-dangerous/wellness-editor>

¹⁰ <https://www.cdc.gov/healthywater/drinking/private/wells/disease/nitrate.html>

¹¹ <https://phys.org/news/2020-09-dangerous-bacteria-school.html>

¹² <https://www.farmerhealth.org.au/page/safety-centre/water-tanks>

¹³ <https://tinyurl.com/y3c559cq>

¹⁴ <https://onlinelibrary.wiley.com/doi/10.1002/ajhb.23356>

harmful to human health: antimony (a carcinogen), and bisphenol A (BPA). Following a study¹⁵ that examined chemical levels in water left for four weeks at 70°C/158°F, it is believed that frequent consumption of warmed water can become harmful, and the dangers are likely to be more acute for children¹⁶. Subsequently boiling or heating this water will not rid the supply of these chemicals.



*Figure 4 Even bottled water in left in the sun has its dangers.
Credit: Mark Thiessen (2019), (via [Gibbens, 2019](#))*

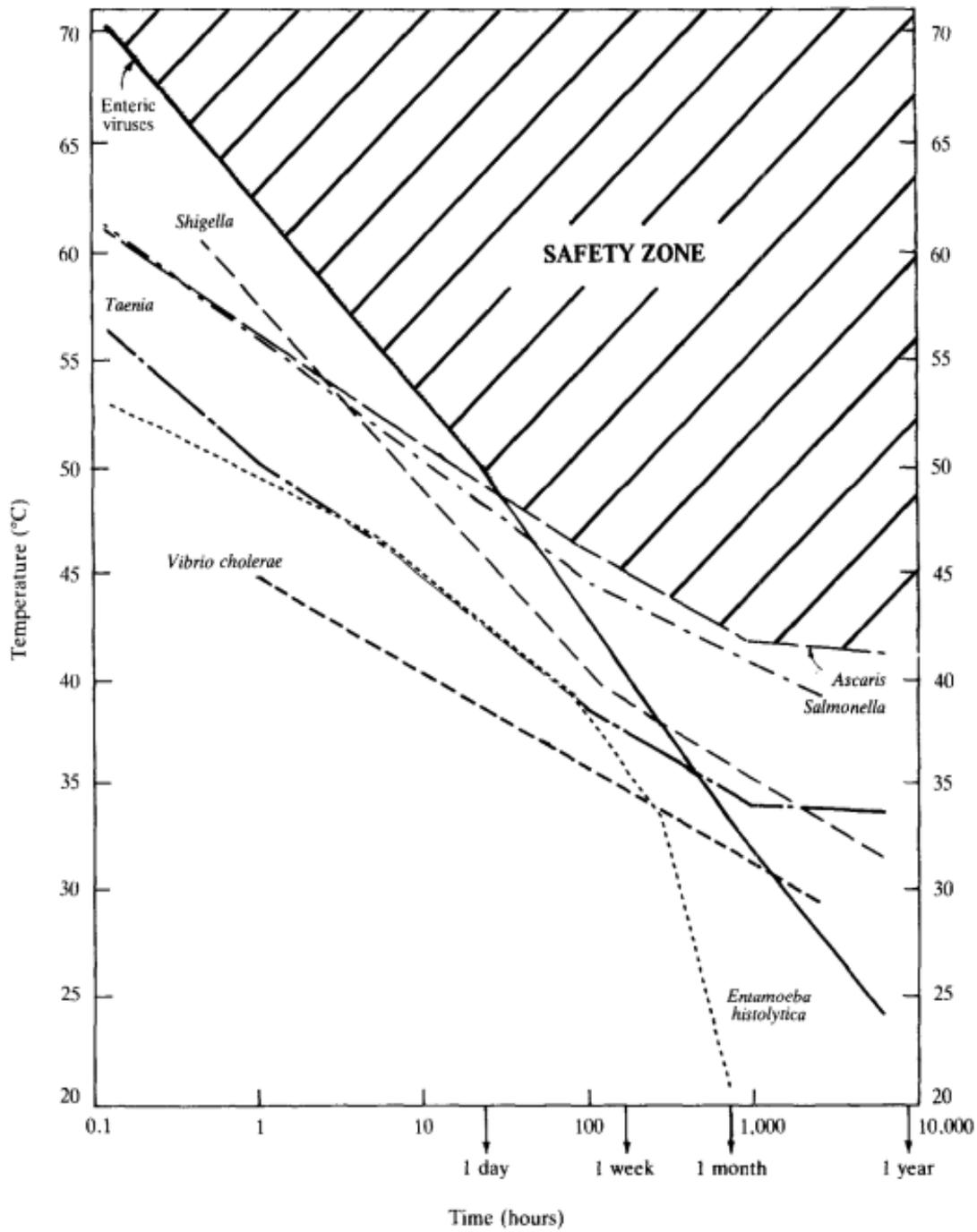
When considering the benefits of using surplus energy to heat a water supply, it is essential that the temperature is controlled and monitored and the water is stored securely, is able to flow, and is consumed shortly after storage. The process of boiling or heating water, that is then stored for a period of time, does not necessarily ensure the water is clean and safe for consumption.

¹⁵ University of Florida Institute of Food and Agricultural Sciences. "Don't drink the (warm) water, study says." ScienceDaily. ScienceDaily, 22 September 2014.

¹⁶ <https://www.sciencedaily.com/releases/2014/09/140922110139.htm>

Appendix

Temperature-time relationship for safe water pasteurization (Feachem et al 1983, p.79)¹⁷



¹⁷ <http://documents1.worldbank.org/curated/en/704041468740420118/pdf/multi0page.pdf>