Solar water disinfection (SODIS) - treating drinking water using only PET bottles and sunlight

SODIS newsletter no.1 - July 2008

Compiled by the
Swiss Federal Institute of Aquatic Science and Technology (Eawag)
Department for Environmental Sanitation in Developing Countries (Sandec)

Breaking news: Re-launch of SODIS newsletter

More than 2400 people have subscribed to our mailing list in the past months and years, many of them without ever receiving any sign of life from our side through this channel. The fact that no SODIS newsletter has been produced since 2006 is not a consequence of lacking progress in the worldwide promotion of SODIS – much rather have the many projects absorbed our time and attention.
In an attempt to make up for the long silence, we now launch a new newsletter to disseminate information on key projects, events, and publications related to the issues of household water treatment and safe storage (HWTS), and solar water disinfection (SODIS) in particular.
This first - and exceptionally long - newsletter will be followed by shorter updates every few months. Suggestions and feedback are welcome!

Contents

SODIS team at Eawag

Prem Gurung left the SODIS team after six years of tireless work in the coordination and backstopping of SODIS projects in Asia and Africa. Two new project officers joined the team in March/April 2008. The SODIS team at Eawag/Sandec now consists of:
Martin Wegelin, Monika Tobler, Regula Meierhofer (team leader), Valérie Cavin, and Samuel Luzi

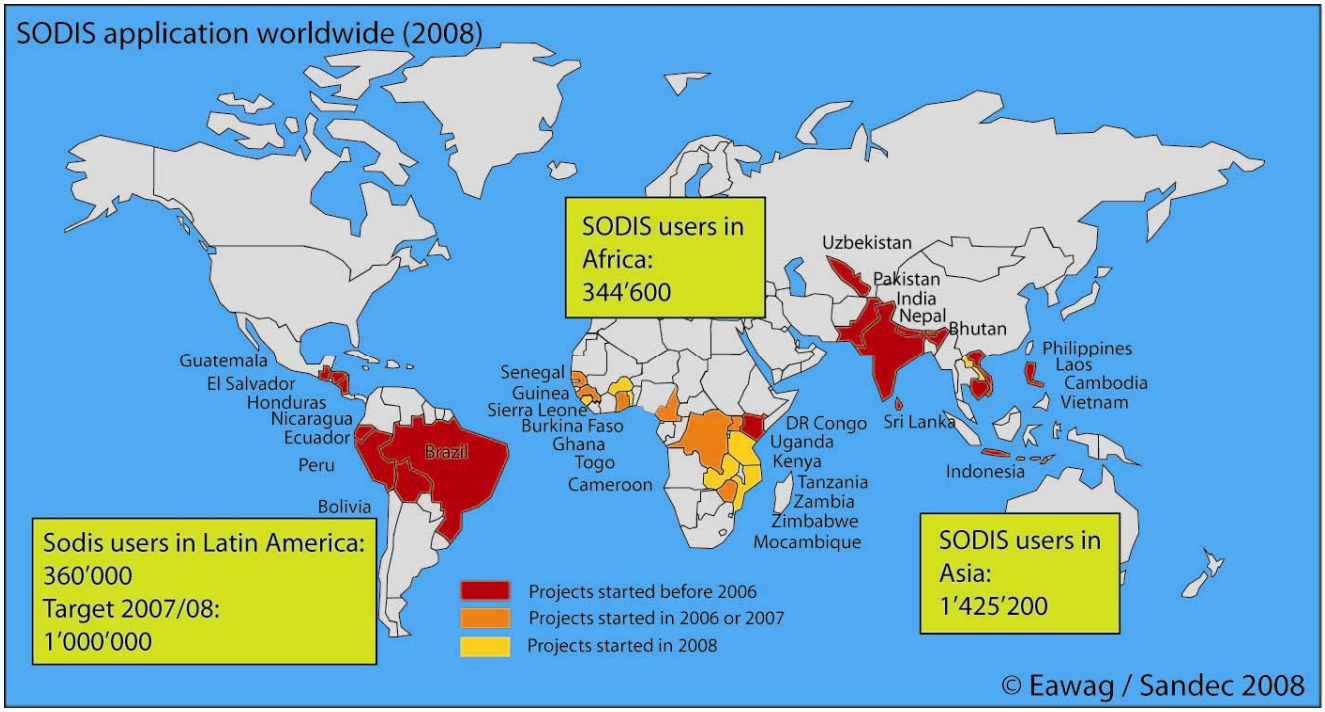
Contact details: http://www.eawag.ch/organisation/abteilungen/sandec/schwerpunkte/src/team/index_EN

Events

Following two earlier regional training and coordination workshops in Uganda and Vietnam in 2007, another SODIS workshop took place in Cameroon between April 2 and 4, 2008. The workshop brought together SODIS project coordinators from the new projects in Burkina Faso, Cameroon, Kenya, Mozambique, Senegal, Sierra Leone, Tanzania, Togo and Zambia. Participants from recently started SODIS projects learned from the experiences already gathered in the promotion of SODIS in Kenya, Cameroun and Senegal. Participants also discussed options for the integration of SODIS with other approaches aiming to promote appropriate practices regarding water supply, sanitation and hygiene, e.g., Community Led Total Sanitation (CLTS) and Participatory Hygiene and Sanitation Transformation (PHAST).

Projects

SODIS projects are currently implemented in 33 countries worldwide. An estimated 2 million of the people have so far been trained in the application of SODIS.



In 2008, new SODIS projects have been launched in Burkina Faso (implemented by Helvetas), Laos (International Relief & Development), Mozambique (International Relief & Development), Senegal (two projects, implemented by Enda Graf Sahel and Promotion SODIS Casamance, respectively), Sierra Leone (Safer Future Youth Development Project), Tanzania (two projects, implemented by Plan International and the Diocese of Ruaha, respectively), Togo (Amitié et Action pour le Dévelopment, 2AD), and Zambia (Keepers Zambia Foundation).
SODIS projects are funded from diverse sources, e.g., the SOLAQUA Foundation, Migros, or diverse sections of Lions and Rotary Clubs.

Case studies of earlier projects can be found under:
http://www.sodis.ch/Text2002/T-Projects.htmhttp://www.sodisafricanet.org/English/text/project.htm

Publications

► SODIS efficiency

The efficiency of SODIS regarding the inactivation of bacterial and viral pathogens has been demonstrated in earlier studies. Links to the respective scientific publications can be found on the SODIS website: http://www.sodis.ch/Text2002/T-Research.htm.
Recent studies, mainly conducted in the group of Kevin McGuigan (Royal College of Surgeons in Ireland), investigate the efficiency of SODIS regarding more persistent pathogens (i.e. cyst-forming parasites). Result show a good disinfection of Giardia sp., and the need for longer exposition times to inactivate oocysts of Cryptosporidium parvum as compared to non-spore forming bacteria (e.g., Escherichia coli, Salmonella type bacteria, or Vibrio cholerae) and viruses. Cysts of Amoeba sp. are only inactivated if the water temperature reaches a temperature of at least 50°C for the duration of 1 hour.

Lonnen, J., Kilvington, S., Kehoe, S.C., Al-Touati, F., McGuigan, K.G. (2005). Solar and photocatalytic disinfection of protozoan, fungal and bacterial microbes in drinking water. *Water Research* 39 (5), pp. 877-883.

After 8 h simulated solar exposure, SODIS achieved at least a 4 log unit reduction in viability against protozoa (the trophozoite stage of Acanthamoeba polyphaga), fungi (Candida albicans, Fusarium solani) and bacteria (Pseudomonas aeruginosa, Escherichia coli).

Méndez-Hermida, F., Castro-Hermida, J.A., Ares-Mazás, E., Kehoe, S.C., McGuigan, K.G. (2005) Effect of batch-process solar disinfection on survival of Cryptosporidium parvum oocysts in drinking water. *Applied and Environmental Microbiology* 71 (3), pp. 1653-1654.

Excystation levels of Cryptosporidium parvum oocysts decrease with increasing duration of SODIS exposure. After 6 h of SODIS exposure, 27% of oocysts were capable of excystation; however, only 7.5% of neonatal mice were infected. This suggests that SODIS exposure may produce oocysts that are capable of excysting but whose sporozoites are incapable of producing an infection.

Berney, M., Weilenmann, H.-U., Simonetti, A., Egli, T. (2006). Efficacy of solar disinfection of E. coli, S. flexneri, S. typhimurium and V. cholerae. *Journal of Applied Microbiology* 101: 828-836.

Resistance to sunlight at 37°C was in the following order: Salmonella Typhimurium > Escherichia coli > Shigella flexneri > Vibrio cholerae. Physiological response to SODIS might be different among enteric bacteria.

Heaselgrave, W., Patel, N., Kilvington, S., Kehoe, S.C., McGuigan, K.G. (2006). Solar disinfection of poliovirus and Acanthamoeba polyphaga cysts in water - A laboratory study using simulated sunlight. *Letters in Applied Microbiology* 43 (2), pp. 125-130

SODIS at 25°C totally inactivated poliovirus after 6-h exposure. No SODIS-induced reduction in A. polyphaga cyst viability was observed for sample temperatures below 45°C. Total cyst inactivation was onlyobserved after 6-h SODIS exposure at 50°C (3.6 log unit reduction) and after 4 h at 55°C (3.3 log unit reduction.

Dejung, S., Fuentes, I., Almanza, G., Jarro, R., Navarro, L., Arias, G., Urquieta, E., Torrico, A., Fenandez W., Iriarte M., Birrer Ch., Stahel W.A., Wegelin, M. (2007). Effect of solar water disinfection (SODIS) on model microorganisms under improved and field SODIS conditions. *Journal of Water Supply: Research and Technology - AQUA* 56 (4), pp. 245-256.

Inactivation of non-spore forming bacteria: required dose values ranging between 15 and 30 Wh m-2 for 90% inactivation, 45 to 90 Wh m-2 for 99.9%, and 90 to 180 Wh m-2 for 99.9999% inactivation (UV-A dose accumulated during one to two days: 85 to 210 Wh m-2).

Boyle M., Sichel C., Fernández-Ibáñez P., Arias-Quiroz G.B., Iriarte-Puña M., Mercado A., Ubomba-Jaswa E., McGuigan K.G. (2008). Bactericidal Effect of Solar Water Disinfection under Real Sunlight Conditions. *Applied and Environmental Microbiology* 74 (10) p. 2997-3001. doi:10.1128/AEM.02415-07

Exposure time required for complete inactivation (at least 4-log-unit reduction) under conditions of strong natural sunlight was as follows: C. jejuni, 20 min; S. epidermidis, 45 min; enteropathogenic E. coli, 90 min; Y. enterocolitica, 150 min.

► SODIS promotion and acceptance by water users

The rate of acceptance of the SODIS method after one year of promotion in the projects coordinated by Eawag varies considerably and ranges between 20 and 80% (article in preparation). The variance is explained by the type of promotion activities and the local conditions that determine the utility of SODIS relative to other methods of centralized or household water treatment. Experience shows that continuous community education efforts over several months and the exploitation of multiple channels for information dissemination are highly conducive to the sustainable application of SODIS. Case studies with single information events (for example a two-hour SODIS training) have shown that such interventions are hardly sufficient to ensure a wide and sustainable application of SODIS in a given community (see for example: Rainy and Harding 2005)!

Altherr, A.-M., Mosler, H.-J., Tobias, R., Butera, F. (2008). Attitudinal and relational factors predicting the use of solar water disinfection: A field study in Nicaragua. *Health Education and Behavior 35* (2): 207-220

The results show that intention to use and actual use are mainly related to an overall positive attitude, intention to use is related to the use of SODIS by neighbors, and actual use is related to knowledge about SODIS; SODIS users reported a significantly lower incidence in diarrhea than SODIS nonusers.

Rainey R.C., Harding A.K. (2005). Acceptability of solar disinfection of drinking water treatment in Kathmandu Valley, Nepal. *International Journal of Environmental Health Research* 15 (5): 361 – 372

4 months after a single training event, only 9% of households routinely adopted SODIS. Participants mentioned the benefit of treating water to reduce stomach ailments, but this did not outweigh the perceived barriers of heavy domestic and agricultural workloads, other cultural barriers, uncertainty about the necessity of treating the water, and lack of knowledge that untreated drinking water causes diarrhea.

► Leaching of chemical substances from PET bottles

Several studies have been published in reaction to concerns raised regarding potential health risks from chemical compounds released from PET bottles.
Montuori et al. found very low concentrations of plasticizers (DEHA, DEHP) in the water stored in PET bottles Similar results were obtained by Schmid et al. (article in preparation) in experiments conducted at Empa (Switzerland) under the conditions that are typical for the SODIS process.
The leaching of antimony (a catalyst in the PET production process) has been investigated by and Shotyk and Krachler, as well as Westerhoff et al. It was observed that the diffusion of antimony from PET bottles into water increases with storage time and temperature. Under conditions present in the SODIS process (storage time in the range of a few days, temperatures below 65°C), no dangerously high concentrations of antimony in the water must be expected.

Montuori, P., Jover, E., Morgantini, M., Bayona, J. M. and Triassi, M. (2007). Assessing human exposure to phthalic acid and phthalate esters from mineral water stored in polyethylene terephthalate and glass bottles. *Food Additives & Contaminants* 25 (4), 511 — 518.

Concentrations of phthalates are nearly 20 times higher in samples bottled in PET than those from glass bottles with total levels of phthalates of 3.52 and 0.19 µg l-1, respectively. However, the observed levels do not represent a significant exposure pathway when considering the US Environmental Protection Agency (USEPA) reference dose.

Westerhoff P., Prapaipong P., Shock E., Hillaireau A. (2007). Antimony leaching from polyethylene terephtalate (PET) plastic used for bottled drinking water. *Water Research* doi:10.1016/j.watres.2007.07.048.

For exposure temperatures of 60, 65, 70, 75, 80, and 85 degrees C, the exposure durations necessary to exceed the 6 ppb MCL are 176, 38, 12, 4.7, 2.3, and 1.3 days, respectively. Clearly, only a small fraction of the antimony in PET plastic bottles is released into the water.

Shotyk W., Krachler M. (2007). Contamination of Bottled Waters with Antimony Leaching from Polyethylene Terephthalate (PET) Increases upon Storage. *Environ. Sci. Technol.* 41 (5), 1560-1563.

The leaching of Sb from PET(E) bottles shows variable reactivity and ranges between an average of 19% (Canadian bottles) and 90% (European bottles) during 6 months storage at room temperature. Only Two of the brands were at or above the maximum allowable Sb concentration for drinking water in Japan (2 íg/L).

► SODIS mechanism at cellular level

The mechanism of inactivation of pathogenic organisms during the SODIS project was investigated at the Environmental Microbiology Department at Eawag in recent years. The Ph.D. thesis of Michael Berney investigated different factors that influence the efficiency of solar inactivation, mainly of E.coli. The results generally confirm the efficiency of SODIS in inactivating bacteria from drinking water.

Berney, M., Weilenmann, H.-U., Egli, T. (2006) Flow-cytometric study of vital cellular functions in Escherichia coli during solar disinfection (SODIS). *Microbiology* 152: 1719-1729

A better understanding of the process of injury or death of E. coli during SODIS was gained by investigating six different cellular functions, namely: efflux pump activity, membrane potential, membrane integrity, glucose uptake activity, total ATP concentration and culturability. The study confirms the lethal effect of SODIS with cultivation-independent methods and gives a detailed picture of the 'agony' of E. coli when it is stressed with sunlight.

Berney, M., Weilenmann, H.-U., Egli, T. (2006) Gene expression of Escherichia coli in continuous culture during adaptation to artificial sunlight.*Environmental Microbiology* 8 (9): 1635-1647.

The induction of several SOS response-genes strongly points to DNA damage as a result of UVA exposure. It supports the hypothesis of the production of reactive oxygen species by UVA light.

Berney, M., Weilenmann, H.-U., Ihssen, J., Bassin, C., Egli, T. (2006). Specific growth rate determines the sensitivity of enteric bacteria to thermal, UVA and solar disinfection. *Applied and Environmental Microbiology* 72 (4): 2586-2593.

Generally, fast-growing cells were more sensitive to the stresses than slow-growing cells. The findings emphasize the need for accurate reporting of specific growth rates and detailed culture conditions in disinfection studies to allow comparison of data from different studies and laboratories and sound interpretation of the data obtained.

Internet resources

A new webpage has been launched with the goal of linking up the SODIS projects in Africa. This webpage features a blog, active participation is encouraged!
http://www.sodisafricanet.org/.
http://blog.sodisafricanet.org/
The Fundacion SODIS, coordinating the SODIS projects in Latin America, has recently redesigned its website: http://www.fundacionsodis.org.

Several SODIS videos are now available on Youtube:

Sri Lanka (in English): http://de.youtube.com/watch?v=LwJ9p5UHwhc (documentary pt1)
http://de.youtube.com/watch?v=5RXkT_7fdpQ (documentary pt2)
http://de.youtube.com/watch?v=gwivMQkAcfg
http://de.youtube.com/watch?v=RN_c22teWME

Nepal (in Nepali): http://de.youtube.com/watch?v=5s9fZ1Fi0nM (documentary pt1)
http://de.youtube.com/watch?v=8KKanLz36bs (documentary pt2)
http://de.youtube.com/watch?v=g5o2tJ8gb0Q

Pakistan (in Urdu): http://de.youtube.com/watch?v=kh47lXnqzyI

South India (in Tamil): http://de.youtube.com/watch?v=3A7I5S8k_ro

Phillipines (in English): http://de.youtube.com/watch?v=FnjO-y8-Crw

Sierra Leone (in English): http://de.youtube.com/watch?v=CXkgyaIreuc (documentary pt1)
http://de.youtube.com/watch?v=nJiV0qKm1T8 (documentary pt2)

Bolivia (in Spanish): http://de.youtube.com/watch?v=DSBz8f87ohQ

Water Sch$_2$ool (in English): http://de.youtube.com/watch?v=jBsyH7aGUGg

ENERGY GLOBE Award
in English: http://de.youtube.com/watch?v=bz4SWNt9ZeU
in German: http://de.youtube.com/watch?v=xnBfsbrZc0c

Household water treatment and safe storage (HWTS) news

► Events

UNICEF held a meeting in New York on the 29/30th of April with the goal to coordinate and strengthen approaches to promote methods of household water treatment and safe storage on a larger scale. Boiling, chlorination, SODIS, and ceramic filtration were confirmed as viable options for water treatment at household level.
The WHO Network for Household Water Treatment and Safe Storage met in Accra, Ghana, between the 2nd and 5th of June 2008. The network has been active in the research, advocacy, and promotion of different methods of household water treatment and safe storage.
http://www.who.int/household_water/en

► Publications

Different studies have demonstrated that household water treatment systems can make a significant contribution to improving the access to safe drinking water, particularly also in comparison or in combination with water treatment at the source.

Wright J., Gundry S., Conroy R. (2004). Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health* 9 (1): 106-117.

The bacteriological quality of drinking water significantly declines after collection in many settings. Policies that aim to improve water quality through source improvements may be compromised by post-collection contamination. Safer water storage and treatment at household level is recommended to prevent the consumption of contaminated water, together with point-of-use water quality monitoring.

Clasen T., Schmidt W.P., Rabie T., Roberts I., Cairncross S. (2007). Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *British Medical Journal* 334 (7597): 782-785.

Interventions to improve water quality are generally effective for preventing diarrhoea in all ages and in under 5s. Significant heterogeneity among the trials suggests that the level of effectiveness may depend on a variety of conditions that research to date cannot fully explain.

One of the major advantages of treating water at household level is the user's independence from the often unreliable and costly centralized water supply systems. Nevertheless, household water treatment systems also entail a cost for water users. These costs accrue either in monetary terms, or as time requirements or long term indirect effects, e.g., through the deforestation due to the collection of fuel wood. The costs of HWTS systems must always be assessed in relation to the effectiveness of a method in eliminating health risks from drinking water.

Clasen T., Haller L., Walker D., et al. (2007) Cost-effectiveness of water quality interventions for preventing diarrhoeal disease in developing countries. *Journal of Water and Health* 5 (4): 599-608.

Source- and household-based interventions are generally cost effective or highly cost effective (costs range between 0.63 and 4.95 USD per person and year) even before the estimated saving in health costs that would offset the cost of implementation. Household-based chlorination was the most cost-effective, followed by solar disinfection. Flocculation/disinfection was strongly dominated by all other interventions. In addition to cost-effectiveness, choices among water quality interventions must be guided by local conditions, user preferences, e.g. regarding the taste of water, or the potential for cost recovery from beneficiaries.

A study contributed by Sobsey et al. identifies ceramic and bio-sand filters as the most sustainably applicable method for household water treatment. Some of the assumptions in this publication are based on single case studies, however, and should be assessed critically. The paper assumes a low SODIS acceptance based on the findings from one single case study (Rainey and Harding 2005, see above), that reported an application rate of 9% of population in a village four months after one single information event had taken place (a two-hour SODIS training). However, as for hand-washing or the brushing of teeth, SODIS demands a change of behavior and therefore needs time and a regular follow up. Furthermore, the ranking of the different HWTS methods in the article by Sobsey et al. creates the misleading impression that one single 'best' method for the treatment of water at household level can be identified. Much in contrast, we are convinced that the users should be able to choose the most appropriate method under the specific local situation from a broader range of options.

Sobsey M.D., Stauber C.E., Casanova L.M., Brown J.M., Elliott M.A. (2008). Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World. *Environ. Sci. Technol.*, ASAP Article, 10.1021/es702746n.

The most effective, widely promoted and used POU HWTs are critically examined according to specified criteria for performance and sustainability. According to the applied criteria, ceramic and biosand filters are identified as most effective according to the evaluation criteria applied and as having the greatest potential to become widely used and sustainable for improving household water quality.

A new research project gives renewed attention to the single most successful method for household water treatment: boiling. This project addresses the questions of the effectiveness in terms of health improvement and the costs for the households in comparison to more recently developed and promoted methods.

Clasen T. F., Thao D. H., Boisson S., Shipin O. (2008) Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water in Rural Vietnam. Environ. Sci. Technol., ASAP Article, 10.1021/es7024802.

Despite certain shortcomings, boiling is still the most common means of treating water in the home and the benchmark against which alternative household-based disinfection and filtration methods must be measured. Despite high levels of faecal contamination in source water, 37% of stored water samples from self-reported boilers met the WHO standard for safe drinking water (0 TTC/100 mL), and 38.3% fell within the low risk category (1–10 TTC/100 mL). The estimated cost of wood used to boil water was US$ 0.272 per month for wood collectors and US$ 1.68 per month for wood purchasers, representing approximately 0.48% to 1.04%, respectively, of the average monthly income of participating households.

Sidelines

Hygiene is increasingly highlighted as a critical element of the prevention of infectious diseases. A fascinating book sheds light on the fluctuating cultural connotations of hygiene habits throughout history: http://women.timesonline.co.uk/tol/life_and_style/women/the_way_we_live/article3498349.ece?OTC-HPtoppuff&ATTR=ind25

World Water Day has long passed, but Stephen Colbert's reflections on water are fresh as ever: http://www.comedycentral.com/colbertreport/videos.jhtml?episodeId=164042

Further information / contact

www.eawag.ch
www.sodis.ch

info@sodis.ch

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