Solar disinfection of water – a case study from Kenya

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The women in this rural Kenyan project asked, 'Does SODIS work?' This article describes the bacteriological tests that they undertook, comparing raw water from various sources with the same water treated by SODIS, and also their reactions and questions regarding the technique.

The technique of solar disinfection has been well documented and researched by others, but when introduced to women in rural Kenya, their first question was 'Does it work?' The Water Supply and Sanitation Project implemented by Christian Community Services works with rural self-help groups to improve their access to clean, safe domestic water. Operating in the northern rift area of Kenya, the groups are building household rainwater catchment systems, protecting shallow hand-dug wells and using rope and washer pumps.

This ensures a water supply, but one important issue is how to make sure the water is safe. As the project objective is to improve the health status of the community, environmental hygiene and sanitation training have been undertaken in order to reduce the risk of waterborne disease transmission (i.e. the faecal–oral cycle).

Rainwater, collected in roof catchment tanks, is a good source of safe water provided precautions are taken to maintain the cleanliness of the system. However, other common sources of water in the area that are not so safe include the rivers, unprotected shallow wells and springs which may be contaminated by pathogens. A high incidence of diarrhoea and even typhoid is reported, suggesting that a contamination problem exists.

Currently the community members treat their water by settlement or storage. Disinfection by boiling is practised but, owing to time pressure and the effort involved in collecting firewood and boiling water, the practice is often neglected.

An alternative method of water disinfection, SODIS (solar disinfection of water) has been promoted with some of the groups to provide safe household drinking water. This article reports the experiences of these groups.

What is SODIS?

The technique of SODIS has been researched and reported widely.[1] The UV-A component of sunlight, in synergy with infrared radiation (heat), is effective in destroying the following pathogenic bacteria: *E. Coli, Vibrio Cholerae, Str. Faecalis, S. Paratyphii and S. typhii*; as well as viruses: bacteriophage F2, rotavirus, encephalomyocarditis virus; and yeasts and moulds. The inactivation of spore- and cyst-forming organisms, such as protozoa and helminths, by SODIS has not been systematically assessed.[2] SODIS is also:

- ideal to disinfect the small quantities of water used for consumption
- a water treatment process depending on solar energy alone
- an alternative water treatment option for use mainly at household level
- an old, but so far not widely applied, water purification method.

Practical technique

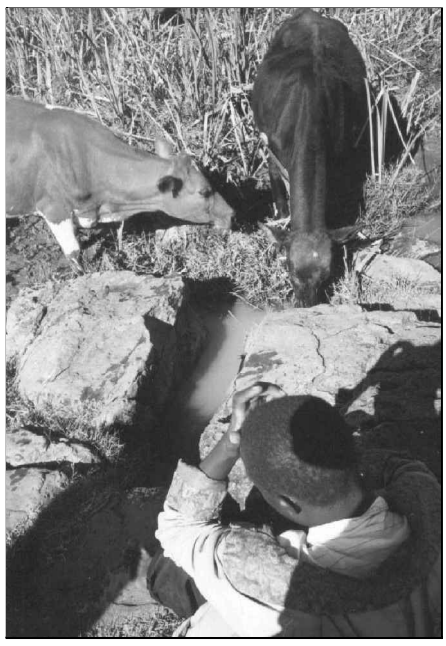
The treatment basically consists in filling transparent plastic (PET – polyethylene terephthalate – plastic), or glass bottles with water and exposing them to full sunlight for at least five hours. Two-litre bottles or smaller are the recommended size. The process is more effective if the water is aerated by shaking to introduce oxygen while filling the bottles and then the bottles are placed on a piece of shiny, galvanized corrugated iron sheet (GCI), or house roof, in the hot sun from 9 a.m. to 3 p.m. Recommended exposure times:

- six hours under a bright or up to 50 per cent cloudy sky
- or two consecutive days under 100 per cent cloudy sky.

Our research on the SODIS method

Plastic, two-litre PET bottles were filled with water and placed in the sun on a number of different surfaces for a minimum of six hours. Some of the bottles had been painted half black. The level of cloud cover was also estimated. Water temperature was measured at two-hourly intervals. This was repeated for four days.

What is the ideal surface on which to put the bottle? The tests showed that there was no significant difference between the maximum daily temperature



Water from this spring was made safe using SODIS

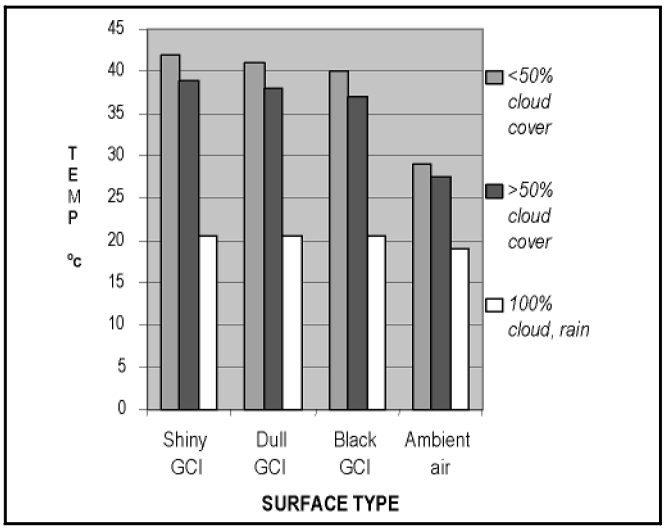


Figure 1 SODIS water temperature: three surfaces, half-black SODIS bottles

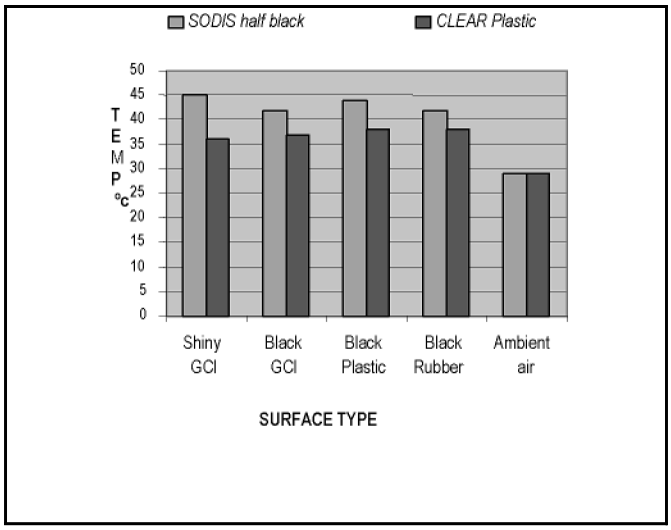


Figure 2 SODIS water temperature: four different surfaces, two bottle types

of water for five different surfaces (Figures 1 and 2). However, it can be seen that the highest water temperatures are reached with shiny GCI sheet and half-black bottles (Figure 2). This is confirmed in Figure 1, where also the highest water temperatures were with shiny GCI, irrespective of cloud cover.

Effects of cloud cover. The results showed that cloud cover affects temperature, but in tests of the inactivation of bacteria, the faecal coliform count reduced from between 22 and 7 FC/100ml to zero FC/100ml for both <50% cloud and >50% cloud with one day of SODIS. On rainy days, two days of SODIS were needed to reduce the faecal coliform to zero; the maximum temperature was only 20.5ºC.

Half-black painted or clear bottles? In Figure 2 it can be seen that the temperature of the water in the half-black SODIS bottle is roughly between 4 and 10ºC higher than the water temperature in a clear SODIS bottle. This will enhance the synergy effects. However, extensive tests on inactivation of faecal coliform using SODIS with clear and half-black bottles showed that the inactivation with clear bottles was as effective as half-black bottles.[3]

Initially the bottles were painted half black, and the GCI sheet was also painted black in order to absorb more heat. However, further research has shown that unpainted bottles on shiny GCI sheet is as effective in killing germs, and much simpler too, as paint is not needed. It is therefore recommended that clear plastic PET bottles be used for SODIS.

Effect on community health. Between October 2002 and September 2003, 180 households in five villages and three distinct climatic zones were monitored for disease incidence: 90 household using SODIS and 90 households not using SODIS. There was overall a 62 per cent reduction in waterborne diseases among the households which used SODIS compared to non-users. The diseases monitored in the survey included typhoid, diarrhoea, cholera, malaria and worms.[4]

SODIS use with community self-help groups

Using the power of sunlight is not a new concept to rural Kenyan women; outside the house there is often a raised wooden platform on which pots, plates and utensils are placed to dry after washing. The women say that the sunlight helps to kill any germs. The concepts and practice of SODIS for disinfecting household drinking water builds upon this.

The equipment needed to 'try out' using SODIS was obtained. A SODIS kit consists of the following:

- three to six PET plastic bottles, one to two-litre in size, can be bought secondhand in the local market, or are available after drinking the orange cordial. It is important to find bottles without scratches and with tight-fitting lids.
- A simple table with a GCI sheet surface is made on which to place the bottles.
- The bottles are placed in the sun, on the dish rack, on a raised platform or on an existing roof surface (i.e. away from animals).
- The cost of a SODIS kit with three bottles and GCI sheet was about US$1.50.

The women found the use of SODIS straightforward. The bottles were cleaned, the cap checked for tightness and the bottles were filled completely with the raw water. The sources of water were unprotected springs, protected shallow wells and rainwater tanks. Early in the morning the bottles were put out in the sun. On bright, sunny days and on partly cloudy days the bottles were left out all day (eight hours) and on fully cloudy days for two consecutive days.

After SODIS, the water was either left outside or brought into the house to cool overnight. The water in the SODIS bottle was decanted into another storage bottle or was drunk straight from the SODIS bottle.

The community test SODIS

The main concern of the users of SODIS was, 'Does it work? Does it kill the germs?' In order to answer this question a series of bacteriological tests for faecal coliforms were carried out using a DELAGUA membrane filter/ incubation kit in August 2000 to April 2002. When shown the results of these tests on their own water the community members were convinced. Table 1 compares faecal coliform counts for raw water and SODIS treated water. Faecal

Table 1. Bacteriological water tests on SODIS and other water

Water source and type	Raw water	SODIS water	SODIS practice
	FC per 100 ml		
Protected well, rope to draw water	4 to 18	0 to 1	8 hours hot sun
Protected well, hand pump	0 to 2	–	SODIS not tested
Rainwater tank	0	0	8 hours hot sun
Unprotected spring	8 to 15	0	8 hours hot sun
SODIS water stored in the house	0	–	No recontamination
Unprotected spring used by Monica, cloudy water	244	0	16 hours hot sun
Mondui Spring, unprotected, cloudy water	175 – 500	0	8 hours hot sun
Protected well with handpump	2 to 18	0	8 hours hot sun
SODIS water stored in the house†	1 to 4	–	Recontamination
Protected well with handpump	12	0	5 hours hot sun*
Protected well with handpump	0	–	SODIS not tested
Various rainwater tanks	0	0	8 hours hot sun*

Note: * Indicates that the SODIS was undertaken by staff to verify the technique. The turbidity of the water was clear unless indicated. FC = Faecal coliform

coliform is an ideal indicator of pathogenic micro-organisms which are human faecal in origin. WHO recommends this as the indicator organism when testing facilities are limited.[5] The results show:

- that a protected well with a handpump has good-quality water compared to unprotected sources
- that rainwater is a clean, safe source: no faecal coliforms were seen
- that SODIS works: the faecal coliforms were reduced to one or zero.

More importantly, the group members were able to experiment with disinfecting the water themselves, and see the results. One woman, Monica, SODISed the water for two consecutive days. This might be considered a sensible precaution when the turbidity of the water is >20 NTU (Nepholometric Turbidity Units), although tests undertaken by staff after eight hours of SODIS of this water showed that the faecal coliforms had been killed. One woman, Helen, reduced the turbidity of her raw spring water using alum before the SODIS treatment.

The results of the tests were not always 100 per cent destructive of faecal coliform by SODIS. Where contamination was still evident, the group member explained how she was performing SODIS and the reasons for the failure were analysed. After re-teaching, the SODIS was successfully carried out. One possible source of recontamination of the clean SODIS water was the household storage container into which the SODIS water was transferred. (See Table 1[a].) Discussion with the group members and awareness raising helped reduce the incidence of recontamination.

The community members were advised to SODIS the water for the whole day, eight hours, rather than the five hours minimum, to be sure.

Acceptability of SODIS

The acceptability of SODIS to group members was assessed by two methods: individual or group interviews and group matrix ranking, comparing alternative methods of getting safe drinking water. Some of the comments given by women group members, as well as their queries are given in Box 1.

The ranking (given in Table 2) promoted much lively discussion and showed the depth of knowledge that the community has on these issues. SODIS ranked number one.

Box 1. Reactions to SODIS from group members

'I use SODIS now every day and it provides for all the household drinking water needs.'

'SODIS is easy to use. I just put the bottles out in the morning and "forget" about them. In the evening when I have finished my other work I just bring them in.'

'Before I used to boil water, which was time consuming and the smoke from the fire gave the water a bad taste. SODIS water tastes good.'

'I do not need to go and collect so much firewood now. SODIS saves time that I then use to care for my family's needs.'

'SODIS is cheap and we can get the bottles ourselves.'

'SODIS does make water safe, we no longer get headaches and diarrhoea' (Headaches are associated with typhoid.)

Challenges and questions raised by group members

'Does SODIS really kill all the harmful micro-organisms? What about amoebae (cysts) and worms?'

'At cloudy times, during the rainy season, will SODIS still be effective?'

'After how long should SODIS water be drunk?' (A question relating to the re-growth of micro-organisms)

'We find care needs to be taken to keep the SODIS bottles clean and replace them if they become scratched or broken.'

'Can we use other methods for the black surface, as GCI sheet is expensive? What about black, plastic sheet?'

'Culturally, we associate black with magic, so half-black bottles are a problem. Can clear bottles be used?' (This question has now been answered and clear bottles are also recommended)

Table 2. Matrix ranking: group preference for water treatment (Score: 0 = good, low cost; 5 = bad, high cost.)

Method/ criteria	Capital cost	Recurrent cost	Ease of use	Effect on environment	Efficiency in disease control	Total score	Overall rank
Boiling	3.5	3.5	4.5	5	1	17.5	7
Chlorination	2.5	3	2.5	4	1	13	4
Rainwater tank	5	2	1.5	0.5	1	10	2
Protected spring/well	5	1.5	2.5	1	2	12	3
Filtration	2	2	2	4	5	15	5
SODIS	1.5	1.5	1	0.5	0.5	5	1
No treatment	1	4	3	3	5	17	6

Conclusions and suggestions

- The technique of SODIS using bottles effectively inactivates faecal coliforms from a variety of water sources.
- There is a positive effect in reducing waterborne diseases when SODIS is used.
- SODIS was adopted in the groups, but an important question remains as to the total effectiveness of SODIS to destroy protozoa that cause disease.
- The technique is acceptable to the rural community, who find it easy to use, low cost, firewood saving and time saving.
- It is essential to ensure an adequate supply of PET bottles for SODIS adoption to be successful.
- SODIS should be further promoted as an acceptable method of disinfecting water for household water and thereby reducing the risk of waterborne diseases.

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software review

Performance Indicators for Wastewater Services – IWA Manual of Best Practice
R. Matos, A. Cardoso, R. Ashley, P. Duarte, A. Molinari and A. Schulz, ISBN: 1900222906, 192pp, £52.50 / US$84.00 / €84.00 (IWA members); £70.00/ US$112.00 / €112.00 (non-members)

Many water utilities in developing countries struggle to achieve acceptable levels of performance, but there is often a lack of an effective system for monitoring and evaluating the quality of their services. As a result, and especially with moves towards greater involvement of the private sector, there is increasing interest from both operators and regulators in methodologies to quantify performance as a management tool.

This new *IWA Manual of Best Practice*, combined with SIGMA software, consists of a performance indicator methodology which simplifies an otherwise complex evaluation procedure. The methodology benefits from experience based upon a similar approach in the water supply sector, which has been revised following three years of evaluation. This experience has enabled the wastewater services manual to be developed in a way that is more directly responsive to user needs and perspectives. The wastewater performance indicator manual has maintained the generic principles and approach adopted in the original water supply manual, with adaptations necessary for application to wastewater services.

Sigma Lite is the freeware software package, which incorporates the methodology to guide the process of selecting and implementing a system of indicators for the utility. Indicators can be tracked in time to discover how the utility's performance is evolving, or can be compared with indicators from other companies (benchmarking) in order to assist utility managers in their decision-making processes. Sigma Lite features all the indicators, variables and context information in the IWA methodology, but has limited features. A more advanced and versatile version of the software is also available, but this needs to be purchased separately.

The layout of the manual and software is clear and well structured. Utilities in developing countries should not have too much difficulty acquiring the skills to operate the program. Of course, the results from any software are only as good as the input data. The key issue regarding the applicability of the methodology and the software in developing countries is therefore the availability of reliable data for the input variables, which in many cases may be a significant limitation. However, the software has been designed in such a way that as few or as many of the parameters as are available may be utilized, and this should therefore make the program useful for the majority of service providers, large and small.

In summary, this product will be an invaluable management tool for all those concerned with managing the performance of wastewater services, including utility managers and policy makers, regulators and other stakeholders.

Managers of service providers – both in the public and private sector – as well as those responsible for regulation increasingly need to consider the options available for developing a comprehensive system for gauging the quality of the services that they offer. The IWA performance indicator methodology offers an excellent system for enabling this to be possible. For the benefits that it offers, the product is well worth the money.

Those who want to download the software for free without the manual and user guide, can obtain it from the internet at www.sigmalite.com.

If you are considering purchasing this IWA product, you should also have a look at alternatives such as the World Bank's *Benchmarking Water and Sanitation Utilities Start-up Kit*. This is also available for free from the internet at http://www.worldbank.org/html/fpd/water/topics/uom_bench.html, and it looks from the information on the website as if it is covering similar ground. However it is more generic and may therefore be less focused on wastewater services.

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