SODISWATER

Deliverable 26b

Final Report

Publishable Final Activity Report for the SODISWATER Project Sept 2006-Feb 2010

Solar Disinfection of Drinking Water for use in Developing Countries or in Emergency Situations

European Union Contract Number FP6 2006 INCO-DEV 031650

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1. PROJECT EXECUTION

Project Objectives

Solar disinfection (SODIS) is a simple technique for disinfecting drinking water in developing countries or in the aftermath of human disasters. Microbially contaminated drinking water is stored in transparent containers such as plastic bags, plastic or glass bottles. These are placed in direct sunlight for periods of up to 8 h before consumption. Previous studies have reported a reduction in incidence of diarrhea among those children who drank water exposed to direct sunlight compared with another group that drank water not exposed to sunlight. The SODISWATER project hopes to increase the number of communities in developing countries using SODIS through a variety of field- and laboratory-based studies.

1.1.1 General Objectives

1. To demonstrate that Solar Disinfection (SODIS) of drinking water is an appropriate, effective and acceptable intervention against waterborne disease for vulnerable communities in developing countries without reliable access to safe water.
2. To evaluate and test different diffusion and behavioural change strategies in areas with different social and cultural conditions for sustainable adoption of solar water disinfection.
3. To disseminate these research outcomes throughout the international aid and emergency relief communities so that SODIS is adopted as one of a range of standard water quality interventions (e.g. filtration, chlorination, desalination, etc.) for use in the immediate aftermath of natural (Tsunami, flood, earthquake, hurricane/typhoon) or man-made disasters (war-zone, famine, refugee camp).
4. To develop a spectrum of appropriate SODIS enhancement technological innovations that can be matched to varying socio-economic conditions. Such technological innovations would include UV dosimetric indicators of disinfection, photocatalytic inactivation and continuous flow compound parabolic collector arrays for small community distribution systems.

1.1.2 Scientific Objectives of SODISWATER

1. Assessment of the change in health reasonably attributed to the provision of solar disinfected drinking water at the point of use in three African countries
2. Assessment of the relationship between solar disinfected drinking water and selected health indicators (including morbidity due to non-bloody diarrhoea and dysentery, weight loss, mortality, growth rates, productivity, care-giver burden, and school attendance).
3. Demonstration of the effectiveness of SODIS at household level.
4. Demonstration of the degree of acceptance of SODIS as a disinfection method.
5. Determine SODIS efficacy against selected waterborne viruses: Hepatitis A, Coxsackie A & B, Polio virus.
6. Determine SODIS efficacy against selected waterborne protozoa (oo)cyst stage *Cryptospridium parvum, Entamoeba histolytica, Naegleria fowler Acanthamoeba polyphaga (*which will be studied as a model protozoa that can be readily cultured and manipulated in the laboratory).
7. Determine SODIS efficacy against selected waterborne helminths*: Ascaris lumbricoides ,*& *Caenorhabditis elegans (*which will be studied as a model nematode that can be readily cultured and manipulated in the laboratory).
8. Determine SODIS efficacy against selected waterborne bacteria: Enteropathogenic *E. coli (*EPEC*), Yersinia enterocolitica, Campylobacter jejuni.*
9. Conduct a pilot feasibility study of the most promising SODIS enhancement innovation technologies based in one of the African partner countries.
10. Guide for deriving diffusion and behavioural change strategies from the standardised survey.
11. Report on the analysis of strategies used in previous case studies.
12. Standardised social monitoring tool for the evaluation of the success of campaigns.
13. Standardised survey of current water usage and practices in Health Intervention Study communities.
14. Publications on SODIS diffusion and adoption factors
15. International Publications & Presentations on efficacy & health benefits of SODIS.
16. To host an international conference on all relevant aspects of SODIS to help promote the technique among target users.

1.1.3 Technological Objectives of SODISWATER

1. Design and construct a prototype low-cost continuous flow SODIS reactor with add-on compound parabolic concentrator (CPC).
2. Design and construct a batch photocatalytic SODIS reactor.
3. Research and develop a UV dosimetric sensor for feedback control of continuous flow systems.
4. Design and construct a low cost UV dosimetric indicator for use with batch SODIS.
5. Test all enhancement and control sensor technologies under real sun conditions with identified model microorganisms with high environmental stress tolerance.
6. Undertake a cost based analysis of technologies in relation to deployment in a developing country.
7. Produce a SODIS promotion brochure for dissemination purposes at Govt. & NGO level.

Produce a tailor made SODIS presentation set for use at international conferences

1.2 Participant Organisations

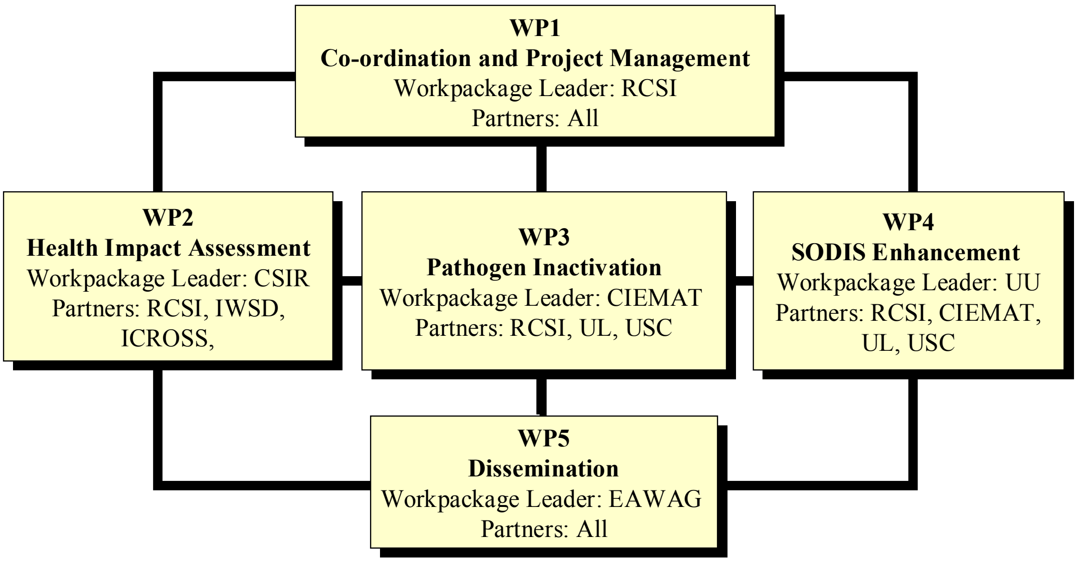
1. Royal College of Surgeons in Ireland, (R.C.S.I.), Ireland
2. University of Ulster, (UU), United Kingdom
3. Council for Science and Industrial Research, (CSIR), South Africa
4. Swiss Federal Institute of Aquatic Science and Technology, (Eawag), Switzerland
5. Institute of Water and Sanitation Development, (IWSD), Zimbabwe
6. Plataforma Solar de Almeria - Centro de Investigaciones Energéticas Medioambientales y Tecnológicas, (PSA-CIEMAT), Spain
7. University of Leicester, (UL), United Kingdom
8. International Community for the Relief of Suffering and Starvation, (ICROSS), Kenya
9. University of Santiago de Compostela, (USC), Spain

1.3 Work Packages

The SODISWATER project was broken down into five distinct work packages with each contractor having a clearly defined role. Each work package was assigned a lead contractor responsible for the management of that work package and for the communication of progress to the coordinator. The lead contractor assigned to each particular work package was assigned because of their particular expertise in the field, which dominates that package. The work packages and main task involved are:

1. **WP1: Coordination, Management & Programme Review:** (Tasks Coordination**:** Reports (milestone review), Meetings, Management, SODISWATER Website)
2. **WP2: Health Impact Assessment:** (Tasks: Ethical clearance and associated issues, Study area selection, Liaison with authorities, Fieldworker training, Data collection procedures, Development of data collection instruments, Establishing analytical methods, Pilot studies, Household selection, pre-survey, Training in solar disinfection, Monitoring for 12 months (Water sample, Anthropometry, Diarrhoea morbidity, SODIS compliance and socio-economic factors, Diarrhoea Mortality), Post study SODIS use protocol compliance, Data analysis Feedback)
3. **WP3: SODIS Pathogen Inactivation:** (Tasks: Bacterial Pathogen Inactivation, Viral/Parasitic Pathogen Inactivation, Field Validation of Simulation Model, SODIS based reactor development, Disinfection Analysis & Modelling)
4. **WP4: SODIS Enhancement Technologies** (Tasks Development of: Continuous flow SODIS reactor, Continuous flow photocatalytic SODIS reactor, Batch photocatalytic SODIS reactor, UV dosimeter for batch SODIS, UV feedback control sensor for continuous flow SODIS, Prototype Testing, Cost Based Analysis)
5. **WP5: SODIS Adoption & Dissemination.** (Tasks: Analysis of previous case studies, Setting up the adoption study, Survey of current usage trends, Derivation of strategies, Field experiments, Evaluation of the strategies, Development of a brochure, Development of a presentation set, Design of a conference on SODIS, Publications & Conferences.)

PERT CHART



Deliverables List

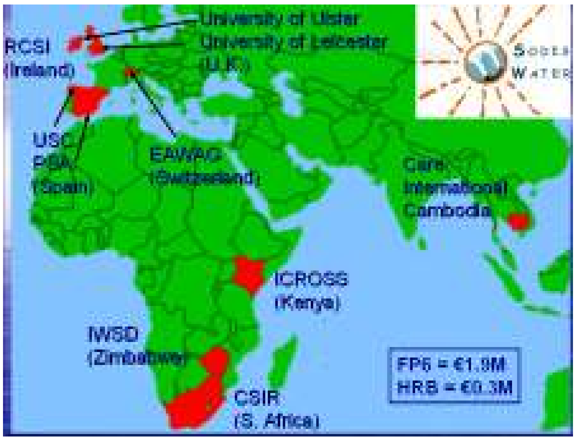
Deliverable No.	Deliverable Name	Delivery Date	Achieved Y/N	Comment
1	Webpage creation for all project related information	1	Y	
2	Review of progress	6	Y	
2b	Ethical Approval for the HIAs obtained	6	Y	
3	Report about the analysis of previous SODIS case studies	6	Y	
4	Standardised community current usage survey	7	Y	
4b	Review of progress	12	Y	
5	Field Manual: This will describe full details on how field trials will be conducted	12	Y	
6	Report on efficacy of SODIS against bacterial waterborne pathogens	12	Y	
7	Guide for deriving diffusion and behavioural change strategies from the data of a standardised survey	12	Y	
8	Standardised social monitoring tool for the evaluation of the success of campaigns	12	Y	
8b	Report on feasibility of unassisted flow-thru SODIS reactor	12	Y	
8c	Review of progress	18	Y	
9	Continuous flow SODIS reactor with add-on CPC	18	Y	

10	Continuous flow photocatalytic SODIS reactor with add-on CPC	18	Y	
11	Batch photocatalytic SODIS reactor	18	Y	
Deliverable No.	**Deliverable Name**	**Delivery Date**	**Achieved Y/N**	**Comment**
12	UV dosimeter for batch SODIS	18	Y	
13	UV feedback control sensor for continuous flow SODIS	18	Y	
13b	Review of progress	24	Y	
14	Data and report on prototype testing under real sun conditions and comparing enhancement technologies	24	Y	
15	Report on inactivation parameters for use under varying conditions	24	Y	
15b	Review of progress	30	Y	
16	Cost Based Analysis on enhancement technologies for deployment in developing country	30	Y	
17	Report on efficacy of SODIS against parasitic/viral waterborne pathogens	30	Y	
18	Report on SODIS diffusion and adoption factors	30	Y	
18b	Report on pilot studies of enhancement technologies	30	Y	
18c	Pro-Poor Business Action Plan	30	Y	
19	Identification of health determinants	36	Y	
20	SODIS presentation set	42	Y	
21	SODIS brochure	42	Y	
22	Assessment of acceptance/compliance of the SODIS method	42	Y	
23	Assessment of the impact of the intervention on health determinants /health outcomes	42	Y	
24	SODIS conference	36	Y	Occurred month 37
25	Technology Implementation Plan	42	Y	Included as part of D27 "Final report on use and dissemination of knowledge"
26	Final Report to EC	42	Y	
27	Final plan for using & disseminating knowledge	42	Y	

2. EXECUTIVE SUMMARY OF SODISWATER PROJECT

2.0 COORDINATOR SUMMARY

The origins of the SODISWATER Project lie in the 2004 Indian Ocean Tsunami disaster. Prior to the tsunami, despite more than 10 years of world class research in the area of solar disinfection of drinking water by many researchers, very few aid agencies were prepared to promote SODIS as a water treatment option, even in situations of dire emergency or need. It was obvious to the entire SODIS community that specific gaps in the knowledge were creating barriers preventing adoption by those communities that might benefit most. It was for that reason that the SODISWATER project came into being. Four specific topics were identified as being of primary importance for the successful dissemination of the SODIS technique to target communities:



SODISWATER Project Partners

- Health Impact Assessments: In 2004 the only clinical trials of SODIS were those conducted by RCSI and ICROSS among the semi-nomadic, rural Maasai community in Sub-Saharan Kenya. No data was available on whether SODIS was effective in other geographical, climatic or socio-economic environments. Under the work-package leadership of Martella du Preez in the CSIR, the SODISWATER project conducted Health Impact Assessments (HIAs) among peri-urban and rural communities in Kenya, Zimbabwe and S Africa. A fourth HIA separately funded by the Irish government was subsequently run among rural communities in Cambodia in parallel with the EU SODISWATER HIAs and using the same protocols and methodologies.

- Previously Untested Waterborne Pathogens: At the start of the project many bacterial species had been tested and shown to be susceptible to SODIS. However, only limited data was available regarding its efficacy against viral, protozoan and other eukaryotic pathogens. Dr Pilar Fernandez of the Plataforma Solar de Almeria lead the work-package targeting the studies of how effective SODIS was against the most important waterborne pathogens including enteropathogenic *E. coli, Yersinia enterocolitica, Campylobacter jejuni* (gastroenteritis), *Cryptosporidium parvum* (cryptosporidiosis), *Entamoeba histolytica* (amoebic dysentery), *Naegleria fowleri* (meningoencephalitis), *Acanthamoeba polyphafga* (encephalitis (model organism)), *Ascaris lumbricoides* (ascariosis), and viruses like Hepatitis A virus, Coxsackie virus A (aseptic meningitis), and Polio virus.

- SODIS Enhancement Technologies: The SODIS technique relies on the use of 2-litre plastic bottles which are filled with available water and placed in the sun for at least 6 hours exposure. Complications arise if there is insufficient available sunlight or if the household contains a large number of people relying on this technique. Dr Anthony Byrne of the University of Ulster lead the Enhancement Technologies work-package whose mission was to investigate technologies which could enhance SODIS by providing larger treated volumes, shorter inactivation times or indications that a sufficient solar dose for disinfection had been received.

- Dissemination: Experience had shown that the results of effective scientific research does not easily transform into everyday usage, particularly among communities in the developing world. Hans Mosler of the Swiss Federal Institute of Aquatic Science and Technology, (Eawag) spearheaded the work-package investigating the most effective promotion strategies for introducing SODIS into a community in Zimbabwe. In addition this work-package took responsibility for the other more traditional dissemination activities (publications, conference presentations, etc.)

The SODISWATER Project was officially launched in September 2006. The total budget of €2.7 million (EU contribution of €1.9 was shared among 10 partner organisations based in eight countries across Europe, Africa and Asia. Although the project duration was originally planed to be 36 months post-election violence, political unrest and economic hyperinflation caused significant disruption to the project in Zimbabwe and Kenya which necessitated a 6 month extension changing the end date from Aug 31st 2009 to February 28th 2010. The Cambodian project will finish in September 2010.

The SODISWATER Project Team: 1. Kevin McGuigan (RCSI) 2. Patrick Dunlop (UU) 3. Mike Meegan (ICROSS) 4. Priyajit Samaiyar (Care Cambodia) 5. Hipolito Gomez-Couso (USC) 6. Barry McGowan (RCSI) 7. Silvie Kraemer (Eawag) 8. Fungai Makoni (IWSD) 9. Elvira Ares-Mazas (USC) 10. Martella du Preez (CSIR) 11. Hans Mosler (Eawag) 12. Wayne Heaselgrave (UL) 13. Bongi Moyo (IWSD) 14. Sinead Kierans (RCSI) 15. Kevin Murray (CSIR) 16. Ronan Conroy (RCSI) 17. Tony Byrne (UU) 18. Simon Kilvington (UL) 19. Pilar Fernandez (CIEMAT) 20. Joseph Kodamanchalay (Care Cambodia) 21. Eunice Ubomba-Jaswa (RCSI), 22. Maria Boyle (RCSI) 23. Inmaculada Polo-Lopez (CIEMAT) 24. Dhea Al-Roussan (UU)

In almost every respect, the SODISWATER Project has exceeded all expectations. The most important research outcomes from the project are:

<u>Health Impact Assessments:</u> Results

1. For children under age 5 years, proper use of SODIS (compliance > 75%) resulted in significant reductions in rates of dysentery ranging between 30% and 65% in Kenya, S Africa and Cambodia. No significant results were available from the Zimbabwe study which was irretrievably and adversely affected by political unrest, economic crises and a prolonged outbreak of cholera throughout

Some of the SODISWATER field teams in (a) S Africa, (b) Cambodia, (c) Kenya, and (d) Zimbabwe the country. While the distribution of freely available chlorine tablets by the major aid agencies in Zimbabwe for those at risk was welcomed by all on humanitarian grounds, it nevertheless produced drastic reductions in SODIS compliance within the test study group who no longer saw a need to practice the technique. By the time that the cholera epidemic had passed and chlorine tablets were no longer freely available, most of the SODIS bottles that had been distributed to the test groups were either used for other purposes (storing cooking oil, milk etc.) or lost.

Summary Table of the most significant results from the SODSWATER HIAs

Country	**Endpoint**	**Incidence rate ratio**§	**95% Confidence Interval**	**Sig**
Kenya	Dysentery days	0.56*	0.40 to 0.79	<0.001
	Dysentery episodes	0.55*	0.42 to 0.73	<0.001
	Non-dysentery days	0.70*	0.59 to 0.84	<0.001
	Non-dysentery episodes	0.73*	0.63 to 0.84	<0.001
Cambodia	Dysentery days	0.43*	0.20 to 0.95	0.036
	Dysentery episodes	0.46*	0.25 to 0.85	0.014
	Non-dysentery days	0.39*	0.32 to 0.48	<0.001
	Non-dysentery episodes	0.37*	0.30 to 0.46	<0.001
South Africa	Dysentery 75% to 100% Compliance	0.35*	0.17 to 0.76	0.011

§*Incident rate ratio = diseases incident rate in SODIS group divided by incident rate in control group*
** Statistically significant.*

2. Studies of the effects of prolonged solar exposure on chemicals leaching from the container plastic into the water were conducted. Under SODIS conditions, bottles were exposed to 6 hours of sunlight, followed by overnight room temperature storage. They were then emptied and refilled the following day and exposed to sunlight again. No genotoxic effects were observed for water samples that had been in PET bottles and exposed to normal SODIS conditions (strong natural sunlight) over 6 months.

<u>*Previously Untested Waterborne Pathogens:*</u> Results

3. The list of waterborne microbial species that are now known to be inactivated by SODIS is as follows:

Microbe	**Species**	**Microbe**	**Species**
Bacteria	*Campylobacter jejuni** *Enterococcus sp.* *Enteropathogenic E coli** *Mycobacterium avium** *Mycobacterium intracellulare** *Pseudomonas aeruginosa* *Salmonella typhi* *Salmonella typhimurium* *Shigella dysenteriae* Type I *Shigella flexneri* *Streptococcus faecalis* *Staphylococcus epidermidis** *Vibrio cholerae* *Yersinia enterocolitica**	**Viruses**	Bacteriophage f2 Encephalomyocarditis virus Polio virus Rotavirus Coxsackie virus A/B* Hepatitis A*
		Protozoa	*Acanthamoeba polyphaga* (cyst) *Cryptosporidium parvum* (oocyst) *Entamoeba sp. ** (cysts) *Giardia sp* (cysts) *Naegleria sp. **

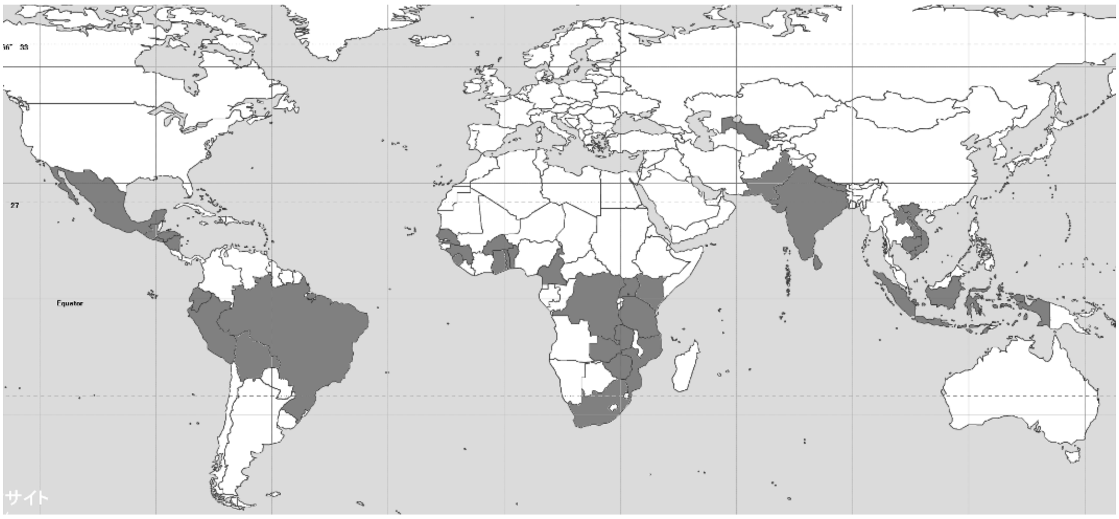
Fungi	*Candida albicans* *Fusarium sp.**	**Helminth**	*Ascaris sp (ova)**

* SODISWATER research output

SODIS Enhancement Technologies: Results

4. The standard plastic bottle has proven to be deceptively effective compared to many of the enhancement technologies examined. Neither chemical-based indicator tape nor continuous flow recirculation reactors proved reliable. The most promising candidate technologies are solid-state based UV Feedback control system for automated batch control and large volume enhanced batch reactors (EBR) fitted with compound parabolic collectors (CPCs) for operation under low sunlight/overcast conditions. However our cost-benefit analysis of these technologies indicates that at this time neither confers sufficient benefit to justify further investigation.
5. Insufficient time was available for full field testing of the EBR within the SODISWATER Project but these prototypes will be fully tested under African Field conditions as part of an Irish govt. funded project based in Uganda (Water is Life project see http://www.dkit.ie/waterislife/topic/solar-disinfection-of-drinking-water)

Dissemination: Results



Developing World countries shaded in gray where SODIS is used (33 known as of April 2010).

6. The most effective dissemination strategy was identified as household visits by trained promoters in conjunction with the use of memory aids such as stickers within the household to integrate the SODIS into into the daily routine.
7. SODIS is now an accepted household water treatment and storage intervention against waterborne disease and is actively promoted by the WHO in the aftermath of humanitarian disasters.
8. According to the Eawag SODIS Reference Centre, as of April 2010 SODIS is relied upon daily by more than 4.5 million people and in more than 30 countries.
9. The SODISWATER Project has generated an impressive critical mass of new scientific knowledge which has been published in 22 peer-reviewed articles with 2 more submitted for review and another 7 in preparation for submission.
10. Eight early stage researchers have completed post-graduate degrees (7 PhDs and 1 MSc) by submitting theses based on SODISWATER research. An additional four are currently in preparation.

The Future of SODIS & SODISWATER:

The efficacy of solar disinfection is now proven beyond doubt. Most of the major challenges surrounding SODIS lie outside the laboratory. Significant questions which demand attention in the immediate future are:

a. Efficacy of SODIS compared with other point of use household water treatments such as chlorination and filtration. Is there any benefit associated with applying SODIS in addition to chlorination or filtration as has been observed in some locations?

b. Efficacy of SODIS outside of the under-5 year age group. A community sector of particular interest would be communities with high numbers of people living with HIV/AIDS.
c. Can SODIS compliance increase through the use of simple CPC reflectors? There is an additional psychological question here since the addition of the reflector may raise the perception of the SODIS bottle from recycled plastic bottle to valued technology.
d. What are the risks associated with long-term consumption of SODIS water. Although the preliminary genotoxicity studies revealed no risks associated 6-month usage of plastic bottles under SODIS regimes, more sensitive tests are urgently required on a range of PET bottles.
e. If more sensitive toxicity studies reveal genotoxic risks should we develop a bespoke glass SODIS container for mass production

FUTURE IMPLEMENTATION STRATEGY

The primary aim of the SODISWATER Project was to develop an implementation strategy for SODIS which would help with the dissemination of this technique to key stakeholders. In this regard we have achieved our objective in that we have developed suitable material for each level of enquiry.

Communities at risk: Through the groundbreaking work carried out in the Dissemination work-package we now know the most effective means of introducing SODIS technology in peri-urban Sub-Saharan African communities - trusted community leaders acting as trained promoters in conjunction with memory aids around the household.

Aid Agencies: Through our involvement with the WHO HWTS Network and hosting the HWTS09 conference in Dublin, we have raised the profile of SODIS with the most famous actors on the water treatment and development aid stage. SODIS is now accepted and promoted by the WHO as an appropriate emergency intervention against waterborne disease. SODIS is now the first rung on the “Water Ladder”. If there are insufficient funds to enable the distribution of the more expensive HWTS options (filtration, chlorination, etc.), SODIS represents an appropriate and affordable intervention until such time as circumstances change.

Govt. Depts.: Any calls for information at this level can be dealt with using the SODIS Brochure (Deliverable 21), SODIS Presentation (Deliverable 20) and/or personal communications from the project coordinator or work-package leaders who can act as advocates or knowledge brokers for the technology.

2.1 WORK-PACKAGE 2 HEALTH IMPACT ASSESSMENT-EXECUTIVE SUMMARY:

SODIS refers to the solar disinfection of water using a 2-litre transparent plastic soft-drink bottle placed in the sun for at least 6 hours. This disinfection method can potentially produce drinking water that can reduce the incidence of diarrhoea in young children. The study reported herein aimed to broaden the current limited evidence base by conducting health impact studies in three African countries, namely, South Africa, Kenya and Zimbabwe.

Specific objectives for the health impact assessments were:

1. Assessment of the change in health reasonably attributed to the provision of solar disinfected drinking water at the point of use in three African countries;
2. Assessment of the relationship between solar disinfected drinking water and selected health indicators (including morbidity due to non-bloody diarrhoea and dysentery, weight loss, mortality, growth rates);
3. Demonstration of the effectiveness of SODIS at household level; and
4. Demonstration of the degree of acceptance of SODIS as a disinfection method.

2.1.1 Literature summary

Nine million children under five years of age die from diarrhoea each year. The vast majority of cases are preventable by increasing the availability of clean water and improving sanitation and hygiene. However, the associated costs and logistics have focused much attention on home water treatment interventions. Solar disinfection is by far the simplest and cheapest method.

The effectiveness of the method relies on both optical (through UV-A and UV-B irradiation) and thermal processes, achieved by exposing water in a clear plastic 2-litre bottle to the sun for at least six hours. Laboratory studies have confirmed the ability of the method to inactivate bacteria.

Few field studies have been performed to test SODIS. In particular, the distinction between dysentery and non-dysentery diarrhoea has not been investigated. The field studies reported herein address this deficiency and attempt to broaden the general evidence base for SODIS.

2.1.2 Field study design

The study focused on dysentery and non-dysentery diarrhoea in children between 6 months and 5 years of age. Anthropometric measurements were also recorded. There were seven main phases:

1. **Initialisation**: This phase included selection of appropriate study areas, liaison with the relevant national, regional and local authorities and communities, and recruitment of field workers and supervisors. Questionnaires were developed, a paper-based daily diarrhoeal diary developed, and ethical clearance obtained. Two databases were developed to capture (1) field data and (2) diarrhoeal diary data. A field manual was developed and a manual for diarrhoeal diary data entry.
2. **Pilot study**. This involved preliminary training followed by in-the-field testing and practice of the procedures in one small area in each country.
3. **Pre-survey**. This involved the selection of the households and children to participate in the study. Associated demographic information and other key household characteristics were recorded on handheld computers and downloaded onto laptops. Participating households were provided with their hard-copy diarrhoeal diaries and test households provided with their SODIS bottles. Associated instructions and demonstrations were also given.
4. **12-month main survey**. This comprised (a) ongoing daily recording by child carers of the nature of the stools produced by the children and (b) four three-monthly monitoring visits during which (i) water samples were taken and analysed, (ii) anthropometry measurements obtained, and (iii) data downloaded from handheld computers onto laptop databases.
5. **Post-survey compliance**. Upon completion of the year-long study, all control households were offered training in the use of the SODIS bottles. If they indicated a willingness to adopt SODIS, they were given SODIS bottles and the necessary instructions. The degree of compliance of SODIS in all the households using the bottles was evaluated after six months.
6. **Data analysis**. The data collected from the main survey has been analysed statistically to determine the effectiveness of the use of SODIS on diarrhoea in young children. The results are reported herein.
7. **Feedback**. Feedback to local participating communities has occurred and selected final project documents will also be provided to appropriate community leaders.

2.1.3 Field study area descriptions

- **South Africa**. The study area was in a peri-urban area north of Pretoria. While living conditions in the selected South African areas were relatively good compared to many other African countries, unemployment was high. Long distance commuting of those with employment contributes to a lack of child supervision. This and other factors such as high numbers of HIV and AIDS orphans and inappropriate use of government child support grants have resulted in a general lack of social cohesion.

- **Kenya**. The study took place in peri-urban and rural communities in the vicinity of the town of Nakuru north of the capital Nairobi. Living conditions in the Kenyan study areas were characterised by extreme poverty and somewhat limited access to safe water and adequate sanitation.
- **Zimbabwe**. The selected study area was a peri-urban informal settlement called Hatcliff about 10 km from the capital Harare characterised by abject poverty and very high unemployment. Access to water was limited and erratic and sanitation facilities were limited.

2.1.4 Factors seriously impeding study

- **Kenya**. The violence and uncertainty associated with the political unrest in March 2009 resulted in the loss of 414 children from the study. Delays in payment of funds to ICROSS in Kenya resulted in an inability to pay salaries which in turn resulted in a loss of local project staff members. As a result, some planned work could not be completed.
- **Zimbabwe**. Political unrest and uncertainty had significant effects on the ability to carry out the project work, though over a much longer period than in Kenya. Organisational changes in the Institute for Water and Sanitation Development (IWSD), responsible for execution of the SODIS project, also caused delays. During the period of the main survey endemic cholera broke out. Local NGOs responded by providing chlorine solutions, soap and food. Even though these necessary practices would inevitably impact on the SODIS study, the decision was made to continue. Samples could sometimes not be obtained because participants were away tending farms. Delays in the payment of funds from the European Commission at the end of 2008 also hampered the execution of the study.


(a)


(b)

(a) The Nakuru slum district where the peri-urban portion of the study was completed in Kenya. In the foreground, a child collects water from a cracked pipe directly above an open sewer. (b) A mother in the same area shows a field officer her SODIS bottles. Note she has supplemented the original two bottles supplied by the project with 3 additional bottles which she obtained herself.

2.1.5a Results – South Africa

SODIS effectiveness

- **Dysentery**: A significant reduction in risk of dysentery resulted when participants complied well with the recommended protocol for using the SODIS bottles. Equivalently, when compliance was low no significant reduction in risk occurred.
- **Non-dysentery diarrhoea**: Using SODIS bottles did not affect the overall risk of non-dysentery diarrhoea nor did the degree of compliance to the SODIS protocol affect this risk. In particular, even good compliance did not affect the risk.
- **Disinfection**: Based on whether or not participants said they had put the SODIS bottle out in the sun the previous day, the average difference in *E. coli* concentrations in the SODIS bottles between those that did not and did was about 0.5 $\log_{10}$ units. This indicated a general disinfection effectiveness of the SODIS protocol.

Health risk factors

- **Water** source: There was a substantially lower risk of dysentery in those children drinking standpipe water.
- **Water** drawing **method**: The risk of dysentery was substantially increased by the use of a scoop to draw water from the storage container compared to pouring from the container.
- **Toilet** facilities: Compared with those without access to a toilet, those with access to a flush toilet had a significantly lower rate of dysentery.

Acceptance of SODIS
- **During study**: There were indications of a general decreasing acceptance of the use of SODIS.
- **Post-study**: Very few control households showed a willingness to adopt SODIS at the end of the main field study.

2.1.5b Results – Kenya

SODIS effectiveness
- **Dysentery**: A significant (roughly 45%) reduction in days with dysentery and dysentery episodes resulted when using the SODIS bottles.
- **Non-**dysentery **diarrhoea**: A significant (roughly 30%) reduction in days with non-dysentery diarrhoea and non-dysentery diarrhoea episodes resulted when using the SODIS bottles.

Health risk factors
- **Toilet** facilities: The risk of dysentery rose with increasing numbers of people sharing a toilet.

2.1.5c Results – Zimbabwe
Only a limited analysis was possible because of the lack of data integrity. No insights were gained relating to SODIS effectiveness, health risk factors or acceptance of SODIS.

2.1.6 Discussion and conclusions

Country	Endpoint	Incidence rate ratio§	95% Confidence Interval	Sig
Kenya	Dysentery days	0.56*	0.40 to 0.79	<0.001
	Dysentery episodes	0.55*	0.42 to 0.73	<0.001
	Non-dysentery days	0.70*	0.59 to 0.84	<0.001
	Non-dysentery episodes	0.73*	0.63 to 0.84	<0.001
Cambodia	Dysentery days	0.43*	0.20 to 0.95	0.036
	Dysentery episodes	0.46*	0.25 to 0.85	0.014
	Non-dysentery days	0.39*	0.32 to 0.48	<0.001
	Non-dysentery episodes	0.37*	0.30 to 0.46	<0.001
S Africa	Dysentery 75% to 100% Compliance	0.35*	0.17 to 0.76	0.011

§*Incident rate ratio = incident rate in SODIS group divided by incident rate in control group*
** Statistically significant.*

The outcomes of the field studies in each country were fundamentally determined by events outside the control of the project teams. These included the serious political unrest and financial problems that beset both Kenya and Zimbabwe. Zimbabwe also suffered a severe cholera outbreak. Ultimately, the resulting delays and particularly the loss of participants affected data quantity and overall data quality. In South Africa it is likely that the apparent lack of acceptance of SODIS, probably at least partly caused by a perception that their water quality was adequate, resulted in a dataset that lacked the desired quantity and quality.

Notwithstanding these problems, the dataset that emerged from South Africa was reasonably complete, that from Kenya much less so, and from Zimbabwe even less so.
Statistical analysis of the data revealed that in South Africa, use of SODIS significantly reduced the risk of dysentery. In Kenya it reduced the risk of dysentery days (i.e. days on which dysentery occurred), dysentery episodes, non-dysentery diarrhoea days and non-dysentery diarrhoea episodes. In Zimbabwe, there was no evidence that SODIS was associated with the risk of dysentery. However, this is not necessarily a negative conclusion in respect of SODIS effectiveness because of the lack of data integrity. It may only be a negative conclusion in respect of the ability to conduct studies of this kind.
Very little anthropometric data was obtained in Zimbabwe. While such data were collected in South Africa and Kenya, there was no evidence that weight and height of the children was affected by SODIS. However, again, this is not necessarily a negative conclusion in respect of SODIS because of the recognised difficulties in obtaining a sufficiently high data quality, particularly using inexperienced personnel.
Various factors that potentially affect dysentery risk were investigated. These included the type of water source, the way in which water was drawn from the in-house storage container, hand washing in various situations (after going to the toilet, after removing a baby's nappy, etc.), and toilet facilities (type of toilet and the number of people sharing it). While in South Africa and Kenya some factors could be statistically associated with the risk of dysentery, there was no common factor to the two countries.
In essence therefore, given the variety of difficulties faced in all three countries, and the associated lack of data quality and quantity, there is no obvious evidence that SODIS is not effective in respect of diarrhoea. On the contrary, in those two countries in which data quality was better, namely South Africa and Kenya, positive evidence was found for SODIS effectiveness.

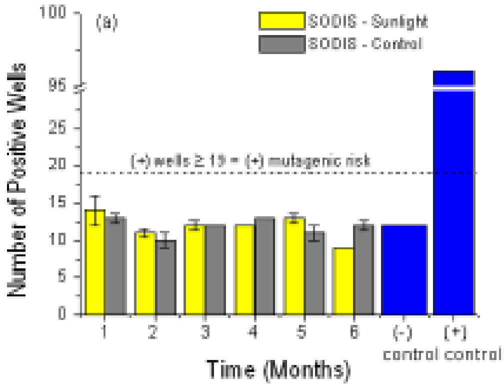
TOXICITY STUDIES
Preliminary studies of possible genotoxic effects arising from photodegradation of SODIS bottles after prolonged use were completed by RCSI, CIEMAT & CSIR personnel based in PSA. The concern was that chemicals may leach from the plastic into the water as the container material degrades under the sun. AMES toxicity assays were carried out to determine if any genotoxic events could be detected.

No genotoxic effects were observed for water samples that had been in (a) PET bottles and exposed to normal SODIS conditions (strong natural sunlight) over 6 months. Under SODIS conditions, bottles were exposed to 6 hours of sunlight, followed by overnight room temperature storage. They were then emptied and refilled the following day and exposed to sunlight again. Genotoxicity was detected after 2 months in (b) water stored in PET bottles and exposed continuously (without refilling) to sunlight for a period ranging from 1 to 6 months. However, similar genotoxicity results were also observed for the dark control (without refill) samples at the same time-point and in no other samples after that time; therefore it is unlikely that this genotoxicity event is related to solar exposure.

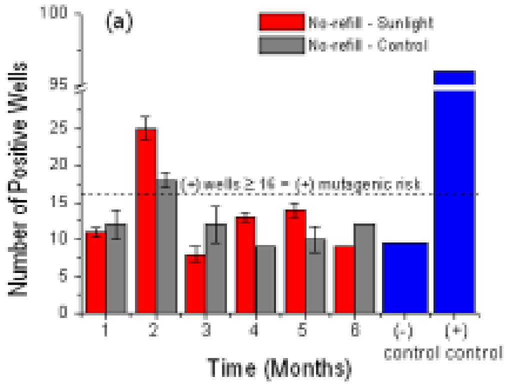
Plastic SODIS bottles filled with water and set out on the roof of the CIEMAT laboratories in Almeria Spain. Bottles were exposed over 6 months. Assays were conducted every month.

The primary outcome of this aspect of the research is the recommendations that:

1. SODIS bottles should be replaced at least every 6 months
2. Further, more sensitive studies of the health effects of photodegradation products in SODIS water are required.



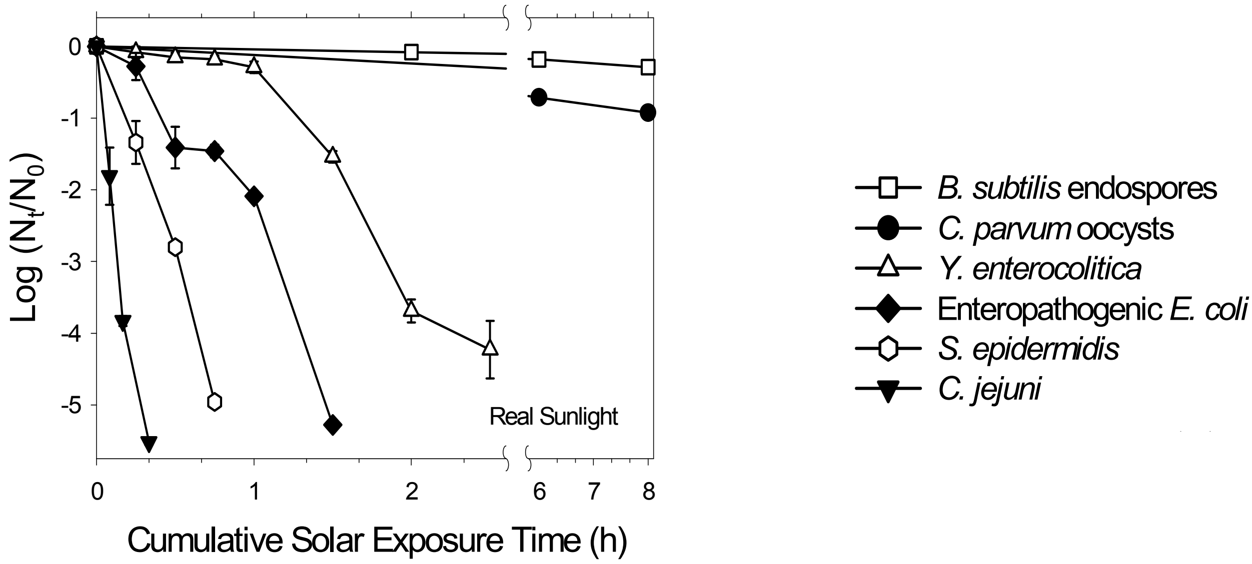
(a)



(b)

(a) PET bottles exposed to normal SODIS conditions (strong natural sunlight) over 6 months. Under SODIS conditions, bottles were exposed to 6 hours of sunlight, followed by overnight room temperature storage. (b) PET bottles exposed <u>*continuously*</u> *(*<u>*without refilling*</u>*) to sunlight for a period ranging from 1 to 6 months. Significant genotoxic events are represented by columns which cross the dashed horizontal line*

2.2 WORK-PACKAGE 3 PATHOGEN INACTIVATION -EXECUTIVE SUMMARY:
The aim of this workpackage is to determine whether important waterborne and/or diarrhoeal pathogens are susceptible to SODIS. Previous work has clearly demonstrated that a wide variety of viral and bacterial pathogens can be inactivated with batch SODIS however there still remains a considerable number of important waterborne microbes which are still untested. These pathogens were the bacteria Enteropathogenic *E. coli, Yersinia enterocolitica, and Campylobacter jejuni* (gastroenteritis), the protozoa *Cryptosporidium parvum* (cryptosporidiosis), *Entamoeba histolytica* (amoebic dysentery), *Naegleria fowleri* (meningoencephalitis), *Acanthamoeba polyphafga* (encephalitis (model organism)), the helminths *Ascaris lumbricoides* (ascariosis), and viruses like Hepatitis A virus, Coxsackie virus A (aseptic meningitis), and Polio virus.



Inactivation kinetics of bacterial populations exposed to real sunlight conditions expressed in units of log reduction.

<u>*Main findings and results*</u>:

- The works done in WP3 demonstrated the critical importance of evaluating the parameters like flow rate, total volume, temperature of water, and solar energy when attempting the task of up-scaling SODIS, particularly when large reactors are proposed.
- Characterizing the uninterrupted UV dose required for inactivation of likely microorganism must be incorporated into the design SODIS reactors. For example: we determined that the lethal uninterrupted UV dose for 2.5 l of suspensions of *E. coli* K-12 of around 10^6 CFU ml^{-1} in real well-water using a CPC has been experimentally determined to be 108 kJ m^{-2} corresponding to 2160-2520 kJ m^{-2} of global radiation.
- We also demonstrated the feasibility of SODIS for drinking water disinfection even on cloudy days and for high turbidity values (100 and 300 NTU) in real conditions using natural well water and natural (non-treated) soil.
- The capability of SODIS to inactivate *Cryptosporidium parvum* oocysts in natural well water under real solar light have been also shoown. Depending on temperature and turbidity of water samples exposure times required may vary.
- PET bottles containing turbid waters contaminated with *C. parvum* oocysts, significantly reduced the potential viability of *C. parvum* oocysts on increasing the percentage of oocysts that took up the dye PI (indicator of cell wall integrity), although longer exposure periods appear to be required than those established for the bacterial pathogens usually tested in SODIS assays.
- For the first time, USC evaluated the thermal contribution in the survival of *C. parvum* during SODIS procedures, independently of the UV radiation, showing a significant contribution in the inactivation of C. parvum oocysts during SODIS procedures under natural sunlight.
- Disinfection model equations obtained are valid to predict the viability and infectivity of *C. parvum* oocysts when they are exposed to SODIS under the range of conditions assayed in the experiment. The viability and infectivity values obtained are high correlated, although the viability values obtained by inclusion/exclusion of the fluorogenical vital dye PI overestimate the infectivity as it is widely known.
- SODIS has been shown to be an effective method in the treatment of contaminated water at the household level, through the synergism of UV radiation and temperature. However, for the user of SODIS it is important that the method is constantly assessed and improved to make sure that pathogenic organisms are killed and the method is easy to use.

2.3 WORKPACKAGE 4 SODIS ENHANCEMENT TECHNOLOGIES -EXECUTIVE SUMMARY:

The goal of this workpackage was to research and develop technologies which would enhance the efficacy of SODIS for either point of use or point of source treatment. Continuous flow systems were developed with the aim to treating larger volumes of water which may address the drinking water requirement of small remote communities. These continuous flow systems were designed to require minimal maintenance and minimal operator time so feedback control sensors are critical for operation. The efficacy of batch SODIS reactors may be enhanced either by the addition of a photocatalytic agent which will increase the disinfection rate and/or the incorporation of an inexpensive sensor (indicator tape) which will which will allow the user to know when the water has been exposed to a sufficient dose of solar radiation.

In order to achieve the goal, eight specific workpackages were undertaken and Partner 2 (UU) were responsible for coordination of all activities within WP4. In the first 12 months, Partner 6 (CIEMAT-PSA) undertook water disinfection experiments using the existing solar photoreactors at of Plataforma Solar de Almería (Spain). The evaluation of the disinfection rates of *E.coli* as a function of the incoming solar UV energy (295-385 nm) received in the solar reactor showed that total disinfection occurs only when a minimum UV dose was received in the system. The so-called "lethal UV dose" was around $30W·h/m^2$ for the case of 2.5 L of water containing 10^6 CFU/mL. A report was produced concerning the results. Partner 2 (UU) collaborated with Partner 6 to design and construct reactors for continuous flow and batch photocatalytic SODIS systems. Glass tubes and polymer bags were coated with nano-particle titanium dioxide by Partner 2 and delivered to Partner 6 for testing. Partner 1 (RCSI) worked on the development of a UV indicator tape for batch SODIS, however, the dye utilised did not have a long enough dark shelf-life for practical deployment. Partner 2 also undertook some work on UV indicator dyes with some success. Partner 2 also designed and fabricated a UV sensor control system for automated batch reactor control. All prototypes were delivered to the Plataforma d'Almeria (Partner 6) in southern Spain for testing under real sun conditions. Testing involved close collaboration between all partners involved in WP4, including Partner 7 (UL) and Partner 9 (USC), with the staff and students from other partners working at the Plataforma de Almeria. This collaboration between partners was beneficial for everyone involved. Insufficient time was available for full field testing of the EBR within the SODISWATER Project but these prototypes will be fully tested under African Field conditions as part of an Irish govt. funded project based in Uganda (Water is Life project see http://www.dkit.ie/waterislife/topic/solar-disinfection-of-drinking-water)

Following prototype testing and the analysis of results, we undertook a detailed economic analysis, including monetary and non-monetary benefits, in order to determine the most suitable technologies for deployment in developing countries. It was found that an automated static batch system with UV sensor feedback control would be the most appropriate, given both costs and non-monetary benefits. Due to time and resource constraints, the automated static batch system could not be deployed for testing in a developing country. Instead, a 25 L batch SODIS reactor was tested in South Africa with the helpful collaboration of Partner 3 (CSIR) and with personnel from Partner 1. Although this system operated well under good and intermediate solar irradiance, under cloudy conditions (during the rainy season) the log kill of *E. coli* was not sufficient.

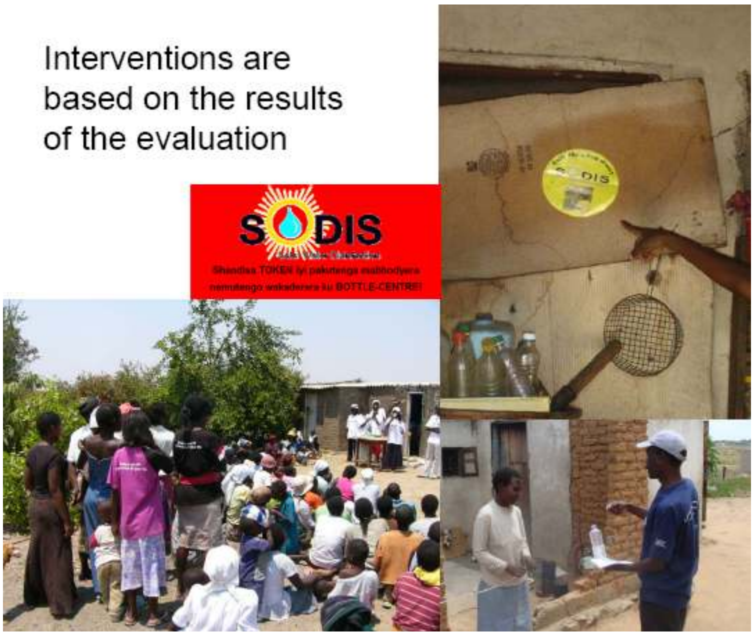
A detailed "Pro-Poor Business Assessment" was undertaken for the SODIS enhancements developed during WP4 based upon the Working Paper produced by the Dutch Royal Tropical Institute (KIT). Although the enhanced SODIS technology scored highly with regards feasibility, the sustainability of a business venture, at this stage, scored poorly. Before proceeding to a full pro-poor business plan, the consortia should address the following concerns: identification of a) funding for the potential business venture; b) project partners in both developed and developing worlds; c) distributions channels.

All deliverables have been met for WP4 and overall the work-package was judged as being extremely successful.

A 25 litre enhanced batch reactor fitted with a compound parabolic collector

2.4 WORK-PACKAGE 5 DISSEMINATION ACTIVITIES-EXECUTIVE SUMMARY:

Dissemination and adoption of SODIS has been examined in a three year longitudinal study. Interviews took turns with intervention strategies, which allowed to test for their effects. Different strategies which were meant to enhance the behaviour change necessary for SODIS (from drinking raw water to preparing and consuming SODIS) were employed over time and in several areas. These were: (a) household visits: trained promoters from the respective area go to households and educate the residents about SODIS and its advantages (b) pass-on-task: a snowball system where people are asked to pass on information about SODIS along with a token which could be redeemed at bottle shops for half-priced bottles, where another token was given and asked to pass along. This can be coupled with a competition; (c) Memory aids: stickers which serve as a reminder to prepare SODIS, like prompts ("prompting" a behaviour inside the home) or public commitment (publicly displaying the household's choice to use SODIS). (d) Daily routine integration: arousing tension through presenting what needs to be done to prevent water borne diseases ("knowledge and tension") or contracts which state when and where exactly someone plans on preparing SODIS ("implementation intention"). Household visits coupled with memory aids proved most successful. The pass-on-task with competition looks promising if coupled with a daily routine or possibly memory aids. Interventions change behaviour via different psychological factors. A behaviour change process could be identified which outlines the development that possible SODIS users go through from drinking raw water to drinking SODIS water on a regular basis over a long time.



Examples for different interventions: (clockwise, starting from left). a token, prompt, household visit and the pass-on-competition

SODISWATER Deliverable 24 was to host a conference on SODIS in the final year of the project. The project coordinator was successful in arranging that this event was folded into the Research Working Group of the WHO Household Water Treatment and Safe Storage (HWTS) Network 2009 international conference (HWTS09) which was held in the RCSI (Partner 1) in Sept 2009. All of the available SODISWATER research outputs were presented at this event (See HWTS09 Book of abstracts which forms most of the Deliverable 24 report) before the maximally appropriate audience who could benefit from this research dissemination.

A PDF brochure highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This is available for download on the project website (http://www.rcsi.ie/sodis/news/index.htm).

A PowerPoint presentation highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This is available for download on the project website (http://www.rcsi.ie/sodis/news/index.htm).

3. DETAILED DESCRIPTION OF RESEARCH ACTIVITIES

3.1. WP2 HEALTH IMPACT ASSESSMENT

SODIS refers to the solar disinfection of water using a 2-litre transparent plastic soft-drink bottle placed in the sun for at least 6 hours. This disinfection method can potentially produce drinking water that can reduce the incidence of diarrhoea in young children. Little data were available on the effectiveness of this method prior to 2007 and the start of this study. It was limited to only four papers (Conroy et al., 1996; Conroy et al., 1996; Conroy et al., 2001, Rose et al., 2006).

Figure 1: SODIS bottle in the sun on the roof of a Kenyan rural dwelling.

The study reported herein aimed to broaden this limited evidence base by conducting SODIS-related health impact studies in three African countries, namely, South Africa, Kenya and Zimbabwe.

3.1.1.1 OBJECTIVES AND DELIVERABLES

The overall objective of the study was to show that solar disinfection of drinking water is an effective intervention against waterborne disease, especially diarrhoeal childhood diseases, at household level and as emergency relief in the aftermath of natural or man-made disasters.

Specific objectives for the health impact assessments were:

1. Assessment of the change in health reasonably attributed to the provision of solar disinfected drinking water at the point of use in three African countries;
2. Assessment of the relationship between solar disinfected drinking water and selected health indicators (including morbidity due to non-bloody diarrhoea and dysentery, weight loss, mortality, growth rates);
3. Demonstration of the effectiveness of SODIS at household level; and
4. Demonstration of the degree of acceptance of SODIS as a disinfection method.

The specific deliverables were:

1. No. 2b: Ethical approval for the HIAs obtained;
2. No. 5: Field Manual: This will describe full details on how field trials will be conducted;
3. No.19: Identification of health determinants (health risk factors);
4. No.22: Assessment of acceptance/compliance of the SODIS method; and
5. No.23: Assessment of the intervention on the health outcomes (dysentery and non-dysentery diarrhoea).

3.1.1.2 LITERATURE SUMMARY

Although diarrhoea is a preventable and treatable disease nearly nine million children under five years of age die from it each year (Jensen, 2009). The World Health Organization estimates that 94% of the cases of diarrhoea are preventable by increasing the availability of clean water and improving sanitation and hygiene (Anonymous, 2007). The prohibitive cost and logistics associated with universally supplying people with piped water has made different methods of treating water in the home an attractive alternative worldwide.

Home Water Treatment (HWT) interventions to improve the quality of drinking water at household level have been shown to effectively reduce diarrhoea in children. These methods include, amongst others, ceramic filters (Fewtrell et al., 2005; Clasen et al., 2007; du Preez et al., 2008) chlorination (Sobsey et al., 2003), combinations of flocculation and chlorination (Reller et al., 2003; Crump et al., 2004), safe storage (Quick et al., 2002) and solar disinfection (Conroy et al., 1996). In respect of their costs and ease of use, solar disinfection of water is the only method that can be practised at almost zero cost and with the minimum of training.

The fundamental principles of solar disinfection (SODIS) were first discussed in 1877 by Downes and Blunt (1877). In 1980 Acra and his colleagues from the American University of Beirut laid the foundations for the further development of solar irradiation of water and oral rehydration solutions (Acra et al., 1980; Acra et al., 1989).

Microbial disinfection by sunlight is both optical and thermal. The UV radiation spectrum is commonly subdivided into three wavelength bands: UVC 190-290nm; UV-B 290-230 nm and UV-A 320-400nm. Solar UV radiation that reaches the surface of the earth consists mainly of UV-A (320-400 nm) and UV-B (290-300 nm). UV-B irradiation halts the fission process of cells by the formation of cyclobutane pyrimidine dimers (Fernández Zeňoff et al., 2006). UV-A irradiation causes indirect damage to lipids, proteins and the DNA through photosentizers. These consist of humic acids in water and flavins and porphyrins in the microbial cell (Curtis et al., 1992; Reed et al., 2000). When photosenitizers absorb UV-A photons they enter an excited state during which they react with molecular oxygen to form reactive oxygen species such as hydroxyl radicals, superoxide, and hydrogen peroxide. These optical and thermal processes are strongly synergistic at temperatures above 45 °C.

Laboratory studies have confirmed the effectiveness of SODIS as a disinfection method that inactivates bacteria to produce drinking water that is safe (McGuigan et al., 1998; McGuigan et al., 1999; Navntoft et al., 2008; Boyle et al., 2008; Ubomba-Jaswa et al., 2008).

Published information on the effectiveness of SODIS as an intervention in field studies consists of only three trials (Conroy et al., 1996; Conroy et al., 1999; Rose et al., 2006). The trials reported on by Conroy et al. (1996; 1999) were carried out on children in Kenya who were drinking heavily contaminated water with high levels of disease risk. Importantly these trials did not allow for the differentiation between dysentery, which has serious health consequences, and non-dysentery diarrhoea. This was an important weakness, as Gundry and his colleagues reported that dysentery in children in rural South Africa and Zimbabwe is related to faecal contamination of source water, while non-dysentery diarrhoea was unrelated to water quality (Gundry et al., 2009).

Accordingly the health impact assessments reported herein were designed to specifically assess the relationship between solar disinfected drinking water and dysentery and non-dysentery diarrhoea in a multi-country study to broaden the existing evidence base.

3.1.2 FIELD STUDY DESIGN

3.1.2.1 INTRODUCTION

To address the above-mentioned overall objective, this study specifically focussed on dysentery and non-dysentery diarrhoea in children between 6 months and 5 years of age in the three African countries of South Africa, Zimbabwe and Kenya. Anthropometric measurements were also recorded to determine general growth of the children over a period of one year.

Figure depicts the overall schedule. Chapter references refer to the Field Manual.

3.1.2.2 phase 1: Initialisation

Choice of study areas

Census data and other locally available information were obtained to establish if there was sufficient number of children between 6 months and 5 years of age in potential study areas. The general health and safety of the project team and the accessibility of the areas to the team were also considered.

Key role players in the relevant administrative and decision making structures of each country were identified. Community leaders and the communities themselves were involved in the choice of study areas. Introductory meetings and information sessions were convened.

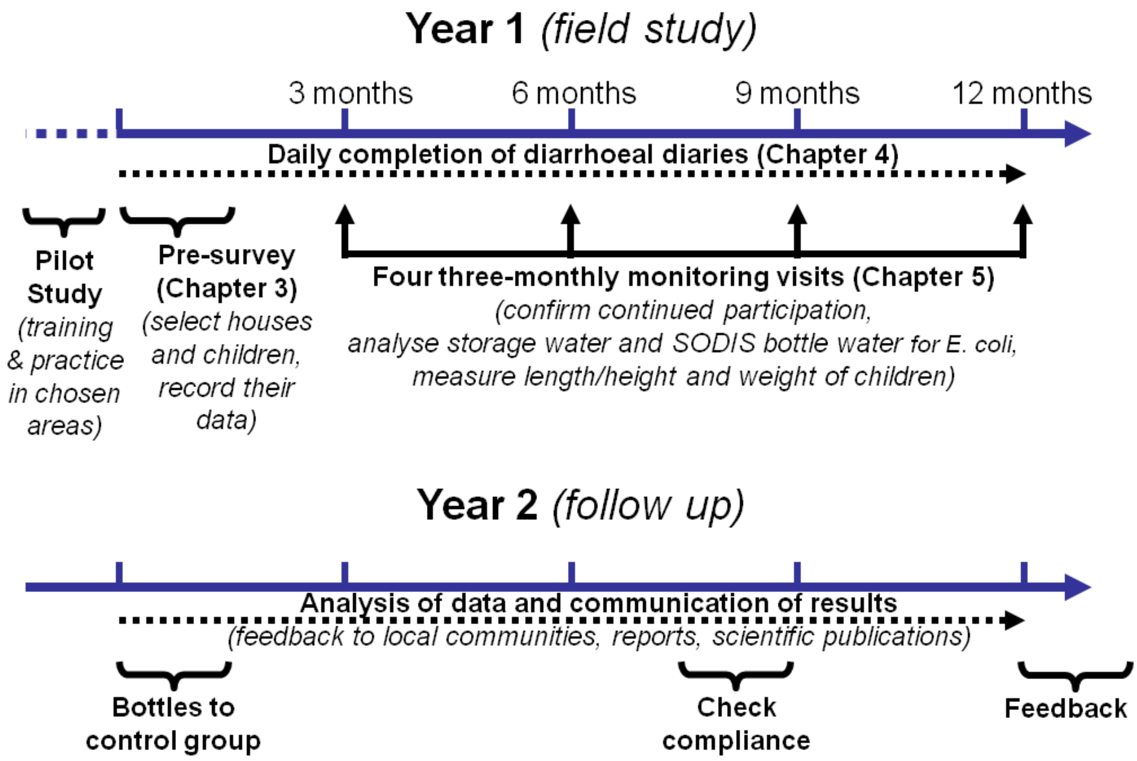


Figure 2: Schematic overview of field study schedule.

They had the following objectives:

- **Provision of an overview of the project:** This entailed presenting to the community the objectives of the overall project and the field study in particular. Sufficient detail was given so that the community understood the underlying principles of the study and what it aimed to achieve.

- **Facilitation of discussion on the study design:** When the objectives were understood the study design was discussed. This helped the team assess its feasibility in each area. Local community members were employed on the project whenever possible.

- **Determination and allocation of roles and responsibilities:** This helped create a clear understanding of what the community involvement would entail. Local community leaders were involved and helped with project coordination at the community level. This included identification of specific community members to assist the project team, community liaison, and facilitating cooperation. Appropriate community members were then formally recruited.

Both rural and peri-urban communities were included to broaden the scope of the data and hence potentially provide more SODIS-related information on the effect of such different communities. Accordingly, the Zimbabwe study area was informal and peri-urban with very low socio-economic status. The South African study areas were generally more formal and peri-urban with a higher socio-economic status. In Kenya the study areas included both rural and peri-urban areas with a low socio-economic status.

Formal permission was obtained from the appropriate authorities at all levels in each country before the study commenced. Local and district leaders were also kept informed of the progress of the study for the duration of the study.

3.1.2.3 Questionnaires

The following questionnaires were developed to help capture data and information directly relevant to the objectives of the study.

- **Pre-Survey phase**

    - **Household**. Data on individual households, including hygiene and water use practices.
    - **Children**. Personal data on individual children (one or more per household).

- **Main survey phase**
    - **Participation**. Confirming ongoing participation or recording reasons for leaving the study.
    - **Storage Water**. Storage water sample bottle barcode, etc.
    - **Anthropometry**. Child height and weight.
    - **SODIS Bottle**. SODIS bottle sample bottle barcode, etc.
    - **Child Death**. Date and cause of death (if known).
    - **Lab Quanti-Tray Fill**. Used in laboratory to record sample bottle barcodes and associated Quanti-Tray barcodes.
    - **Lab Quanti-Tray Wells**. Used in laboratory to record Quanti-Tray barcodes and associated numbers of positive wells.

These questionnaires were loaded onto Symbol Pocket PC handheld computers using the Pendragon proprietary software. These handheld computers were used in the field to capture all the necessary data.

Figure 3: "Symbol Pocket PC" handheld computer used to capture field data.

3.1.2.4 Diarrhoeal "smiley" diary development

A paper-based method based on that of Gundry and Wright (2004) was developed for recording (a) the number of loose stools produced daily by the participating children and (b) whether or not those stools contained blood or mucus. It involved the use of a printed page with simple happy (smiley) faces (☺) representing normal stools and sad faces for loose stools (☹). A special box is marked if blood or mucus is present. The diary does not require people to be literate (**Figure 4**).

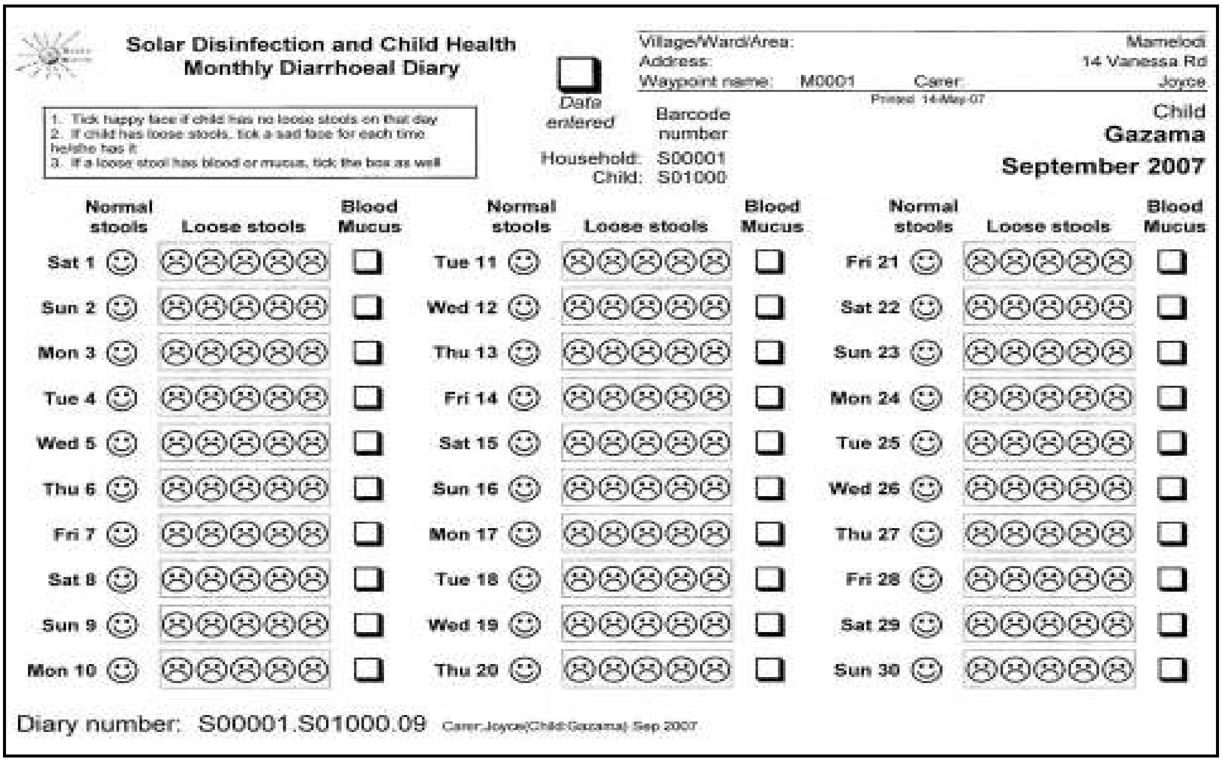
Each page was personalised with each child's name and their carer and covered one calendar month. It also conveniently showed household details, the child's name, a unique diary number (comprised of the household barcode, child barcode and 2 digit relative month code). Twelve such pages were produced for each child, one per month for twelve months. This was done using the SODIS Country Master Database described below (Section 0).

3.1.2.5 Ethical clearance

Ethical clearance, a prerequisite in all three countries, was obtained from the respective organisations in each country, namely:

1. South Africa: Faculty of Health Sciences Ethical Committee, University of Pretoria, South Africa;
2. Zimbabwe: Medical Research Council of Zimbabwe; and
3. Kenya: KEMRI (Kenya Medical Research Institute).

This task addressed Deliverable No. 2b: Ethical Approval for the HIAs obtained.


Solar Disinfection and Child Health
Monthly Diarrhoeal Diary

1. Tick happy face if child has no loose stools on that day
2. If child has loose stools, tick a sad face for each time he/she has it
3. If a loose stool has blood or mucus, tick the box as well

Data entered

Village/Ward/Area: Mamelodi
Address: 14 Vanessa Rd
Waypoint name: M0001 Carer: Joyce
Printed 14-May-07

Barcode number
Household: S00001
Child: S01000

Child
Gazama
September 2007

	Normal stools	Loose stools	Blood Mucus		Normal stools	Loose stools	Blood Mucus		Normal stools	Loose stools	Blood Mucus
Sat 1	☺	☹☹☹☹☹	☐	Tue 11	☺	☹☹☹☹☹	☐	Fri 21	☺	☹☹☹☹☹	☐
Sun 2	☺	☹☹☹☹☹	☐	Wed 12	☺	☹☹☹☹☹	☐	Sat 22	☺	☹☹☹☹☹	☐
Mon 3	☺	☹☹☹☹☹	☐	Thu 13	☺	☹☹☹☹☹	☐	Sun 23	☺	☹☹☹☹☹	☐
Tue 4	☺	☹☹☹☹☹	☐	Fri 14	☺	☹☹☹☹☹	☐	Mon 24	☺	☹☹☹☹☹	☐
Wed 5	☺	☹☹☹☹☹	☐	Sat 15	☺	☹☹☹☹☹	☐	Tue 25	☺	☹☹☹☹☹	☐
Thu 6	☺	☹☹☹☹☹	☐	Sun 16	☺	☹☹☹☹☹	☐	Wed 26	☺	☹☹☹☹☹	☐
Fri 7	☺	☹☹☹☹☹	☐	Mon 17	☺	☹☹☹☹☹	☐	Thu 27	☺	☹☹☹☹☹	☐
Sat 8	☺	☹☹☹☹☹	☐	Tue 18	☺	☹☹☹☹☹	☐	Fri 28	☺	☹☹☹☹☹	☐
Sun 9	☺	☹☹☹☹☹	☐	Wed 19	☺	☹☹☹☹☹	☐	Sat 29	☺	☹☹☹☹☹	☐
Mon 10	☺	☹☹☹☹☹	☐	Thu 20	☺	☹☹☹☹☹	☐	Sun 30	☺	☹☹☹☹☹	☐

Diary number: S00001.S01000.09 Carer:Joyce(Child:Gazama) Sep 2007

Figure 4: Example of a monthly diarrhoeal diary (using fictitious names and addresses).

3.1.2.6 Database development

The following two Access databases were developed for use in this study.

- **SODIS Country Master Database**. A copy of this database was used in each participating country to store the data downloaded from the Pocket PC handheld computers used to collect the field and laboratory data. The database consisted of:
  - **Tables**. A table existed for each of the above-mentioned questionnaires. Other tables were also created to facilitate various other database operations.
  - **Queries**. The primary purpose of these queries was to check the integrity of downloaded data as soon as possible after capture. This allowed the problems detected to be fixed, if possible, as soon as possible while the conditions of their collection were fresh in people's minds. The queries specifically facilitated the detection of incorrect, inconsistent or missing data. For the two Pre-Survey tables they detected invalid barcodes in 3 circumstances, duplicate and unmatched barcodes each in 2 circumstances, households with no children, children of invalid age, etc. For the main survey (monitoring) tables the queries also detected invalid and duplicate barcodes each in 10 possible circumstances and unmatched barcodes in 14 different circumstances.
  - **Forms**. 16 forms were developed to act as user-friendly interface "windows".
  - **Report**. Two reports were developed. The first allowed printing of "house detail" pages kept in ring-bound files that provided basic location information and names of carers and children for field workers. The second allowed printing of personalised monthly diarrhoeal diaries for each child in the study, distributed manually to each household.

- **Diarrhoeal Diaries Individual Database**. This database was designed to allow multiple copies of it to be used in each country by different individuals to capture data from the monthly paper "smiley diaries". These individual databases were then combined into a single database for each country at the end of the study. The database consisted of:
  - **Tables**. The main table is the one containing the actual diarrhoeal diary data for each child. Other tables were also created to facilitate various other database operations.
  - **Queries**. Most queries were created to check data integrity such as invalid diary numbers, diary numbers with ambiguous barcodes, duplicate diary numbers, checking for the same child occurring in different households, checking for missing diaries, and checking for daily data problems like days with nothing marked by the carer.

- **Forms**. Seven forms were developed to act as user-friendly interface "windows", allowing, for example, inserting new data and viewing and editing of existing data, etc.

3.1.2.7 Development of manuals

This sub-section addresses Deliverable No. 5: Field Manual: This will describe full details on how field trials will be conducted.

In an endeavour to obtain data from the different countries that could be compared, standard procedures were devised that would be implemented in as much the same way as possible in the three countries. To facilitate this, two manuals were developed that defined these standard procedures before any field work started.

1. **SODISWATER Field Manual**. This was used by project team members involved in the practical field work and the subsequent data capture from handheld computers onto laptop computers. It contained the following:
    a. Glossary;
    b. Confidentiality of personal data;
    c. Using the equipment (laptops, handheld computers, GPS, anthropometry, *E. coli* Quanti-Trays, etc.);
    d. Pre-survey (choosing the area and households, barcodes, SODIS bottles, the daily routine, household protocols, and database management);
    e. Diarrhoeal diaries (printing, distribution, use, monthly collection, data entry, and data integration);
    f. Monitoring visits (The daily routine, and database management).

2. **SODISWATER Diarrhoeal Diaries Data Entry Manual**. This was used by project team members or other persons specifically recruited to capture the diarrhoeal data from the paper "smiley diaries" into the specially-designed Diarrhoeal Diaries Individual Databases.
    a. Glossary;
    b. Creating individual databases;
    c. Entering new diaries;
    d. Editing existing diaries;
    e. Viewing existing diaries;
    f. Viewing/editing the main table; and
    g. Checking for problems;

These two manuals are available as separate documents.

3.1.2.8 PHASE 2: PILOT STUDY

Field supervisors from each country attended a training course in South Africa. The course covered the following:

- The overall structure of the field study (summarised in Section 3.1.2.1 above);
- The practical use of:
    - Barcodes;
    - The Garmin etrex GPS;
    - The handheld computers, including downloading of data; and
    - The Colilert method for measuring *E. coli* concentrations.
- Database management;
- Printing, distribution, use, and collection of the diarrhoeal diaries;
- Diarrhoeal diary data capture into the database (Section 0);
- The Pre-Survey; and
- The main survey (monitoring visits).

Figure 5: Attentive fieldworkers during the pilot study training course.

The SODISWATER Field Manual and the SODISWATER Diarrhoeal Diaries Data Entry Manual were used as course material during the practical sessions (Section 0). Potential problems were highlighted and procedures for avoiding and solving them were discussed.

Immediately after this training a pilot study, aimed at in-the-field familiarisation and testing of all procedures, was conducted in South Africa in a limited number of households. After assessment of the outcomes, recommendations for changes to the proposed procedures were considered and implemented prior to full implementation of the main study. These changes were captured in updated manuals.

The participating countries subsequently carried out their own pilot studies in their own countries to test and assess procedures under their respective local conditions.

3.1.2.9 PHASE 3: PRE-SURVEY

Once study areas had been identified and the associated permissions obtained, individual households and children were identified. The original aim was to have at least 1 000 children in each country. However, this was not possible in all three countries. Household identification was done randomly and some chosen to use the SODIS bottle (the test group) while others (the control group) used their water in their normal way.

The criteria for selecting the households were:
1. Storage of drinking water in the house was essential.
2. A drinking water tap in the house or garden was not permitted.
3. At least one child (but not more than 5) between 6 months and 5 years old had to reside in the house. A child could only be included if their 5th birthday was AFTER the day on which the visit to that household occurred.

An information sheet explaining the aim of the study, what was expected from the household, the study period and the kind of questions a household would be asked to answer, was read to participants or read by the participants themselves. Written consent was then obtained from the head of each household. These documents were translated from English (see **Appendix A**) to the local languages in Kenya and Zimbabwe. These were re-translated back into English to ensure the original intent of the questions was clear.

Once consent had been given, the two pre-survey questionnaires (household and children) were completed on the handheld computers. Each child was given two SODIS bottles and the carers were also thoroughly trained in their use. This training was repeated on an ongoing basis throughout the study when considered necessary. Household detail sheets were also printed which contained location information and names of carers and children.

Diarrhoeal diary sheets were also printed and distributed to the households. Carers were carefully instructed how to complete a diary and requested to fill in the diary every day for the one year's duration of the field study.

3.1.2.10 PHASE 4: 12-MONTH MAIN SURVEY

The main survey comprised two main activities.

First, daily records of loose stools and whether or not they contained blood or mucus were kept by the carers using the printed diarrhoeal diaries. These were collected by field staff at regular intervals. When diary sheets were detected that had been incorrectly completed, fieldworkers repeated the appropriate instructions. The capture of these data from the printed sheets into the Diarrhoeal Diaries Individual Databases (Section 0) also occurred continually throughout the main survey.

Secondly, monitoring visits to all households took place four times at three-monthly intervals over the one-year survey period. The first monitoring visit occurred three months after the pre-survey. This allowed some time for health-related effects to manifest.

Figure 6: Transporting typical small water storage containers used in the households.

At each household, participation was confirmed or child deaths or reasons for leaving the study recorded. If participation was confirmed children were weighed and their heights or lengths measured. Samples of the water stored in the test and control households and the solar-disinfected water (test households only) were collected. For each activity handheld questionnaires were completed that recorded the necessary data (e.g. anthropometric) and information (e.g. sample bottle barcodes, etc.). If necessary, ongoing guidance was provided by the field workers appropriate use of the SODIS bottles.

Cases of severe diarrhoea detected in children were managed by referring them to local clinics or district hospitals where treatment was free. Oral rehydration salts were provided to mildly sick children.

Upon return to the laboratory each day, water samples were analysed and the data on the handheld computers were downloaded into the SODIS Country Master Database (Section 0) on laptops and the handheld batteries charged in readiness for the next day.

The procedures in the field and laboratory were guided by the details in the relevant manuals (Section 0).

3.1.2.11 Analytical methods

3.1.2.11a Water quality

Upon return to the laboratory each day, water samples were analysed for the bacterium *Escherichia coli* (*E. coli*) using the Colilert® method. The method uses Quanti-Trays® that contain 51 small wells in which *E. coli* colonies grow if present . The concentration (Most Probable Number – MPN, counts/100ml) of *E. coli* in the original sample was obtained from a table using the number of positive wells in the Quanti-Tray after 18 hours incubation at 37 ºC.

Figure 7: The Quanti-Tray used in the Colilert method to measure E. coli concentrations.

3.1.2.11b Anthropometry

Anthropometry is the study of human measurements. The recumbent height of children less than 24 months old was measured on a Raven Rollametre 100 (0.01 cm precision) consisting of a small foam or plastic mattress with a headpiece and a foot-board. Two observers were employed, with one person holding the head in place and exerting a gentle upward traction on the mastoid processes while pressing the headpiece firmly against the crown of the head. The second person was responsible for the correct position of the knees and feet of the subject. The height of the children older than 24 months was measured using a stature metre.

Body weight was measured on minimally clad subjects on digital battery-operated calibrated weighing scales. Uncooperative babies were weighed in the arms of the mother or adult family member whose weight was subtracted later. Personnel taking the measurements were not standardised. The following measurements were taken at each of four monitoring visits that took place over a period of one year: Child height (or baby length) (cm) and weight (kg) (**Figure 8**).

Figure 8: Anthropometry measurements: Weight, height and length.

Anthropometric measurements are traditionally standardised against internationally accepted cut-off points of nutritional status. Nutritional indicators are usually calculated (Z score = (measured value–median reference value)/(standard deviation of reference)) relative to the reference population, namely the American population (WHO, 1986). In view of the inapplicability of using the American population as a reference for Africans, suitable growth norms were developed by using the study data to construct norms for height-for-age, weight-for-age and height-for-weight. This was done by fitting a fractional polynomial curve to the data, adjusting the number of polynomial terms until no improvement in fit could be obtained by adding a further term. The fractional polynomial procedure was used to fit a curve corresponding to the tenth centile of each index. The endpoints were defined as falling below the 10th centile for each index – height-for-age, weight-for-age and height-for-weight. The odds ratio associated with use of SODIS was calculated in relation to each index.

3.1.2.12 PHASE 5: POST-SURVEY COMPLIANCE

Upon completion of the year-long study, all control households were offered training in the use of the SODIS bottles. If they indicated a willingness to adopt SODIS, they were given SODIS bottles and the necessary instructions. The degree of compliance of SODIS in all the households using the bottles was evaluated after six months.

3.1.2.13 PHASE 6: DATA ANALYSIS

The data collected from the main surveys in each country was submitted to the database developer at the end of each survey. The databases were "cleaned" of problematic data, collated and prepared for analysis by statisticians. These analyses aimed to determine whether or not correlations exist between the use of SODIS and its effectiveness in reducing either dysentery or non-dysentery diarrhoea in young children. The effects of a variety of factors, such as water quality, sanitation, hygiene behaviour etc., were also examined. The approach and results appear in this report.

3.1.2.14PHASE 7: FEEDBACK

Feedback to local participating communities has occurred. Selected final project documents will also be provided to appropriate community leaders. The poster produced in South Africa is shown in Appendix B.

3.1.3 FIELD STUDY AREA DESCRIPTIONS

3.1.3.1 South Africa

The South African health impact assessment was conducted in a peri-urban area in, and in the vicinity of Soshanguve north of Pretoria, Gauteng Province. In comparison to other African countries the inhabitants of this area have a relatively high standard of living. The average salary is R1 400 per month. Most families have their own house and often rent out back rooms to paying customers. There are several large shopping centres in the area and satellite educational institutions for tertiary learning.

Figure 9: South African peri-urban household.

However, the unemployment rate is high 25.8% (STATSA, 2009). Opportunities for work in the area are limited and women find it particularly difficult to find employment. Some income is generated by managing small shops and day-care centres for pre-schoolers. There are many schools that provide employment and a few larger businesses such as garages (selling petrol etc. and servicing vehicles) and cafes selling food. Many men are taxi drivers. Commuting to and from Pretoria and Johannesburg, the two main cities of Gauteng Province, is common because relatively well-paid jobs are available in these cities. However, the long distances commuted require leaving very early in the morning and arriving back home very late. As a result children are often left to fend for themselves or left with siblings or grandparents.

It also became evident that the study participants were aware of some hygiene factors but seldom understood the connection between hygienic behaviour and health in terms of infectious organisms.

The high HIV and AIDS rate and associated death toll in the area has resulted in a large number of orphans dependent on foster care or accommodation in orphanages. The high number of teenage pregnancies is an important factor contributing to irresponsible parenting. Government grants for these teenagers that are intended as child support are sometimes squandered on alcohol or on needs of the other household members. This lack of social cohesion in the study area may have contributed to poor engagement in the study and hence the degree of compliance to SODIS protocols.

3.1.3.2 Kenya

The study took place in the vicinity of the town of Nakuru north of the capital Nairobi. The area included both peri-urban communities and rural communities. The population of approximately 300 000 people resides in the following sub-districts: Bondeni, Kaptembwa, Lanet, Mogotio, Salgaa and Wanyororo. These are characterised by extreme poverty. An average income was approximately Ksh350 per day.

Figure 10: Kenyan peri-urban and rural households.

Housing in the peri-urban area consisted of semi-detached rooms. Buildings consisted of 15-20 rooms. Up to five people lived in a single room. Drinking water access per household typically consisted of one standpipe. The tap was typically padlocked to prevent unauthorised use of the water. Inhabitants usually had access to four to six pit toilets situated within the building site.

Houses in the rural areas consisted of typical round mud houses and some brick buildings with corrugated iron roofs. A variety of water sources was used including springs, protected and unprotected boreholes, unprotected dug-wells, standpipes, river water and canal water. Sanitation facilities consisted of mostly pit latrines and a few flush toilets.

3.1.3.3 Zimbabwe

The selected study area was a peri-urban informal settlement called Hatcliff about 10 km from the capital Harare. It has a population of about 6 000 people living in about 2 200 households. Some live in abject poverty. Sanitation, at 52% coverage, consisted of pit latrines. Using the street and bush as latrines was common in the area. The community had access to unprotected wells, boreholes and standpipes. Water availability at the standpipes was very erratic during the study period. During 2008 the standpipes did not received any water. Very few people had formal employment. Subsistence farming and selling of vegetables or other commodities from informal shops were the main means of income generation. Many households are simply constructed from four poles covered with thick plastic sheets. Humanitarian organisations were very active in the area during the study period.

3.1.4 FACTORS SERIOUSLY IMPEDING STUDY

3.1.4.1 Kenya

3.1.4.1a Political unrest

In March 2009 political elections caused eruptions of violence all over Kenya. The study area was one of the areas hardest hit. Many of the participating household members fled the area or were displaced and some were killed. Field workers could not enter the areas during this period. This lack of contact with field workers caused uncertainty amongst the participants about the continuation of the study. As a result some participants left the study. Almost 414 children no longer participated in the study.

3.1.4.1b Financial constraints

Delays in payment of funds to ICROSS meant that salaries could not be paid and staff had to be laid off at the end of March 2009. As a result the fourth monitoring visit could not be carried out. Data are therefore only available for the first three monitoring visits. The planned post-SODIS compliance phase could also not be undertaken.

3.1.4.2 Zimbabwe

3.1.4.2a Political unrest

The study was initiated in September 2007 at the height of the political unrest. A number of conditions set by politicians of the ruling party at the time hampered household selection and prevented participation in an open and free manner. Overall progress was slow and delays were common throughout 2007 and at the beginning of 2008. The situation worsened when all NGOs were banned from doing any work in the area by the Ministry of Labour in May 2008. Water sampling was also affected by political campaigns and the elections for Provincial elections. During the ban contact could not be maintained with the participants. Consequently the participants lost interest in the study to such a degree that when work could be resumed after the ban was lifted in August 2008, the process of household selection and randomization to test and control groups had to be repeated.

Further delays in the execution of the study could also be attributed to organisational changes at the Institute for Water and Sanitation Development (IWSD). By the end of December 2008 the senior field supervisor of the SODISWATER project in Zimbabwe emigrated to South Africa. When the replacement field supervisor was appointed, the Zimbabwean team was provided with a schedule aimed at restoring the control and test group households and execution of the monitoring visits.

3.1.4.2b Cholera outbreak

At the time of the field study endemic cholera had broken out in Zimbabwe and thousands of people were ill or dying. UNICEF initiated an aggressive campaign of distributing chlorine tablets (Aquatabs) to all the inhabitants in affected areas, including Hatcliff. Additional boreholes were drilled and the water from the boreholes was chlorinated. NGOs also provided households with chlorine solutions, bars of soap and food. Shelters were constructed where hygiene information and Aquatabs were freely available.

Notwithstanding the inevitable effects of these important practices on the water quality, a decision was made to continue with the SODIS study.

3.1.4.2c Cultural factors

Field workers were unsuccessful in obtaining water samples and diarrhoea information on many occasions. Some of the participants were unavailable because they were tending their farms during the rainy season some distance away from Hatcliff.

On the other hand, the application of SODIS sometimes changed local behaviour. For example, many participants feared poisoning and would not leave their SODIS bottles unattended.

3.1.4.2d Financial constraints

Delays in the payment of funds from the European Commission at the end of 2008 hampered the execution of the study. The uncontrolled inflation rate also had a serious detrimental effect on exchange rates. This required complex practices to manage funds during the study period.

3.1.5 RESULTS

3.1.5.1 SOUTH AFRICA

introduction

The health impact assessment in South Africa was initiated in 2008. The start and end dates used to distinguish between data in the SODIS Master Country Database collected during the four monitoring visits were as follows:

1. 2008/02/12 to 2008/05/13
2. 2008/05/14 to 2008/09/01
3. 2008/09/02 to 2008/11/04
4. 2008/11/05 to 2008/12/31

The analysis that follows investigated various relationships between source water types, water quality, gender and age in terms of the dysentery and non-dysentery days that were recorded.

3.1.5.1a DATABASE CLEANUP

Notwithstanding many data integrity checks in the design of the handheld computer questionnaires, the master country database and the diarrhoeal diary database, it is inevitable in studies of this nature that invalid, inconsistent and incomplete data still occur.

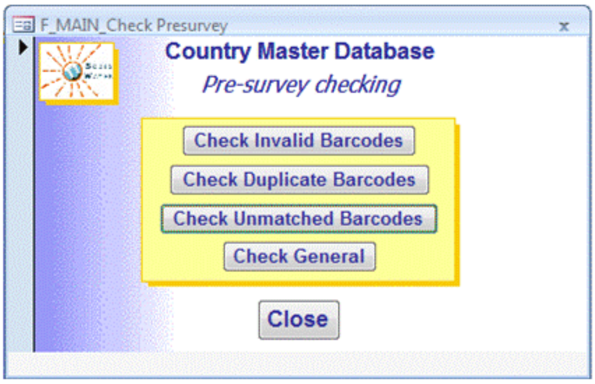


Figure 11: Example of one of the many database screens allowing checking of data integrity.

Upon completion of the field work and laboratory work, these were dealt with in the following ways. Under no circumstances were fixes introduced unless the correctness of the fix was certain.

- Invalid barcodes were either corrected or associated records deleted (if an appropriate fix was uncertain).
- In some cases invalid dates (referring to 2004) were detected, inevitably caused by the date on the handheld computer not being correctly set on the day it was used in the field. These were either fixed or left unchanged when this could not have any adverse effect.
- Records in tables in the Access database with duplicate barcodes were fixed as follows: If the records were identical, then one was deleted. If they were not identical, they were usually both deleted since it could generally not be established which one was the correct one. The exception was the diarrhoeal diary data because original diaries could be examined to establish which one was correct. It was important to fix records with duplicate barcodes because these cause inconsistencies during data extraction.
- It was not possible to rectify problems caused by unmatched barcodes. (An unmatched barcode is one that exists in one table and should appear in another table but does not.) Not fixing these problems does not cause inconsistencies during data extraction. They only result in missing data points.
- Minor problems like the question “May a sample be taken?” being answered in the negative when a sample was actually taken were fixed by changing the answer to positive.

3.1.5.1b NUMBERS OF DATA TYPES

Table 1 shows a summary of the numbers of various data types obtained during the field study and presented for statistical analysis. It should be noted that numbers actually used in the analyses described in the following sub-sections may be less than those in the table.

Table 1: South African field study summary of numbers of data types.

Data type	Number
Children in control group (without SODIS bottle)	386
Children in test group (using SODIS bottle)	438
Male children	402
Female children	421
Total children	824
Households	649
Households using standpipes	323

Households using protected boreholes		231
Households using unprotected boreholes		82
Households using protected springs		10
Households using protected dug wells		1
Households using other water sources		1
Households for which water source not established		1
Children with some diarrhoeal diary data		718
Non-dysentery diarrhoea days		2 692
Non-dysentery diarrhoea episodes		1 043
Dysentery days		1 379
Dysentery episodes		307
Storage water *E. coli* measurements	(Monitoring visit 1)	425
	(Monitoring visit 2)	394
	(Monitoring visit 3)	436
	(Monitoring visit 4)	418
SODIS water *E. coli* measurements	(Monitoring visit 1)	191
	(Monitoring visit 2)	171
	(Monitoring visit 3)	191
	(Monitoring visit 4)	182
Children with some anthropometry data	(Monitoring visit 1)	541
	(Monitoring visit 2)	548
	(Monitoring visit 3)	513
	(Monitoring visit 4)	389

3.1.5.1c ASSESSMENT OF HEALTH OUTCOMES

This section addresses Deliverable No.23: Assessment of the intervention on the health outcomes (dysentery and non-dysentery diarrhoea).

Approach

Data were analysed with Stata/SE, Release 11. Stata's robust variance estimation routines for clustered data, implemented in the statistical survey procedures, were used to adjust for the effects of the multistage sample design. Data were stratified on district (four levels) with the primary sample unit identified as village (19 units) and the second-stage sample unit of household.

Initial analysis confirmed that incidence rates of dysentery were over-dispersed, making a Poisson regression inappropriate. Generalised negative binomial regression was used to calculate incidence rate ratios (IRR). This also allows for variation in disease rates between individuals who have the same risk factor profile and allows this variation to be modelled as a function of predictor variables (such as age, water source type, compliance, etc.).

Compliance with the SODIS protocol was measured by calculating the proportion of 360 days on which diarrhoea diaries had been recorded. This measure allowed calculation of compliance for both test and control households. This allowed testing of whether or not associations between compliance and the effect of SODIS on disease rates in the test households were attributable to socio-demographic factors correlated with compliance by testing for a similar association between compliance and disease rates in the control households.

Data were available on 383 children in 297 households randomised to solar disinfection and 335 control children in 267 households. The median number of days for which diarrhoeal data had been recorded was

182, (25th percentile 122, 75th percentile 274). Control and test groups did not differ in the average quantity of data (P=0.415, Ordinary Least Squares regression, adjusted for clustering within households).

3.1.5.1d Dysentery

Intention to treat analysis

The incidence of dysentery was first examined using a generalised negative binomial regression model, as described above. Extra-Poisson variation in incidence of dysentery was significantly associated with compliance. It was also significantly greater in one of the four districts. Incidence rates were lower in households drinking water from a standpipe than from any other source (IRR 0.38, 95% CI 0.12 to 1.2, P=0.091) and lower in those drinking solar disinfected water (IRR 0.64, 95% CI 0.39 to 1.0, P=0.071) though both effects were of borderline statistical significance.

Analysis by compliance

The effect of compliance was compared with the incidence of dysentery. Compliance was 75% to 100% in 25% of those randomised to solar disinfection, 50% to 75% in 40%, 25% to 50% in 18% and less than 25% in 16% (**Table 2**). Variation in baseline risk was adjusted for in each of the compliance groups by entering compliance level as three dummy variables (omitted category: <25% compliance). Effect of SODIS within each level of compliance was assessed by using four dummy terms, one for each level of compliance. Incidence rate ratios are given in **Table 3**.

3.1.5.1e Non-dysentery diarrhoea

The variation in risk of non-dysentery diarrhoea was also investigated. Solar disinfection was not significantly associated with risk overall (P=0.419). There was no significant effect of compliance on risk (P=0.150), nor was there evidence that those with 75% compliance or better had a reduced risk compared with controls (P=0.415).

3.1.5.1f Water quality

E. coli data in storage water and SODIS bottles were transformed to a log scale and analysed using interval regression. This allows values of zero to be analysed as representing <1 cell forming unit (CFU) and values above the upper threshold of the system to be analysed as representing a value greater than the threshold. The advantage of this method is that it allows the presence of values which are interval-censored (not known precisely, but known to lie in a defined interval). In these cases, the intervals are defined by the minimum and maximum detectable concentrations.

Compared with control, participants with 75% compliance or better achieved a reduction of 65% in dysentery which was statistically significant. However, there was no significant reduction in risk at lower levels of compliance.

The relationship between *E. coli* concentrations and duration of the field study was modelled using fractional polynomial regression. This allows the calculation of the least complex curve to fit the observed data by permitting a statistical test of the model improvement brought about by the addition of an additional polynomial term.

Initially, contamination levels in the stored water of both test and control groups declined. However, by week 10, levels of contamination in the control group had begun to rise. This rise was also seen in the test group, but it occurred more slowly. Nevertheless, by the 40th week of the trial there was essentially no difference between the *E. coli* levels of the two groups.

Table 2: South African dysentery rates (days per year) as a function of compliance.

	Compliance range			
	< 25%	**25%–50%**	**50%–75%**	**75%-100%**
	Control group			
No. of children	61	72	113	83
No. of households	46	58	96	62
Dysentery incidence rate	11.7	1.8	2.7	7.4
Mean no. of days with diarrhoeal data	47.2	133.2	203.2	313.6
	Test group			
No. of children	61	70	152	96
No. of households	51	53	125	64
Dysentery incidence rate	8.8	4.2	2.0	2.4
Mean no. of days with diarrhoeal data	55.1	128.7	209.4	310.7

Table 3: South African dysentery incidence rate ratios at different compliance levels.

Factor	Incidence Rate Ratio (95% CI)	Significance (P)
Use of standpipe water	0.37 (0.13 to 1.01)	0.053
	Use of SODIS water	
< 25% Compliance	0.86 (0.15 to 5.0)	0.853
25% to 50% Compliance	1.75 (0.46 to 6.7)	0.387
50% to 75% Compliance	0.84 (0.24 to 2.9)	0.766
75% to 100% Compliance	0.35 (0.17 to 0.76)	0.011

At first follow-up visit (median time since start of study: 10 weeks), *E. coli* concentrations were not significantly different between test and control (P=0.366). However, at second monitoring visit (median time since start of study: 17 weeks), *E. coli* concentrations in stored water in test households was on average 0.35 $\log_{10}$ units lower than in controls (P=0.040). At the third monitoring visit (median time since start of study: 34 weeks) the mean difference was similar (0.39 log units, P<0.001). However, at the fourth visit (median time since start of study: 41 weeks), there was no significant difference (P=0.982).

Figure shows *E. coli* concentrations in stored drinking water in test and control households. The values are predicted for a fractional polynomial interval regression, and are displayed as points rather than lines to illustrate the gaps between monitoring visits.

E. coli concentrations in SODIS bottles of households who had and had not put a bottle out the previous day were also examined. **Figure 1** shows the time trend already evident in the control data. Levels of *E. coli* fell sharply in the first half of the study, but rose in the second. Over the whole study period, the average difference between compliers and non-compliers was 0.5 $\log_{10}$ units (P=0.026), adjusted for weeks since the start of study. As can be seen, however, this adjustment can only be partial, since there are no data on compliers after week 36.

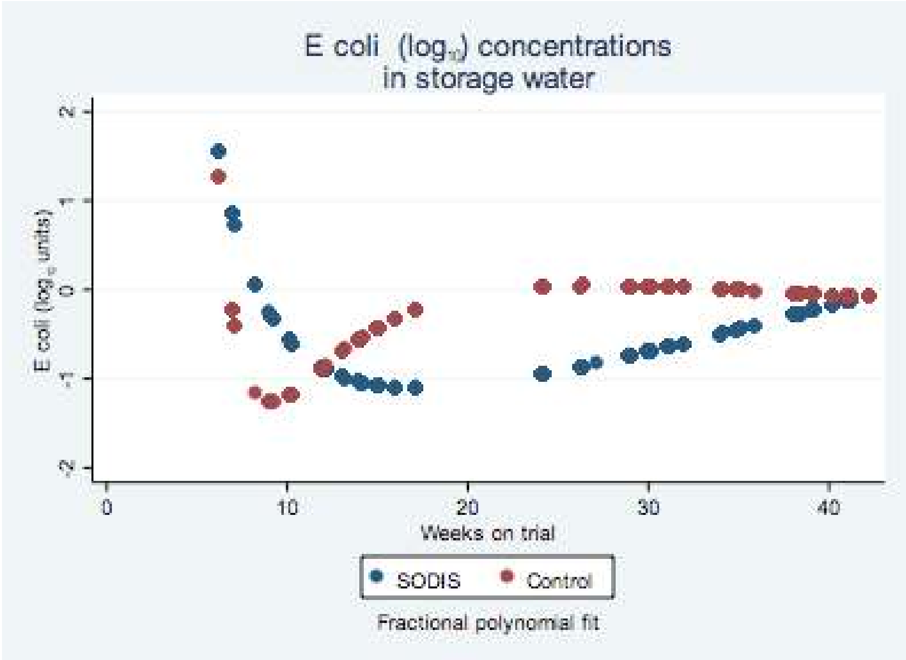


Figure 12: *E. coli* concentrations in storage water in South African test (SODIS) and control households over the field trial period.

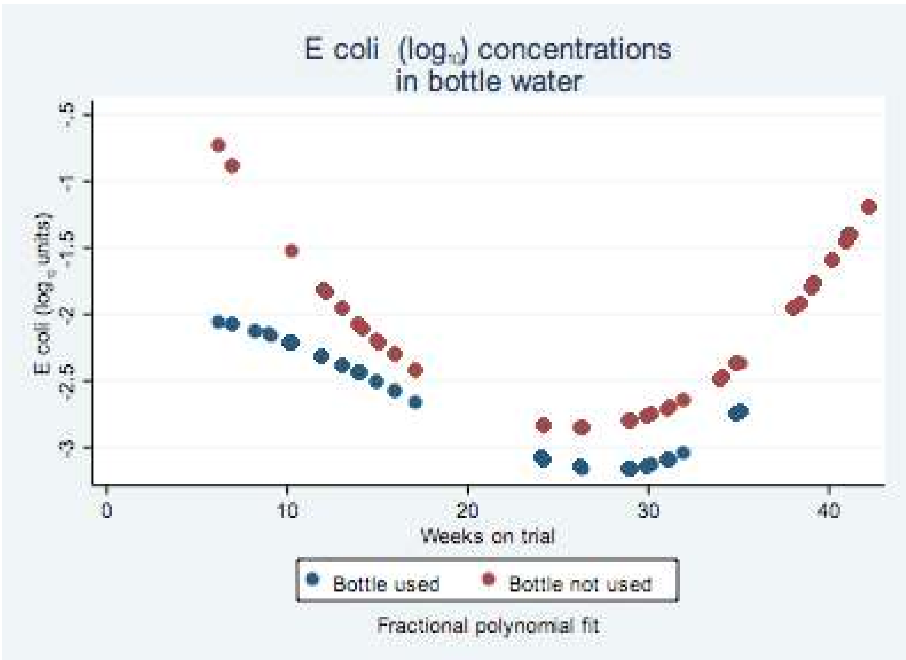


Figure 1: The average difference in *E. coli* concentrations in SODIS bottles between compliers (bottle used) and non-compliers (bottle not used) to the SODIS protocol in South Africa.

3.1.5.1g Anthropometry

The odds ratios associated with use of SODIS were calculated as described above (Section 0) and appear in **Table** .

There was significant variation in the prevalence of underweight children between monitoring visits, probably due to selective participant attrition. Adjusting for this, there was no material change in the odds ratios associated with solar disinfection. There was also no significant relationship between water source characteristics and anthropometry indices.

Table 3: South African odds ratios and adjusted odds ratios for weight-for-age, height-for-age and weight-for-height of children.

Endpoint	Odds Ratio	Adjusted odds ratio*
Weight-for-age	1.1 (0.71 to 1.8)	1.1 (0.71 to 1.8)
Height-for-age	0.96 (0.62 to 1.5)	0.95 (0.60 to 1.5)
Weight-for-height	0.97 (0.65 to 1.4)	0.97 (0.66 to 1.4)

*Adjusted for visit number

The effect of solar disinfection on the three anthropometry indices adding compliance to the model was examined. There was no significant variation in the indices between compliance groups (<25%, 25%-50%, 50%-75% and 75% to 100%). The effect of SODIS at each monitoring visit was examined separately. Again, there was no significant effect observable at any of the four follow-ups.

Table 4: South African mean height and weight changes of children.

	Control		Test		
	N	**Mean**	**N**	**Mean**	**Sig. (P)**
Height change	46	6.57	56	4.08	0.579
Weight change	46	1.69	56	1.0	0.355

The difference between the mean height and weight of the control children without SODIS water (mean difference=2.49) and the difference in the mean height and weight (0.62) of children with SODIS was not significant (**Table**).

3.1.5.1h HEALTH Risk factors

In order to put the above results relating to health indicators in perspective, the risk of dysentery diarrhoea associated with various risk factors was examined. This sub-section addresses Deliverable No.19: Identification of health determinants (health risk factors).

Water source

There were 287 households of the 564 whose water came from standpipes (51%). These accounted for 370 of the 718 children in the study group (52%). There was a substantially lower risk of dysentery in those children drinking standpipe water, with an incidence rate ratio of 0.36 (P=0.049). There was no evidence that any other water source type was associated significantly with risk of dysentery. There was also no evidence of an interaction effect between water source type and the effect of SODIS (t = –0.12, P=0.908).

Water drawing method

Water storage containers used in the households consisted of narrow mouthed 25 L and wide-mouth 50 to 100 L containers. Usually water is poured into cups from narrow mouthed containers and scooped from wide-mouthed containers. Only 48 households (8.5%) used a scoop to draw water, while the remainder poured water from their containers. The risk of dysentery was substantially increased by the use of a scoop, with an incidence rate ratio of 39.3, P<0.001. There were too few households to examine the possible interaction with the effect of SODIS with any degree of confidence.

Hand washing

There were high levels of reported hygiene: 556 householders reported washing their hands before preparing food (98.6%), 554 (98.2%) before eating, 557 (98.8%) after using the toilet and 553 (98.0%) after changing a nappy. There was insufficient variation in hand washing behaviour to analyse the effect on dysentery.

Toilet facilities

The majority of the households have access to a pit toilet in their yard. There were 447 households (79%) with access to a toilet, of which 62 households (11%) had access to flush toilets. There was no evidence that access to a toilet reduced dysentery risk (incidence rate ratio 1.1, P=0.716). However, compared with those without access to a toilet, those with access to a flush toilet had a significantly lower rate of dysentery, with an incidence rate ratio of 0.03 (P=0.001). However, it is likely that this association is at least partly the product of other household characteristics associated with access to a flush toilet.

3.1.5.1i ACCEPTANCE OF SODIS

This sub-section addresses Deliverable No.22: Assessment of acceptance/compliance of the SODIS method.

The compliance levels on an ongoing basis in the test group were also examined. It was assessed on the basis of the answer to the question "Did you put out a SODIS bottle yesterday?" **Figure 2** shows the relationship between compliance and duration of study. The points show individual households, and the line shows the logistic fit. Initial compliance was better than 75%. However, by week 40, reported compliance was less than 30%. This decrease in apparent compliance indicates a general decrease in acceptance of the SODIS protocol as the year-long field study progressed.

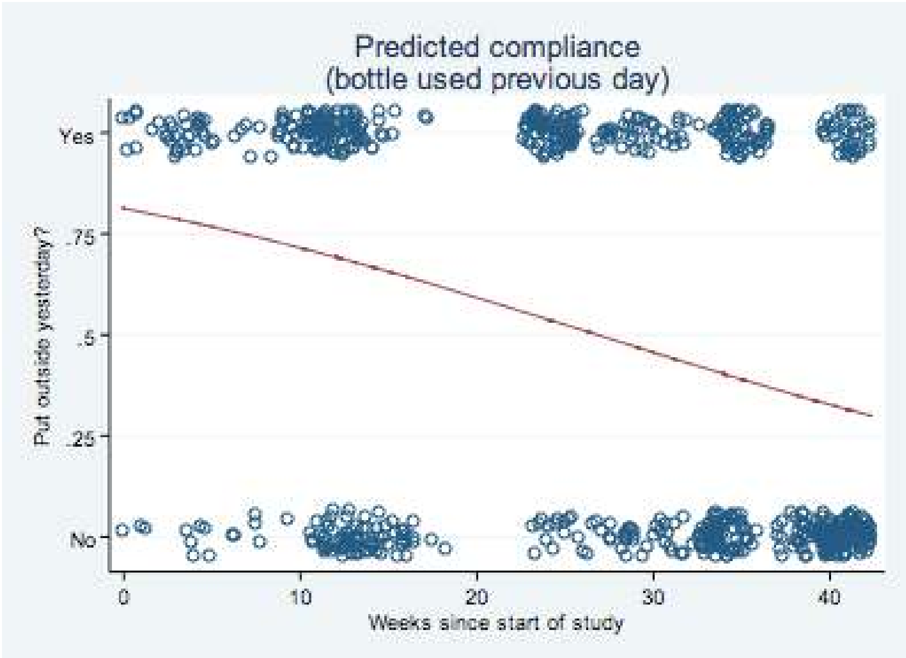


Figure 2: The relationship between compliance and duration of the South African study: The points show individual households, and the line shows the logistic fit.

Very few control households showed a willingness to adopt SODIS at the end of the main field study. Assessment of post study compliance was determined by interviewing 92 households who used SODIS bottles during the main study. The questionnaires were administered by the previously trained field workers. A summary of the questions asked and the responses received from the participants are shown in **Table** .

The results of the questionnaire confirmed that a significant proportion of the community perceived their drinking water to be of good quality. 72.2% thought that additional disinfection was unnecessary. Although SODIS was considered as an easy method for water disinfection, 68.8% of those interviewed considered it time consuming. Noteworthy is the fact that 94.8% of the respondents thought that 4 litres of solar disinfected water was an adequate volume. This may be explained by the fact that solar disinfected water was only used for the children under five years of age and that an adequate volume of water was available from other sources (e.g. standpipes and boreholes) for the rest of the family. Most interviewees also indicated that they did not think it was odd to use SODIS. However, some (37.5%) did feel that using SODIS was looked upon by others as odd.

During visits to the communities it became evident that SODIS was not necessarily seen as useful in the community and that participants were aware of this, in spite of their responses to the questionnaire. They became more and more disinterested as the study progressed. Some participants complained that the study was going on for too long. This may indicate that they were using SODIS because they were asked to and not out of their own conviction. It is quite conceivable that the Hawthorn effect (interviewees provide the answers or conduct themselves in a way they think is expected of them by the interviewer) played an important role in the outcome of the results.

Table 5: Summary of the main questions and responses obtained for SODIS use in South Africa.

Question	% Yes	% No
Is your drinking water safe?	80.4	19.8
Is chlorinated water safe?	54.2	45.8
Is SODIS water safe?	96.9	4.1
Is it important that your drinking water does not make you sick?	96.9	3.1
Do you see a need for additional water treatment?	27.8	72.2
Is doing SODIS time consuming?	68.8	30.2
Is it difficult to do SODIS?	17.7	82.3
Is it easy to remember to put out your SODIS bottles?	98.0	2.0
Does SODIS provide enough water for drinking?	94.8	5.2
Do you think doing SODIS is a good thing?	97.9	2.1
Do you think doing SODIS is odd?	2.2	92.8
Do other people think you are odd because you do SODIS?	37.5	62.5

Responses to the questions pertaining to why others did not use SODIS and why the compliance was so low indicated that participants rated ignorance in the rest of the community about SODIS as the main reason. This was confirmed by responses such as: “They think it will make their children sick”, “SODIS cannot disinfect water”, “people not using SODIS think we are crazy to use it” and “it is a waste of time.”

3.1.5.1j SUMMARY OF OBSERVATIONS AND CONCLUSIONS

SODIS EFFECTIVENESS

- **Dysentery**: A significant reduction in risk of dysentery results when participants comply well with the recommended protocol for using the SODIS bottles. Equivalently, when compliance is low no significant reduction in risk occurs.
- **Non-dysentery diarrhoea**: Using SODIS bottles did not affect the overall risk of non-dysentery diarrhoea nor did the degree of compliance to the SODIS protocol affect this risk. In particular, even good compliance did not affect the risk.
- **Storage water quality**: On average, the difference in storage water quality, based on *E. coli* concentrations, between test and control group was not significant in the first and last (fourth) monitoring visit. However, they were significantly different during the second and third monitoring visits.
- **Disinfection**: Based on whether or not participants said they had put the SODIS bottle out in the sun the previous day, the average difference in *E.* coli concentrations in the SODIS bottles between those that did not and did was about 0.5 $\log_{10}$ units. This indicates a general disinfection effectiveness of the SODIS protocol.
- **Anthropometry indices**:
  - The use of SODIS did not significantly affect the odds ratio weight-for-age, height-for-age and weight-for-height of children.
  - The use of SODIS did not significantly affect the mean anthropometry indices (height and weight) of participating children, compared with those in the control group.
  - There was no significant variation in the anthropometry indices as the degree of compliance increased.
  - There was also no significant relationship between water source characteristics and anthropometry indices.

HEALTH RISK FACTORS

- **Water source**: There was a substantially lower risk of dysentery in those children drinking standpipe water. There was no evidence that any other water source type was associated significantly with risk of dysentery. There was also no evidence of an interaction effect between water source type and the effect of SODIS.

- **Water drawing method**: The risk of dysentery was substantially increased by the use of a scoop to draw water from the storage container compared to pouring from the container.
- **Hand washing**: High reported levels of hygiene and insufficient variation in the data precluded an analysis of the effect of hand washing on risk of dysentery.
- **Toilet facilities**: There was no evidence that access to a toilet reduced dysentery risk. However, compared with those without access to a toilet, those with access to a flush toilet had a significantly lower rate of dysentery.

ACCEPTANCE OF SODIS

- **During study**: Compliance, based on the answer to the question "Did you put out a SODIS bottle yesterday?", decreased from above 75% at the start of the study to less than 30% at week 40. This indicates a general decreasing acceptance of the use of SODIS.
- **Post-study**: Very few control households showed a willingness to adopt SODIS at the end of the main field study. One of the main reasons may be that many perceived their water to be of adequate quality.

3.1.5.2 RESULTS - KENYA

INTRODUCTION

The health impact assessment in Kenya was initiated in 2008. The start and end dates used to distinguish between data in the SODIS Master Country Database collected during the three monitoring visits were as follows:

1. 2008/07/22 to 2008/10/07
2. 2008/10/08 to 2009/01/06
3. 2009/01/07 to 2009/03/14

The analysis that follows investigated various relationships between source water types, water quality, gender and age in terms of the dysentery and non-dysentery diarrhoea days that were recorded.

3.1.5.2a DATABASE CLEANUP

The databases were cleaned by team members in Kenya and sent to the database developer for preparation for statistical analysis. No invalid barcodes were detected in either the diary or main databases. No duplicate barcodes were detected in the main database. However, when the three individual diarrhoeal diary databases were merged into one, a few duplicate barcodes were detected. These were fixed in the same way as the South African data.

The checks for unmatched barcodes only indicated missing data, not inconsistent data. Therefore, no changes were made to the database on the basis of unmatched barcodes.

3.1.5.2b NUMBERS OF DATA TYPES

Table shows a summary of the numbers of various data types obtained during the field study and presented for statistical analysis. It should be noted that numbers actually used in the analyses described in the following sub-sections may be less than those in the table.

Table 6: Kenyan field study summary of numbers of data types.

Data type	Number
Children in control group (without SODIS bottle)	554
Children in test group (using SODIS bottle)	579
Male children	568
Female children	565
Total children	1 133
Households	798
Households using standpipes	440
Households using protected boreholes	64

Households using unprotected boreholes	73
Households using protected springs	1
Households using protected dug wells	2
Households using unprotected dug wells	3
Households using rivers	163
Households using canals	1
Households using other water sources	51
Children with some diarrhoeal diary data	1 089
Non-dysentery diarrhoea days	8 085
Non-dysentery diarrhoea episodes	3 829
Dysentery days	2 850
Dysentery episodes	1 128
Storage water *E. coli* measurements (Monitoring visit 1)	471
(Monitoring visit 2)	447
(Monitoring visit 3)	441
(Monitoring visit 4)	0
SODIS water *E. coli* measurements (Monitoring visit 1)	262
(Monitoring visit 2)	232
(Monitoring visit 3)	232
(Monitoring visit 4)	0
Children with some anthropometry data (Monitoring visit 1)	656
(Monitoring visit 2)	653
(Monitoring visit 3)	632
(Monitoring visit 4)	0

3.1.5.2c ASSESSMENT OF HEALTH OUTCOMES

This section addresses Deliverable No.23: Assessment of the intervention on the health outcomes (dysentery and non-dysentery diarrhoea).

Approach

Data were analysed with Stata/SE, Release 11. Stata's robust variance estimation routines for clustered data, implemented in the survey procedures, were used to adjust for the effects of the multistage sample design, with children sampled within houses, and stratified by village (6 units).

Initial analysis confirmed that incidence rates of dysentery were overdispersed, making a Poisson regression inappropriate. Generalised negative binomial regression was used to calculate incidence rate ratios. Generalised negative binomial regression allows for variation in disease rates between individuals who have the same risk factor profile, and allows this variation to be modelled as a function of predictor variables.

3.1.5.2d Dysentery and non-dysentery diarrhoea

There were 765 households, with 404 (53%) randomised to solar disinfection. The total number of children randomised was 1089, with 555 (51%) randomised to solar disinfection. There was no difference in age or sex distribution between test and control groups. Median follow-up (determined by the number of monitoring visits) was 14 months; 25% of participants had 9 months or less, 75% had 17 months or less and 21% had 17 or 18 months. **Table** shows the rates of dysentery and non-dysentery diarrhoea.

Table 7: Kenyan unadjusted annual rates of dysentery and non-dysentery diarrhoea.

	Dysentery		Non-dysentery diarrhoea	
Group	Days	Episodes	Days	Episodes
Control	5.20	2.02	10.89	4.75
Test (SODIS)	3.34	1.31	8.07	3.65

Table shows incidence rate ratios for each endpoint with estimates adjusted for water source (standpipe versus other water source), study area (entered as 5 dummy variables) and child age in whole years (4 dummy variables). Dispersion was parameterised by study area (5 dummy variables).

Table 8: Kenyan incidence rate ratios for dysentery and non-dysentery days and episodes with estimates adjusted for water source, study area and child age.

Endpoint	Incidence rate ratio	95% CI	Sig
Dysentery days	0.56	0.40 to 0.79	<0.001
Dysentery episodes	0.55	0.42 to 0.73	<0.001
Non-dysentery days	0.70	0.59 to 0.84	<0.001
Non-dysentery episodes	0.73	0.63 to 0.84	<0.001

All diarrhoea endpoints were significantly reduced by use of solar disinfection, with reductions of roughly 45% in the incidence of dysentery and approximately 30% in the incidence of non-dysentery diarrhoea.

3.1.5.2e Anthropometry

The data were analysed using the same approach as for South Africa. The odds ratio associated with use of SODIS was calculated in relation to each endpoint: height-for-age, weight-for-age and height-for-weight (**Table**). As for South Africa, there was significant variation in the prevalence of underweight children between follow up visits, probably due to selective participant attrition. Adjusting for this, there was no change in the odds ratios associated with solar disinfection. Accordingly, only the unadjusted odds ratios are shown.

Table 9: Kenyan odds ratios for weight-for-age, height-for-age and weight-for-height of children.

Endpoint	Odds ratio
Weight-for-age	0.82 (0.51 to 1.3)
Height-for-age	0.91 (0.56 to 1.5)
Weight-for-height	1.1 (0.72 to 1.7)

3.1.5.2f Health RISK FACTORS

This sub-section addresses Deliverable No.19: Identification of health determinants (health risk factors).

Water source

There were 419 households of the 765 whose water came from standpipes (55%). These accounted for 609 of the 1,089 children in the study group (56%). However, there was no evidence that children drinking from standpipe water sources had a lower rate of dysentery (incidence rate ratio 0.81, P=0.247). In view of the disruption to water supplies and the necessity for some households to move to escape the outbreaks of violence, it is perhaps not surprising that a single measure of water source is not associated with risk.

Water drawing method

A total of 423 households (45%) used a scoop to draw water, while the remainder used a cup. The risk of dysentery was, however, unrelated to the use of a scoop (IRR 0.97, P=0.882).

Hand washing

There were high levels of reported hygiene: 718 householders reported washing their hands before preparing food (93.8%), 761 (99.5%) before eating, 744 (97.2%) after using the toilet and 591 (77.2%) after changing a nappy. There was therefore insufficient variation in hand washing behaviour to analyse the effect on dysentery except washing after changing a nappy. This item was not associated with risk of dysentery (IRR 1.3, P=0.167)

Toilet facilities

There were 708 households (92.6%) with access to a toilet, of which 51 households (7%) had access to flush toilets. There was no evidence that access to a toilet reduced dysentery risk (incidence rate ratio 1.1, P=0.723) and there appeared to be no advantage to having access to a flush toilet in particular (IRR 1.0, P=0.920).

The number of people sharing the toilet ranged up to 200. A quarter of households used toilets shared with 8 people or fewer, of whom 5% were sole users. Half of households used toilets shared by 15 people or fewer and three quarters used toilets shared by 30 people or fewer. Risk of dysentery rose by 15% for each one quartile increase in the number of people using the toilet (P=0.041).

Figure 15: A Kenyan rural communal toilet.

3.1.5.2g ACCEPTANCE OF SODIS

This sub-section addresses Deliverable No.22: Assessment of acceptance/compliance of the SODIS method.

Due to the financial and political problems outlined above, it was not possible to quantitatively assess the degree of acceptance of SODIS. Notwithstanding these problems, observations by the fieldworkers confirmed satisfactory adherence to the SODIS protocol for most of the study period.

3.1.5.2h SUMMARY OF OBSERVATIONS AND CONCLUSIONS

SODIS EFFECTIVENESS

- **Dysentery**: A significant (roughly 45%) reduction in days with dysentery and dysentery episodes results when using the SODIS bottles.
- **Non-dysentery diarrhoea**: A significant (roughly 30%) reduction in days with non-dysentery diarrhoea and non-dysentery diarrhoea episodes results when using the SODIS bottles.
- **Anthropometry indices**:
    - The use of SODIS did not significantly affect the odds ratios for weight-for-age, height-for-age and weight-for-height of children.

HEALTH RISK FACTORS

- **Water source**: There was no evidence of a lower risk of dysentery in those children drinking standpipe water. However, this may be as a result of disruption to water supplies and the need for some households to move to escape the outbreaks of violence.
- **Water drawing method**: Either a scoop or a cup was used. The risk of dysentery was not related to the use of a scoop.

- **Hand washing**: There were generally high reported levels of hygiene (and therefore insufficient variation in the data for analysis) except for washing after changing a nappy. However, this was not associated with a risk of dysentery.
- **Toilet facilities**: There was no evidence that access to a toilet reduced dysentery risk and there appeared to be no advantage to having access to a flush toilet in particular. However, the risk of dysentery rose with increasing numbers of people sharing a toilet.
-

3.1.5.3 RESULTS - ZIMBABWE

Introduction

The health impact assessment in Zimbabwe was initiated in 2008. As a result of political unrest the field work had to be abandoned (See Section 3.4 of Chapter 3). The field work was re-initialised in 2009. The start and end dates used to distinguish between data in the SODIS Master Country Database collected during the four monitoring visits were as follows:

1. 2009/03/01 to 2009/06/30
2. 2009/07/01 to 2009/09/30
3. 2009/10/01 to 2009/11/30

Data obtained from the field study lacked consistency and accuracy. Consequently only a limited analysis was warranted.

3.1.5.3a DATABASE CLEANUP

The databases were cleaned by team members in Zimbabwe and sent to the database developer for preparation for statistical analysis. No invalid, duplicate, or unmatched barcodes were detected. However, there was evidence that the laboratory data may not have been captured using the handheld computers, as the protocol required. This raises some concerns about the integrity of these laboratory data.

3.1.5.3b NUMBERS OF DATA TYPES

Table 0 shows a summary of the numbers of various data types obtained during the field study and presented for analysis.

3.1.5.3c ASSESSMENT OF HEALTH OUTCOMES

This section addresses Deliverable No.23: Assessment of the intervention on the health outcomes (dysentery and non-dysentery diarrhoea).

Approach

Data were analysed with Stata/SE, Release 11. Stata's robust variance estimation routines for clustered data were used to adjust for the effects of the multistage sample design, with children sampled within houses, and stratified by village. There were 839 children recruited. However, diarrhoea diary data are only available on 670 (80%) and anthropometry on 480 (57%). Diarrhoea and anthropometry data are available from 418 (50%).

Table 10: Zimbabwean field study summary of numbers of data types.

Data type	Number
Children in control group (without SODIS bottle)	547
Children in test group (using SODIS bottle)	292
Male children	437
Female children	402
Total children	839
Households	648
Households using protected boreholes	21
Households using unprotected boreholes	43
Households using protected dug wells	45

	Households using unprotected dug wells	539
	Children with some diarrhoeal diary data	670
	Non-dysentery diarrhoea days	1 249
	Non-dysentery diarrhoea episodes	494
	Dysentery days	382
	Dysentery episodes	127
Storage water *E. coli* measurements	(Monitoring visit 1)	387
	(Monitoring visit 2)	339
	(Monitoring visit 3)	318
	(Monitoring visit 4)	0
SODIS water *E. coli* measurements	(Monitoring visit 1)	70
	(Monitoring visit 2)	38
	(Monitoring visit 3)	54
	(Monitoring visit 4)	0
Children with some anthropometry data	(Monitoring visit 1)	480
	(Monitoring visit 2)	0
	(Monitoring visit 3)	0
	(Monitoring visit 4)	0

There were 28 children in Hatcliffe Ext 4 who were the only participants drinking from a protected borehole, of whom 6 were randomised to SODIS. There was no dysentery recorded in this group. These children have been excluded from the analysis.

There were 228 children randomised to SODIS (35.5%) and 414 (64.5%) to control. Randomisation to SODIS varied significantly by village, with as few as 20% or as many as 45% of children randomised (P<0.0001, Chi squared test).

3.1.5.3d Dysentery

Incidence of dysentery was modelled using generalised negative binomial regression. Compliance with protocol was measured, as above, using the proportion of diary days filled in. The rate of dysentery was lower in those with higher compliance, whether SODIS or control. There was no evidence, however, that SODIS itself was associated with risk of dysentery. In univariate analysis, the incidence rate ratio was 1.4 (95% CI 0.71 to 2.7, P=0.337). Adjusting for compliance with protocol changed this little: IRR=1.5, 95% CI 0.79 to 2.8, P=0.215.

3.1.5.3e SUMMARY OF OBSERVATIONS AND CONCLUSIONS

Only a limited analysis was possible because of the lack of data integrity.

SODIS EFFECTIVENESS

- **Dysentery**: There was no evidence that use of SODIS was associated with risk of dysentery.

3.1.6 DISCUSSION AND CONCLUSIONS

The overall objective of the study related primarily to the effectiveness of using the SODIS method of solar disinfection in respect of waterborne disease. The study used the incidence of two forms of diarrhoea in children between 6 months and 5 years old as indicators of effectiveness. It also attempted to use anthropometric measurements, specifically weight and height, as health indicators. As secondary objectives, the study also intended to better understand the role of certain risk factors related to diarrhoea and the degree to which the SODIS method was accepted by the target communities. The two forms of diarrhoea were dysentery (or bloody diarrhoea) and non-dysentery (non-bloody) diarrhoea.

WP2 Summary Table for effect of SODIS on

Country	Endpoint	Incidence rate ratio[§]	95% Ci	Sig
Kenya	Dysentery days	0.56	0.40 to 0.79	<0.001
	Dysentery episodes	0.55	0.42 to 0.73	<0.001
	Non-dysentery days	0.70	0.59 to 0.84	<0.001
	Non-dysentery episodes	0.73	0.63 to 0.84	<0.001
S Africa	Dysentery days	0.64	0.33 to 1.2	0.181
	Dysentery episodes	0.81	0.54 to 1.2	0.291
	Non-dysentery days	0.87	0.54 to 1.4	0.553
	Non-dysentery episodes	0.79	0.57 to 1.07	0.128
	Dysentery < 25% Compliance	0.86	(0.15 to 5.0)	0.853
	Dysentery 25% to 50% Compliance	1.75	(0.46 to 6.7)	0.387
	Dysentery 50% to 75% Compliance	0.84	(0.24 to 2.9)	0.766
	Dysentery 75% to 100% Compliance	0.35	(0.17 to 0.76)	0.011
Zimbabwe	Dysentery days	1.4	0.73 to 2.8	0.299
	Dysentery episodes	1.3	0.78 to 2.3	0.302
	Non-dysentery days	1.9	1.2 to 2.9	0.006
	Non-dysentery episodes	1.6	1.06 to 2.4	0.024
Cambodia	Dysentery days	0.43	0.20 to 0.95	0.036
	Dysentery episodes	0.46	0.25 to 0.85	0.014
	Non-dysentery days	0.39	0.32 to 0.48	<0.001
	Non-dysentery episodes	0.37	0.30 to 0.46	<0.001

[§]*Incident rate ratio = incident rate in SODIS group divided by incident rate in control group)*

The SODIS technology is extremely simple, requiring very little training in its effective use. However, the design of a study that tests its effectiveness is particularly complex. The design of the field studies, including their location, the choice of households, and the choice of monitoring parameters and monitoring frequency, was guided by a statistician. In order to ensure statistically useful data, relatively large numbers of children were required to participate. This created significant logistical challenges. It also determined to some extent the location of the field study sites.

The main field study occurred over a period of one year. It therefore covered the whole hydrological cycle, which therefore ensured possible seasonal differences caused, for example, by different rainfall patterns, were included. Possible seasonal effects were however not explicitly examined.

The field staff made use of local community members whenever possible. They helped with translation, water sample collection, and anthropometric measurements. Many were not highly educated although all attended an in-depth training course. This was based on a detailed manual which described all field methods, data capture protocols, laboratory work and database maintenance.

The three countries chosen for the field studies, namely South Africa, Kenya and Zimbabwe, had both similarities and differences, even though peri-urban and/or rural communities were chosen in each. However, these differences were ultimately not important deciding factors. The outcomes of the field studies in each country were much more fundamentally determined by events outside the control of the project teams. These included the serious political unrest and financial problems that beset both Kenya and Zimbabwe. Zimbabwe also suffered a severe cholera outbreak.

Notwithstanding these problems, a field study began in each country with a so-called pre-survey. Having obtained all necessary permissions to work in each chosen area, individual households were chosen with children of the correct age. A test group and a control group were randomly selected. The test group was given SODIS bottles and associated instructions. The carer in each household was also given a printed diarrhoeal diary, one page per month, personalised to each child. They were asked to record the nature and frequency of stools produced by the children. This data, ultimately captured on a specially-designed database, provided the basic data on the incidence of diarrhoea.

Monitoring the water quality in the SODIS bottles and in the household storage containers, and taking anthropometric measurements, were then planned to take place four times at three-monthly intervals. For the reasons given above, some countries did not complete all four monitoring visits. Field data capture was done using handheld computers on which questionnaires had been loaded. The captured data were typically downloaded to the main database on a daily basis upon return to the laboratory or office.

In Kenya there was much anecdotal evidence of enthusiastic acceptance of the method. This occurred even to the point of participants in the control group wanting to start using the SODIS bottles long before the end of the study. In South Africa this was less so. A possible reason is that the water was of relatively better quality, and indeed was perceived to be adequate by many in the community. In South Africa, therefore, their participation in the field study was possibly driven more out of dedication to the research than a real perceived need for the technology. Insufficient information is available to assess the situation in Zimbabwe.

The above-mentioned disruptions to the monitoring visits in Kenya and Zimbabwe had some well-defined impacts on project execution (like having to omit the fourth monitoring visit altogether). However the delays introduced and particularly the loss of participants were also likely to not only have affected data quantity, but also overall data quality.

Notwithstanding these problems, the dataset that emerged from South Africa was reasonably complete, that from Kenya much less so, and from Zimbabwe even less so. The statistical analysis of the South African data showed that a significant reduction in dysentery occurred as long as participants complied well with the recommended protocol. Compliance with the SODIS protocol over the study period was determined using the degree to which participants filled in the diarrhoeal diaries as a proxy. This was based on the assumption that if a household carer was thorough in filling out the daily diary, they were likely to also be thorough in their use of the SODIS bottles.

In Kenya, the effectiveness of SODIS was even more evident. Significant reductions in dysentery days (i.e. days on which dysentery occurred), dysentery episodes, non-dysentery diarrhoea days and non-dysentery diarrhoea episodes occurred.

In Zimbabwe, there was no evidence that SODIS was associated with the risk of dysentery. However, this is not necessarily a negative conclusion in respect of SODIS effectiveness because of the lack of data integrity. It may only be a negative conclusion in respect of the ability to conduct studies of this kind.

Very little anthropometric data was obtained in Zimbabwe. While such data were collected in South Africa and Kenya, there was no evidence that weight and height of the children was affected by SODIS. However, again, this is not necessarily a negative conclusion in respect of SODIS because of the recognised difficulties in obtaining a sufficiently high data quality, particularly using inexperienced personnel.

Various factors that potentially affect dysentery risk were investigated. These included the type of water source, the way in which water was drawn from the in-house storage container, hand washing in various situations (after going to the toilet, after removing a baby's nappy, etc.), and toilet facilities (type of toilet and the number of people sharing it). While in South Africa and Kenya some factors could be statistically associated with the risk of dysentery, there was no common factor to the two countries.

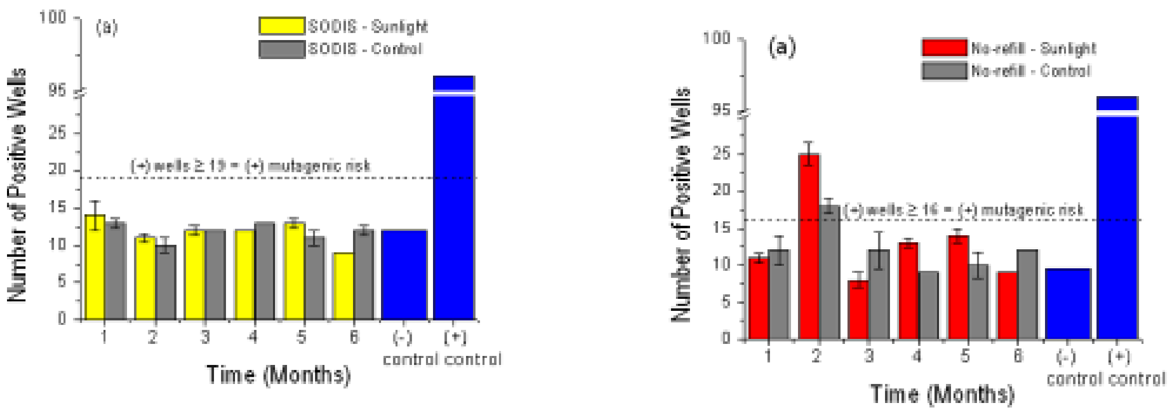
In essence therefore, given the variety of difficulties faced in all three countries, and the associated lack of data quality and quantity, there is no obvious evidence that SODIS is not effective in respect of diarrhoea. On the contrary, in those two countries in which data quality was better, namely South Africa and Kenya, positive evidence was found for SODIS effectiveness.

3.1.7 TOXICITY STUDIES

Preliminary studies of possible genotoxic effects arising from photodegradation of SODIS bottles after prolonged use were completed by RCSI, CIEMAT & CSIR personnel based in PSA. The concern was that chemicals may leach from the plastic into the water as the container material degrades under the sun. AMES toxicity assays were carried out to determine if any genotoxic events could be detected.

Plastic SODIS bottles filled with water and set out on the roof of the CIEMAT laboratories in Almeria Spain. Bottles were exposed over 6 months. Assays were conducted every month.

No genotoxic effects were observed for water samples that had been in (a) PET bottles and exposed to normal SODIS conditions (strong natural sunlight) over 6 months. Under SODIS conditions, bottles were exposed to 6 hours of sunlight, followed by overnight room temperature storage. They were then emptied and refilled the following day and exposed to sunlight again. Genotoxicity was detected after 2 months in (b) water stored in PET bottles and exposed <u>continuously</u> (<u>without refilling</u>) to sunlight for a period ranging from 1 to 6 months. However, similar genotoxicity results were also observed for the dark control (without refill) samples at the same time-point and in no other samples after that time; therefore it is unlikely that this genotoxicity event is related to solar exposure.



(a) (b)

(a) PET bottles exposed to normal SODIS conditions (strong natural sunlight) over 6 months. Under SODIS conditions, bottles were exposed to 6 hours of sunlight, followed by overnight room temperature storage. (b) PET bottles exposed <u>*continuously*</u> *(*<u>*without refilling*</u>*) to sunlight for a period ranging from 1 to 6 months. Significant genotoxic events are represented by columns which cross the dashed horizontal line*

The primary outcome of this aspect of the research is the recommendations that:

1. SODIS bottles should be replaced at least every 6 months
2. Further, more sensitive studies of the health effects of photodegradation products in SODIS water are required.

3.1.8 GLOSSARY

Anthropometry: The study of human measurements. In this research the following measurements are taken: Child height (or baby length) (cm) and weight (kg).

Barcode: A unique barcode (with associated number) used to identify individual children, households and sample bottles. Each could be automatically scanned (or manually inserted) onto the handheld computers either during monitoring visits (for households and children) or in the laboratory (for sample bottles). All barcodes have the syntax: ANNNNN where A=country ID and N=digit from 0 to 9, e.g. K00005 for a Kenyan barcode.

Borehole: A hole drilled into the ground for the purposes of extracting groundwater.

Canal: An artificial waterway usually constructed for irrigation of crops. It is usually lined with either plastic or concrete to prevent the water seeping away.

Carer: The single person in the household primarily responsible for (a) caring for the children and (b) filling in the diarrhoeal diary every day.

Control group: The group of households not allocated a SODIS bottle. The results of the test group are compared against this group to determine the effectiveness of solar disinfection.

Country computer: The main computer (a laptop) used in each country for SODIS-related work.

Database, Master country: The database in each country containing the data captured in the pre-survey and measured in each subsequent three-monthly (monitoring) visit.

Diarrhoea: Three or more loose stools in one day.

Diarrhoeal diary: A paper form used to keep a record of the number of loose stools and the presence of blood or mucus produced by the children selected for the study (in both the test and control groups).

Dysentery day: A single day in which one or more stools (whether regarded by the carer as "normal" or loose) contain either blood or mucus. Dysentery can be associated with *Shigella* bacterial species.

Dysentery episode: When one or more consecutive dysentery days occur followed by three consecutive days on which neither dysentery nor non-dysentery diarrhoea occurs.

E. coli: The bacterium *Escherichia coli*. It is used in this study to indicate the degree of microbial contamination of the storage water and water in the SODIS bottle.

Field worker: Person responsible for (a) helping the supervisor during the pre-survey and monitoring visits and (b) collecting completed diaries from households on a monthly basis.

GPS (Global Positioning System): Used to refer to the Garmin etrex device that is used in this study to (a) mark the waypoints of households and (b) locate these houses on subsequent field visits.

Handheld computer: Small computers used in the field or laboratory to capture responses to questionnaires (including automatic scanning of barcodes). For example, individual questionnaires include:

- Household details (address, head, etc.);
- Child details (name, date of birth, etc.);
- Participation confirmation (during monitoring visits);
- Anthropometry measurements during monitoring visits);
- Storage samples (during monitoring visits);
- SODIS bottle samples (during monitoring visits);
- *E. coli* measurements in the water samples;
- etc.

Incident rate ratio: Ratio of the incidence rate in the test group to the incidence rate in the control group.

Intention to treat analysis: An analysis based on the initial treatment intent (in this case use of SODIS), not on the treatment eventually administered. Everyone who begins the treatment is considered to be part of the trial, whether they finish it or not.

Monitoring visit: A visit to all households four times at three-monthly intervals (*i.e.* over one year) during which:

- Continued participation of the household is confirmed;

- Anthropometry measurements of the children are taken;
- Storage water samples are taken; and
- SODIS bottle water samples are taken (if the household is in the test group).

Non-dysentery diarrhoea day: A single day in which there are three or more loose stools and none contain blood or mucus.

Non-dysentery diarrhoea episode: When one or more consecutive non-dysentery days occur followed by three consecutive days on which neither dysentery nor non-dysentery diarrhoea occurs.

Odds ratio: The ratio of the odds of exposure among the test group to the odds of exposure among the control group.

Pre-survey: A period at the start of the study involving identification of participating households and the completion of the pre-survey questionnaires (including allocation of unique barcodes to households and each individual child) which capture important information about the household (names, address, GPS waypoint and name, protocols relating to water use and hygiene).

***Non-dysentery diarrhoea*:** Diarrhoeal episodes during which loose watery stools without blood or mucus is produced.

Protected water source: A source of drinking water that is physically protected from potential sources of contamination (especially faecal). This may be achieved by restricting access to the source (especially to animals) by a fence of other enclosure. It also includes dug wells lined with bricks or concrete.

SODIS Bottle: The 2-litre transparent plastic soft-drink bottle that is filled to 5 cm from the top with water, shaken well and placed in the sun, for example on the roof, for at least 6 hours to disinfect the water. This study tests how effective this process is.

Spring: A location where groundwater comes out of the ground onto the surface.

Standpipe: A vertical small diameter pipe with a tap at the upper end.

Storage water: The water stored in the household and used for domestic purposes, particularly drinking.

Supervisor: Person primarily responsible for (a) completing the pre-survey questionnaires on the handheld computers, and (b) completing the other questionnaires at each of the subsequent four (three-monthly) visits to the households, and (c) downloading the captured responses to the questionnaires on a daily basis to the country computer.

Test group: The group of households allocated a SODIS bottle. Also referred to as the intervention group.

Unprotected water source: A source of drinking water that is not physically protected (*e.g.* by a fence or other enclosure, or concrete lining in the case of a borehole) from potential source of faecal contamination (*e.g.* by animals).

Well: A hole dug into the ground for the purpose of extracting water.

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3.1.10 WP2 APPENDIX A Information leaflet and consent form

INFORMATION LEAFLET AND CONSENT FORM

Title of the research study: Solar Disinfection of Drinking Water for use in Developing Countries or in Emergency Situations

Title: SODISWATER
INCO-DEV: International cooperation with developing countries.
Contract Number:

Introduction:
We are researchers of the_____ (Name of institution)
We are doing this research as part of a bigger study funded by the European Union.

Name of Researcher/s: ______________________________________
Contact numbers: ____

Purpose of the study:
To investigate how well sunlight can purify water for drinking purposes. This will be done by observing whether children younger than five years that drink such water are healthier than those who do not. Health will be measured by how often they have diarrhoea.

How your household was selected
Your house is one of 400 houses selected with the help of your community leaders. Each house that was selected was given a number like this 1, 2, 3, 4, 5……400. All these numbers were mixed. The first 200 hundred that were picked are the households that will be asked to put their drinking water in the sun. The remaining 200 hundred will be asked to give their children ordinary drinking water the way they usually do.

Taking part: what it involves
If you (the carer/ parent) agree to participate, the following things will happen:

- You will have to answer some questions about how you live, and the water you drink.
- You will be asked to note, every day, when your young child/children or children you take care of have diarrhoea.
- Your children or the children you take care of which are part of the study will be asked to drink water purified by sunlight.
- The water you normally use for drinking in your house will be tested for the presence of bacteria that cause diarrhoea.
- The water purified by sunlight at your house will be tested for the presence of bacteria that cause diarrhoea.
- Your children or the children in your care will be weighed and their height measured.
- Taking part in the study cannot harm you or the children in any way.
- The study will take one year to complete. During this year we will visit your house every two weeks to collect information on diarrhoea. Information on the quality of the water will be collected every two months. The children's height and weight will also be recorded every two months.

Confidentiality:

- All information gathered during this study will be confidential and used only for research purposes.
- It will not be shared with anyone else.
- It will be stored in a way that protects your identity.
- Results from the study will be reported as group data and will not identify you in any way.
- Your identity and those of the children will be kept confidential at all times.

Questions:
If there is anything that you are not clear about, please feel free to ask one of us or contact us at the

contact numbers provided.
M du Preez 012 841 3950 Wouter le Roux 012 841 2189

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CONSENT TO PARTICIPATE IN SODISWATER RESEARCH STUDY
Title of research study:

Solar Disinfection of Drinking Water for use in Developing Countries or in Emergency Situations

Short Title: SODISWATER

I have been provided with an information sheet about this study. The information on the sheet has been explained to me. I understand what is involved in the study, and I agree to take part. I understand that I am free to withdraw from the study at any time.

Signature of Householder: ____________________ Date: _____________

Name: _________________

Signature of Researcher: ____________________ Date: _____________

Name: _________________

Signature of Witness: ____________________ Date: _____________

Name: _________________

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3.1.11 APPENDIX b South African Community Feedback Poster

SODISWATER

Cleaning water with sunshine to make children healthy

The Aim

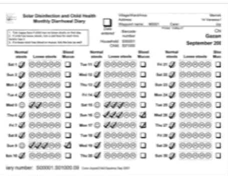
Bottles disinfecting in the sun …

… and 6 hours later safe to drink.

This poster reports on the South African part of a research project funded by the European Commission that also took place in Kenya and Zimbabwe.

The aim of the study was to determine whether drinking water disinfected in a bottle by the sun improved the health of young children. The number of times the children had **dysentery** (bloody diarrhoea) or **non-bloody diarrhoea** was used to indicate their health. A person has diarrhoea when they produce three loose stools in one day.

The Field Study



The study included 649 households with children between 6 months and 5 years old. 348 children were given SODIS bottles to put in the sun and drink from (these were the 'test group'). Another 438 children drank their usual water (these were the 'control group').

Using a handheld computer to capture the data

Child carers were asked to fill in a paper 'diarrhoeal diary' which recorded their children's stools every day, including whether or not it contained blood (which indicates dysentery).

Measuring weight, height and length

All children were visited four times over a period of one year (i.e. every three months). Their **weights and heights** (or **lengths** in very young children) were measured and samples of the household **storage water** and **SODIS bottle water** were collected. Data were captured on small handheld computers and downloaded onto the main database each day. The water samples were analysed in a laboratory for the bacterium *E. coli* which can cause dysentery and non-bloody diarrhoea.

Analysing for *E. coli* in the laboratory

The Results

The health of those children who drank SODIS water was compared with the health of those children who did not.

In South Africa it was found that when people used the SODIS method properly it reduced the number of times the children had dysentery. Those that did not use it properly did not have this health benefit. It may be that the South African participants thought their water was already of good quality and therefore did not feel that the SODIS method was necessary.

In South Africa it was found that the risk of dysentery in the children was less when:

1. Drinking water from standpipes (compared with those drinking water from other sources);
2. Water was poured from storage container (compared to using a scoop); and
3. There was access to a flush toilet (compared with those who did not have access to a toilet).

This information, however, has nothing to do with drinking SODIS water. It simply tells us about the normal dysentery risks when SODIS water is not used.

Helpful fieldworkers

In Kenya where the water was generally of worse quality and the people were much poorer, the SODIS method was shown to be very effective. It significantly reduced the number of times the children had dysentery and non-bloody diarrhoea.

Unfortunately, the **weight, height and length data** were not of good enough quality to establish whether or not they were affected by drinking the SODIS water.

Happy children

3.2 WORK-PACKAGE 3 SODIS PATHOGEN INACTIVATION

Objective: The aim of this workpackage is to determine whether important waterborne and/or diarrhoeal pathogens are susceptible to SODIS. Previous work has clearly demonstrated that a wide variety of viral and bacterial pathogens can be inactivated with batch SODIS however there still remains a considerable number of important waterborne microbes which are still untested. These pathogens were the bacteria Enteropathogenic *E. coli, Yersinia enterocolitica, and Campylobacter jejuni* (gastroenteritis), the protozoa *Cryptosporidium parvum* (cryptosporidiosis), *Entamoeba histolytica* (amoebic dysentery), *Naegleria fowleri* (meningoencephalitis), *Acanthamoeba polyphafga* (encephalitis (model organism)), the helminths *Acaris lumbricoides* (ascariosis), and viruses like Hepatitis A virus, Coxsackie virus A (aseptic meningitis), and Polio virus.

Main findings and results:

- The works done in WP3 demonstrated the critical importance of evaluating the parameters like flow rate, total volume, temperature of water, and solar energy when attempting the task of up-scaling SODIS, particularly when large reactors are proposed.
- Characterizing the uninterrupted UV dose required for inactivation of likely microorganism must be incorporated into the design SODIS reactors. For example: we determined that the lethal uninterrupted UV dose for 2.5 l of suspensions of *E. coli* K-12 of around 10^6 CFU ml^{-1} in real well-water using a CPC has been experimentally determined to be 108 kJ m^{-2} corresponding to 2160-2520 kJ m^{-2} of global radiation.
- We also demonstrated the feasibility of SODIS for drinking water disinfection even on cloudy days and for high turbidity values (100 and 300 NTU) in real conditions using natural well water and natural (non-treated) soil.
- The capability of SODIS to inactivate *Cryptosporidium parvum* oocysts in natural well water under real solar light have been also shoown. Depending on temperature and turbidity of water samples exposure times required may vary.
- PET bottles containing turbid waters contaminated with *C. parvum* oocysts, significantly reduced the potential viability of *C. parvum* oocysts on increasing the percentage of oocysts that took up the dye PI (indicator of cell wall integrity), although longer exposure periods appear to be required than those established for the bacterial pathogens usually tested in SODIS assays.
- For the first time, USC evaluated the thermal contribution in the survival of *C. parvum* during SODIS procedures, independently of the UV radiation, showing a significant contribution in the inactivation of C. parvum oocysts during SODIS procedures under natural sunlight.
- Disinfection model equations obtained are valid to predict the viability and infectivity of *C. parvum* oocysts when they are exposed to SODIS under the range of conditions assayed in this experiment. The viability and infectivity values obtained are high correlated, although the viability values obtained by inclusion/exclusion of the fluorogenical vital dye PI overestimate the infectivity as it is widely known.
- SODIS has been shown to be an effective method in the treatment of contaminated water at the household level, through the synergism of UV radiation and temperature. However, for the user of SODIS it is important that the method is constantly assessed and improved to make sure that pathogenic organisms are killed and the method is easy to use.

3.2.1 Description of tasks

Task 3.1 Bacterial Pathogen Inactivation

Batch solar disinfection (SODIS) inactivation kinetics were determined for suspensions in water of *Campylobacter jejuni*, *Yersinia enterocolitica*, enteropathogenic *Escherichia coli*, *Staphylococcus epidermidis*, and endospores of *Bacillus subtilis*, exposed to strong natural sunlight. The exposure time required for complete inactivation (at least 4-log-unit reduction and below the limit of detection, 17 CFU/ml) under conditions of strong natural sunlight (maximum global irradiance ~1050Wm^{-2}±10Wm^{-2}) was as follows (Figure 16): *C. jejuni*, 20 min; *S. epidermidis*, 45 min; enteropathogenic *E. coli*, 90 min; *Y. enterocolitica*, 150 min. Following incomplete inactivation of *B. subtilis* endospores after the first day, reexposure of these samples on the following day found that 4% (standard error, 3%) of the endospores remained viable after a cumulative exposure time of 16 h of strong natural sunlight. SODIS is shown to be effective against the vegetative cells of a number of emerging waterborne pathogens; however, bacterial species which are spore forming may survive this intervention process. This task was done by partners 1 and 6 (RCSI and PSA-CIEMAT).

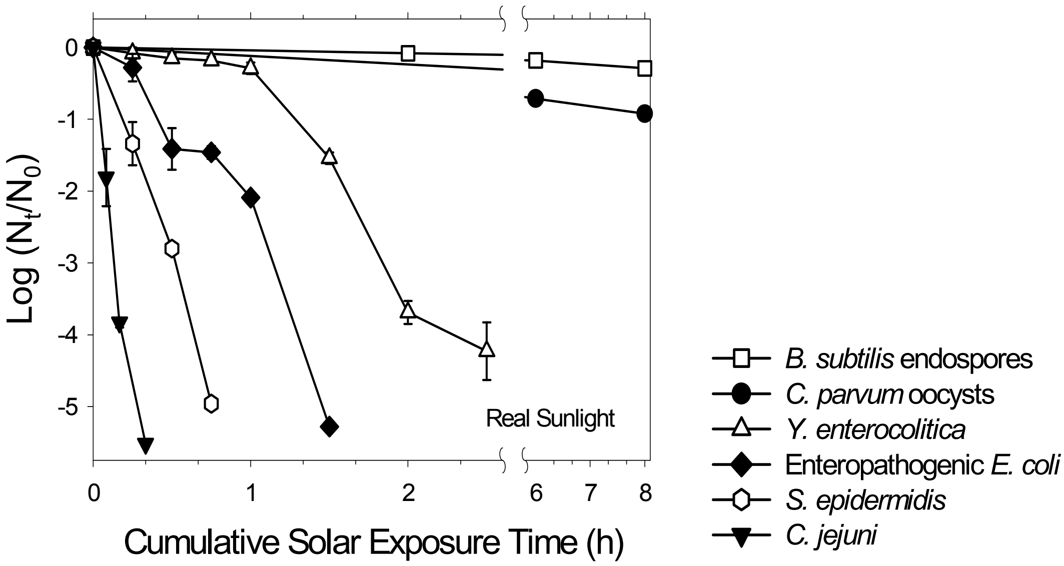


Figure 16. Inactivation kinetics of bacterial populations exposed to real sunlight conditions expressed in units of log reduction.

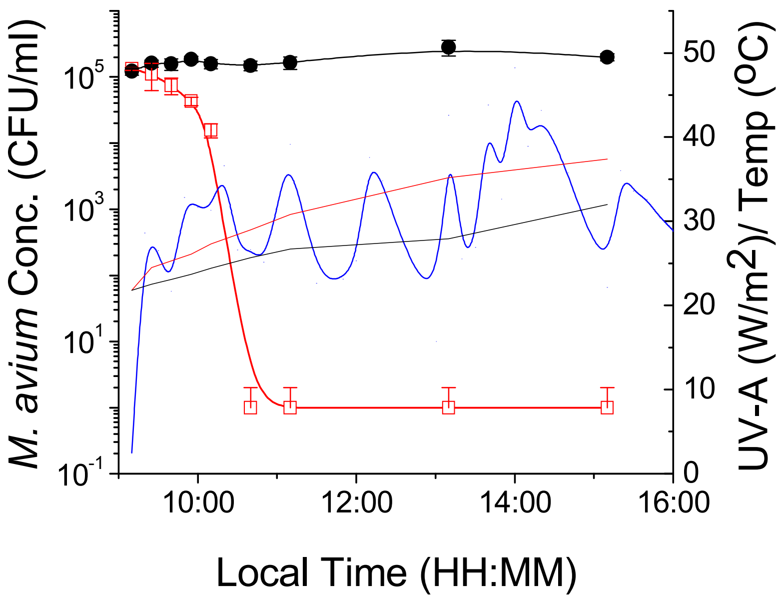


Figure 17. Inactivation curve of *M. avium* in PET bottles under natural sunlight conditions (-□-), dark control (-●-), solar irradiance on day of experiment (––), water temperature in solar exposed sample (––) and water temperature in dark control (––).

CSIR group have also determined the susceptibility of *Mycobacterium avium* and *Mycobacterium intracellulare* (MAC organisms) to solar disinfection, by examining the inactivation kinetics of MAC under natural sunlight conditions for a variety of different solar conditions (Figure 17). MAC organisms pose a specific and significant threat to highly immunocompromised individuals. MAC organisms represent an unusual pathogen class. They are environmental and not faecal-associated pathogens. They are resistant to a range of disinfection regimes including chlorination and have the remarkable ability to enter and grow in drinking water distribution systems where they persist in biofilms. In light of the fact that MAC organisms contribute significantly to morbidity and mortality of immunocompromised patients, it is essential that drinking water and water for general usage is free from MAC.

Task 3.2 Viral/Parasitic Pathogen Inactivation

University of Ulster group did the experimental work to complete this task. UL produced models for testing SODIS against a variety of protozoa, helminth and viral waterborne pathogens. The tests were done using a solar simulator with a global irradiance of ~870 Wm^{-2}, similar to a strong sunny day in the South of Spain. The following protozoa and helminth were tested against SODIS and SODIS enhanced with riboflavin (SODIS-R):

- *Entamoeba histolytica* (using *Entamoeba invadens* model)
- *Naegleria fowleri* (using *Naegleria gruberi* model)
- *Acanthamoeba* spp
- *Giardia lamblia*
- *Ascaris lumbricoides* (using *Ascaris suum* model)

Table 11. Results of protozoa and helminth inactivation during SODIS tests done in a solar simulator during 6h exposure. Efficacy of SODIS with and without riboflavin.

Protozoa	Illness	SODIS (6h @ 550 W/m^2)	SODIS-R (6h @550 W/m^2)
Entamoeba invadens Cysts	Amoebic dysentery (reptile model)	1.92 Log kill	1.90 Log kill
Naegleria gruberi Cysts	Non-pathogenic *Naegleria* model	3.59 Log kill	3.84 Log kill
Acanthamoeba castellanii Cysts	Encephalitis	2.16 Log kill	3.14 Log kill
Giardia lamblia Cysts	Giardiasis	1.96 Log kill	1.94 Log kill
Ascaris suum ova	Ascariasis	1.42 Log kill	0.56 Log kill

† 6h @ 550 W/m^2 which is approximate to 870 W/m^2 on the Oriel 1000W system

The following viral pathogens were also tested in the solar simulator (Table 2).

- Hepatitis A virus.
- Coxsackie A/B virus.
- Polio virus.

For this purpose UL laboratory had to fulfil all security guidelines regarding bio-security. In particular, for polio testing, the U.K. government introduced the 'Anti crime, terrorism and security Act'. The virus has to be handled in a highly secure category 3 facility. Although in order for UL lab to use the category 3 facility; lots of paperwork and training needed to be sorted out. This fact delayed the completion of this task on tome and was completed by month 42 instead 36.

Table 12. Results of viral inactivation during SODIS tests done in a solar simulator during 6h exposure. Efficacy of SODIS with and without riboflavin.

		Exposure (hr) and Log_{10} reduction in viability			
Organism	**Condition**	**1 hr**	**2 hr**	**4 hr**	**6 hr**
Coxsackievirus	SODIS	3.76	4.34	4.34	4.34
	SODIS-R	4.25	4.25	4.25	4.25
Poliovirus	SODIS	3.84	4.17	4.17	4.17
	SODIS-R	4.34	4.34	4.34	4.34
Hepatitis A virus	SODIS	2.42	3.93	4.51	4.51
	SODIS-R	3.84	4.42	4.42	4.42

† 6h @ 550 W/m^2 which is approximate to 870 W/m^2 on the Oriel 1000W system

Task 3.3 Field Validation of Simulation Model

The aim of this task was to demonstrate the capability of real (or natural) sunlight to inactivate bacterial, protozoa and viral pathogens in water. We selected three model waterborne pathogens to test SODIS under natural conditions in the facilities of PSA (partner 6) and to compare real sunlight SODIS results with solar simulator results. The waterborne models used were *Escherichia coli* (tested by PSA and RCSI), *Cryptoporidium parvum* oocysts (tested by USC at PSA facilities), and *Acanthamoeba* cysts (tested by UL at PSA facilities).

For this different real water sources were also analysed and a well water source from PSA facilities was selected as a matrix to prepare bacterial suspensions. 2L-PET bottles were used to do the 'standard SODIS tests' since this way is the most frequently found in the specialised literature. Involved partners evaluated different experimental parameters like natural well water, turbidity and temperature of water samples. Good inactivation results were obtained, for *EPEC* (RCSI) and *C. parvum* (USC) with natural well water under natural sunlight at the solar facilities of PSA (Figure 18).

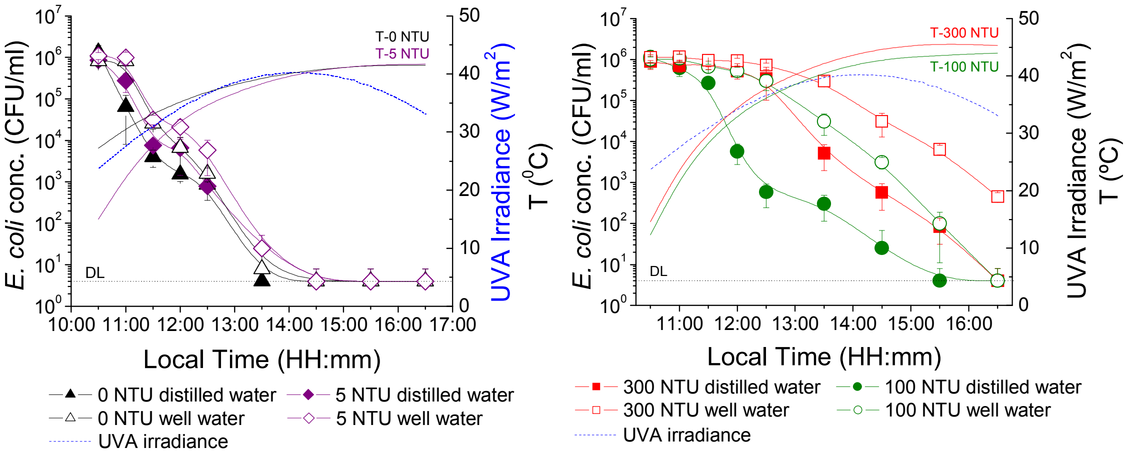


Figure 18. *Inactivation curve of E. coli in 2l-PET bottle during sunlight exposure for different turbidity values: 0, 5 (left), 100, and 300 NTU (right) with well water and non-autoclaved soil under sunny conditions.*

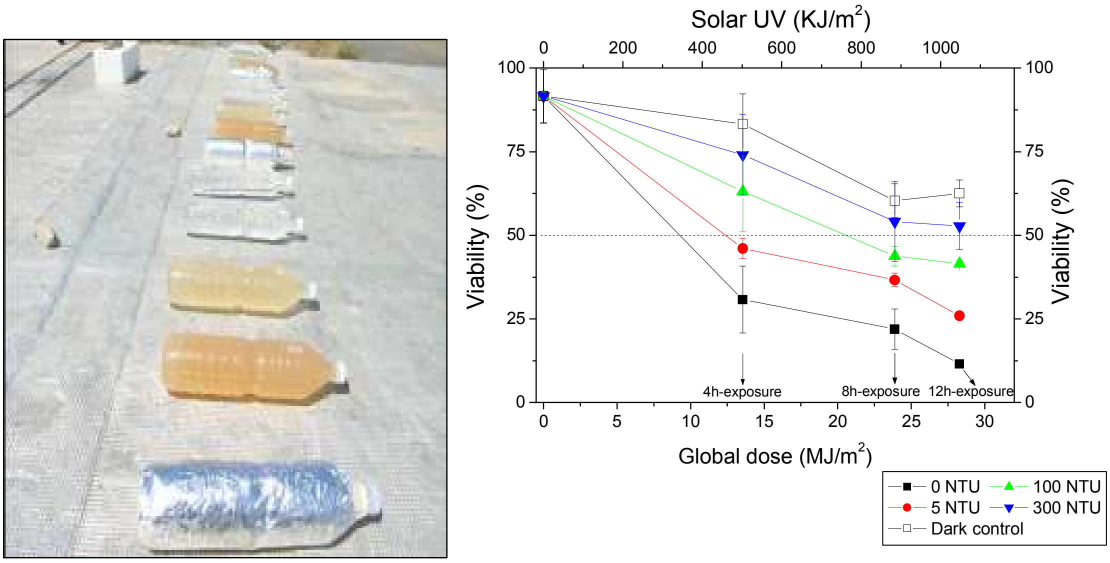


Figure 19. *Exposure to full sunshine of water samples of turbidity 0, 5, 100 and 300 NTU experimentally contaminated with Cryptosporidium parvum oocysts and held in 1.5 l transparent PET bottles, and of dark controls, on the roof of the laboratory at the Plataforma Solar de Almería (Spain) (left picture). Inactivation kinetics of C. parvum oocysts suspended in water samples of different turbidity levels and exposed to real sunlight for 4, 8 and 12 h in 1.5 l PET bottles at constant temperature of 20-25 °C (right graph).*

The inactivation kinetics for *C. parvum* oocysts suspended in water of different levels of turbidity and exposed to natural sunlight are shown in Figure 21. After an exposure time of 4 h and a cumulative dose of global radiation of 13.55 mJ/m^2, the oocyst viability decreased from 91.60% to 30.75, 46.05, 63.05, 74.04 and 83.30 for samples of 0, 5, 100, 300 NTU and the dark control samples, respectively. The oocyst viability decreased further after an exposure time of 8 h, and after an exposure time of 12 h, the oocyst viabilities were 11.54, 25.96, 41.50, 52.80 and 62.50% for turbidity levels of 0, 5, 100, 300 NTU and dark control samples. The cumulative global radiation dose received by these samples was 28.28 mJ/m^2.

Task 3.4 SODIS based reactor development

The objective of this work was to analyze the effects of different parameters which may change in the real conditions of use SODIS on the efficiency of solar disinfection under real solar light. The parameters under study were: 1) solar (UVA) irradiance and dose, 2) type of reactor (flow-through, or batch system), 3) temperature of the water, 4) water quality (distilled versus natural well water), and 5) turbidity. The well knowledge of these parameters will permit a good design of a up-scale SODIS reactor within WP4.

The experimental work was done in collaboration between RCSI and PSA. They used the prototypes of solar photoreactors constructed in the facilities of Plataforma Solar de Almería (Figure 20). The experimental plan of work was focused in the determination of the role that different parameters play on the solar disinfection at pilot scale (total volume of treatment > 10 L). Water temperature, total volume, irradiated surface, flow rate and the use of CPC are now under study in real well water with *E. coli* K12 in flow SODIS reactors.

One of the most important findings was the effect of flow rate on SODIS disinfection results. Flow rate values tested were 0, 2, and 10 L/min. It was found that increasing flow rate had a detrimental effect on inactivation of an initial 6 log concentration of bacteria and hence 0 L/min or no flow resulted in the best disinfection results with bacterial concentration reaching the detection limit (4 CFU/ml). For 2 and 10 L/min flow rates there was still a residual concentration of 2 log *E. coli* K-12 left over after 5 hours exposure to UV irradiation (see details on Deliverable 15).

Figure 20. *Picture of the 14 l-solar CPC reactor (a) and 70 l-solar CPC reactor (b) at PSA facilities (Almería, Spain).*

An interesting knowledge has been found about lethal UVA dose to inactivate a certain suspension of bacteria: The evaluation of the disinfection result as a function of the incoming solar UV energy (295-385 nm) received in the solar reactor let us to conclude that the total disinfection occurs only when a minimum UV dose is received in the system. The so-called "lethal UV dose" is of around 30Wh/m^2 for the case of 2.5 L of water containing 10^6 CFU/mL. It has been experimentally proven that this value is not correlated with light intensity, since the same lethal dose has been determined for different irradiance values. It was also found that when bacteria were exposed to the minimum dose, inactivation does not occur immediately but through a gradual process.

Task 3.5 Disinfection Analysis & Modelling
In the present work USC group have investigated the combined effect of solar radiation intensity, exposure time and turbidity on the survival of C. parvum oocysts during experimental SODIS exposures using a experimental design.

For this purpose simulated sunlight studies were carried out to study parameters like varying turbidity, pH and solar irradiance, for disinfection analysis and modelling using *Cryptosporidium parvum* oocysts as target. SODIS experiments with the solar lamp at different values of turbidity (5, 100 and 300 NTU), irradiance (200, 600 and 900 W/m^2), and exposure times (4, 8, and 12 h) were made with purified oocysts of *C. parvum* at a constant temperature of 30ºC. The viability of Cryptosporidium oocysts were determined by the inclusion/exclusion of the fluorogenic vital dyes 4',6-diamidino-2-phenylindole (DAPI) and propidium iodide (PI). The infectivity was determined by a suckling murine model using Swiss-CD1 mice. Once the experimental series were completed, the mathematical model was developed. As a result, two equations have been found to model the disinfection in the mentioned conditions.

1) Regression of viability results on the variables with significant effects in ANOVA gave the following equation:

$$\text{Viability (\%)} = 81.5148+2.1317T-9.0450I-4.5433t+2.9608TI-3.4933It$$

Where R^2 = 87.58%, R^2 (adjusted for df) = 84.62%, standard error of estimate = 3.8349, mean absolute error = 2.7316, F value = 29.61, ($p<0.0001$).

2) Regression of infectivity on the variables with significant effects in ANOVA gave the following equation:

$$\text{Infectivity (\%)} = 85.5521+5.0856T-16.6613I-7.9658t+5.9458TI-5.9456It$$

Where R^2 = 82.50%, R^2 (adjusted for df) = 78.34%, standard error of estimate = 8.3814, mean absolute error = 5.6047, F value = 19.80, ($p<0.0001$).

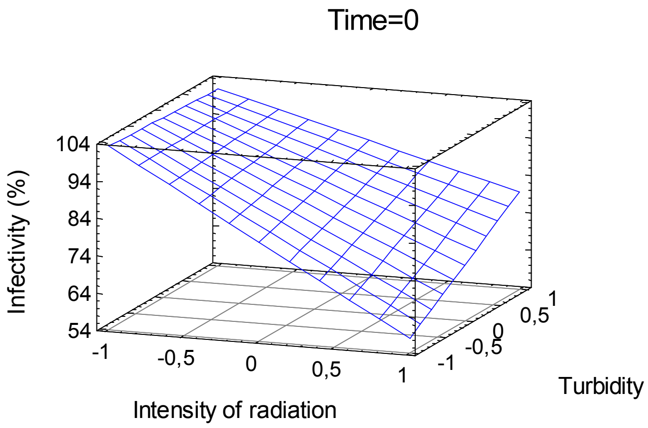


Figure 21. Response surface obtained for the oocyst infectivity at exposure time of 8 h.

Table 13. Experimental domains and coding of the three variables investigated[a,b]

Coded value	**Real values**		
	Turbidity (NTU)	Intensity of radiation (Wm^{-2})	Exposure time (h)
-1	5	200	4
0	100	600	8
1	300	900	12

[a]Coding: $V_c=(V_n-V_0)/\Delta V_n$; V_c= coded value; V_n=natural value; V_0=natural value in the centre of the domain; ΔV_n=increment in V_n corresponding to one unit of V_c
[b]Decoding: $V_n=V_0+(\Delta V_n V_c)$

Effect of water temperature
USC also studied the survival of *Cryptosporidium parvum* oocysts after exposition to temperature profiles recorded on PET bottles under natural sunlight. C. parvum oocysts were exposed during 4, 8 and 12 h to temperature profiles obtained into PET bottles in previous SODIS studies carried out

under field conditions. A significant increase in the number of oocysts that included the fluorogenical vital dye PI and in the spontaneous excystation were observed. Moreover, a significant decrease in the intensities of infection in suckling mice was detected at the end of all exposure times.

3.2.3 Deliverables of WP3

All the works done in tasks 3.1-3.5 were used to complete the deliverables listed below on time. Only deliverable 17 was completed 6 months later due to the delay on viral studies, which was due to lab security reasons. Main findings and results have been published or are submitted for publication in indexed scientific journals of the field.

DL No.	Deliverable Name	Leader	Person Months	Nature	Dissemination level	Delivery Date
6	Report on efficacy of SODIS against bacterial waterborne pathogens	CIEMAT	16	R	CO	12
15	Report on inactivation parameters for use under varying conditions	CIEMAT	12	R	PU	24
17	Report on efficacy of SODIS against parasitic/viral waterborne pathogens	CIEMAT	45	R	PU	30

3.3 WORK-PACKAGE 4 SODIS ENHANCEMENT TECHNOLOGIES

Objectives

- Design and construct a prototype continuous flow reactor with add-on compound parabolic concentrator (CPC).
- Design and construct a continuous flow photocatalytic reactor, with add-on CPC.
- Design and construct a batch photocatalytic reactor.
- Research and develop a UV dosimetric sensor for feedback control of continuous flow systems.
- Research and develop a UV dosimetric sensor for indication of batch treatment time.
- Test all enhancement and control sensor technologies under real sun conditions with identified model microorganisms with high environmental stress tolerance.
- Undertake a cost based analysis of technologies in relation to deployment in the developing world

3.3.1 Description of work

The goal of this workpackage was to research and develop technologies which would enhance the efficacy of SODIS for either point of use or point of source treatment. Continuous flow systems were developed with the aim to treating larger volumes of water which may address the drinking water requirement of small remote communities. These continuous flow systems were designed to require minimal maintenance and minimal operator time so feedback control sensors are critical for operation. The efficacy of batch SODIS reactors may be enhanced either by the addition of a photocatalytic agent which will increase the disinfection rate and/or the incorporation of an inexpensive sensor (indicator tape) which will which will allow the user to know when the water has been exposed to a sufficient dose of solar radiation

3.3.2 Tasks

Task 4.1 Continuous flow SODIS reactor:

In the first 12 months, Partner 6 (CIEMAT-PSA) undertook experiments using the existing solar photoreactors at of Plataforma Solar de Almería (Spain). The experimental plan of work developed up to this point was focused on the effect of salient parameters on the solar disinfection at pilot scale (total volume of treatment > 10 L). Water temperature, total volume, irradiated surface, flow rate and the use of CPC were studied in real well water with *E. coli* K12 in flow SODIS reactors. The evaluation of the disinfection rates of *E.coli* as a function of the incoming solar UV energy (295-385 nm) received in the solar reactor showed that total disinfection occurs only when a minimum UV dose was received in the system. The so-called "lethal UV dose" was around $30 W{\cdot}h/m^2$ for the case of 2.5 L of water containing 10^6 CFU/mL. It was experimentally proven that this value is not correlated with light intensity, since the same lethal dose was determined for different irradiance values. It was also found that when bacteria were exposed to the minimum dose, inactivation does not occur immediately but through a gradual process. The feasibility of single pass SODIS reactors for water disinfection was assessed and the report corresponding to DL8b was delivered. A SODIS prototype with add-on CPC was also designed and constructed (DL 9).

Task 4.2 Continuous flow photocatalytic SODIS reactor:

Partner 2 (UU) collaborated with Partner 6 to identify suitable materials to be coated with nanoparticle TiO_2 (Degussa P25) for photocatalytic (PC) assisted SODIS reactors. Borosilicate glass tubes (30 and 50 mm external diameter) were purchased from Schott Glass. Partner 2 designed and constructed a custom dip-coating device for the immobilisation of nanoparticle TiO_2 onto 1.5 meter tubes (the inside face of the 50 mm tubes, and the outside of the 30 mm tubes). Partner 2 delivered TiO_2 coated borosilicate glass tubes to Partner 6 for construction and testing of continuous flow photocatalyitc SODIS reactor (recirculating batch). This completed the work for Deliverable 10.

Task 4.3 Batch photocatalytic SODIS reactor:

Partner 2 undertook an extensive review of polymer materials which had suitable characteristics for batch SODIS (UV stability, UV transmission, oxygen permeability, low cost, durability, ease of processing). A range of materials were acquired and assessed for oxygen permeability, UV transmission and UV stability (artificial weathering). Film thicknesses of 0.1 mm were analysed to ensure continuity during film comparisons.

a) Oxygen permeability was measured using a custom built assembly (which held a 2.5 x 2.5 cm piece of polymer material) attached to a dissolved oxygen meter. Atmospheric oxygen travelling across the polymer into the deoxygenated water was measured at room temperature and the permeability of the film calculated. Fluorinated polymers (FEP, fluorinated ethylene-propylene) and PTFE, Polytetrafluoroethylene) were 100 times more permeable to oxygen than PET (Polyethylene terephthalate).

b) UV transmission was measured before and during artificial weathering of selected polymer films in a Q-lab QUV accelerated weathering chamber (repeated cycles of light (UVA), humidity, and rain at a fixed temperature of 50°C). The % transmission was used an indicator of polymer aging (chemical degradation of the polymer) within the films, visual analysis of the films confirmed film failure and breakdown. Films were analysed at 25 day intervals, conditions equivalent to 3 months in Arizona (dry and humid reference test site), for a total 100 days (equal to 1 year in the field). Figure a summarises the %transmission results. Initially PET showed good UVA transmission but poor UVB and UVC transmission. LDPE (Low density polyethylene) and FEP both initially showed good UVA, B and C transmission. Following 3 months artificial weathering the LDPE sample contained cracks and tears consistent with photochemical breakdown of the polymer (Figure 32). The UV transmission was also significantly decreased following 3 months artificial weathering. Although the PET sample remained intact until month 12, significant film stress was observed at month 9. The UV transmission steadily decreased until photochemical breakdown was observed at month 12. FEP showed excellent UV stability following 12 months accelerated weathering. UVA, B and C transmission was not significantly reduced during the 1 year trail. Fluoroplastics are well known for stability in the outdoor environment, with manufacturers claiming excellent film stability following 10 year trails.

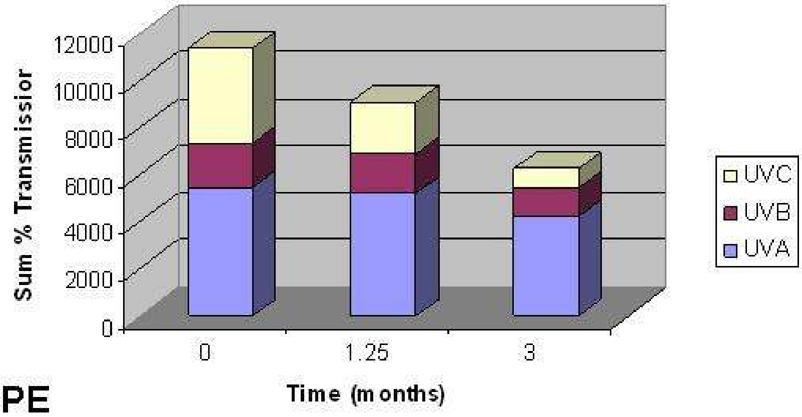
c) Low cost methods to incorporate TiO_2 into the polymer films were investigated including thermal pressing of commercial TiO_2 powder (Degussa P25) into the polymer. In this method the polymer was heated to just below its melting point and pressure applied to emboss TiO_2 powder into the surface of the polymer. Upon cooling a thin layer of TiO_2 powder is maintained within the surface of the polymer. The effect of the addition of the TiO_2 to polymer UV stability and weathering was assessed.

d) The design of a "SODIS bag" was evaluated taking into consideration research previously carried out at EAWAG in relation to user compliance, surface area to volume ratio, and ease of manufacturing. A conceptual design was made which addressed some of the key problems.

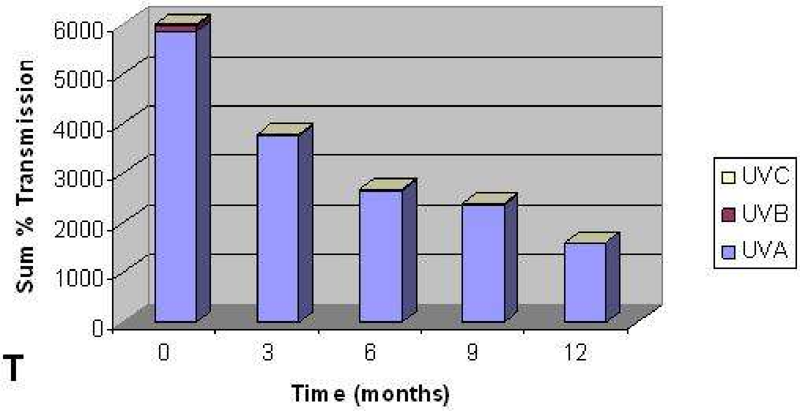
Partner 2 delivered TiO_2 coated borosilicate glass tubes to Partner 6 (CIEMAT) for construction and testing of static batch photocatalyitc SODIS reactor. Partner 6 also designed and constructed a 25 L PMMA batch SODIS reactor with add-on CPC. A range of polymer bags/pouches were made from FEP, PET, PVC and LDPE (500 mL and 1500 mL volumes) and delivered to Partner 6 for testing under real sun conditions. This completed the work for Deliverable 11.

Task 4.4 UV dosimeter for batch SODIS:
Preliminary studies at Partner 1 (RCSI) showed that both *V. cholerae* and *E.]* were completely inactivated by approximately 300 minutes under real and simulated sunlight conditions (Figure). Indicator tape was developed with the use of chloral hydrate, and it was determined that the film did not change colour due to temperature effects (up to 42 °C) and only change to red when sufficient UV dose was received. These results were reproducible upon visual inspection during and after each experiment (Figure). However, the use of chloral hydrate was discontinued as it was found to be unstable after prolonged periods in the dark. Some work undertaken at Partner 2 (UU) based upon published work by Mills et al in Strathclyde showed that reversible and non-reversible colorimetric indicators could be produced using TiO_2 films with methylene blue. Preliminary results suggest that these 'intelligent inks' could be tuned to give the required UVA dosage (Deliverable 12).

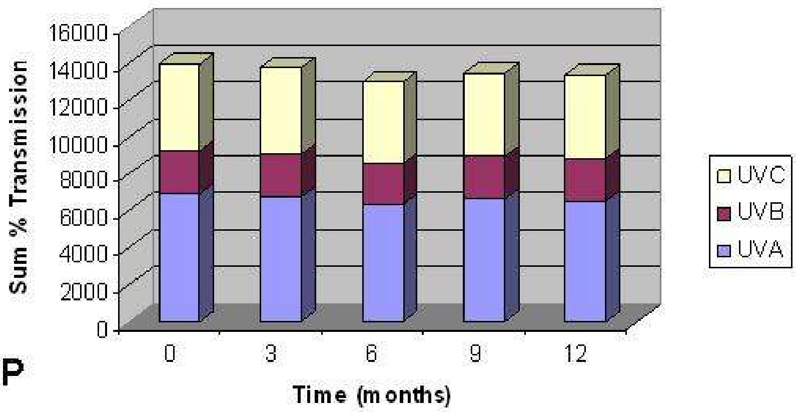
Task 4.5 UV feedback control sensor for continuous flow SODIS:



a) LDPE



b) PET



C) FEP

Partner 2 acquired commercial TiO_2 based photodiodes from SgLux which were incorporated with the necessary electronics to give a voltage or current output capable of driving a pump or valve. Partner 6 provided typical UVA data recorded at their site for calibration of the sensor. The sensor was shown to exhibit a linear response across an appropriate range of UVA intensities when tested under simulated solar light (Figure). The output voltage (or current) could be easily adjusted to provide the required input to control an electronic valve or pump. In-house TiO_2 sensors were also fabricated on

ITO coated glass. The ITO is patterned via photolithography and etching to give defined electrode arrays. TiO_2 coatings are then deposited onto the sensors via sputtering, sol-gel methods or electrophoretic deposition. The hardware and software were designed and fabricated at Partner 2 to allow automatic operation of a sequential batch reactor (based in the UV dose concept) for testing at Partner 6 (CIEMAT). This completed the work for Deliverable 13.

Figure 22. UV transmission of polymers during accelerated weathering tests.

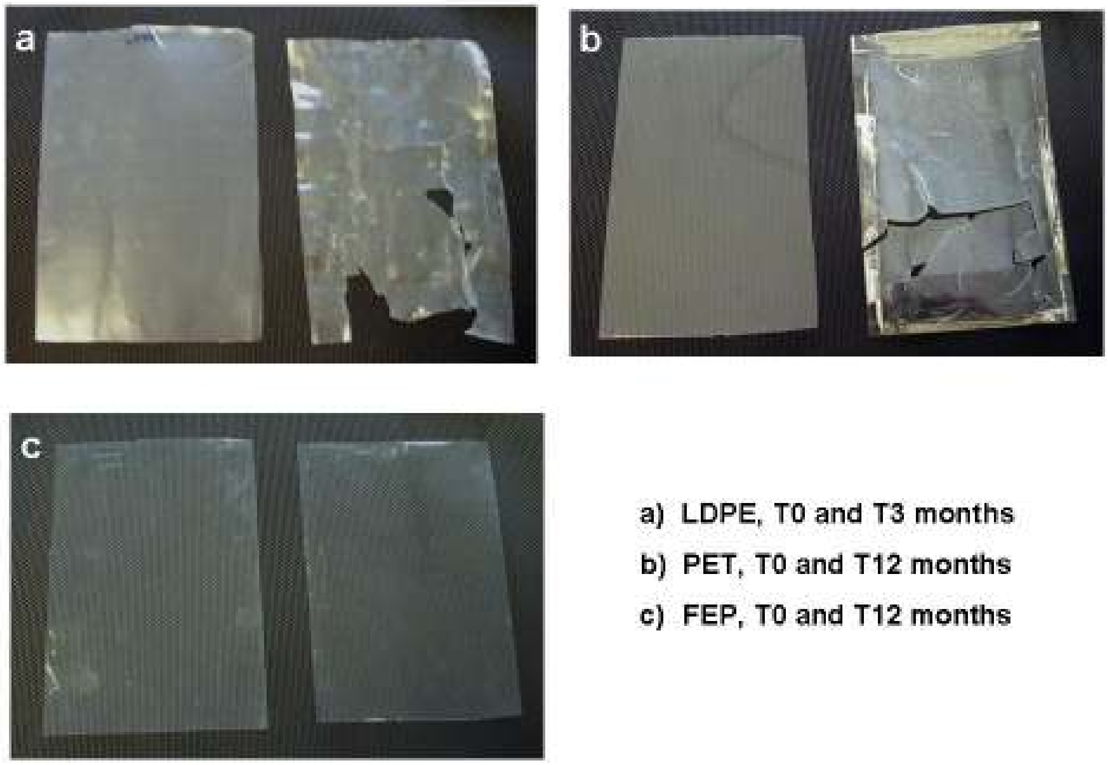


Figure 33. Visual analysis of polymer samples during accelerated weathering tests. a) LDPE failed following 3 months weathering, b) PET failed following 12 months weathering, c) FEP showed no significant changes in UV transmission following 12 months weathering.

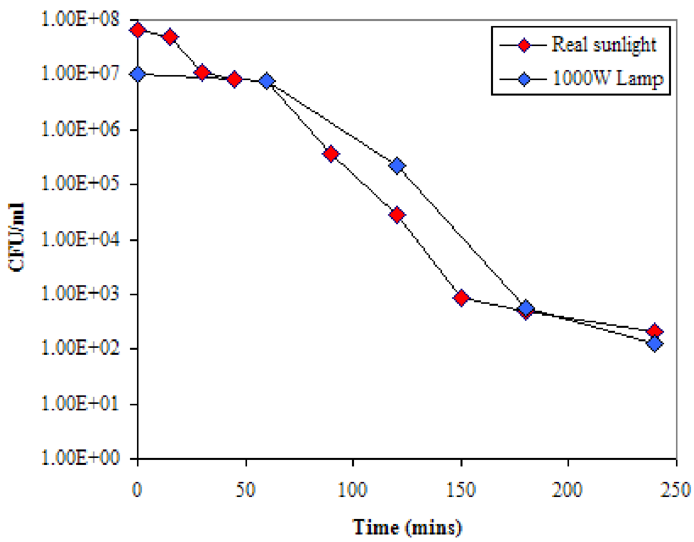


Figure 24. Comparison of inactivation curves for both simulated and real sunlight UV exposure conditions (5.1 W/m^2, 41^oC)

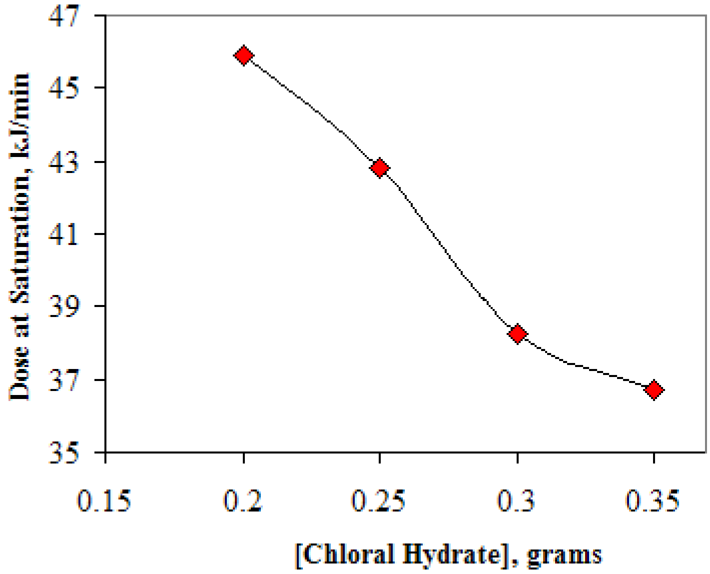


Figure 25 Dose required for complete colour change versus concentration of active ingredient (Chloral Hydrate) in indicator tape.

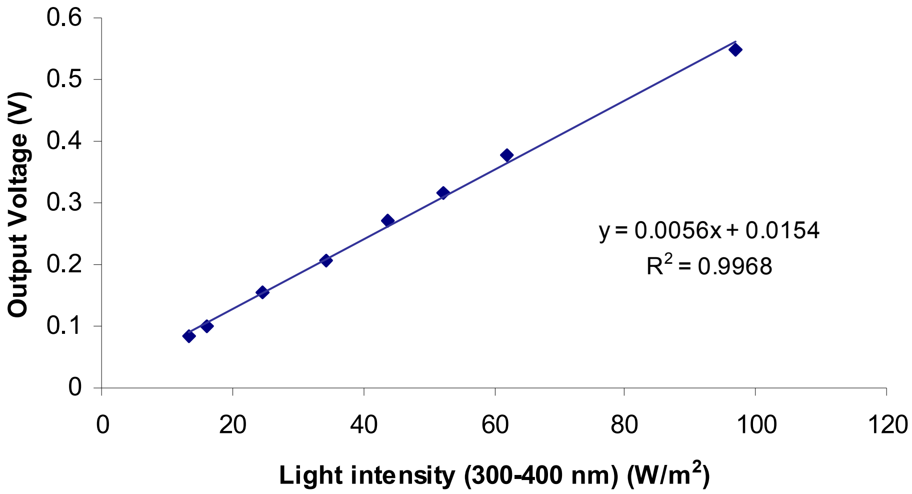


Figure 26 Sensor calibration using simulated solar light.

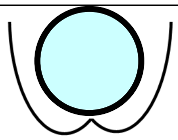
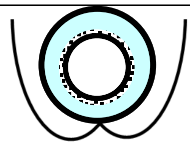
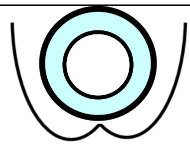
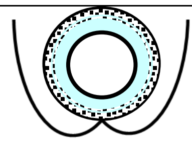
Task 4.6: Prototype Testing:

Batch SODIS and Batch Photocatalytic SODIS Reactors
TiO_2 borosilicate tubes were incorporated into the CPC-SODIS reactors used at Partner 6 (CIEMAT). *E. coli* suspensions were prepared in distilled water ($1x10^6$ CFU/mL) and treated under batch conditions. A range of batch reactors incorporating different coated glass configurations were examined (Figure and Table 44: Efficiency of reactor configuration during batch PC-CPC-SODIS.Table 4). The inclusion of the TiO_2 coating on the external surface of the internal glass tube slightly enhanced the rate of disinfection; however the optimum batch disinfection rate was achieved using the uncoated single large tube with CPC (Table 4). Experiments were also carried to investigate the effects of weather conditions on the disinfection efficiency. Detailed modelling of data was undertaken to allow prediction of the optimal reactor configuration, and to allow comparison and investigation of the disinfection kinetics of SODIS and solar photocatalysis under the wide range of climatic conditions examined.

Partner 9 (USC) investigated SODIS enhancement using CPC's (concentration factors of 1, and 1.9) in water contaminated with *C. parvum* oocysts at different turbidity values (0, 5, and 100 NTU). Using both CPCs, enhanced disinfection of *Cryptosporidium* was observed

Figure 27: CPC SODIS reactor containing different immobilised catalyst configurations (left). Picture of "Uncoated external, TiO_2 coated internal" configuration before installing (right).

Table 44: Efficiency of reactor configuration during batch PC-CPC-SODIS.

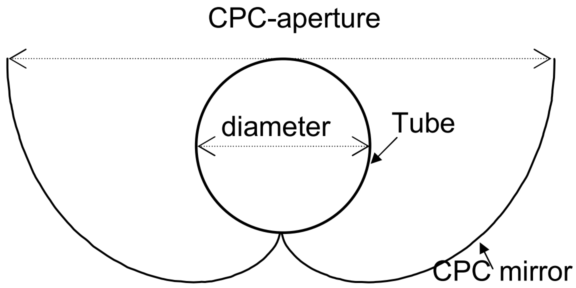
Uncoated external	**>**	**TiO_2-coated internal–uncoated external**	**>**	**Uncoated internal–uncoated external**	**>**	**TiO_2-coated external-uncoated internal**
	**>**		**>**		**>**	

Based on experimental results conducted on the continuous flow SODIS reactor in Task 4.1, a prototype was constructed by Partner 6 to disinfect 25 L of water containing *E. coli* K12. The reactor was made from a transparent metacrilate tube and includes a CPC. The system is operated under batch conditions, without flow (
Figure and Figure).

Partner 6, in collaboration with Partner 1, tested this prototype for the disinfection of water containing *E. coli* K12 under different conditions e.g. distilled and natural well water, under diverse climate conditions and seasons (Figure) different turbidity values, over irradiation periods of 5 and 7 hours.

Partner 2 produced a range of polymer bags/pouches were made from FEP, PET, PVC and LDPE and these were delivered to Partner 6 for testing under real sun conditions with 500 mL and 1500 mL volumes. Photocatalytic polymer bags were prepared in LDPE (LDPE bags containing titanium dioxide embossed into the bottom section of bag). A 1500 mL PET bottle was used as the control reactor. *E. coli* suspensions were prepared in distilled water ($1x10^6$ CFU/mL) and filled into the bags/pouches. In collaboration with Partner 1, SODIS bags were exposed to sunlight at PSA-CIEMAT and samples taken to determine the rate of bacterial inactivation as a function of exposure time. The rate of disinfection was not significantly affected by the choice of polymer material. All polymer bags were more efficient that the PET bottle with complete disinfection observed in <60 min (90 min required with PET bottle). The addition of TiO_2 increased the rate of disinfection in the LDPE bags by ~30%.

Figure 28*: Batch CPC SODIS (25 L total volume).*



Irradiated length: 92.5 cm
Irradiated width: 62.5 cm
Aperture area: 0.58 m^2
External diameter of tube: 20 cm
Thickness of tube: 1 cm
Total volume: 25 L
Irradiated volume: 25L

Figure 29*: Diagram of the CPC mirror and tube used in the reactor and dimensions of the SODIS system.*

Recirculating Batch (Continuous flow) Photocatalytic SODIS Reactor
TiO_2 coated borosilicate glass tubes (0.4 mg/cm^2) were incorporated into the CPC-SODIS reactors used at Partner 6 (Figure). *E. coli* suspensions were prepared in saline solution ($1x10^6$ CFU/mL) and re-circulated through a range of 7 L reactors incorporating different coated glass configurations at a flow rate of 2 L min^{-1} (Table 15). In all cases, the presence of the photocatalyst gave enhanced disinfection efficiencies in comparison to SODIS alone. Optimum PC-SODIS disinfection was obtained with catalyst coated on both glass surfaces.
Table 15 shows the configurations tested in order of efficiency. Experiments under full sun and cloudy conditions showed that PC-CPC-SODIS is capable of disinfection under cloudy conditions, however increased time is required. Modelling of data was undertaken to allow prediction of the optimal reactor configuration and allow comparison and investigation of the disinfection kinetics of SODIS and solar photocatalysis under the wide range of climatic conditions examined.

UVA feedback control of continuous flow or large scale static batch SODIS
The hardware and software was designed and fabricated at Partner 2 to allow automatic operation of a sequential batch reactor (based in the UV dose concept) and tested at Partner 6 (CIEMAT). The system was fitted to a CPC photoreactor which used a single glass borosilicate tube for batch SODIS. The system was shown to automatically fill, accurately measure the incident light intensity, calculate the lethal UVA dose, subsequently empty the reactor and repeat the treatment cycle until the inlet reservoir was empty or the treated reservoir filled. Experiments using *E. coli* in natural well water ($1x10^6$ CFU/mL) were carried out to assess the total treatment time required for sequential batch SODIS (The lethal dose required is 30 Wh m^2, with an additional 2 hours post irradiation in the dark required to reach full inactivation, therefore total treatment time is the sum of the time taken for the dose plus the post irradiation time. E.g. With a constant irradiation of 30 W m^2, total treatment time in a CPC1 reactor would be 1+2 = 3 hours). Upon receipt of UVA doses of 20, 30, 40, 60, 70 and 80

Wh m^2 samples were discharged from the reactor, stored in sterile containers in the laboratory and analysed at 15 minute intervals to follow and confirm post irradiation inactivation. Experiments were also conducted exposing contaminated well water to the above doses, the reactor shielded from the sun and samples taken for analysis at 15 min intervals post irradiation. Full inactivation was not observed for the samples taken following receipt of 20, 30, 40, and 60 Wh m^2 and stored in the lab for the post irradiation period. Disinfection of water remaining in the reactor for post-irradiation inactivation with the above UVA doses was observed within 2 hours. Experiments with a UVA dose of 70 and 80 Wh m^2 confirmed complete inactivation following SODIS treatment (post irradiation treatment was not required). We conclude that to provide microbiologically safe drinking water in a sequential batch system a UVA dose of between 70 and 80 Wh m^2 is required.

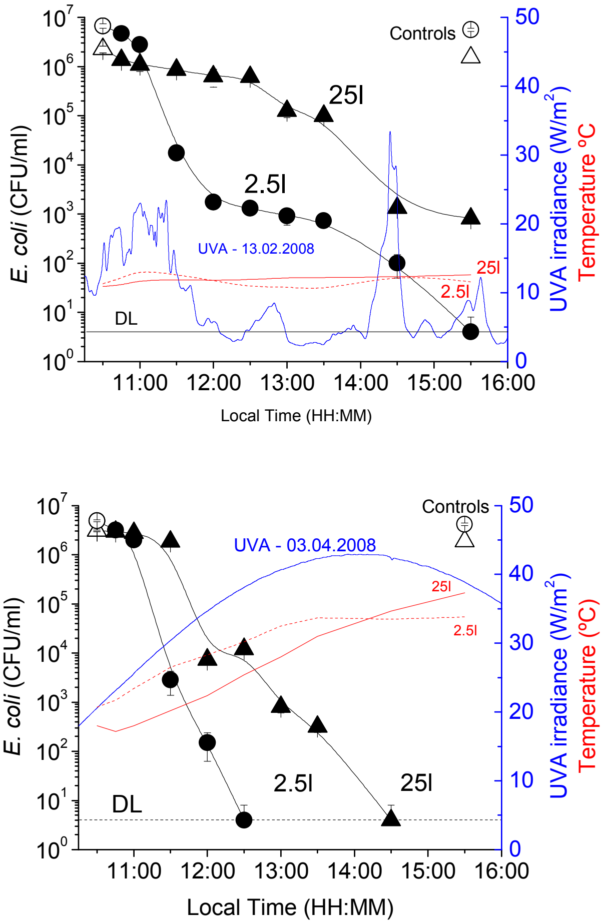
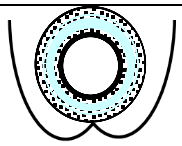
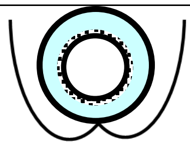
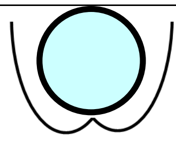
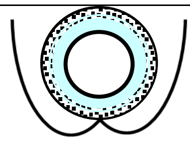
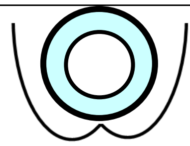


***Figure 30**: E. coli inactivation in a CPC 2.5 L batch reactor compared with a 25 L batch reactor in natural well water in winter (13 Feb. 2008, left) and in spring (03 Apr. 2008, right) at Partner 6 (CIEMAT) facilities.*

Table 15: Efficiency of reactor configuration during re-circulatory PC-CPC-SODIS.

TiO_2-coated internal–TiO_2-coated external	**>**	**TiO_2-coated internal–uncoated external**	**>**	**Uncoated external**	**>**	**TiO_2-coated external-uncoated internal**	**>**	**Uncoated internal–uncoated external**
	**>**		**>**		**>**		**>**	

Deliverable 14 “Data and report on prototype testing under real sun conditions and comparing enhancement technologies” was delivered. Furthermore, Acanthamoeba disinfection trials were undertaken in collaboration with Partner 7 at PSA-CIEMAT. Also partner 9 travelled to PSA-CIEMAT to undertake *C. parvum* disinfection studies.

Insufficient time was available for full field testing of the EBR within the SODISWATER Project but these prototypes will be fully tested under African Field conditions as part of an Irish govt. funded project based in Uganda (Water is Life project see http://www.dkit.ie/waterislife/topic/solar-disinfection-of-drinking-water)

Task 4.7: Cost Based Analysis on enhancement technologies for deployment in developing country

A detailed economic assessment of the SODIS enhancement technologies developed and tested during WP4 was prepared (including the cost of materials, manufacture, equipment, maintenance, personnel training, running costs, life-time etc.). The economic appraisal included a qualitative analysis of the options and a quantitative analysis which compared the cost of water production for each of the options over a ten year period. Based on an evaluation of efficiency of the technologies and the cost based analysis, recommendations were made to the consortium. This completed the work required for Deliverable 16.

Figure 31. 25 L EBR filled with water

Although the cost-based analysis identified the automatic modular batch system as the most suitable for deployment, there was not enough resource available to test this option under real sun in an African partner country. Therefore, Partner 6 provided a 25 L EBR reactor and Partner 1 provided personnel to allow the reactor to be tested at Partner 3 in South Africa. The objective of this work was to determine microbial efficiency of the 25 L EBR reactor under real conditions (ground water and sunlight) in South Africa where there is need for a simple cost effective point-of-use water treatment method. The EBR prototype was shipped from the Plataforma Solar de Almería, Spain to South Africa and was then assembled on the roof of building 21 on the CSIR campus. The reactor consists of a cylindrical methacrylate tube with an inlet port at one end and an outlet valve in the bottom, placed along the linear focus of a CPC with a concentration factor of 1. For each experiment *Escherichia coli* K-12 (ATCC 23631) was inoculated into 25 liters (Figure) of ground water from a tap at CSIR (Table) and used to determine the efficiency of the reactor. All experiments were conducted under natural solar conditions during the months of January and February, during the rainy season. As a result most days are partly- cloudy even on high intensity days. Solar irradiance (UV-A) was measured every 10 min with a global UV radiometer (Model PMA 2100, Solar Light Company). Water temperatures were measured each time a sample was withdrawn.

Figure , shows complete inactivation of bacteria occurring within 5 hours, during high solar irradiance conditions. Solar irradiance was 38.8 W/m^2 at the start of the experiment reaching a high of 51.22 W/m^2 during the experiment with the water temperature peaking at 39.8ºC. Re-growth of bacteria did not occur 24 and 48 hours post irradiation. These results compared well with those obtained in CIEMAT-PSA, where complete inactivation in under 5 hours also occurred during the summer months.

Figure , shows inactivation of bacteria on a clear day, however, solar intensity only reached a maximum of 39 W/m^2 during the course of the experiment. Complete inactivation of bacteria was not achieved after 5 hours exposure and a residual concentration of 10 CFU/ml of bacteria remained. During the rainy season UVA intensity typically declines due to the build-up of clouds and later during rain great fluctuates. Figure illustrates the inactivation that occurs during solar conditions that are likely to be experienced during the rainy season. During the 5 hours of solar exposure only a 1 log reduction of bacteria was achieved, despite the high irradiance levels that occurred at the beginning of the experiment.

Cl^-	8.2 mg/l	Na^+	4 mg/l
NO_3^-	0.96 mg/l	NH_4^+	< 0.1 mg/l
SO_4^{2-}	< 5 mg/l	K^+	11 mg/l
F^-	< 0.2 mg/l	Mg^{2+}	10 mg/l
Br-	< 0.2 mg/l	Ca^{2+}	74 mg/l
PO_4^{3-}	< 0.2 mg/l	HCO_3^-	73 mg/l
pH	6.5	Conductivity	18.2 mS/m
Turbidity	< 0.1 NTU	Bacteria	10 CFU/ml

Table 16. Average physical and chemical properties of the ground water used.

This work demonstrates the effectiveness of the 25 L EBR to disinfect water under high solar intensity conditions within a 5 hour solar exposure period. This was observed under solar conditions in Spain as well as under solar conditions in South Africa. During periods of low solar intensity conditions on clear days an exposure period of > 5 hours will be required to achieve at least a 3 log reduction in bacterial concentration. Significant disinfection is not achieved under cloudy and rainy days in the EBR. Inactivation studies of other microbial organisms that are prevalent in South Africa are still to be conducted and may require a longer exposure time to be inactivated. The report on pilot studies of enhancement technologies completed the deliverable 18b.

Task 4.8: Pro-Poor Business Action Plan

A detailed “Pro-Poor Business Assessment” was undertaken for the SODIS enhancements developed during WP4 based upon the Working Paper produced by the Dutch Royal Tropical Institute (KIT). The KIT screening tool identifies “sustainability” and “feasibility” as the two main areas which determine the overall attractiveness of a pro-poor business proposition. A series of questions were completed and a detailed scoring system used to ascertain the viability of a pro-poor business based upon technologies assessed under WP4 reactor developed and tested during WP4. Although the enhanced SODIS technology scored highly with regards feasibility, the sustainability of a business venture, at this stage, scored poorly. As a result the screening tool did not recommend progression to development of a full pro-poor business plan and suggests that the consortia addressing the following concerns: identification of a) funding for the potential business venture; b) project partners in both developed and developing worlds; c) distributions channels. The report has been submitted to the consortia, completing Deliverable 18c.

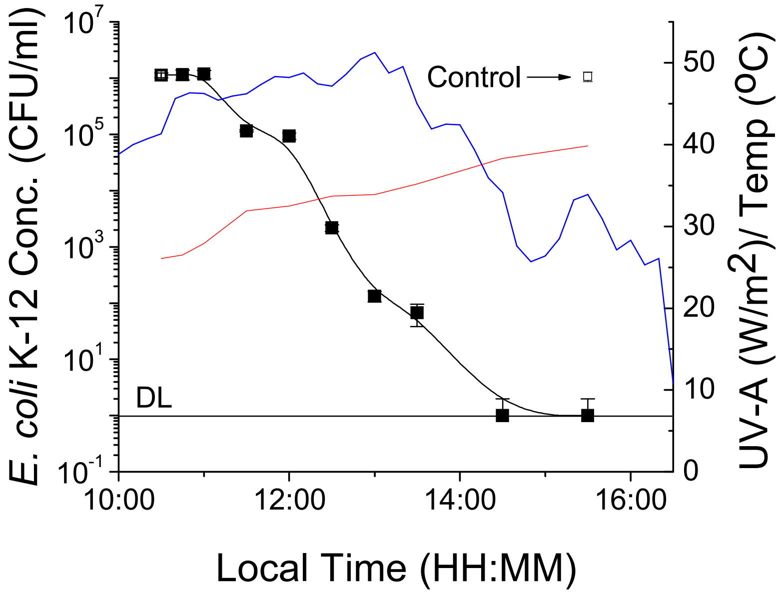


Figure 32. Inactivation curve of E. coli K-12 under high solar intensity conditions in the 25 L EBR (-■-), solar irradiance on day of experiment (-), water temperature in 25 L (-) and detection limit (DL) (-) of < 1 CFU/ml. Each point represents the average of triplicates, and bars show the standard errors.

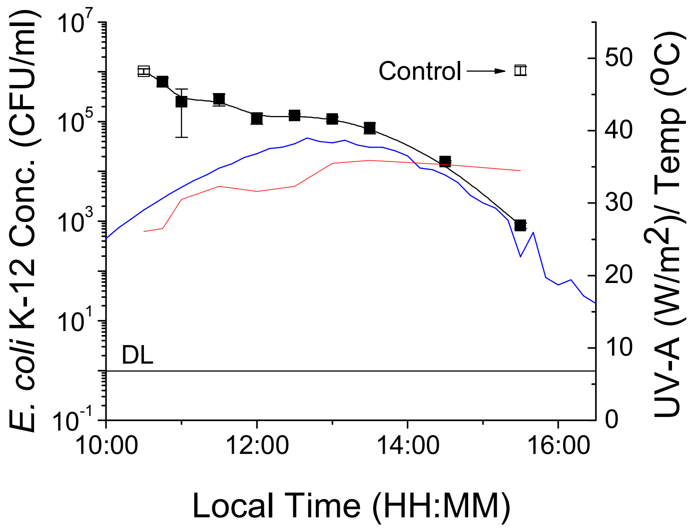


Figure 33. Inactivation curve of E. coli K-12 under a clear day with intermediate solar intensity conditions in the 25 L EBR (-■-), solar irradiance on day of experiment (-), water temperature in 25 L (-) and detection limit (DL) (-) of < 1 CFU/ml. Each point represents the average of triplicates, and bars show the standard errors.

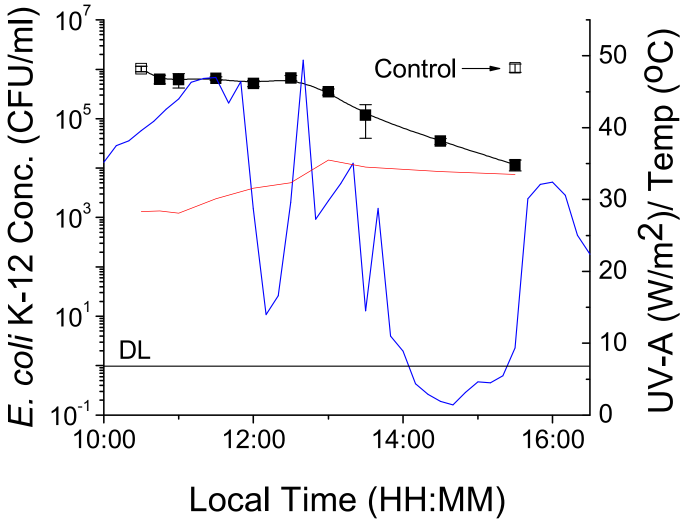


Figure 34. Inactivation curve of E. coli K-12 under a typical day during the rainy season in the 25 L EBR (-■-), solar irradiance on day of experiment (-), water temperature in 25 L (-) and detection limit (DL) (-) of < 1 CFU/ml. Each point represents the average of triplicates, and bars show the standard errors.

3.4 WORK-PACKAGE 5 DISSEMINATION ACTIVITIES

Dissemination and adoption of SODIS has been examined in a three year longitudinal study. Interviews took turns with intervention strategies, which allowed to test for their effects. Different strategies which were meant to enhance the behaviour change necessary for SODIS (from drinking raw water to preparing and consuming SODIS) were employed over time and in several areas. These were: (a) household visits: trained promoters from the respective area go to households and educate the residents about SODIS and its advantages (b) pass-on-task: a snowball system where people are asked to pass on information about SODIS along with a token which could be redeemed at bottle shops for half-priced bottles, where another token was given and asked to pass along. This can be coupled with a competition; (c) Memory aids: stickers which serve as a reminder to prepare SODIS, like prompts ("prompting" a behaviour inside the home) or public commitment (publicly displaying the household's choice to use SODIS). (d) Daily routine integration: arousing tension through presenting what needs to be done to prevent water borne diseases ("knowledge and tension") or contracts which state when and where exactly someone plans on preparing SODIS ("implementation intention"). Household visits coupled with memory aids proved most successful. The pass-on-task with competition looks promising if coupled with a daily routine or possibly memory aids. Interventions change behaviour via different psychological factors. A behaviour change process could be identified which outlines the development that possible SODIS users go through from drinking raw water to drinking SODIS water on a regular basis over a long time.

3.4.1 Zimbabwe dissemination strategy study:

The research for the dissemination of SODIS was done as a longitudinal study over the course of three years. Five research areas have been chosen in peri-urban high-density settlements close to Harare, Zimbabwe. Since SODIS requires a behaviour change from drinking raw water to drinking solar treated water, different behaviour change strategies have been implemented and evaluated with interviews. All in all, 8 panel interviews have been carried out with the same 850 subjects being interviewed at every panel plus an additional 100 subjects each at Panel 2, 3, 4, 6, and 7.

Figure 35: Structured face-to-face interviews in Epworth

The very first step of the study at hand was to implement SODIS information events.

In April 2007, a baseline was carried out, which served to explore the target group, their circumstances, living conditions, water treatment behaviour and attitudes, to refine the questionnaire and to plan the first set of interventions. Before these interventions were implemented, panel 1 was carried out, so that the meantime self-dissemination of SODIS could be analysed. After that, four intervention phases alternated with panels, whereby each panel interview served to plan the next set of interventions. Two additional panels were inserted into this design, because at one point of time there was a delay due to difficult living circumstances in Zimbabwe in general and between April and July 2008, while presidential elections were taking place, all NGO work (including our kind of research work) was banned by the government. The overall research design is visualized with the help of figure 37.

Figure 36: Information event introducing SODIS into the community

As can be seen in figure 37, additionally to the panel interviews, diffusion check interviews and monitoring interviews have been carried out. Diffusion Check is a way of surveying spatial change in the density of adoption by inhabitants of the intervention areas and around the intervention areas. From September 2007 to June 2009, 5 Diffusion Checks have been carried out, with a total of about 6000 people interviewed with a short 10 minute interview.

This kind of spatial survey revealed that the number of users in surrounding areas is the most important factor for determining the density of users in any given area. Risk awareness of unsafe water and perceived potential to contract waterborne diseases are also important factors. After some time, it becomes increasingly important to identify the number of neighbours and friends (as opposed to official SODIS promoters) who talk about SODIS. Based on the results of other survey tools, it can be concluded that it is of utmost importance to first increase the number of users by promotional work. Additionally, monitoring has also been done with short interviews of about 10 to 15 minutes (panel interviews take about 45 to 60 minutes) that were carried out every third day with the same group of 250 subjects. That way, short time changes in behaviour can be analysed with modelling and simulation.

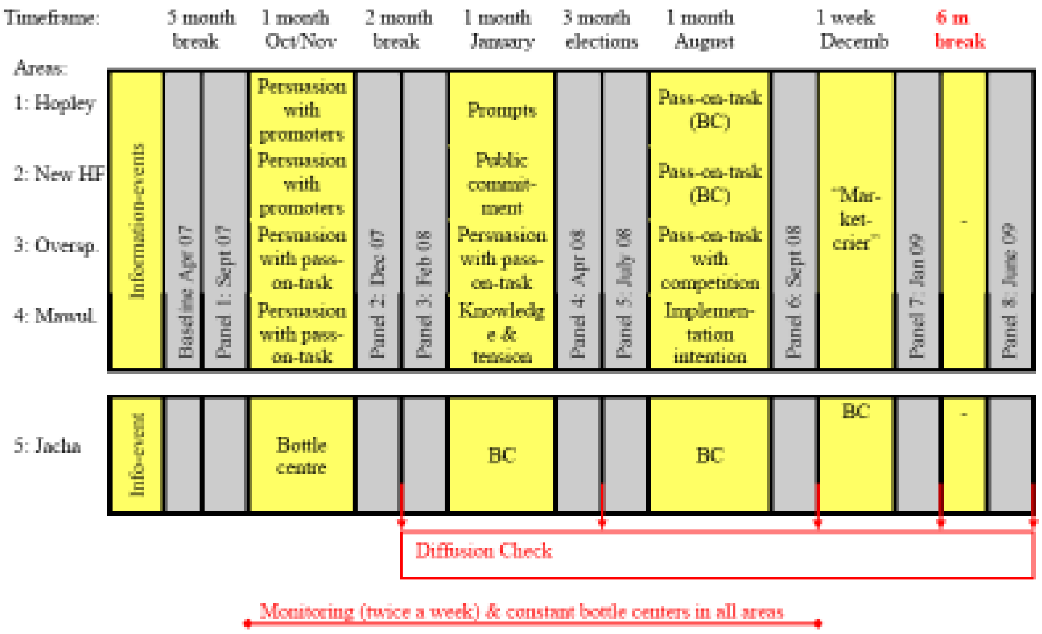


Figure 37: Design of longitudinal research at hand

Through different behaviour changing strategies, more than 100,000 people started using SODIS regularly within a project which was carried out in Zimbabwe. These large numbers of users were achieved by engaging advocates from within the local community to educate individual households about SODIS. Within 3 months, more than 90% of the households that had received visits from promoters were using SODIS. Figure 38 shows the development of different user types over time.

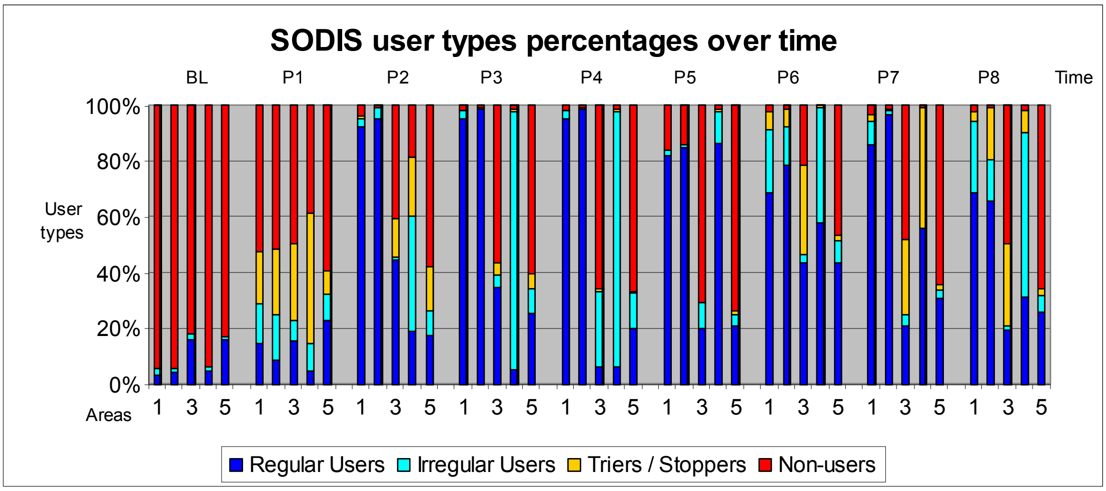


Figure 38: Sodis user type percentages over time and area

Results of the panel interviews showed which behaviour change interventions are most effective. Household visits carried out by promoters proved to be the most successful method of disseminating the method. It is important that the promoters are well trained, have a good social status, and present in-depth background knowledge in addition to the convincing advantages of SODIS. The "Pass-on-Task" is a system that was developed to enhance self-dissemination of SODIS: People pass on information about SODIS with vouchers for plastic bottles, which they redeem at a bottle shop. Here, more information and vouchers are given to pass on. This system should be coupled with a competition, where people who pass on the most vouchers win or get something in return for their efforts. So-called memory aids like prompts or public commitment, which are stickers or posters with a statement about SODIS, help to remind users to prepare SODIS. Handing out such material at the end of a promoter-visit helps users to form the "SODIS-habit".

Main research findings concern the behaviour change process. Different stages of behaviour change have been identified as well as factors driving this change. The first stage, the uptake decision, can be influenced by persuasion. From behaviour theory, variables were recognized which have been proven to influence intention and behaviour and simultaneously can be influenced by persuasion. It could be shown that persuasion factors have a stronger influence on the uptake of SODIS use and on intention to use SODIS in the future than on the amount of SODIS water consumed (Kraemer & Mosler, 2010). Next was a closer look at interventions and how they chance behaviour.

The following factors have been shown to change behaviour and were analyzed in this study: intention, subjective norm, behavioural control, convictions, habit, frequency of talking, knowledge and tension. The used interventions had different effects on these behaviour change factors. Promoters influence more factors more successfully than expected, while the effect of the pass-on-task was not as good as expected. Prompts and public commitment work very similarly and create more tension than the "knowledge and tension strategy" (Kraemer & Mosler, submitted).

As a last step, the five stages of the Transtheoretical Model of Change (TTM) were analysed and the psychological factors that differentiate between types of users and relapsers. Factors of perceived need, attitude, intention and habit were used to differentiate between non-users, fluctuaters, irregular users, regular users, relapsers (all user types derived from TTM) and late beginners (a user type identified by analyses). Non-users have a lower value in nearly all the examined factors than the other user groups. Distinguishing factors between the other groups were identified. Once it is known which factor(s) drive the development from one stage or user group to the other, these factors can be used for interventions (Kraemer & Mosler, accepted). For more details about these findings and the behaviour change process identified, please see Kraemer, 2010.

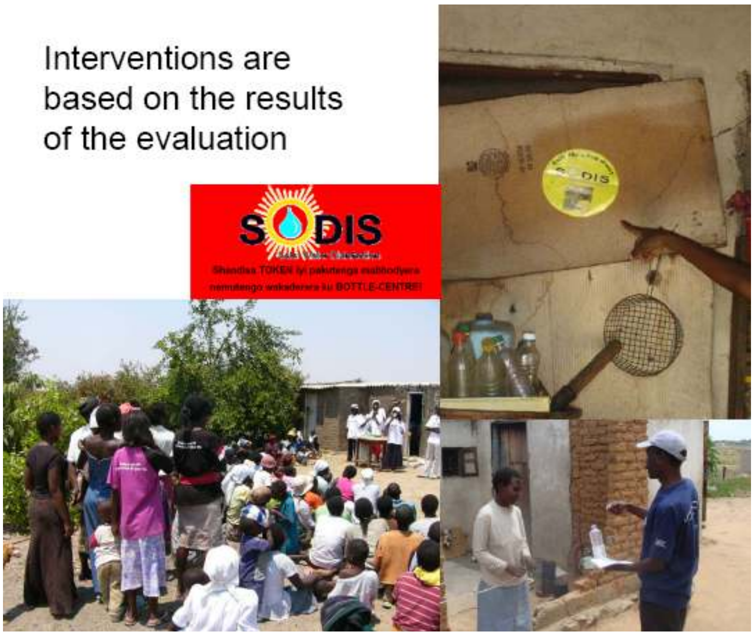


Figure 39: Examples for different interventions: a token, prompt, household visit and the pass-on-competition (clockwise, starting from left).

References:
Kraemer, S.M., & Mosler, H.-J. (2010). Persuasion factors influencing the decision to use sustainable household water treatment. International Journal of Environmental Health Research, 20(1), 61-79.
Kraemer, S. M., & Mosler, H.-J. (accepted). Differentiating between user types and relapsers of Solar Water Disinfection in a long-term study in Zimbabwe. Journal of Health Psychology.
Kraemer, S. M., & Mosler, H.-J. (submitted). Effectiveness and effects of promotion strategies for behaviour change. Applied Psychology: An International Review.
Kraemer, S.M. (2010). The Behaviour Change Process of Solar Water Disinfection (SODIS). PhD Thesis, University of Zurich, Zurich.

3.4.2 SODIS Conference

SODISWATER Deliverable 24 was to host a conference on SODIS in the final year of the project. The project coordinator was successful in arranging that this event was folded into the Research Working Group of the WHO Household Water Treatment and Safe Storage (HWTS) Network 2009 international conference (HWTS09) which was held in the RCSI (Partner 1) in Sept 2009 (see www.rcsi.ie/hwts09). All of the available SODISWATER research outputs were presented at this event before the maximally appropriate audience who could benefit from this research dissemination. (See Deliverable 24a HWTS09 Book of abstracts and 24b Photo journal of the 3-day conference event, also available at http://picasaweb.google.com/HWTS09/HWTS09) A list of the 84 attendees is included in Table 17**.**

3.4.3 SODIS Brochure

A PDF brochure highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This represents Deliverable 21 and is available for download on the project website (http://www.rcsi.ie/sodis/news/index.htm).

3.4.4 SODIS Presentation

A PowerPoint presentation highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This represents Deliverable 21 and is available for download on the project website (http://www.rcsi.ie/sodis/news/index.htm).

Table 17

HWTS 09 Attendees list - 31/08/2009

Last Name	Title	First Name	Organization	Country
Abadie Rosa	Miss	Ghislaine	London School Of Hygiene & Tropical Medicine	UK
Ale	Mr	Oludare	Safe Water For Africa Community Initiative	NIGERIA
Ale	Mrs	Yetunde	Safe Water Africa Community Initiative	NIGERIA
Alper	Mr.	John	UC Berkeley	USA
Ares-Mazas	Dr	Elvira	University of Santiago De Compostela	SPAIN
Aschkenasy	Dr	Miriam	Oxfam America	USA
Austin	Mr.	Glenn	Path	USA
Baker	Mr.	Derek	Centre for Affordable Water and Sanitation Technology	CANADA
Balam	Mr.	Ian	Fundacion Cantaro Azul	MEXICO
Barnard	Dr	Tobias	University of Johannesburg	SOUTH AFRICA
Barnes	Dr	Joe		IRELAND
Bastable	Mr	Andy	Oxfam GB	UK
Boisson	Miss	Sophie	London School Of Hygiene & Tropical Medicine	UK
Bradner	Prof.	Curt	Thirst-Aid	USA
Brown	Dr	Joe		USA
Byrne	Dr	Tony	University of Ulster	N. IRELAND
Cantwell	Dr	Ray	Samaritan's Purse Canada	CAMBODIA
Clasen	Dr.	Thomas	London School Of Hygiene & Tropical Medicine	UNITED KINGDOM
Dangol	Mrs	Biju	Environment & Public Health Organization (ENPHO)	NEPAL
Dundon	Ms	Susan		ARGENTINA
Dunlop	Dr	Patrick	University of Ulster	N. IRELAND
Edmondson	Mr	Paul	Medentech	IRELAND
Ekpeogu	Mr	Anthony	Rural Africa Water Development Project (RAWDP)	NIGERIA
Elledge	Mr.	Myles	RTI International	USA
Elmore-Meegan	Dr	Michael	Icross	KENYA
Ezeji	Mr	Augustine	Rural Africa Water Development Project (RAWDP)	NIGERIA
Fernandez-Ibanez	Dr	Pilar	Plataforma Solar De Almeria	SPAIN
Fisher	Mr.	Michael	UC Berkeley	USA
Freeman	Mr.	Matthew	London School Of Hygiene And Tropical Medicine / Emory University	UK
Garcia-Fernandez	Ms	Irene	Plataforma Solar De Almeria	SPAIN

Gately	Mr	Michael	Medentech	IRELAND
Gill	Mr	Laurence	Trinity College Dublin	IRELAND
Gomez-Couso	Dr	Hipolito	University of Santiago De Compostela	SPAIN
Gotestrand	Mr.	Simon		DENMARK
Himley	Mr.	Stephen	Path	USA
Holtslag	Mr	Henk		NETHERLANDS
Howells	Miss	Jennifer		UNITED STATES
Hunter	Prof	Paul	University of East Anglia	UNITED KINGDOM
Jenkins	Dr.	Marion (Mimi)	University Of California Davis	USA
Jiang	Dr.	Fanxiao	WHO	CHINA
Kraemer	Dr.	Silvie	Eawag	SWITZERLAND
Kwak	Ms	Cecilia	Population Services International	USA
Laamanen	Mrs	Merja	Scan-Water	FINLAND
Lantagne	Ms.	Daniele	London School Of Hygiene & Tropical Medicine	UK
Liang	Ms.	Kaida	University Of North Carolina	USA
Makoni	Mr	Fungai	Institute of Water and Sanitation Development (IWSD)	ZIMBABWE
McCarton	Mr	Liam	Development Technology Centre, DIT.	IRELAND
McGrath	Mr	Oran	Medentech	IRELAND
McGuigan	Dr	Kevin	RCSI	IRELAND
Meierhofer	Mrs.	Regula	Eawag	SWITZERLAND
Mitchell	Ms.	Susan	Abt Associates	USA
Mosler	Prof. Dr.	Hans-Joachim	Eawag, Swiss Federal Institute Of Aquatic Science And Technology	SWITZERLAND
Mulligan	Mr	Derek	Careaid International Ltd	IRELAND
Nelson	Dr.	Kara	University Of California, Berkeley	USA
Ngai	Mr	Tommy Ka Kit	University Of Cambridge	ENGLAND
Nze	Mr	Judah	Rural Africa Water Development Project (RAWDP)	NIGERIA
O'Callaghan	Mr	Kevin	Medentech	IRELAND
Odediran	Mr	Oluwafemi	United Nations Children's Fund	USA
Oriard	Mr.	Tim	Cascade Designs, Inc.	USA
Peletz	Ms.	Rachel	London School Of Hygiene And Tropical Medicine	UNITED KINGDOM
Polo-Lopez	Ms	Maria Inmaculada	Plataforma Solar De Almeria	SPAIN
Potgieter	Prof	Natasha	University of Yenda	SOUTH AFRICA
Rainey	Dr.	Rochelle	USAID	USA
Rayner	Ms	Justine	Potters For Peace	UK

Saade	Mr.	Camille	Academy For Educational Development	USA
Saladin	Mr.	Matthias	Fundacion SODIS/EAWAG	SPAIN
Samaiyar	Mr	Priyajit	Care International Cambodia	CAMBODIA
Shipin	Dr	Oleg	Asian Institute of Technology	THAILAND
Sloan	Mr.	Jeffrey	World Chlorine Council	U.S.A.
Sobsey	Prof	Mark	University of North Carolina	USA
Sreenivasan	Dr.	Nandini		DENMARK
Stafford	Mr	Ulick	Medentech	IRELAND
Sutton	Dr	Sally	Rural Water Supply Network / WSP	UNITED KINGDOM
Tamas	Dr.	Andrea	Eawag	SWITZERLAND
Terfa	Mr	Waltaji	WHO Ethiopia	ETHIOPIA
Toledo	Mr.	Erick	The International Center	USA
Torkelson	Mr.	Andrew	University Of California-Berkeley	USA
Ubomba-Jaswa	Dr	Eunice	RCSI	IRELAND
Williams	Dr.	Jeff	HaloSource Incorporated	USA
Young-Rojanschi	Ms.	Candice	Brace Centre for Water Resources Management, McGill University	CANADA
Zhang	Prof	Rong	National Center For Rural Water Supply Technical Guidance	CHINA

Group Photo showing the majority of the 84 delegates from 49 different organisations and 22 different countries at the HWTS09 conference hosted by the SODISWATER Project in RCSI, Dublin, Ireland in September 2009. A complete photo journal of the 3 day conference has been prepared as Deliverable 24b and is also available at http://www.rcsi.ie/sodis/library/index.htm

3.4.5 Articles Published in scientific peer-reviewed journals*:*

1. **Alrousan DMA**, **Dunlop PSM***, McMurray TA, **Byrne JA.** Photocatalytic inactivation of E. coli in surface water using immobilised nanoparticle TiO2 films. Water Research (2009) 43;47 – 54.
2. **Boyle MA, Sichel C, Fernández-Ibáñez P,** Arias-Quiroz GB, Iriarte-Puña M, **McGuigan KG .** Bactericidal effect of solar water disinfection under real sunlight conditions. *Applied & Environmental Microbiology.* 2008;74(10):2997-3001. PMID: 18359829.
3. **Dunlop PSM, McMurray TA, Hamilton JWH, Byrne JA.** Photocatalytic inactivation of *Clostridium perfringens* spores on TiO_2 electrodes. Journal of Photochemistry and Photobiology A: Chemistry 2008:196(1);113-119
4. **Dunlop PSM**, Galdi A, McMurray TA, Hamilton JWJ, Rizzo L, **Byrne JA** Comparison of photocatalytic activities of titanium dioxide immobilised on glass, *Journal of Advanced Oxidation Technologies.* (2010) 13(1), 99-106.
5. **Gómez-Couso H,** Fontán-Sainz M, Fernández-Alonso J, **McGuigan KG , Ares-Mazás E.** Effect of radiation intensity and water turbidity on the survival of *Cryptosporidium parvum* oocysts during simulated solar disinfection. *Acta Tropica*. 2009, 112(1):43-8. PMID: 19539587
6. **Gómez-Couso, H.,** Fontán-Sainz, M., Fernández-Alonso, J. and **Ares-Mazás.** Excystation of *Cryptosporidium parvum* at temperatures that are reached during solar water disinfection., E. Parasitology, 2009, 136: 393-399.
7. **Gómez-Couso, H.,** Fontán-Saínz, M., **Sichel, C., Fernández-Ibáñez, P. and Ares-Mazás E**. Efficacy of the solar water disinfection method in turbid waters experimentally contaminated with *Cryptosporidium parvum* oocysts under real field conditions. Tropical Medicine and International Health, 2009, 14: 620-627.
8. **Gómez-Couso, H.,** Fontán-Sainz, M. **and Ares-Mazás E.** Thermal contribution to the inactivation of *Cryptosporidium* in plastic bottles during solar water disinfection procedures. E. American Journal of Tropical Medicine and Hygiene, 2010, 82: 35-39.
9. **Kraemer SM, Mosler HJ. .** Persuasion factors influencing the decision to use sustainable

household water treatment. *International Journal of Environmental Health Research,* 2010:*20*(1), 61-79.
10. **Kraemer SM, Mosler HJ.** Differentiating between User Types and Relapsers of Solar Water Disinfection in a Long-Term Study in Zimbabwe. *Journal of Health Psychology.In Press. March 2010.*
11. Malato S, **Fernández-Ibáñez P,** Maldonado MI, Decontamination and disinfection of water by solar photocatalysis: Recent overview and trends Catalysis Today 2009:**147(1)**;**1-59**
12. **Méndez-Hermida F*, Ares-Mazás E, McGuigan KG , Boyle M, Sichel C, Fernández-Ibáñez P.** Disinfection of *Cryptosporidium parvum* oocysts in drinking water using natural sunlight and the photocatalyst TiO_2. *Journal of Photochemistry & Photobiology B:* 2007;88: 105-111. PMID: 17624798
13. **Murinda S**, & **Kraemer SM** (2008). The potential of solar water disinfection as a household water treatment method in peri-urban Zimbabwe. *Physics and Chemistry of the Earth, 33*(8-13), 829-832.
14. **Navntoft C, Ubomba-Jaswa E, McGuigan KG , Fernández-Ibáñez P*.** Enhancement of batch solar disinfection (SODIS) using non-imaging reflectors. *Journal of Photochemistry & Photobiology B: Biol.* 2008;93:155-161. PMID: 18835188
15. **Sichel C.,** J. Blanco, S. Malato, **P. Fernández-Ibáñez** "Effects of experimental conditions on E. coli survival during solar photocatalytic water disinfection" *J. Photochem. Photobiol. A: Chem.* 189 (2007) 239-246.
16. **Sichel C., P. Fernández-Ibáñez,** J. Blanco, S. Malato "Solar photocatalytic disinfection of agricultural pathogenic fungi: Fusarium species" *Applied Catalysis B: Environ.* 74 (2007) 152-160.
17. **Sichel C., J. Tello,** J. Blanco, S. Malato, **P. Fernandez-Ibañez*** Effect of UV- intensity and Dose on the Photoactalytic Disinfection of Bacteria and Fungi under natural sunlight. *Catalysis Today,* 2007:129(1-2);152-160.
18. Sunnotel O, Verdoold R, **Dunlop PSM,** Snelling WJ, Lowery CJ, Dooley JSG, Moore JE, **Byrne JA.** Photocatalytic inactivation of *Cryptosporidium parvum* on nanostructured titanium dioxide films, *Journal of Water and Health*, (2010) 8(1), 83-91.
19. **Ubomba-Jaswa E*, Fernández-Ibáñez P*, McGuigan KG** . A preliminary Ames-fluctuation assay assessment of the genotoxicity of drinking water that has been solar disinfected in polyethylene terephthalate (PET) bottles. *Journal of Water & Health.* Jan. 2010. In Press (JWH-S-09-00226[1])
20. **Ubomba-Jaswa E, Fernández-Ibáñez P*, Navntoft C, Polo-López MI, McGuigan KG** . Investigating the microbial inactivation efficiency of a 25 litre batch solar disinfection (SODIS) reactor enhanced with a compound parabolic collector (CPC) for Household Use. *Journal of Chemical Technology & Biotechnology*, Jan. 2010. In Press.
21. **Ubomba-Jaswa E, Navntoft C, Polo MI, Fernández-Ibáñez P*, McGuigan KG** . Solar disinfection of drinking water (SODIS): An investigation of the effect of UVA dose on inactivation efficiency. *Photochemical & Photobiological Sciences*, 2009;8(5): 587-595. PMID: 19424529.
22. **Ubomba-Jaswa E, Boyle MA, McGuigan KG .** Inactivation of enteropathogenic *E. coli* by solar disinfection (SODIS) under simulated sunlight conditions. *Journal of Physics: Conference Series*. 2008;101:1-4 (online) doi:10.1088/1742-6596/101/1/012003.

Submitted:

1. **Du Preez M, Conroy RM, McGuigan KG .** Solar disinfection of drinking water in the prevention of dysentery in South African children aged under 5 years: the role of compliance. *Environmental Science & Technology.* March 2010.
2. **Kraemer, SM,** & **Mosler, HJ.** Effectiveness and effects of promotion strategies for behaviour change. *Applied Psychology: An International Review.*

In preparation:

1. **Du Preez M, Conroy RM, Samaiyar P, Murinda S, Elmore-Meegan M, McGuigan KG.** A multi-country study of solar disinfection (SODIS) of drinking water in the prevention of waterborne disease in children aged under 5 years: A tale of four studies. *Water Research*. July 2010
2. **Elmore-Meegan M, Du Preez M, Conroy RM, McGuigan KG.** Solar disinfection (SODIS) of drinking water in the prevention of dysentery in peri-urban Kenyan children aged under 5 years. *Archives of Disease in Childhood*. June 2010
3. **Heaselgrave, W. Kilvington, S.** Antimicrobial activity of simulated solar disinfection (SODIS) against bacterial, fungal and protozoan pathogens and its enhancement with riboflavin. *Applied &*

Environmental Microbiology Dec 2009.

4. **Heaselgrave, W. Kilvington, S.** The efficacy of solar disinfection (SODIS) against helminth and protozoan pathogens and its enhancement with riboflavin. *Applied & Environmental Microbiology* Feb 2010.
5. **Kraemer, SM,** & **Mosler, HJ.** (July 2010). What effects the transition between user types in the long run?
6. **Mosler, HJ, Kraemer, SM,** Johnston, R., & (March 2010). Achieving long-term use of SODIS: a longitudinal study in Simbabwe. *Bulletin of the World Health Organisation.*
7. **Samaiyar P, Conroy RM, McGuigan KG.** Solar disinfection (SODIS) of drinking water in the prevention of dysentery in rural Cambodian children aged under 5 years**:** efficacy under conditions of high compliance. *Environmental Science & Technology.* Aug 2010

3.4.6 CONTRIBUTIONS TO CONGRESSES /CONFERENCES

SODISWATER project has been reported within the following events (Conferences):

1. **Boyle MA.** 12-16, November 2006. Poster "Solar Disinfection of Drinking Water is an Effective Intervention Against Waterborne Disease in Developing Countries or in the Aftermath of Natural (or Man-made) Disasters" at the 55th American Society of Tropical Medicine and Hygiene (ASTMH) Annual Meeting in Atlanta, USA.
2. **Byrne J. A.,** 23-25 July 2007. Poster presentation: P Dunlop, "Point-of-Use Solar Photocatalytic Disinfection for Developing Countries" at the 2nd International Conference on Semiconductor Photochemistry, Aberdeen, July 2007. Abstract emailed to consortia members, copy of poster attached.
3. **Byrne, J.A.,** "Photocatalytic treatment of water with nano-titania", Water Network, Cranfield University, March 2010, *invited lecture*
4. **Byrne, J.A.,** "Solar photocatalytic disinfection of water for developing countries", Solar'10, 14 - 17 February 2010, Cairo, Egypt, *Plenary Lecture*
5. **Byrne, J.A.,** "Solar photocatalytic disinfection of water for developing countries", UK Nanoforum, London, November 2009, *Invited Lecture*
6. **Byrne, J.A.,** "Solar photocatalytic disinfection of water", Photocatalytic Products and Technologies Conference" PPTC'09, Portugal, May 2009. *Key Note Lecture*
7. **Byrne, J.A.,** "Photocatalysis for water and waste water treatment," EuroNanoForum 2009, Prague, June 2009. *Key Note Lecture*
8. **Byrne, J.A.,** "Nanomaterials for photocatalytic water treatment", Nanomaterials 2009, Bonn, Germany, June 2009, *Invited Lecture*
9. **Byrne, J.A.,** "Semiconductor photocatalysis for the treatment of water contaminated with problematic pollutants", IWWE 2009, Resource Irish Water Waste & Environment & Recover Irish Recycling & Waste Management, ESAI Water Seminar, Dublin March 2009
10. **Byrne JA, Dunlop PSM, Alrousan DM, Polo-López MI, Fernández-Ibáñez** P (2009) "Pilot Scale Solar Photocatalytic Disinfection of Water" presented at the International Research Colloquium of the Network to Promote Household Water Treatment and Safe Storage (HWTS), Dublin, Ireland.
11. **Conroy RM.** 6th – 7th May 2010. All models are wrong but which model is useful: Some interesting facts**.** Solar disinfection of water Cambodia project dissemination conference. Phnom Penh, Cambodia.
12. **Dunlop PSM**, **Alrousan DM, Byrne JA** (2009) "Water Treatment in Developing Regions - Using Nanotechnology to Enhance Solar Disinfection" presented at ICPC-NanoNet: Nanotechnology for Water Purification online workshop series.
13. **Dunlop PSM, Alrousan DM, Polo-López MI, Fernández-Ibáñez P, Byrne** JA (2009) "Photocatalytic Enhancement of Solar Water Disinfection for Applications in Developing Regions" presented at the ULE2009, International Workshop on Urbanisation, Land Use, Land Degradation and Environment, Denizil, Turkey.
14. **Dunlop PSM, Alrousan DM, Polo-López MI, Fernández-Ibáñez P, Byrne** JA (2009) "Enhancing Solar Water Disinfection (SODIS) for Application in Developing Regions" presented at the International Research Colloquium of the Network to Promote Household Water Treatment and Safe Storage (HWTS), Dublin, Ireland.
15. **Dunlop PSM, Byrne JA, Alrousan DM** (2009) "Photocatalysis for drinking water purification" presented at the OECD Conference on Potential Environmental Benefits of Nanotechnology, Paris, France.

16. **du Preez P, Ubomba-Jaswa E.** Oral presentation to the South African National Bottled Water Association (SANBWA) titled "Solar disinfection of drinking water (SODIS) - Saving lives with sunlight." November 2009
17. **du Preez M, R, Conroy, K. Murray, McGuigan KG .** 21st - 23rd September 2009. Presentation: Solar disinfection as an intervention against diarrhoea: A randomised controlled trail in a South African peri-urban area. International Research Colloquium of the Network to promote Household Water Treatment and Safe Storage (HWTS). Royal College of Surgeons in Ireland, Dublin
18. **Elmore-Meegan M.** 30th November 2009. Health care in regions of absolute Poverty. Dept International health, Faculty of Medicine. University of Tampere, Finland
19. **Elmore-Meegan M.** 21st - 23rd September 2009. International Research Colloquium of the Network to promote. Household Water Treatment and Safe Storage (HWTS), Twenty years of SODIS in Kenya. Royal College of Surgeons in Ireland, Dublin
20. **Elmore-Meegan M.** 12th Feb 2009. Global health and interdependency, The Royal College of Surgeons Charter day lecture. Dublin.
21. **Elmore-Meegan M.** 5th December, 2007. Emerging mega-trends in Global health. Future shocks; disasters and relief in a changing world. RedR Conference, Royal College of Nursing, London,
22. **Elmore-Meegan M**. 29th Nov 2007. Locally appropriate technologies in low income settings - SODIS as a low cost sustainable technology. Dept International health, Tampere University, Finland.
23. **Fernández-Ibáñez P, C. Sichel, C. Navtoft,** 23-25 July 2007, Poster communication: "Drinking water disinfection and gallic acid removal with immobilized TiO_2 in solar reactor" in the 2nd Int. Conf. on "Semiconductor Photochemistry" (SP-2), The Robert Gordon University, Aberdeen (UK).
24. **Fernández-Ibáñez P.** 18-20 April 2007, Prague, Czech Republic. International workshop Cost Action 540 WG2 Meeting. Gave an oral communication entitled "Experience and capabilities of the PSA pilot plant testing".
25. **Fernández-Ibáñez P.** 16th February 2007, Granada, Spain. "Desinfección fotocatalítica de aguas con radiación solar y sus aplicaciones" for the Group of Physics of Fluids and Biocolloids, University of Granada.
26. **Fernández-Ibáñez P. Sichel C.**,8th-10th November 2006, Gran Canaria, Spain. SPEA-4 Conference, 4th European Meeting on Solar Chemistry and Photocatalysis: Environmental Applications. Presented a poster entitled "Solar and Solar Photocatalytic Disinfection of Agricultural Pathogenic Fungi".
27. **Fernández-Ibáñez P.** 26th-27th October 2006, EPFL, Lausanne, Switzerland. Cost Action 540 Phonasum Working Group Meeting. Photocatalytic Technologies and Novel-Surface Materials. Critical Issues on Bactericide Surfaces. Gave a short communication entitled "Inactivation of Fungi by solar TiO_2 photocatalysis".
28. **Gómez-Couso, H., Fernández-Alonso, J**., Fontán-Sainz, M., **Ares-Mazás, E. McGuigan, K.G.** October 29th- November 2nd 2008, Marrakech, Morocco. Second MELIA Project Workshop on Technological perspectives for rational use of water resources in the Mediterranean region. Presented a poster entitled ?Combined influence of environmental factors on Cryptosporidium during simulated solar disinfection of drinking water?. Proceedings of the Second MELIA Project Workshop: 412-416.
29. **Gómez-Couso, H.,** Fontán-Saínz, M., **Sichel, C., Fernández-Ibáñez, P. Ares-Mazás, E.** May 31st- June 5th 2009, Naxos, Greece. 15th International Symposium on Health-Related Water Microbiology. Presented a poster entitled ?Efficacy of solar disinfection (SODIS) of turbid waters experimentally contaminated with Cryptosporidium parvum oocysts under real field conditions?. Proceedings of the 15th International Symposium on Health-Related Water Microbiology: 349-350.
30. **Gómez-Couso, H.,** Fontán-Saínz, M., **Sichel, C., Fernández-Ibáñez, P. Ares-Mazás, E.** May 31st- June 5th 2009, Naxos, Greece. 15th International Symposium on Health-Related Water Microbiology. Presented a poster entitled ?Use of CPC mirrors to enhance SODIS procedures against Cryptosporidium parvum.? Proceedings of the 15th International Symposium on Health-Related Water Microbiology: 350-352.
31. **Gómez-Couso, H.,** Fontán-Saínz, M., **Sichel, C., Fernández-Ibáñez, P. Ares-Mazás, E.** May 31st- June 5th 2009, Naxos, Greece. 15th International Symposium on Health-Related Water Microbiology. Presented a poster entitled ?Temperatures reached during SODIS procedures induce spontaneous excystation of C. parvum?. Proceedings of the 15th International Symposium on Health-Related Water. Microbiology: 352-354.
32. **Gómez-Couso, H.,** Fontán-Saínz, M., **Fernández-Ibáñez, P. Ares-Mazás, E.** September 21st-23rd 2009, Dublin, Ireland. International Research Colloquium of the Network to Promote

Household Water Treatment and Safe Storage (HWTS). Gave an oral communication entitled SODIS and Cryptosporidium: optical and thermal effects on the oocyst viability under natural sunlight. Final Scientific and Social Programme: 33.

33. **Gómez-Couso, H.,** Fontán-Saínz, M., Fernández-Alonso, J., **Navntoft, C., Fernández-Ibáñez, P. Ares-Mazás, E.** September 21st-23rd 2009, Dublin, Ireland. International Research Colloquium of the Network to Promote Household Water Treatment and Safe Storage (HWTS). Presented a poster entitled Advances in SODIS against Cryptosporidium using CPC mirrors over standard PET bottles.
34. Fontán-Saínz, M., **Gómez-Couso, H.,** Martín-Vázquez, S., Otero-Loureiro, P. and **Ares-Mazás, E.** October 11th-15th 2009, Orvieto, Italy. III International Giardia and Cryptosporidium Conference. Presented a poster entitled Kinetics of the temperature-induced spontaneous excystation of Cryptosporidium parvum in water.
35. **Kraemer, S.M., Mosler H.-J.** (2007).”Developing diffusion and intervention strategies for drinking water disinfection”. Presentation held at the Conference of Environmental Psychology in Bayreuth, Germany.
36. **Kraemer, S.M., Mosler H.-J.** (2008). “How to overcome slow uptake of a sustainable water treatment method in a developing country”. Presentation at the Conference of International Applied Psychology (IAPS) in Rome, Italy.
37. **Kraemer, S.M., Mosler H.-J.** (2008). “Using the social network: Promoting of SODIS in high-density areas in Zimbabwe”. Presentation at the International Conference of Psychology (ICP) in Berlin, Germany.
38. **Kraemer, S.M., Mosler H.-J.** (2008) “Using methods of environmental psychology to plan a campaign for disseminating solar water disinfection in high-density areas in Zimbabwe”. Poster at the International Conference of Research for Development (ICRD) of the NCCR (National Center for Competence in Research North-South) in Bern, Switzerland.
39. **Kraemer, S.M., Mosler H.-J.** (2008)“Planning a campaign for SODIS as a household based water treatment using psychological methods”. Poster at the Annual meeting of the North-South-Centre in Zurich, Switzerland.
40. **Kraemer, S.M., Mosler H.-J.** (2009). “Influencing and explaining the dissemination of solar water disinfection (SODIS) in high-density areas in Zimbabwe”. Presentation at the 11th European Conference of Psychology in Oslo, Norway.
41. **Kraemer, S.M., Mosler H.-J.** (2009). “Adoption and Dissemination of Solar Water Disinfection (SODIS) in Zimbabwe”. Presentation at the 8th Biannual Conference of Environmental Psychology in Zurich, Switzerland.
42. **Kraemer, S.M., Mosler H.-J.** (2009). “Planning a campaign for SODIS as a household based water treatment using psychological methods”. Poster at the Household Water Treatment Systems conference in Dublin, Ireland.
43. **Kraemer, S.M., Mosler H.-J.** (2009). “Diffusion check of HWTS Dissemination:
A Study on SODIS in High-density Areas in Zimbabwe”. Poster at the Household Water Treatment Systems conference in Dublin, Ireland.
44. **Kraemer, S.M., Mosler, H.J**. (2009). “Successful campaigning of SODIS: behaviour change and habit building with psychological methods in Zimbabwe”. Presentation at the Household Water Treatment Systems conference in Dublin, Ireland.
45. **McGuigan KG.** 6^{th} – 7^{th} May 2010. SODIS: from benchtop to roof top: A history of solar disinfection of drinking water**.** Solar disinfection of water Cambodia project dissemination conference. Phnom Penh, Cambodia.
46. **McGuigan KG.** 6^{th} – 7^{th} May 2010. Health impact assessment of SODIS in South Africa. Solar disinfection of water Cambodia project dissemination conference. Phnom Penh, Cambodia.
47. **McGuigan KG .** 8^{th}/9^{th} November 2006, Brussels, Belgium. Conference on *Neglected Infectious Diseases*. Organised by INCO Office.
48. **McGuigan KG .** Nov 2nd, 2007. *“Solar disinfection of waterborne protozoan pathogens*”. Centre for Health Studies, CDC Regional Office for Central America and Panama, University del Valle de Guatemala, Guatemala.
49. **McGuigan KG** . Oct 30th, 2007, *“Solar disinfection of waterborn protozoan pathogens*”. Department of Immunology, Instituto de Investigaciones Biomedicas. Universidad Nacional Autonoma de Mexico (UNAM), Mexico City, Mexico.
50. **McGuigan KG** . **Ubomba-Jaswa E, Polo MI, Fernández-Ibáñez P.** September 2009**.“**Investigation of Microbial Inactivation Efficiency of a Water Solar Disinfection (SODIS) System for Household Use” 2^{nd} Environmental Applications of Advanced Oxidation Processes-EAAOP2, Cyprus.

51. **McGuigan KG** . 27th August, 2009. *Solar Disinfection - sustainable remediation of biologically contaminated drinking water using natural sunlight*". Pan *Africa* Chemistry Network (PACN) Conference on Sustainable Water, University of Nairobi, Kenya.
52. **McGuigan KG . Ubomba-Jaswa E, Polo MI, Fernández-Ibáñez P.** June 2009.**"***Effect of Turbidity on Solar Disinfection of Escherichia coli K-12 Contaminated Water in Polyethylene Terephthalate (PET) Bottles***"** 15th International Symposium on Health-related Water Microbiology, Naxos, Greece
53. **McGuigan KG** . **Ubomba-Jaswa E, Boyle MA.** June 2008. "*Enhancing the Effectiveness of Solar Disinfection (SODIS) as a Household Water Treatment Method*", WHO Household Water Treatment and Safe Storage Network, Annual Meeting, Accra, Ghana.
54. **McGuigan KG** . **Ubomba-Jaswa E, Boyle MA.** April 2008."*Photocatalalyic applications against waterborne pathogens and hospital acquired infections*". European Science Foundation COST Action 540 Annual meeting, DIT, Dublin.
55. **McGuigan KG** . Feb. 27th 2008 *"Solar disinfection as an emergency intervention against waterborne disease".* Achieving sustainable access to clean water in Tanzania: Impact on human Health. School of Marine & Atmospheric Sciences, State University of New York, Stony Brook, NY, USA.
56. **McGuigan KG** . Feb 5th, 2008, "*Solar Disinfection of Drinking Water: Saving Lives with Solar UV*". Institute of Physics Invited Lecture, Dept. of Physics & Astronomy, The Open University, Milton Keynes, UK.
57. **McGuigan KG** . Feb 4th, 2008. "*Solar Disinfection of Drinking Water: Saving Lives with Solar UV*". James Clerk Maxwell Guest Lecture, Dept. of Physics & Astronomy, King's College London, UK.
58. **McGuigan KG .** 10th November 2006, Brussels, Belgium. Workshop on *Neglected Infectious Diseases in FP7*, organised by INCO Office. Gave a short oral presentation (attached) on SODISWATER.
59. **Mosler, H.-J.** 6th – 7th May 2010. Achieving long-term use of solar water disinfection using behavior change techniques**.** Solar disinfection of water Cambodia project dissemination conference. Phnom Penh, Cambodia.
60. **Mosler, H.-J.** (2009). How to use psychological theory and behavior change techniques for implementing HWTS interventions. Presentation at the Household Water Treatment Systems conference in Dublin, Ireland.
61. **Sichel C.**16th-18th October 2006, Monte Verítá, Switzerland. 2nd SOLLAB Doctoral Colloquium. Gave and short communication entitled "Solar photocatalytic disinfection of *Fusarium sp.* plant pathogens".
62. **Ubomba-Jaswa E.** 11 April 2007, Dublin, Ireland. 11 April 2007, Dublin, Ireland. Presented a poster on Solar disinfection of Enteropthogenic E. coli. At the RCSI Research Day.
63. **Ubomba-Jaswa E.** 31 March – 1 April 2007 Boyle, Ireland. Poster presented on Solar disinfection of Enteropthogenic E. coli. at the Institute of Physics in Ireland Spring Weekend.

3.4.7 COURSES AND SEMINARS

1. **Kraemer, S.M.** (2007). "SODISwater: solar disinfection of drinking water for use in developing countries or emergency situations". Presentation held at the monthly meeting of the WASH cluster in Harare, Zimbabwe.
2. **Kraemer, S.M.** (2008). "SODIS in Emergency Situations". Presentation at the monthly meeting of the WASH cluster in Harare, Zimbabwe.
3. **Kraemer, S.M.** (2008). "Solar water disinfection". Presentation at the monthly meeting of the WASH cluster in Harare, Zimbabwe.
4. **Kraemer, S.M.** (2008). "SODIS: an example of integrating research and practical social work". Presentation at a lecture for social works at the University of Harare, Zimbabwe.
5. **Murinda, S., Kraemer, S.M.** (2009). „SODIS adoption and dissemination in high-density areas in Zimbabwe". Presentation at the African Regional Training Workshop of the SODIS Reference Center in Nairobi, Kenya.
6. **Kraemer, S.M., Mosler, H.J.** (2009). Environmental Psychology in Developing Countries: The Example of SODIS in Zimbabwe. Presentation at lecture for environmental engineers at the ETH, Zürich, Switzerland.
7. **Kraemer, S.M**., Mosler, H.J. (2009). "SODIS adoption and dissemination in high-density areas in Zimbabwe". Presentation at SIAM workshop for project presentation at the Eawag, Dübendorf, Switzerland.

8. **Mosler, H.J.** (2009). Workshop on Behaviour Change Interventions at the Household Water Treatment Systems conference in Dublin, Ireland.
9. **McGuigan KG** 20 March 2007, Dublin, Ireland. presented a guest lecture entitled “Saving Lives with Sunshine” as part of the RCSI Mini-Medical School programme.
10. **Fernández-Ibáñez P** 21-25 May 2007, Madrid, Spain. gave a class entitled "Solar reactors for water disinfection (photocatalytic and SODIS experiences)" in the Course of Environmental Applications of Solar Energy, CIEMAT.
11. **Fernández-Ibáñez P** 16-30 June 2007, Almería, Spain. gave a class entitled "Disinfection of water with solar photocatalysis and applications" in the Master of Solar Energy, CIESOL, University of Almería.
12. **Fernández-Ibáñez P** 25-29 June 2007, Rabat, Morocco. gave an oral communication entitled "Solar Water Disinfection" in the Summer School of Renewable Energies CIEMAT-CNRST, University of Rabat.
13. **Fernández-Ibáñez P** 9-13 July 2007, Barcelona, Spain. gave an oral communication entitled "Water decontamination, disinfection and desalination with solar energy" in the Barcelona Tech Summer Sessions, Univ. Barcelona and Univ. Politecnica de Catalunya.
14. **Fernández-Ibáñez P** 17-19 July 2007, Alcoi, Spain. gave an oral communication entitled "Solar Disinfection of Water (Photocatalysis and SODIS)" in the Session "Applications of Solar Energy" of Jornadas Científico Técnicas de Verano, Univ. Politecnica de Valencia.

3.4.8 POSTGRADUATE DEGREES.

Completed

1. **Alrousan, D.** PhD. UU. 2006-2009. Solar photocatalytic disinfection of water. Completed.
2. **Boyle MAR**. PhD. RCSI. 2004-2007. Photocatalytic inactivation of planktonic & biofilmic pathogens. Completed.
3. **Fontán-Sainz M**. PhD. USC. 2007-2010. Solar disinfection of drinking water contaminated with *Cryptosporidium.* Completed
4. **Kraemer S.M.** PhD. (2006-2010). The Behaviour Change Process of Solar Water Disinfection (SODIS). PhD, Eawag/University of Zurich. 2006-2009.
5. **Navntoft C.** PhD 2006-2009. PSA. Applications of solar UV to water treatment. Completed
6. **Saladin M.** MSc Eawag/University of Basel 2008-2009. The spatial dissemination of SODIS in peri-urban areas of Harare (Zimbabwe). Completed.
7. **Sichel C.** PhD. PSA. 2005-2008. Solar Photocatalytic Disinfection of Plant Pathogen *Fusarium* Species in Water. Completed
8. **Ubomba-Jaswa E.** PhD. RCSI. 2006-2009, A study of genotoxic implications and enhancement technologies for solar disinfection of drinking water. Completed

Ongoing:

1. **du Preez M**. PhD. RCSI. 2007-2011 A Health Impact Assessment of solar disinfection in a South African peri-urban population. Ongoing.
2. **Elmore-Meegan M.** PhD. 2008-2012 Dept International Health, Faculty of Medicine , Tampere University, Finland The Importance of Local Appropriateness in Health Technology.
3. **Moyo S.** PhD. RCSI. 2007-2011. A Health Impact Assessment of solar disinfection in Zimbabwean and S African rural populations. Ongoing.
4. **Polo-Lopez I**. PhD. CIEMAT-CIEMAT. 2007-2010. "A study of Advanced Oxidation Processes using solar light for disnfection of water polluted with *Phytophthora* and *Pseudomonas syringae*". Date: 2008-2011.

3.4.9 OTHER DISSEMINATION ACTIVITIES

1. **Deliverable 20 Presentation set on SODIS**
   A PowerPoint presentation highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This is available for download on the project website.
2. **Deliverable 21 Brochure on SODIS**
   A PDF brochure highlighting the most Frequently Asked Questions and most important research outputs from SODISWATER has been prepared by partner 4 (Eawag). This is available for download on the project website.
3. **Deliverable 24 Conference on SODIS**
   SODISWATER Deliverable 24 was to host a conference on SODIS in the final year of the project.

The project coordinator was successful in arranging that this event was folded into the Research Working Group of the WHO Household Water Treatment and Safe Storage (HWTS) Network 2009 international conference (HWTS09) which was held in the RCSI (Partner 1) in Sept 2009. All of the available SODISWATER research outputs were presented at this event (See HWTS09 Book of abstracts which forms most of the Deliverable 24 report) before the maximally appropriate audience who could benefit from this research dissemination.

3.4.10 NON-REFEREED ARTICLES:

1. **McGuigan KG** , "Solar Disinfection of Drinking Water: Saving Lives with Sunlight". *European Photochemistry Association Newsletter*. Dec. 2006, 20-23.
2. **Kraemer, S.M.** (2009). Report on diffusion and adoption factors of solar water disinfection in high-density areas in Zimbabwe. Conferences and reports. Retrieved July, 14, 2009, from http://sozmod.eawag.ch/publications.php.
3. **du Preez M,** In July 2009 in collaboration with CSIR's Communication Group produced a CD with video clips featuring the CSIR's involvement in research related to water research articles published in the CSIR Sciencescope water edition magazine. SODIS was one of the main topics. http://www.csir.co.za/publications/sciencescope_archive.html
4. **du Preez M,** Borehole Water Journal - Q3- 2006 - Volume 65, page 9. World Water Watch, published an article titled "Solar disinfection of water gets the EU thumbs-up through research grant."
5. **du Preez M,** Engineering News, November 24-30 Volume 26 No. 26 page 20, published an article: "Water research. Drinking pure sunlight. CSIR aims to prove effectivenes of Solar disinfection of water in global project."
6. **Television News article**
   McGuigan KG In March 2007 liaised with the EuroNews corporation which led to the production and broadcasting of a 9-minute television feature on the FUTURIS section of the channel in recognition of World Water Day on March 22nd. This TV piece has been re-broadcast more than 20 times since March. A DVD containing the piece has been mailed to the Commission and it is available for viewing on the SODISWATER website at http://www.rcsi.ie/sodis/about/smaller.mp4 using Mozilla-Firefox.

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Kevin McGuigan
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