DISCUSSION PAPER:

Domestic solar disinfection of potable water

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Background

Bacteria which are present in water may be killed using a variety of different techniques; such as addition of certain oxidising chemicals, or exposure to heat or radiation. The selection of these disinfection options depends on the volume of water to be supplied, finances and materials available, and the initial quality of the water. Disinfection of domestic water supplies, on a household basis and at low cost, presents particular difficulties.

Experimental work undertaken in Beirut indicated that coliforms present in water stored in transparent water containers were killed within a few hours when the containers were exposed to sunlight (UNICEF, 1984). Tests on samples of water containing cultured pathogenic organisms and stored in 300 ml round pyrex flasks and exposed to intense sunlight showed that the time required for complete destruction of organisms ranged from 15 minutes *(P aerugenosa)* to 90 minutes *(S paratyphi B)*. Under these conditions coliform bacteria were destroyed in 80 minutes. The results suggested that bacteria were killed by exposure to solar radiation in the near-ultraviolet region (315 - 400 nanometres) of the light spectrum. The researchers suggested that their findings had applications for disinfecting small quantities of water for both drinking and preparation of Oral Rehydration Therapy (ORT) solutions.

The Beirut experiments operated on a batch process, in that fixed volumes of water were exposed to sunlight. The time taken for all bacteria to be killed depended upon such variables as the sunlight intensity, thickness of the container walls, container material and colour, initial water quality and container dimensions. In 1990, work started at WEDC (Loughborough University) to investigate whether solar radiation could be used to disinfect water on a continuous (steady flow) basis. The experimental work has been conducted over three years as project work by individual participants on MSc programmes.

It is well-known that certain wavelengths of ultraviolet light are very effective at killing bacteria; the wavelengths from 200 to 290 nm (nanometres) being most effective. The optimum wavelength varies between organisms, but is generally around 260 nm. Light having wavelengths from 370 nm (in the near ultra-violet) to 500 nm (in the blue-green region of the visible spectrum) also have a weaker ability to kill bacteria. For the purposes of the experimental work at WEDC it was assumed initially that solar radiation was responsible for the death of bacteria.

The most favourable locations for solar applications are those countries lying between 15° and 35° North and South, where there is greatest solar radiation intensity, and limited cloud cover and rainfall. The UK, which lies between latitudes 50 and 59°, is not a favourable country for undertaking research into solar disinfection, yet work was possible during periods of fine weather in summer months.

Experimental programme at Loughborough

For the experimental procedures adopted, water flowed slowly from one storage container into another. While flowing, the water was protected from external pollution but was exposed to sunlight. The water samples used consisted of settled sewage, from a local wastewater treatment plant, which were diluted to simulate untreated water. A peristaltic pump was used to maintain a slow but constant flow rate for the transfer of water between containers, so that the water was exposed to solar radiation for as long as possible; for periods of between 2 and 30 minutes. During the tests, solar radiation intensity was measured using an energy sensor, and water samples for bacteriological analysis were taken from both water containers.

Experimental equipment, and especially the panel through which water flowed between storage containers, was modified and improved over the three experimental periods. Efforts were made to keep the equipment both cheap and simple.

During the first year the panel consisted of an inclined metal tray, covered by glass. The water did not, however, flow in a thin film as was hoped, condensation caused the glass to become misted, and the glass did not transmit certain wavelengths of solar radiation (Mozah, 1990).

For the second year, several lengths of Polyvinylidene (PVDF) tubing were placed parallel to one another on an inclined tray and connected together to create a total flow path 9 metres long. PVDF tubing was selected because it is translucent to visible light; and transmits, and is inert to, UV radiation having a wavelength above 150 nm. The tubing used was of 10 mm outside diameter, with a wall thickness of 1 mm (Hussain, 1991).

For the third year, flow was divided between two lengths of PVDF tubing, each having a length of 3 metres. One length of tubing was covered in opaque black tape; which had the effect of shielding the water from direct sunlight, but increasing the temperature by absorbtion of radiation (Addy, 1992).

Results and conclusions

Selected results obtained from experimental programmes are shown in Table 1, below.

Results obtained from experimental work at WEDC to date suggest that bacterial death may result both from exposure to solar radiation and an increase in temperature. The relative importance of each effect has yet to be ascertained, and further study is required in order to understand the conditions necessary for reliable solar disinfection of potable water.

Experimental work in this subject, using both batch and continuous flow processes, is continuing in several countries worldwide (IDRC, 1988). Experimental equipment being used varies considerably in both cost and complexity, and experimental results indicate that bacterial kill depends both on the radiation intensity and exposure time.

References

Acra, A.; Rafford, Z.; Karahagopian, Y. (1984) Solar Disinfection of Drinking Water and Oral Rehydration Solutions, Guidelines for Household application in Developing Countries. UNICEF, Amman, Jordan.

Addy, J.K. (1992) The effect of ultraviolet radiation and temperature in solar disinfection of water. MSc Thesis. WEDC, Loughborough University of Technology, U.K.

Hussain, M.Y.M. (1991) Solar disinfection of water. MSc Thesis. WEDC, Loughborough University of Technology, U.K.

IDRC (1988) Solar Water Disinfection. IDRC-MR231e. Proceedings of a workshop held at the Brace Research Institute, Montreal, Quebec, Canada, 15 - 17 August 1988. IDRC (International Development Research Centre) Canada.

Mozah, J.A. (1990) Disinfection of water by exposure to sunlight. MSc Thesis. WEDC, Loughborough University of Technology, U.K.

TABLE 1. SUMMARY OF RESULTS OF SOLAR DISINFECTION STUDIES (ONLY HIGHEST BACTERIAL KILL RESULTS ARE SHOWN)

PLACE	DATE	% REDUCTION IN COLIFORM BACTERIA		EXPOSURE TIME (mins)	SOLAR RADIATION INTENSITY (W/m^2)	TYPE OF MATERIAL USED FOR WATER EXPOSURE
		TOTAL	FAECAL			
BEIRUT	1979	82	99.99	60	Not known	Glass flasks
WEDC	1990	78	88	2	Not known	Metal tray covered with glass sheet.
WEDC	1991	94	86	30	700	Polyvinylidene fluoride tube
WEDC	1992	Not known	63	5	226	Polyvinylidene fluoride tube
		Not known	34	5	226	Wrapped Polyvinylidene fluoride tube