Solar disinfection of drinking water for households in rural India

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In the developing world, several million deaths each year are attributed to water-borne diseases, especially to childhood diarrhoea. In India, over three-quarters of the population live in rural areas, without access to a reliable supply of safe drinking water, and there is a need for sustainable, low-cost treatment systems for household-level disinfection. Small-scale, point-of-use water treatment methods in these rural communities include boiling, filtration, and chemical disinfection. However, the practical application of these methods is often limited by factors outside the control of the local population, such as the lack of fuel wood for boiling, or the high cost and inconsistent supply of filters and chemical disinfectants.

Solar disinfection offers an alternative approach for those regions where is sunlight is plentiful: at its simplest, transparent plastic or glass containers are first filled with contaminated water, shaken to fully oxygenate the water and then kept for several hours in full sunlight. During illumination, the pathogenic microbes present in the water are inactivated by photo-oxidation, driven by solar UV radiation. There is a general consensus that solar disinfection requires several hours of strong sunlight in order to be fully effective and such intensities are achieved most readily in equatorial and tropical regions, including much of Africa, South America and Asia.

We have developed and optimised a small-scale solar disinfection system, which was then evaluated in three different locations in rural India. The initial laboratory trials used a custom-made polyethylene terephthalate bottle, designed to hold around 1 litre of water. The container has a flattened, rectangular cross-section (length 23.0 cm, width 9.5 cm, depth 5.2 cm) and is fitted with a reflective stainless steel case attached to the rear surface to return the UV radiation through the water under treatment. Figure 1 shows typical test results for a suspension of the faecal indicator bacterium Escherichia coli in water exposed to sunlight in the custom-made solar disinfection system, with complete inactivation over a four-hour period. Experiments have been conducted for several different bacteria (including those responsible for cholera, typhoid and dysentery) under a broad range of sunlight conditions, to establish the operational limits of the method. In general the system is very effective on those days with high-to-moderate sunlight, but less effective in low sunlight, e.g. during the monsoon rains.

Field trials have been carried out in rural villages in three distinct areas of India, each with its own climatic and hydrological conditions, namely (i) the arid zone of Rajasthan where surface water is consumed directly from ponds and open wells, due to the scarcity of treated water, (ii) the flood-prone region of Uttar Pradesh where there is little sanitation and where contaminated groundwater is collected from shallow handpumps, and (iii) the sub-tropical region of Kerala, where some rural households use untreated water from local canals and lakes. In each location, the practical use of the system was investigated in a two-year study, to establish the effect of solar water treatment on the number of cases of diarrhoea and gastro-enteritis, with feedback from participants at the end of the intervention to establish their perceptions as to the advantages or limitations of the process and its overall sustainability. While the detailed results are covered elsewhere, the following general conclusions can be made:

- Women’s groups and similar local organisations proved to be a useful means of engaging with villagers, providing a route to enable the operating principles
to be explained during the implementation phase and also a means of group feedback and discussion at the end of the study.

- A measurable reduction in the number of cases of diarrhoea and gastroenteritis was seen in most of the settlements where solar disinfection was implemented. For example, those households using solar disinfection in the study villages in Rajasthan reported only around a third of the number of cases of the equivalent control during 2004 (Figure 2).

- Almost all of those involved in the field trials were positive about its application, commenting that drinking solar treated water resulted in a greater sense of well-being and an enhanced ability to attend work (adults), or school (adolescents/children).

- Those households not involved in the field trials (e.g. in adjacent villages) felt a sense of exclusion, since word of the effectiveness of the system had spread to adjacent settlements.

- Managing 1 litre bottles at the household level proved a little difficult in rural locations with poor housing infrastructure, with a large number of bottles required per household, especially when the family size was high. The intake of drinking water also varied by season, with one litre containers proving insufficient during the hottest weather.

Following on from our initial field trials we are keen to extend this work in other locations, with a reduced emphasis on the collection of detailed epidemiological data and a greater focus on community participation and the broader aspects of health and hygiene behaviour. It will also be appropriate to evaluate the practical application of larger solar disinfection containers (2-3 litre volume). The fact that there is a historical record of the use of sunlight for the traditional ceremonial purification of drinking water in India may assist in its wider acceptance as a practical approach to water treatment, since it can be explained to rural villagers in this context, as part of the initial awareness programme.
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References

Figure 1  Inactivation of *Escherichia coli* strain ATCC 11775 in moderate sunlight (average irradiance 600 W m$^{-2}$).
Figure 2  Quarterly reported cases of diarrhoea/gastro-enteritis in two study villages in Rajasthan during field trials of solar disinfection (2004): solar disinfection treatment group shown as unshaded bars and control group shown as diagonal shaded bars (20 families in each group)
Photograph 1: In Rajasthan (Jodhpur) this women drinks directly from a village pond, using cupped hands to filter the water through the mesh of her headscarf veil.
Photograph 2  In Kerala (Alappuzha) the backwater canals provide water for all household purposes, including transport, washing, drinking and waste disposal (latrine on right hand side).
Photograph 3: In Uttar Pradesh (Gorakhpur) the solar disinfection containers are kept on the roofs of houses, facing into the sun.