Solar Water Disinfection (SODIS) — destined for worldwide use?

by Martin Wegelin and Bernhard Sommer

Last year's publication of Rob Reed's article 'Sunshine and fresh air: a practical approach to combating water disease' provoked sustained reader interest in what seems such a simple solution to a major problem. Here we can publish the results of extensive field and lab tests.

RESEARCH ON SOLAR water disinfection — applying the solar radiation method — was initiated by Professor Aftim Acra at the American University of Beirut. Acra's work motivated the Integrated Rural Energy Systems Association (INRESA), an associated programme of the United Nations' University, to launch a network project in 1985. The Brace Research Institute in Montreal organized a workshop in 1988 to review the results of this field research; and in 1991, the Swiss Federal Institute for Environmental Science and Technology/Department of Water and Sanitation in Developing Countries (EAWAG/SANDEC) embarked on extensive laboratory and field tests to both assess the potential of SODIS, and to develop an effective, sustainable and low-cost water-treatment method.

Sanitary engineers, photochemists, bacteriologists, and virologists conducted comprehensive laboratory tests. Complementary field tests were carried out in co-operation with CINARA in Cali, Colombia.

Questions	Acceptance of SODIS	Integration of SODIS	Affordability of SODIS
Actions	Changing Water Treatment Habits	Changing Water Handling Habits	Paying for Water Quality Improvement
Criteria and Incentives Enhancing Changes	- simple method (water boiling is cumbersome, sunlight exposure is easy)	- provision of special containers (e.g. half-blackened plastic bottles or plastic bags)	- low investment and operating costs (lower costs than for other methods, e.g. water boiling, chlorination)
	- cost-saving method (water boiling requires energy, e.g. firewood or kerosene, sunlight exposure is free)	- convenience of containers (e.g. direct consumption of treated water from container is simple)	- sustainability of SODIS (containers can be supplied and replaced from locally available resources and material)
	- convenient method (water boiling demands careful handling of hot pots, plastic bottles are practical and easy to handle)	- special attention given to drinking water (e.g. drinking water is treated and stored differently from water used for other purposes)	- consumers recognise health benefits (paying for good water quality is less expensive than paying for medical treatment)

Table 1. Implementing aspects of SODIS.

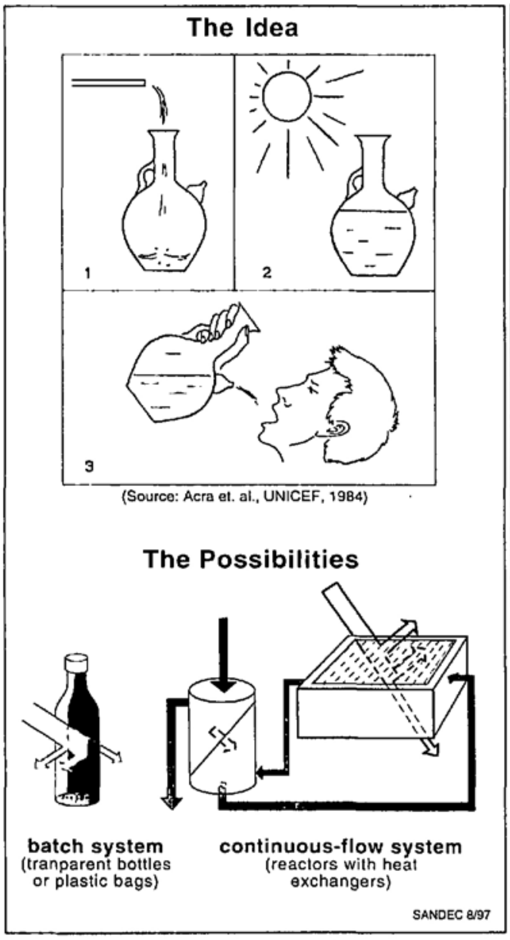


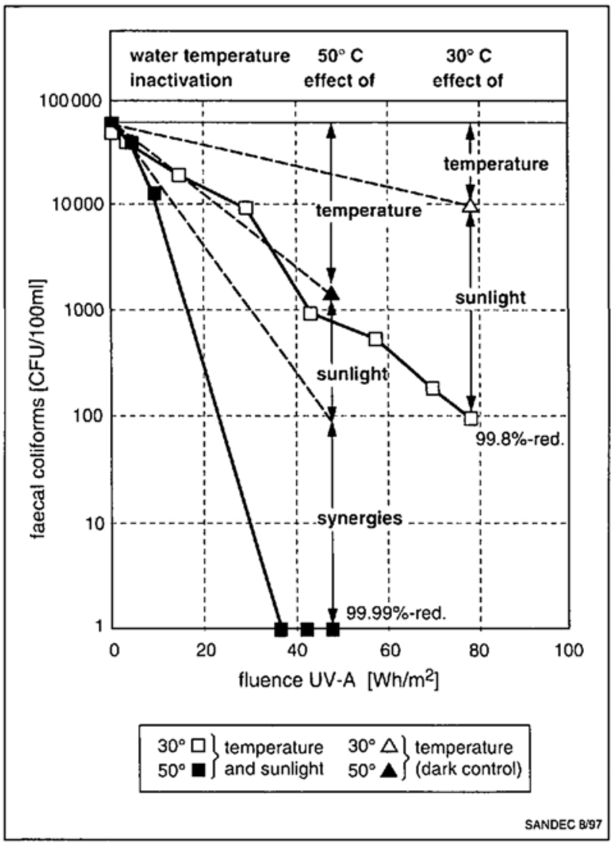
Figure 1. Application of solar water disinfection.

What's the idea?

Micro-organisms are vulnerable to light and heat. Solar energy, free and universally available, is harnessed in the water-treatment process known as solar water disinfection (SODIS). As Figure 1 shows, transparent containers filled with water and exposed to full sunlight for several hours constitute the basic concept. SODIS may be used as a batch process at household level to treat small quantities of drinking-water in bottles or plastic bags. Since the daily capacity of the batch process is limited, however, by the volume of water stored in the sun-exposed bottles, SODIS can also be used in continuous-flow systems, comprising solar collectors and heat exchangers, to increase the daily drinking-water output significantly. Hence, SODIS continuous-flow reactors can be used to disinfect the water supply of institutions such as hospitals and schools.

In the past, two different water-treatment processes using solar energy were developed to improve the microbiological water quality. The first, using predominantly UV-A radiation, is known to have a bactericidal effect. The second, utilizing infrared radiation to raise the water temperature to over 70°C, is known as pasteurization. Simultaneous use of both solar energy sources — UV-A light and infrared radiation — seems a good idea. The two processes were assumed to complement each other, therefore, EAWAG focused on these combined effects and discovered synergies between radiation and heat effects. This constitutes a breakthrough in the development of the technology and significantly enhances the potential of SODIS application.

Figure 2 illustrates the synergies produced by the combined used of radiation and thermal treatment on the inactivation of faecal coliforms. Two different faecal-coliform inactivation tests were carried out at constant water temperatures of 30°C and 50°C, respectively. The combined effect of solar radiation and water temperature is shown by the two curves. A series of parameter tests at water temperatures between 20 and 55°C revealed that the inactivation rate of faecal coliforms remains constant within a 20 to 40°C temperature range. But, at a threshold water temperature of 50°C, the required fluence (dose of solar radiation integrated in the 350 to 450nm wavelength range) of UV-A light is about four times smaller that at 30°C. As the graph indicates, inactivation of bacteria at 50°C can be attributed to three different factors: heat effect, sunlight exposure and synergies caused by the combined application of temperature and radiation. Furthermore, since the oxygen concentration enhances the inactivation of bacteria, SODIS should always be applied under aerobic conditions.



CREPA - Togo

Figure 2 shows the effect of solar radiation and water temperature on inactivation of faecal coliforms; (right), a Togo villager takes a half-blackened bottle and plastic bag to disinfect water using SODIS.

The second phase of the SODIS project developed and field-tested suitable containers and reactors for the water-treatment process. The small diameter quartz tubes used in Phase I were replaced by locally available glass and plastic bottles, as well as plastic bags.

The field tests confirmed the laboratory results. As soon as the water temperature reaches 50°C, the inactivation process is accelerated and usually leads to complete disinfection. Figures 3 and 4, on page 32, show the inactivation curves of faecal coliforms and Vibrio cholerae in plastic bottles and SODIS bags.

EAWAG's SODIS project is currently in its third phase — the most decisive yet. Socio-cultural acceptance, applicability and financial viability are being studied in demonstration projects conducted by local partners in Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand, and China; the sites cover a range of different social, climatic, and living conditions.

But people's health will not improve just because they have new equipment or facilities — they have to use them. Minor improvements to existing water-supply practices are more likely to be accepted than major and sudden changes. SODIS will only be used and applied if the target population is convinced of its advantages over the traditional ways of treating and handling drinking-water. Consumers need to be fully aware of the bacteriological transmission routes of water-borne diseases and how to reduce or avoid them. Finally, private users will only invest in water treatment if they believe they will benefit directly — as health benefits are often indirect, they may be perceived only in the long-term. Table 1 summarizes the implementing aspects of SODIS, and lists criteria and incentives which enhance its acceptance and use.

Equipment

SODIS requires sunlight, exposure time and adequate containers. Plastic mineral-water and soft-drinks bottles are gradually replacing glass. Plastic bottles are made of either PET (polyethylene terephtalate), or PVC (polyvinyl chloride), the latter perhaps containing some additives to increase its elasticity, which, in high concentrations, could diffuse into the water and pose a health risk. PET bottles are inert and, therefore, far preferable for SODIS.

Once the polluted water is bottled and exposed to sunlight, solar radiation has to travel through the wall of the bottle into the water. UV-A light (with a wavelength of between 320 and 400 nm), the most bactericidal sunlight spectrum, should have a high light transmittance through the material of the bottle.

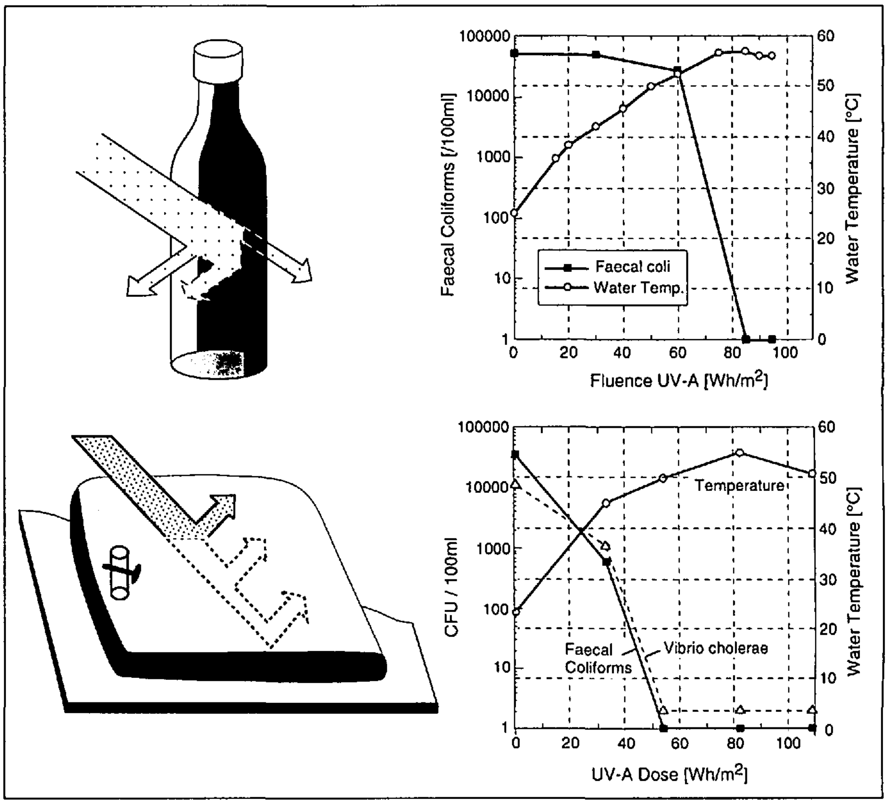
Water temperature is the second most important process parameter. Temperature increase is dependent on container type and support material used. To improve water heating, transparent-plastic bottles should be half-blackened to enhance infrared light absorption as illustrated in Figure 3 on page 32. Furthermore, the ratio between exposed surface area and stored water volume greatly influences temperature development. Flat plastic bags 2-6 cm-full yield a far better area-to-volume ratio than normal round bottles, and reach higher water temperatures. Finally, the type and shape of support material used to carry the plastic bottles or bags directly influence water-temperature development. Half-blackened plastic bottles placed on a corrugated-iron roof offer the best configuration for SODIS batch process application. The water is heated by the infrared light which is absorbed by the black paint. The convective heat is absorbed and conveyed to the bottle by the metal sheet.

The batch process has a limited capacity, however, and its daily output generally corresponds to the water volume stored in the plastic bottles or bags. This capacity can be significantly increased in a continuous-flow system. Such installations — illustrated in Figure 4 — consist of a raw water tank, an exposure vessel called a reactor, a thermovalve, a heat exchanger to preheat the raw water with the energy yielded by the treated water, to be cooled and stored in a treated-water tank. As these systems can be operated by gravity, an electrical pump is unnecessary. The flow is regulated by a thermovalve that opens and closes at the threshold temperature of 50°C. To reduce construction costs, EAWAG and Swisscontact have designed a new

SODIS plant with a modified, flat-plate ECOSOL collector which combines the solar collector and reactor in one unit.[1]

Results

The SODIS demonstration projects are being carried out in conditions different from previous experiments. The process is not applied under strictly controlled conditions; the material and methods used are often not ideal; the raw-water pollution is generally much lower; and the handling of the treated water is, frequently, inadequate. Nevertheless, SODIS does work. Mondomo in Colombia is supplied with untreated water drawn from a small river containing an average faecal-coliform concentration of about 600 CFU/100 ml. The 91 treated-water samples analysed reveal that 69.2 per cent of the SODIS bags and 61.5 per cent of the plastic bottles reduced the level of coliforms to 3 or less CFU/100 ml (a 99.5 per cent removal efficiency).



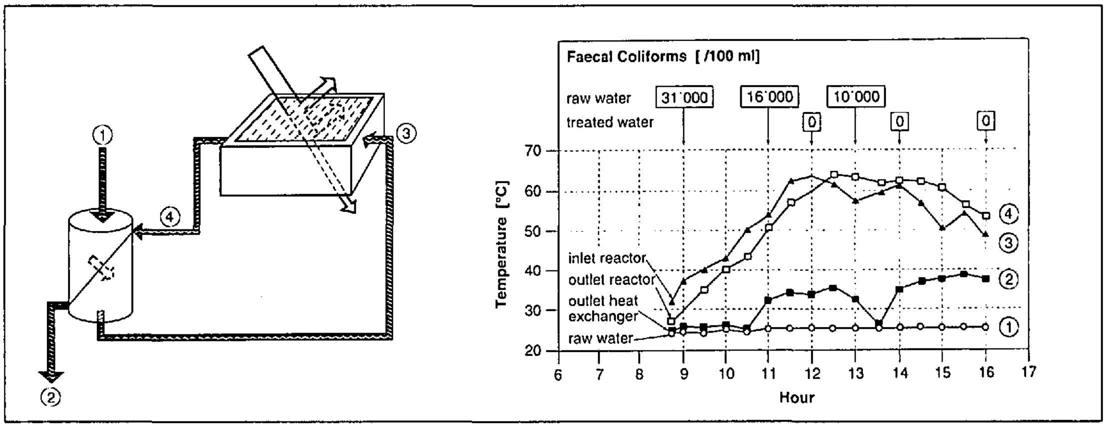


Figure 3. (top) Inactivation of coliforms and vitrocholerae in half-blackened plastic bottles and SODIS plastic bags. Figure 4. (bottom) Layout and performance of SODIS reactor.

The SODIS water-treatment method is simple to apply. Nevertheless, people will have to be introduced to the technique carefully, and get guidance about day-to-day application if they are to benefit fully. Experience in Indonesia illustrates the importance of proper and continuous training. In the rural community of Melikan, 40 per cent of the villagers have started to place their containers on chairs or concrete floors which, compared to exposure on black rocks, corrugated zinc or tile roofs, are not ideal locations — the disinfection efficiency is lower, and only 50 per cent of the exposed water samples were free of faecal coliforms. After people received training, and suitable, corrugated zinc sheets, the number of inadequate applications was reduced to 3 per cent. A better educated populace in the semi-urban community of Dobalan meant correct SODIS application was easier to implement, but still allowed for improvement.

To find out whether people accepted the SODIS method, project workers carried out interviews and surveys. In China, around half of the people interviewed said they still drink untreated water even though they are aware that the quality is poor; while untreated water consumption rises to 100 per cent in other countries. The Chinese regard SODIS application as convenient, and around 55 per cent will continue to use it when the project ends. Acceptance is also high elsewhere: the neighbours of communities involved in the project in Thailand and Indonesia have started to use SODIS, and Melikan has established a plastic-bottle supply scheme; the bottles are sold for $0.20/bottle to old and new consumers, a clear indication of the project's sustainability.

Dissemination

National workshops are being organized in the seven developing countries participating in the SODIS project. Each workshop will include a general introduction to the water-treatment method, participants will hear results and first-hand experiences, and can join in discussions on dissemination strategies at the regional or national level. Hopefully, these workshops will lead to follow-up programmes launching SODIS on a large scale.

EAWAG has produced two videos on SODIS; they are available in English, Spanish, French, and German. The first video presents the water-treatment method as well as the laboratory and field tests carried out in Switzerland, Colombia and Costa Rica; the second introduces SODIS and shows how it has been implemented in the demonstration projects.[2]

References

1. A comprehensive field demonstration programme in Costa Rica will test this new SODIS plant in 1998.
2. Video cassettes can be ordered for $40/video from EAWAG.

Acknowledgements

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