

# SOLAR WATER DISINFECTION

## A GUIDE FOR THE APPLICATION OF SODIS



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This guide has been written by Regula Meierhofer and Martin Wegelin, in close collaboration with Xiomara del Rosario Torres, Bruno Gremion, Alvaro Mercado, Daniel Mäusezahl, Michael Hobbins, Stephan Indergand-Echeverria, Beat Grimm and Christina Aristanti

## Foreword

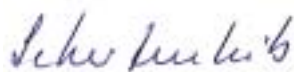
The idea of Solar Water Disinfection was presented for the first time by Aftim Acra in a booklet published by UNICEF in 1984. A research team at EAWAG/SANDEC embarked on comprehensive laboratory experiments in 1991 to assess the potential of this method for the inactivation of bacteria and viruses. Laboratory research revealed synergies in the inactivation of microorganisms through the combined use of UV-A radiation and increased water temperature. Field tests confirmed this effect which significantly enhances the potential of Solar Water Disinfection, SODIS. This simple water treatment process subsequently was field-tested in demonstration projects to assess its socio-cultural acceptance and affordability by the target population. The response and interest for SODIS were very positive.

EAWAG/SANDEC therefore started worldwide SODIS dissemination to promote this method in areas where safe water is unavailable. Since 1999, local SODIS initiatives and activities were launched in several Latin America countries, as well as in Indonesia, Sri Lanka, India, Nepal, Pakistan, Uzbekistan, Kenya, South Africa, Angola, etc. EAWAG/SANDEC supports local partners in developing SODIS information material and promotion strategies, including SODIS publicity campaigns on an international level. The SODIS website <http://www.sodis.ch> is used as communication platform for the exchange of information and experience.

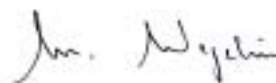
Since some of our partners in developing countries do not have access to this electronic information pool, printed documents still are required. The present SODIS Manual should be regarded as a reference document for people interested in SODIS. It contains information accumulated for more than a decade in collaboration with our cooperation partners.

EAWAG/SANDEC would like to thank all the institutions and persons involved in the SODIS project for their collaboration and assistance. We also would like to express our gratitude to the Swiss Agency for Development and Cooperation, who supported this project from the very beginning. SIMAVI World Water Fund cofinanced SODIS projects in Bolivia and Indonesia and made the publication of this manual possible. AVINA Foundation strongly supports a large SODIS promotion programme in Latin America, and the SOLAQUA Foundation provides seed-money for SODIS projects in Africa and Asia. The financial support of these institutions is gratefully acknowledged. Special thanks goes to Regula Meierhofer who compiled in collaboration with Xiomara del Rosario Torres, Bruno Gremion, Alvaro Mercado, Daniel Mäusezahl, Michael Hobbins, Stephan Indergand-Echeverria, Beat Grimm, and Christina Aristanti, the information contained in this manual and to Sylvie Peter for the careful editing. Last but not least, we extend our thanks to the partners in developing countries for their motivated and dedicated work and efforts to improve the health situation in their project areas.

Duebendorf, October 2002



Roland Schertenleib  
Director of SANDEC



Martin Wegelin  
Programme Officer



## SODIS in brief

Solar Water Disinfection (SODIS) is a simple, environmentally sustainable, low-cost solution for drinking water treatment at household level for people consuming microbiologically contaminated raw water. SODIS uses solar energy to destroy pathogenic microorganisms causing water borne diseases and thereby it improves the quality of drinking water. Pathogenic microorganisms are vulnerable to two effects of the sunlight: radiation in the spectrum of UV-A light (wavelength 320-400nm) and heat (increased water temperature).

A synergy of these two effects occurs, as their combined effect is much greater than the sum of the single effects. This means that the mortality of the microorganisms increases when they are exposed to both temperature and UV-A light at the same time.

SODIS is ideal to disinfect small quantities of water of low turbidity. Contaminated water is filled into transparent plastic bottles and exposed to full sunlight for six hours. During the exposure to the sun the pathogens are destroyed. If cloudiness is greater than 50%, the plastic bottles need to be exposed for 2 consecutive days in order to produce water safe for consumption. However, if water temperatures exceed 50°C, one hour of exposure is sufficient to obtain safe drinking water. The treatment efficiency can be improved if the plastic bottles are exposed on sunlight reflecting surfaces such as aluminium- or corrugated iron sheets.

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# 1. Introduction

## 1.1. The global water quality situation

Water in sufficient quantity and good quality is essential for life. However, at the beginning of the year 2000 one sixth of the world's population, 1.1 billion people, is without access to improved water supply and many more lacking access to safe water [1]. The following technologies are regarded as 'improved water supply': household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection. The water quality in improved water supply systems often is affected from unreliable operation and lack of maintenance, or the water is subject to secondary contamination during collection, transport and storage.

No access to good quality drinking water leads to a high risk of water-borne diseases such as diarrhoea, cholera, typhoid fever, hepatitis A, amoebic and bacillary dysentery and other diarrhoeal diseases. Each year 4 billion cases of diarrhoea cause 2.2 million deaths, mostly among children under the age of five [2]. This is equivalent to one child dying every 15 seconds, or 20 jumbo jets crashing every day. These deaths represent approximately 15% of all child deaths under the age of five in developing countries. Apart from the high infant mortality, diarrhoea affects a numerous children in developing countries in their physical development. Frequent diarrhoea is a cause for children's malnutrition, while malnutrition again increases the likelihood for children to die from an infectious disease such as diarrhoea or an acute respiratory illness. Recent estimates suggest that malnutrition is an associated cause for about half of all deaths occurring among children in developing countries [3].

The public health condition in developing countries can abruptly lead to the dramatic spread of epidemics. Cholera for example remains a risk for such epidemic outbreaks. It is endemic in 80 countries and still of concern to all regions of the world. The number of deaths caused by cholera has declined over the last decades due to the application of simple and adequate curative treatment methods (oral rehydration therapy). Adequate water treatment methods and avoidance of secondary contamination of drinking water, combined with hygiene promotion, are required to prevent the population without access to safe drinking water from illness and death.

The simple act of washing hands with soap and water can reduce diarrhoeal disease transmission by one third [1]. Promotion of household-centred water treatment methods should therefore always be combined with hygiene training. Three key hygiene behaviours are of greatest benefit:

- ◆ Hand washing with soap (or ash or other aid)
- ◆ Safe disposal of faeces
- ◆ Safe water handling and storage [1].

Therefore, a combination of water treatment, safe water storage, health education and adequate sanitation is required to have a positive long lasting effect on public health.



*1.1 billion people have no access to an improved water supply and far more lack access to safe water*

## 1.2. Water Supply: From centralised systems to a household centred approach

In the past, governments in developing countries have invested much effort in the installation of sophisticated water treatment plants and public water supply systems especially in urban areas.

However, the conventional water treatment plants often fail to produce water safe for consumption. The lack of trained operators, reliable supply of chemicals and spare parts, as well as financial constraints, often hinder a reliable operation and maintenance of the systems. Water shortages frequently lead to water supply interruptions and leaky distribution systems worsen the situation. In addition, the rapid population growth in urban areas puts an excessive stress on the existing water and sanitation infrastructures and creates enormous problems in planning and constructing new infrastructure.

Inhabitants of many urban centres in developing countries as well as the rural population therefore only have access to water of poor quality. The treatment of water to be safe for consumption therefore often remains under the responsibility of the individual household. Options that rely solely on time- and resource-intensive centralised solutions will leave hundreds of millions of people without access to safe water, approaches to support the households in these efforts therefore should be promoted as [4].



*The individual household is often responsible for treating its own drinking water.*

The following water treatment methods for application at household level generally are recommended [5] to reduce faecal contamination of drinking water:

- water storage at household level is a simple method to improve the water quality. Plain sedimentation however can only partly remove turbidity and faecal coliforms – the common indicator used to quantify the degree of faecal pollution. The main health risk associated with household water storage is the risk of recontamination through inappropriate handling practices.
- boiling of water kills viral, parasitic and bacterial pathogens. The recommended boiling time is one minute at sea level, adding one minute for every additional 1000 meters in altitude. The main disadvantage of boiling water is the large amount of energy required thereby making it economically and environmentally unsustainable [6; 7].
- water pasteurisation achieves the same effect as boiling at temperatures of only 70°C-75°C, but requires a longer exposure time of approximately 10 minutes.
- water filtration by simple household filters, such as ceramic candle filters, stone and sand filters, will remove a high fraction of solid matter, but may not remove all the microorganisms. Commercially produced filters are relatively costly, and filters made of locally available material are generally of limited treatment efficiency with regard to microbiological water quality improvement.
- water disinfection with chlorine is used to kill microorganisms (bacteria and viruses), but is not efficient enough to inactivate pathogenic parasites (e.g. Giardia, Cryptosporidium and helminth eggs). This type of treatment requires the supply of chlorine either in liquid or powder form. Skilled application is necessary as chlorine is a hazardous and corrosive substance. Water treated by chlorine has a taste which many users do not appreciate.
- solar water disinfection (SODIS) is a simple water treatment method using solar radiation (UV-A light and

temperature) to destroy pathogenic bacteria and viruses present in the water. Its efficiency to kill Protozoa is dependent on the water temperature reached during solar exposure and on the climatic and weather conditions. Microbiologically contaminated water is filled into transparent containers and exposed to full sunlight during 6 hours. Very turbid water with a turbidity of more than 30 NTU cannot be used for SODIS. SODIS is a water treatment method that:

- improves the microbiological quality of drinking water
- does not change the taste of water,
- is applicable at household level,
- is simple in application,
- relies on local resources and renewable energy,
- is replicable with low investment costs.

### 1.3. Transmission of waterborne pathogens

Waterborne pathogens belong to the groups of bacteria, viruses and parasites. Although Viruses are often not detected in the water or the host, they may account for the largest group of causative agents, followed by parasites and bacterias.

#### Characteristics of Pathogens

Many common pathogens are not only transmitted through water but also follow other infectious pathways. Poor general hygiene practices often are a significant source of infection. Furthermore, secondary contamination of drinking water due to incorrect water handling is frequently observed in developing countries [8]. Therefore, interventions aiming at improving the water quality should always consider introducing general hygiene messages. Through such combined measures, significant positive health effects in the target population can be achieved.

The main factors influencing the health related relevance of pathogens transmitted through water are the pathogen's ability to survive in the environment and the number of pathogens necessary to infect a host (human) [9]. Well-known and widely distributed pathogens and their characteristics are listed in Table 1.

The bacteria ***Vibrio cholera***, ***Shigella***, ***Salmonella*** and different pathogenic strains of ***E. coli*** are the most important water-borne pathogens. Gastrointestinal diseases caused by these bacterias can be serious, and usually treatment is required. Dehydration as a result of profuse diarrhoea is frequent among children under 5 years in the developing world [10]. Cholera epidemics are mainly caused by water borne *Vibrio cholera*. Therefore, water treatment is the most important measure for the prevention of cholera epidemics.

Viral diseases are usually symptomatic and acute with relatively short disease periods, high viral shedding, low infectious dose and restricted host variety.



*Solar water disinfection is a water treatment method to be used at household level.*

**Table 1.: Health significance and transmission route of water-borne pathogens**

Pathogen	Health Significance	Transmission Routes	Persistence in water supplies	Infective Dose
<b>Bacteria</b>				
Camplobacter jejuni, C. Coli	High	- Person to person contact	Moderate	Moderate
Pathogenic E.coli	High	- Domestic contamination	Moderate	High
Salmonella typhi	High	- Water contamination	Moderate	High
Other salmonellae	High	- Crop contamination	Long	High
Shigella spp.	High		Short	Moderate
Vibrio cholerae	High		Short	High
Yersinia enterocolitica	High		Long	High
Pseudomonas ae.	Moderate		May multiply	High (?)
Aeromonas spp.	Moderate		May multiply	High (?)
<b>Viruses</b>				
Adenovirus	High	- Person to person contact	?	Low
Polio Virus	High	- Domestic contamination	?	Low
Hepatitis A Virus	High	- Water contamination	?	Low
Hepatitis Non-A Virus	High		?	Low
Enterovirus	High		Long	Low
Norwalk Virus	High		?	Low
Norwalk-Like-Viruses (NLV)	Moderate		?	Low (?)
Rotavirus	High		?	Moderate
<b>Protozoa</b>				
Entamoeba histolytica	High	- Person to person contact	Moderate	Low
Giardia spp.	High	- Domestic contamination	Moderate	Low
Cryptosporidium spp.	High	- Contamination through animals	Long	Low

[Source: 11,12]



SODIS reduces the risk of contracting a disease transmitted by drinking water

Even though helminths and protozoans are not often the cause of acute diarrhoea, they represent an important group of pathogens. An infection with protozoans may cause chronic digestion problems which lead to malnutrition. Malnourished children are much more likely to suffer from various kinds of infections. *Giardia spp.* and *Cryptosporidium spp.* are the two protozoans regularly transmitted through water. Both pathogens have a cystic stage, which is very resistant to environmental influences. It allows them to survive for a long time outside any host. Ingestion of the cysts may cause illness, however, silent infections are very common and support the spread of these pathogens.

#### Multiple transmission routes and possible interventions

The application of SODIS improves the quality of drinking water and therewith reduces the risk of contracting a disease mainly transmitted via drinking water. Unfortunately, many of those so-called waterborne diseases have **multiple transmission routes**.

Consequently **diarrhoea causing pathogens** can be transmitted to humans through food, person-to-person contact, flies or through inadequate hygiene behaviour (e.g. not washing the hands). Children are particularly exposed to many different ways of becoming infected, as illustrated in the "F-Diagram": via faeces, fingers, flies/insects, food, field/ environment and fluids/water.

Interventions simultaneously addressing different contamination routes such as water- or surface transmission as well as secondary contamination, are more effective. Furthermore, if general hygiene education is disseminated at the same time as the technology, other main transmission routes such as person-to-person and food borne transmission can be prevented. Multiple interventions can thus achieve a considerable effect on the population's health.

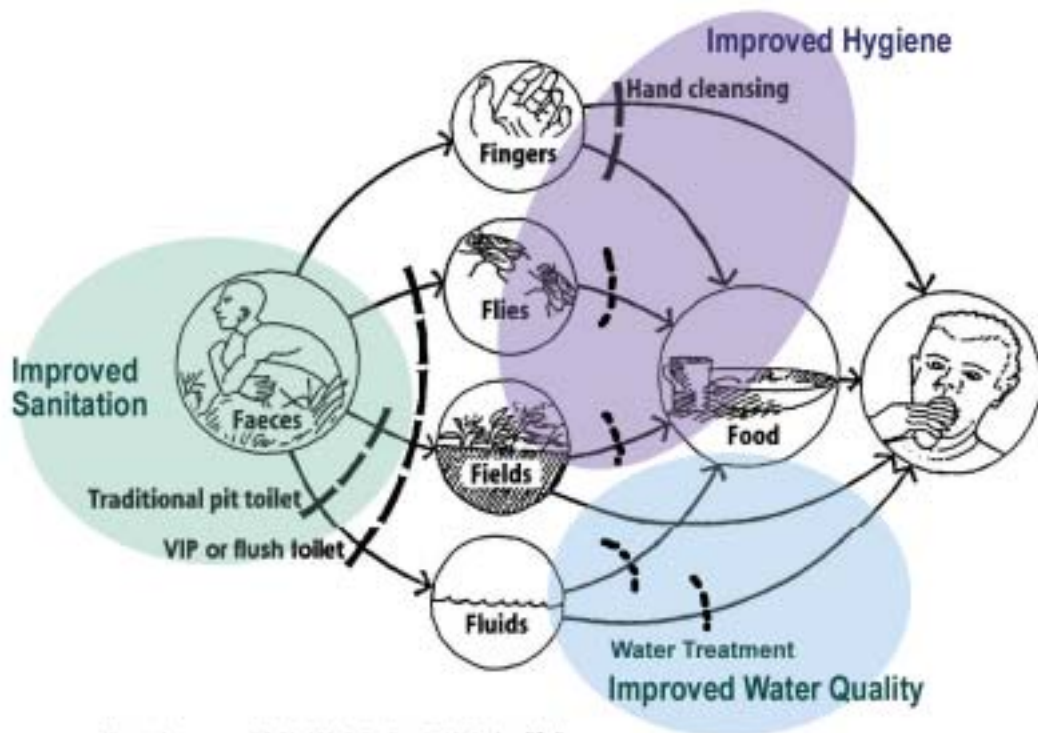


Illustration source: Winblad U. & Dudley E. 1997 (modified)

Figure 2: F-Diagram: Pathogens follow different transmission routes

Interventions at specific points in the water management cycle should address characteristics and survival tactics of a specific pathogen.

Public health measures against the protozoan *Giardia* spp. for example, should target the end of the contamination route. *Giardia* spp. is abundant in the environment, has a large host variety (for example: dogs, cows, pigs, humans) and is highly resistant against environmental factors (through the development of cyst stages). A recontamination of purified water is therefore very likely and can be prevented if water is purified at the end of the contamination path: at household level, shortly before the water is consumed.

Public health interventions, addressing water quality issues and hygiene education, are required when viral infections occur on a large scale. This is because viruses are shed in high amounts, the infectious dose is low and a secondary spread of the virus from person-to-person is very likely. However, as host variability is low (no animal to human transmission), hygienic behaviour can already be sufficient to prevent a contamination of the water.



Interventions should address different transmission routes of pathogens.

Classification of faecal coliforms in water supplies	
No. of coliforms per 100 ml	Remarks
0	In compliance with WHO guidelines
1-10	Low risk
10-100	Intermediate risk
100-1000	High risk
> 1000	Very high risk

Table 3: Classification scheme of faecal coliforms in water supplies [5]



PET-bottles proved to be the best containers for SODIS.

## Classification of water quality

The risk related to different levels of contamination with faecal coliforms must be assessed considering the local circumstances. The risk related to a given contamination increases with the number of people being supplied by a water system. Therefore with the increasing size of a water supply system the quality criteria are higher (i.e. higher standards for towns as compared to small community supplies). SODIS however, is a water disinfection method used at household level supplying one respective family. Therefore the criteria for this point-of-use system should also not be too stringent. WHO Guidelines Vol.1 classifies the presence of 1-10 faecal coliforms or E.coli per 100ml in water supplies as low risk, a concentration of 10-100 ml as intermediate risk.

Table 3 provides a scheme for classifying the health risk of consuming water contaminated with Faecal coliforms.

### 1.4. How the idea of SODIS developed (Historical Outline)

Research on solar water disinfection was initiated by Professor Aftim Acra at the American University of Beirut [12A; 13A]. Acra's work motivated the Integrated Rural Energy Systems Association (INRESA) to launch a network project in 1985. The Brace Research Institute in Montreal organized a workshop in 1988 to review the results of this field research [14].

In 1991 an interdisciplinary team composed of sanitary engineers, photochemists, bacteriologists and virologists from EAWAG/ SANDEC embarked on extensive laboratory and field tests to assess the potential of SODIS and to develop an effective, sustainable and low-cost water treatment method.

In the past, two different water treatment processes using solar energy were used to improve the microbiological water quality. The first, UV-radiation was used for its bactericidal effect. The second, infrared radiation raising the water temperature, is known as pasteurisation. During research phase one, the researchers at EAWAG combined the two effects and discovered a strong synergy between radiation and heat. The experiments showed that at a water temperature of 50°C, only a fourth of the amount of UV-light required at 30°C is necessary to inactivate the same amount of faecal coliforms [15].

At a water temperature of about 30°C, a threshold solar radiation intensity of at least 500 W/m<sup>2</sup> (all spectral light) is required for about 5 hours for SODIS to be efficient. This dose contains energy of 555 Wh/m<sup>2</sup> in the range of UV-A and violet light, 350nm-450nm, corresponding to about 6 hours of mid-latitude (European) midday summer sunshine [15]

During the second phase of the research project, various types of containers were tested under field conditions, using different water qualities and climatic conditions. Locally available material was used such as glass, plastic bottles and plastic bags. During the testing phase, the researchers developed operating guidelines for the water treatment method [16].

During the third phase the socio-cultural acceptance, applicability and financial viability of SODIS were studied in demonstration projects in local communities in Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand and China. The survey assessing the socio-cultural acceptance of SODIS revealed that users appreciate the sustainable and simple water treatment method. An average of 84% of the users stated that they will certainly continue to use SODIS after the conclusion of the demonstration projects. About 13% of the users consider to maybe use it in the future, while only 3% refuse to use SODIS as their health is not affected by the present water quality (SODIS News No.3).

Country	I will continue to use SODIS			
	certainly	maybe	probably not	definitely not
Colombia	90	8	0	2
Bolivia	93	0	0	7
Burkina Faso	70	30	0	0
Togo	93	0	0	7
Indonesia	90	5	3	2
Thailand	97	0	0	3
China	55	45	0	0
average	84	12.6	0.4	3

Table 4: Results of the survey on SODIS acceptance (SODIS News No.3)

The three phases of the research project had to answer the following questions:

Phase	Question	Activity
1	Can sunlight be used for water disinfection?	<b>Preliminary Tests</b> Comprehensive laboratory and field tests were undertaken to determine the potential and limitations of the process.
2	How should installations for the solar disinfection of water be designed and operated?	<b>Field Tests</b> Field tests were conducted to develop equipment and operating guidelines for the water treatment method. Locally available material was used such as glass, plastic bottles and plastic bags. Field tests were performed with local institutions in Colombia, Jordan and Thailand.
3	Is solar water disinfection socio-culturally acceptable and financially affordable?	<b>Demonstration</b> Demonstration projects were conducted to study socio-cultural acceptance and financial aspects of SODIS. Local partners in Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand and China conducted the projects.

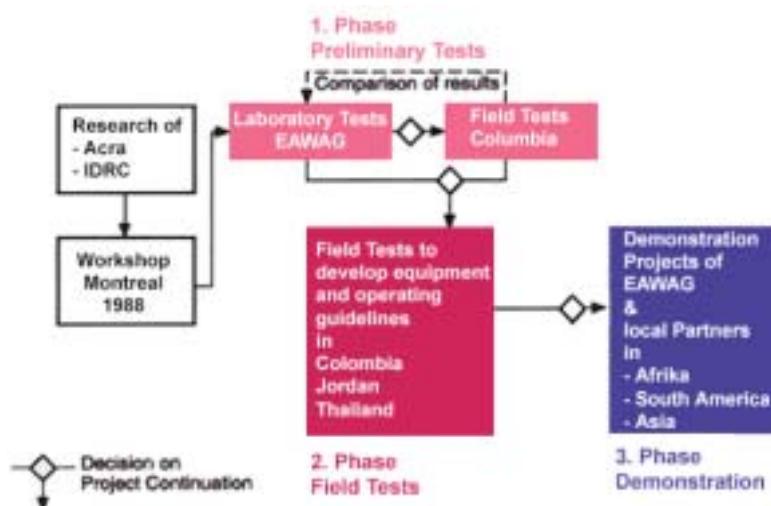


Figure 5: Flow sheet of SODIS research activities

## **SODIS – a sustainable water disinfection method**

My expectations were quite high when we travelled again to Melikan, a small rural village at about 2 hours drive from Yogyakarta. Four years ago Yayasan Dian Desa (YDD), a local NGO selected this village for a demonstration project to field test SODIS. Right in the centre of Melikan is a small lake, which is the most important water source for the community. People wash themselves and their clothes in the lake, the lake is also used for watering the cattle and people also use it as source for their drinking water. Four years ago, this water was not always boiled before consumption due to the lack of firewood. Children playing outside, could also not be dissuaded from drinking the raw water. As a consequence, children and adults from Melikan frequently suffered from diarrhoeal attacks..



*The application of SODIS is so simple that even small girls can do it*

exposed to sunlight either on the roof or on special stands. My heart started to beat faster when we approached the house of my small friends. Near the house we saw SODIS bottles layed down on a wooden stand much higher than the one used 3 years ago. We talked to a woman breastfeeding a baby. She was the mother of the two girls. At our request, she called her daughters and around the corner came two healthy teenagers instead of the small girls I met 3 years ago. Not only the wooden stand had become taller since my last visit, but also the girls had grown up considerably. They were again smiling at me, especially when I gave them the SODIS poster with their photo showing how simple SODIS is to apply. Their continuous use of the water treatment method demonstrates that SODIS is sustainable in Melikan as it could be in other places around the world.

Martin Wegelin, SANDEC

SODIS was well accepted by the inhabitants of Melikan who carefully had been trained in the use of this new water treatment method. Especially the women were very interested in SODIS as they used to get up very early in the morning to collect firewood and boil the water their husbands took to the field. But SODIS would make their life easier, as they now only had to fill a plastic bottle with water and expose it to the sun during the day. When their husbands left for the fields in the morning, they now just could give them the bottle that had been treated during the previous day.

Three years ago, I met many people who praised the different advantages of SODIS. Two girls were smiling at me and showed me how simple SODIS is to apply. But has this enthusiasm for SODIS lasted, did the people also replace the broken bottles?

We drove through the village and stopped at the house of the community leader. The leader informed us that the women are the ones responsible for the application of SODIS. After this visit, we walked through the village and discovered many bottles ex-



*The small girls, now teenagers, continue to use SODIS in Melikan, Indonesia*



## 1.5. Advantages and Limitations of SODIS

### Advantages of SODIS

- SODIS improves the microbiological quality of drinking water.
- SODIS improves the family health.
- SODIS can serve as an entry point for health and hygiene education.
- Public water supply systems in developing countries often fail to provide water safe for consumption. SODIS provides individual users a simple method that can be applied at household level under their own control and responsibility.
- SODIS is easy to understand.
- Everybody can afford SODIS, as the only resources required are sunlight, which is cost free and plastic bottles.
- SODIS does not require a large and costly infrastructure and therefore easily is replicable in self-help projects.
- SODIS reduces the need for traditional energy sources such as firewood and kerosene/gas.
- Consequently the use of SODIS reduces deforestation, a major environmental problem in most developing countries, and SODIS decreases air-pollution created by burning conventional energy sources.
- Women and children often spend much of their time and energy collecting firewood. SODIS reduces this workload as less firewood needs to be collected.
- Financial advantages: Household expenditures can be reduced when the user's family health is improved: less financial resources are required for medical care. In addition, expenses for traditional energy sources such as gas, kerosene and firewood are reduced. Only limited resources are required for the procurement of transparent plastic bottles. Therefore even the poorest can afford SODIS.



*Corrugated iron sheets are the best bottle supports for SODIS*

### Limitations of SODIS

- SODIS requires sufficient solar radiation. Therefore it depends on the weather and climatic conditions.
- SODIS requires clear water.
- SODIS does not change the chemical water quality.
- SODIS is not useful to treat large volumes of water.



## 2. Technical Aspects

### 2.1. Effect of UV-A radiation and Temperature

SODIS uses two components of the sunlight for the water disinfection. The first, UV-A radiation has a germicidal effect. The second component, infrared radiation, raises the water temperature and is known as pasteurisation when the water temperature is raised to 70°C- 75°C. The combined use of both UV-A radiation and heat produce a synergetic effect enhancing the efficiency of the process.

#### Effects of UV-radiation

Solar radiation can be divided into three ranges of wavelength: UV radiation, visible light and infrared radiation.

UV radiation cannot be perceived by the human eye. It is a very aggressive radiation that can cause severe damage to the skin and eyes and destroys living cells. Luckily most of the UV-C and UV-B light in the range of 200 to 320 nm is absorbed by the ozone (O<sub>3</sub>) layer in the atmosphere which protects the earth from radiation coming from space. Only a higher fraction of UV-A radiation in the wavelength range of 320nm – 400nm, near the visible violet light, reaches the surface of the earth.

UV-A light has a lethal effect on human pathogens present in water. These pathogens are not well adapted to aggressive environmental conditions as they find their specific living conditions in the human gastrointestinal tract. Therefore, they are more sensitive to sunlight than organisms commonly abundant in the environment.

UV-A radiation directly interacts with the DNA, nucleic acids and enzymes of the living cells, changes the molecular structure and leads to cell death. UV radiation also reacts with oxygen dissolved in the water and produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides). These reactive molecules also interfere with cell structures and kill the pathogens.

#### Effects of temperature (infrared radiation)

Another aspect of the sunlight is the long-wave radiation called infrared. Also this radiation cannot be seen by the human eye, but we can feel the heat produced by light of the wavelength beyond 700nm . The infrared radiation absorbed by the water is responsible for heating it up.

Microorganisms are sensitive to heat. The following table lists the temperature and exposure time required to eliminate microorganisms. It can be seen that water does not have to be boiled in order to kill 99.9% of the microorganisms. Heating up the water to 50-60°C for one hour has the same effect.

Microorganisms	Temperature for 100 % Destruction		
	1 Min.	6 Min.	60 Min.
Enteroviruses			62 °C
Rotaviruses			63 °C for 30 Min.
Faecal Coliforms	at 80 °C complete destruction		
Salmonellae	62 °C		58 °C
Shigella		61 °C	54 °C
Vibrio Cholera			45 °C
Entamoeba Histolytica Cysts	57 °C	54 °C	50 °C
Giardia Cysts	57 °C	54 °C	50 °C
Hookworm Eggs and Larvae		62 °C	51 °C
Ascaris Eggs	68 °C	62 °C	57 °C
Schistosomas Eggs	60 °C	55 °C	50 °C
Taenia Eggs	65 °C	57 °C	51 °C

Table 6: Thermoresistance of micro-organisms (adapted from [32])

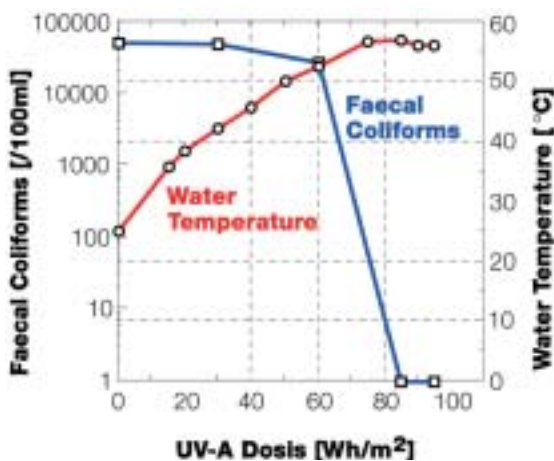


Figure 7: Inactivation of faecal coliforms in a PET-bottle on a black underground [16]

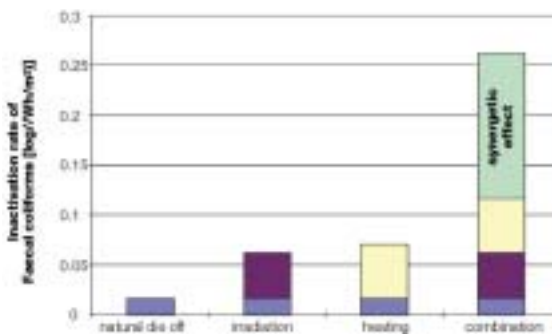


Figure 8: Synergistic effect of UV-radiation and temperature on Faecal coliforms in raw water [15]

### SODIS Process: Synergetic effect of UV-A radiation and temperature

At a water temperature of 30°C, a fluence of **555 W\*h/m<sup>2</sup>** (350-450 nm, dose of solar radiation corresponding to approximately **6 hours of mid-latitude midday summer sunshine**) is required to achieve a 3-log reduction of faecal coliforms. Under these conditions, only the effect of UV-A radiation is present [15].

However, the die off rate of faecal coliforms exposed to sunlight increases significantly, when 2 stress factors, UV-A radiation and increased water temperature are present. At a water temperature of 50°C, a synergetic effect of UV-A radiation and temperature occurs: a 3-log reduction of faecal coliforms only requires a fluence of **140 W\*h/m<sup>2</sup>**. This is equivalent to an **exposure time of only one hour** [15].

## 2.2. Effect of SODIS on pathogens

Human pathogens are adapted to live in the human intestines, where they find a dark, humid environment and temperatures ranging between 36°C and 37°C. Once the pathogens are discharged into the environment, they are very sensitive to the harsh conditions outside the human body. They are not able to resist increased temperatures and they do not have any protection mechanisms against UV radiation. Therefore, temperature and UV radiation can be used to inactivate the pathogens.

Research has shown that pathogenic bacteria and viruses are destroyed by SODIS. The inactivation of the following microorganisms has been documented:

- Bacteria: Escherichia coli (E.coli), Vibrio cholerae, Streptococcus faecalis, Pseudomonas aeruginosa, Shigella flexneri, Salmonella typhi, Salmonella enteritidis, Salmonella paratyphi [13A/15/16]
- Viruses: Bacteriophage f2, Rotavirus, Encephalomyocarditis virus [15]
- Yeast and Mold: Aspergillus niger, Aspergillus flavus, Candida, Geotrichum [13A]

However, the inactivation of spore and cyst forming organisms such as protozoa; Entamoeba histolytica, Giardia intestinalis, Cryptosporidium parvum and helminths by solar water disinfection has not systematically been assessed yet.

These organisms can be destroyed by using temperature (boiling, pasteurisation). Microorganisms have a specific sensitivity to heat. The thermal death point of amoebic and Giardia cysts is at 57°C (during 1 Minute exposure, see Table 6 on Thermoresistance of microorganisms). SODIS will effectively destroy these pathogens if the water in the exposed SODIS bottles reaches a temperature of 57°C for 1 Minute or if the contaminated water maintains a temperature of 50°C during an hour.

Most human pathogens are very fragile, cannot multiply and

die outside the human body. One of the few exceptions is salmonella, which however requires favourable environmental conditions (e.g. appropriate supply of nutrients) to survive.

It is important to note that SODIS does not produce sterile water. Organisms other than human pathogens such as for example Algae, are well adapted to the environmental conditions in the SODIS bottle and may even grow there. These organisms however do not pose a danger to human health.

As SODIS does not produce sterile water, it is necessary to use adequate parameters to assess its efficiency.

### Indicators used to test the efficiency of SODIS

Many waterborne pathogens can be detected directly but require complicated and expensive analytical methods. Instead of directly measuring pathogens, it is easier to use indicator organisms indicating faecal pollution in the water. A faecal indicator organism has to meet the following criteria:

- It is present in high number in human faeces,
- It is detectable by simple methods,
- It does not grow in natural waters,
- Its persistence in water and its removal by the water treatment method is similar to the water-borne pathogens.

Many of these criteria are fulfilled by **Escherichia coli (E.coli, faecal coliform)**. **E.coli is therefore a good indicator** organism to assess faecal contamination of drinking water if the resources for microbiological examination are limited [11]. An important point is, that testing for E.coli is also possible under difficult field conditions in a developing country, for example by using the portable DelAgua field test kit (<http://www.eihms.surrey.ac.uk/robens/env/delagua.htm>).

Some organisms such as Enteroviruses, Cryptosporidium, Giardia and Amoebae however are more resistant than E.coli. The absence of E.coli therefore does not necessarily indicate their removal. Spores of sulfite-reducing Clostridia can be used as an indicator for these organisms [11]. But such analytical methods cannot be used for routine tests under field conditions as they are time-consuming and expensive.

**Total coliform bacteria cannot be used as an indicator** for the sanitary quality of untreated raw water, as they are naturally abundant in the environment.

**Neither is the total count of bacteria an adequate parameter** for the assessment of SODIS efficiency, as harmless organisms, such as for example environmental bacteria or Algae, may grow during sunlight exposure of a SODIS bottle.



*Using the DelAgua field test kit to examine the water quality*

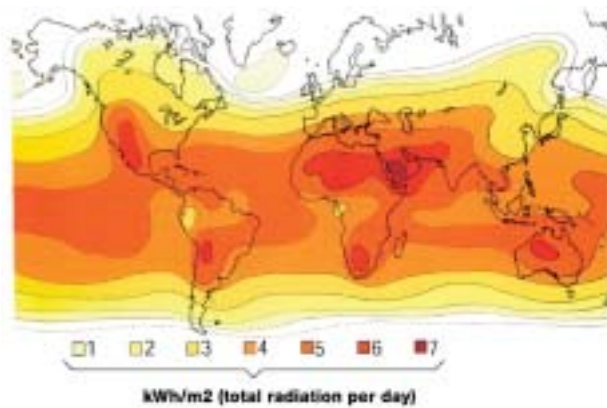


Figure 9: Solar radiation per day in different geographical regions

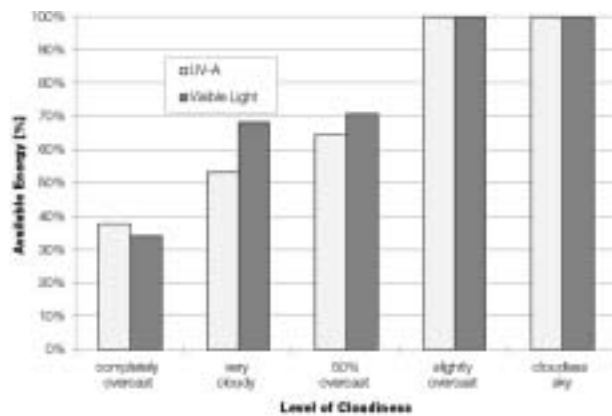


Figure 10: Losses of available solar energy at different weather conditions [16]

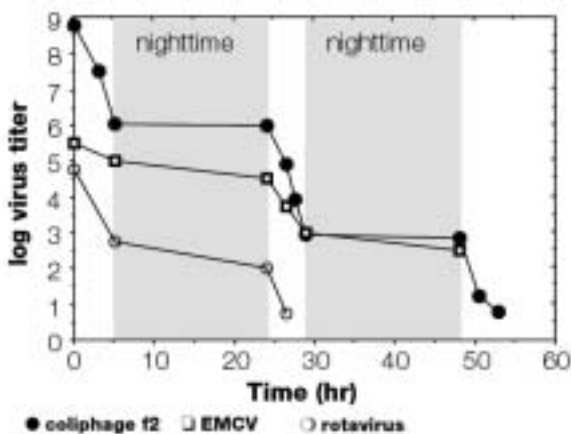


Figure 11: Prolonged SODIS operation (3 days) [15]

## 2.3. Weather and Climate

The efficiency of the SODIS process is dependent on the amount of sunlight available. Solar radiation however is unevenly distributed and varies in intensity from one geographical location to another depending on latitude, season and the time of the day.

### Geographical variation of solar radiation

The most favourable regions for SODIS are located between latitude 15°N and 35°N (as well as 15°S and 35°S). These semi-arid regions are characterized by the highest amount of solar radiation. Over 90% of the sunlight touch the earth as direct radiation due to the limited cloud cover and rainfall (less than 250mm rain and usually more than 3000 hours of sunshine annually).

The second most favourable region lies between the equator and latitude 15°N and 15°S. Due to high humidity and frequent cloud cover, the amount of scattered radiation in this region is high (about 2500 hours of sunshine annually).

It is important to note that the majority of developing countries are located between latitudes 35°N and 35°S. They can therefore rely on solar radiation as an energy source for solar disinfection of drinking water.

### Seasonal and daily variations of solar radiation

The solar UV-A intensity shows both seasonal and daily variations.

The **seasonal variation** depends on the latitude and is mainly responsible for the climate in that region. Regions near the equator encounter lower variance of light intensity during the year than regions in the northern or southern hemisphere. In Beirut for example (latitude: 33°N), the UV-A radiation intensity reaches a peak level of 18 W/m<sup>2</sup> in June and decreases to 5 W/m<sup>2</sup> in December.

The seasonal differences of solar radiation are important for the applicability of solar water disinfection. Prior to the implementation of SODIS in a specific place, the seasonal radiation intensities need to be assessed. A total solar radiation intensity of at least 500 W/m<sup>2</sup> is required for approximately 6 hours for SODIS to be effective.

The solar radiation intensity is also subject to **daily variations**. With increasing cloudiness, less radiation energy is available. During completely overcast days the UV-A radiation intensity is reduced to one third of the intensity recorded during a cloudless day.

During very cloudy days, the SODIS bottles have to be exposed for two consecutive days to reach the required radiation dose and to ensure the complete inactivation of the pathogens [16].

**The SODIS efficiency is dependent on the amount of solar energy available:**

- Expose the bottle to the sun for 6 hours if the sky is cloudless or up to 50% cloudy.
- Expose the bottle to the sun for 2 consecutive days if the sky is more than 50% cloudy.
- At a water temperature of at least 50°C, 1 hour exposure time is sufficient.
- During days of continuous rainfall, SODIS does not perform satisfactorily. Rainwater harvesting or boiling is recommended during these days

**2.4. Water Turbidity**

Suspended particles in the water reduce the penetration of solar radiation into water and protect microorganisms from being irradiated. Therefore, the disinfection efficiency of SODIS is reduced in turbid water.

**=> SODIS requires relatively clear raw water with a turbidity of less than 30 NTU (= Nephelometric Turbidity Units).**

If the water turbidity is higher than 30 NTU, the water needs to be pretreated before being exposed [16]. Bigger particles and solids can be eliminated by storing the raw water for one day and letting the particles settle to the bottom. Afterwards the water is decanted. Solid matter can be separated by filtration, using a sand layer or a cloth. Turbidity also can be reduced by flocculation/ sedimentation using aluminium sulphate or crushed Moringa oleifera seed.

If the water turbidity cannot be reduced by different means of pretreatment, the microorganisms need to be inactivated by temperature rather than by UV-A radiation (solar pasteurisation or water boiling).

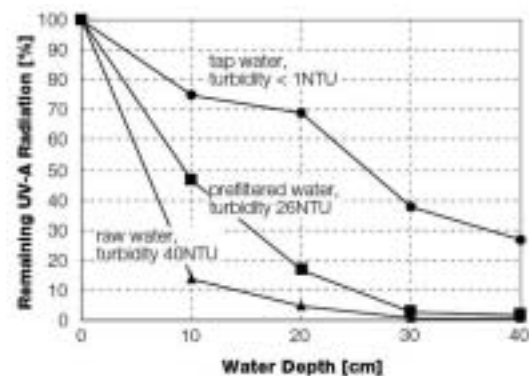
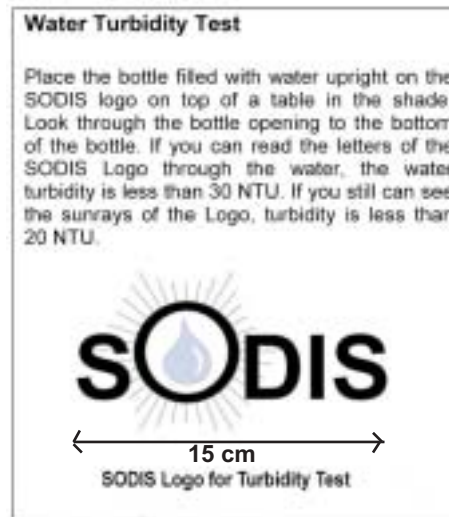


Figure 12: Reduction of UV-A radiation as a function of water depth and turbidity [16]

**2.5. Oxygen**

SODIS is more efficient in water containing high levels of oxygen: Sunlight produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides) in the water. These reactive molecules react with cell structures and kill the pathogens [17].

**=> Aeration of the water can be achieved by shaking the ¾ filled bottle for about 20 seconds before the bottle is filled completely and exposed to the sun.**

Recent research however revealed that the bottles should be shaken only at the beginning of the SODIS process. Once the bottles are exposed to the sun, they should not be moved anymore, as continuous shaking of the bottles during the solar exposure will reduce the efficiency of the process [18].

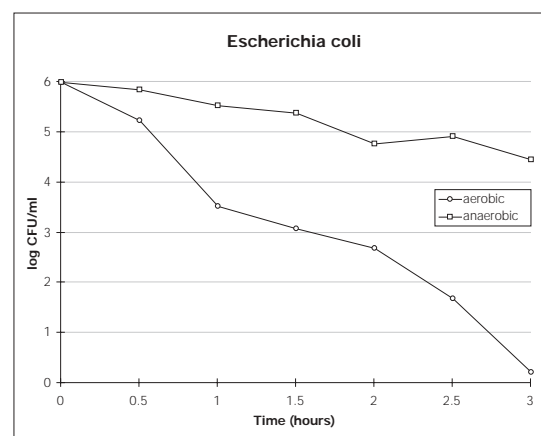


Figure 13: Inactivation of E.coli under aerobic and anaerobic conditions [17]

## 2.6. Material and Shape of Containers

### How to distinguish PET from PVC:

- PVC bottles often have a bluish gleam. This bluish gleam is especially marked at the edges of a piece of bottle material that has been cut out.
- If PVC is burnt, the smell of the smoke is pungent, whereas the smell of PET is sweet.
- PET burns more easily than PVC.

### Plastic bottles: PET or PVC?

Various types of transparent plastic materials are good transmitters of light in the UV-A and visible range of the solar spectrum. Plastic bottles are made of either PET (PolyEthylene Terephthalate) or PVC (PolyVinylChloride). Both materials contain additives like UV-stabiliser to increase their stability or to protect them and their content from oxidation and UV radiation.

The use of bottles made from PET instead of PVC is recommended as PET contains much less additives than bottles made from PVC.

### Plastic bottles or glass bottles?

The transmission of UV radiation through glass is determined by its content of iron oxide. **Ordinary window glass of 2mm thickness transmits almost no UV-A light.** It therefore cannot be used for SODIS. Certain specific glasses (Pyrex, Corex, Vycor, Quartz) transmit significantly more UV-light than the ordinary window glass.

### PET bottles

#### Advantages of PET

- low weight
- relatively unbreakable
- transparent
- neutral in taste
- chemically stable

#### Disadvantages of PET

- limited heat resistance (deformation above 65°C)
- scratches and other aging effects

### Glass bottles

#### Advantages of glass

- no scratches
- no photoproducts
- heat resistant

#### Disadvantages of glass

- easily smashed
- higher weight
- high costs

### Shape of containers

UV radiation is reduced at increasing water depth. At a water depth of 10 cm and a moderate turbidity of 26 NTU, UV-A radiation is reduced to 50% [16]. Therefore, the containers used for SODIS should not exceed a water depth of 10cm.



Exposing SODIS bottles in Bangladesh



PET bottles are very practical and ideal containers for SODIS as:

- PET bottles do not exceed a depth of 10cm when horizontally being exposed to the sun.
- PET bottles can be closed. Thereby the risk of recontaminating the purified water is reduced.
- PET bottles are easily available at low cost, also in developing countries.
- PET bottles are easy to handle (filling, carrying) and can directly be used at the table thereby reducing the risk of recontamination.
- PET bottles are quite durable. Even after several months of application, the bottle still is in good condition. It is recommended to use sturdy bottles (e.g. returnable bottles) to increase the lifetime of the bottles and reduce plastic waste.

### Aging of plastic bottles

Aging of plastic bottles leads to a reduction of UV transmittance which, in turn, can result in a less efficient inactivation of microorganisms. Transmittance losses may be due to mechanical scratches or due to photoproducts. Heavily scratched, old or blind bottles should be replaced [19]. Figure 14a shows the UV light transmittance losses caused by mechanical scratches.

### Photoproducts

Plastic bottles contain UV stabilisers to increase their stability and protect the material against oxidation and UV radiation, as sunlight does not only destroy pathogenic microorganisms but also transforms the plastic material into photoproducts. The UV light leads to photochemical reactions resulting in optical property changes of the plastic material. In the course of time, the additives are depleted from the host material by photochemical reaction or diffusion. This depletion influences the properties of the material; the UV transmittance in the spectral range of 320nm to 400nm is reduced. Figure 14b shows the UV-light transmission losses due to photoproducts [19].

Additives and photoproducts are a potential health risk. However, additives are large molecules which hardly migrate through the PET-material. Laboratory and field tests have shown that photoproducts are generated on the outer surface of the bottles. No migration of photoproducts or additives (UV stabilisers) into the water was observed [19].

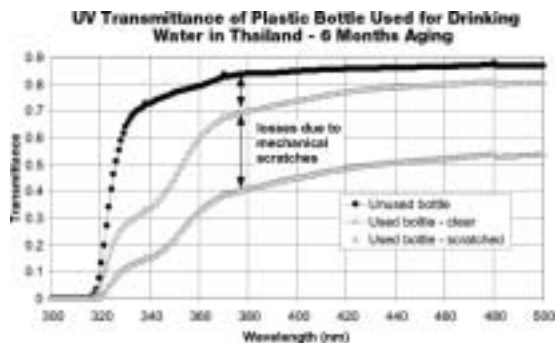


Figure 14a: The UV-transmittance losses due to mechanical scratches

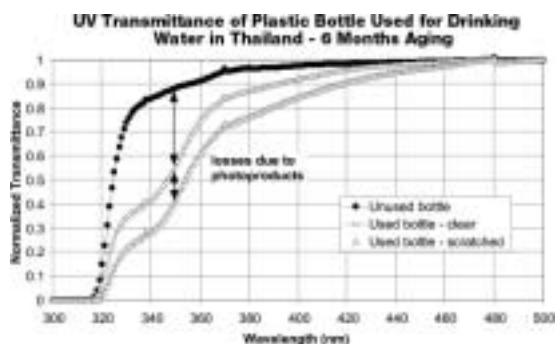


Figure 14b: The UV-transmittance losses due to photoproducts

## Exposing Procedure

**1** Wash the bottle well the first time you use it

**2** Fill the bottle 3/4 full with water

**3** Shake the bottle for 20 seconds

**4** Now fill up the bottle fully and close the lid

**5** Place the bottles on a corrugated iron sheet

**6** or put them on the roof...

**7** Expose the bottle to the sun from morning until evening for at least six hours

**8** The water is now ready for consumption

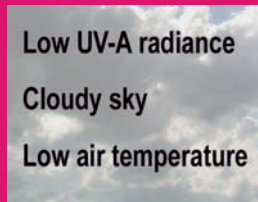
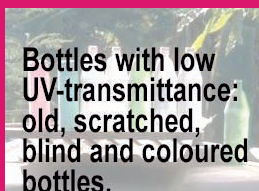
## 2.7. Application Procedure

### Preparation

1. Check if the climate and weather conditions are suitable for SODIS.
2. Collect plastic PET-bottles of 1-2 litre volume. At least 2 bottles for each member of the family should be exposed to the sun while the other 2 bottles are ready for consumption. Each family member therefore requires 4 plastic bottles for SODIS.
3. Check the water tightness of the bottles, including the condition of the screw cap.
4. Choose a suitable underground for exposing the bottle, for example a CGI (corrugated iron) sheet.
5. Check if the water is clear enough for SODIS (turbidity < 30 NTU). Water with a higher turbidity needs to be pre-treated before SODIS can be applied.
6. At least two members of the family should be trained in the SODIS application.
7. A specific person should be responsible for exposing the SODIS bottles to the sun.
8. Replace old and scratched bottles.

## Guidelines to increase the efficiency of SODIS

### Factors reducing the efficiency



## Factors enhancing the efficiency

Use raw water of low turbidity.  
Fill bottles completely to avoid air-pockets reducing solar radiation.

Place bottles horizontally or at a flat angle towards the sun.

Place bottles on a CGI-sheet or an underground which reflects sunlight.

Aluminium foil and a bucket can be used to construct a simple solar collector  
(in areas where these resources are available)

Make sure that no shadow falls on the bottles.  
If a water temp. of 50°C is reached: 1 hour exposure time is sufficient.

Expose the bottles for 2 consecutive days if the sky is 100% cloudy.

Start exposing the bottles as early in the morning as possible.

Continuous rainfall: Rainwater harvesting or boiling the water is recommended

## Increasing SODIS efficiency with Solar Collectors

After thoroughly studying the recommendations of the SODIS website (<http://www.sodis.ch>), I decided to carry out some tests with a simple solar collector to investigate the energy transfer from reflective and absorptive surfaces. The first test I conducted was to demonstrate the temperature increase when a foil lined box was used to increase energy collection. The dimensions of the box were 33cm in length, 28cm in width and 18 cm depth. All the tests were carried out at a latitude of 32° N (and 111° W). The first test started at 9am at a water temperature of 21.1°C. At 2pm the temperature was 42.5°C in the half-blackened PET bottle kept outside the collector, while it was 66.5°C in the half-blackened PET bottle kept in the foil lined box.

Comparing the temperature increase using half-blackened PET-bottle with and without Solar Collector

Hour	without reflector	with reflector
9.00	21.1°C	21.1°C
14.00	42.5°C	66.5°C



My second round of tests was conducted to compare the energy transfer from shiny and black surfaces around the bottles. For this test I used two identical plastic tubs lined with aluminium foil to increase the area of energy collection. In one tub the foil was shiny and in the other tub, the foil was painted black.

The date of this test was 21 March, 2002. The weather from 9am to 2pm was: air temperature increasing from 23°C to 28.3°C, light and variable winds and a very thin layer of cirrus clouds at 9am getting somewhat thicker until 2pm. Thickening clouds and a lowering sun angle after 2pm caused the temperatures to decline thereafter. The test started at 9am with a water temperature of 24.1°C. By 12am, the temperatures were 47.4°C in the black tub and 56.5°C in the shiny tub. By 2pm the water temperature in the black tub had risen to 54.7°C and the water in the shiny tub to 65.0°C.

I also experimented with a smaller, shallower box as collector. Actually it was a shoe-box. But the deeper box, which I used for the tests above, gave the better results. I think it was because the steeper sloping sides focused the energy more efficiently in the bottle. The greater depth also seems to protect the bottle from breezes, reducing the heat loss to moving air. I also found that the foil should not conform to the vertical sides and horizontal bottom of the tub. The foil

Comparing the temperature increase of half-blackened PET-bottles in shiny and black painted solar collectors

Hour	Black coloured reflector	Shiny reflector	Air temperature
9.00	24.1°C	24.1°C	23°C
12.00	47.4°C	56.5°C	28.3°C
14.00	54.7°C	65.0°C	



should slope from the rim of the tub to the bottom of the bottle. I put two pieces of wood in the tub under the foil to hold the bottle in position so that it would not roll from side to side.

Loring Green, Lifewater



### 3. The application in the field

#### 3.1. SODIS testing under different conditions

Many technologies may sound very promising under laboratory conditions, but reveal to be inappropriate or show much lower efficiency at user level. That is the reason why SODIS has been extensively tested for its microbiological efficiency under a wide range of field conditions.

The following table contains the different conditions under which SODIS has been tested:

Situation	Advantage	Limitation
<b>Laboratory research</b>	<ul style="list-style-type: none"> <li>experiment conducted under strictly controlled conditions</li> <li>results are reproducible</li> <li>possibility to study specific microorganisms</li> <li>environmental parameters may be measured and controlled</li> </ul>	Tests only represent a simulation of the real condition; they do not integrate parameters like: <ul style="list-style-type: none"> <li>certain technical aspects (bottles, natural water)</li> <li>climatic conditions</li> <li>human factors</li> </ul>
<b>Field research</b>	<ul style="list-style-type: none"> <li>realised under natural conditions (light, bottles, water, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>do not integrate human factors</li> <li>tend to use optimal technical conditions (e.g. new bottles, good climatic conditions, ideal location for exposure), which are not always available in the field</li> </ul>
<b>Demonstration workshops</b>	<ul style="list-style-type: none"> <li>almost "real" condition</li> <li>tests have to be carried out under conditions that may not be optimal (water, weather, exposure, etc.)</li> <li>all results are directly presented to the workshop participants and have a highly educating effect</li> </ul>	<ul style="list-style-type: none"> <li>do not integrate all sources of error that can be found at user level</li> </ul>
<b>Users' household</b>	<ul style="list-style-type: none"> <li>possibility to know the real quality of water at the moment of consumption</li> <li>all technical and human parameters are considered, including possible secondary contamination</li> </ul>	<ul style="list-style-type: none"> <li>not possible to evaluate the inactivation rate as the initial contamination is not known.</li> <li>difficult to define the source of contamination when bacterial contamination is found</li> </ul>

Table 15: SODIS efficiency under different conditions

Laboratory research has been conducted under strictly controlled conditions, where the most relevant parameters were exactly defined. Selected strains of bacteria or virus were exposed in quartz tubes to artificial radiation simulating sunlight, while defined temperatures were maintained. The laboratory tests allowed quantifying and understanding the effect of UV radiation and heat in the inactivation process of water pathogens.

In a second step, SODIS was tested under real conditions in extensive field research carried out by EAWAG's partner institutions in several developing countries. The next chapter briefly presents the most relevant results from this field research.

Finally, the efficiency of SODIS as disinfection method was presented in demonstration workshops and monitored at household level.

#### 3.2. SODIS efficiency in field research

Since Acra's research in the late seventies, a wide range of field investigations has been carried out. SODIS efficiency was systematically tested for different pathogens, using different water qualities, various types of containers and under different climatic conditions.

The field tests allowed to define the conditions under which a high level of efficiency may be obtained. These criteria have been discussed in chapter 2; below, we just list up the three most important parameters of SODIS application:

- Use of transparent plastic bottles of up to 2 litres volume.
- Expose the bottles 5-6 hours under full sunshine or slightly cloudy sky (half covered) from 9am-3pm.
- Water turbidity shall not exceed 30 NTU.

Fulfilling these requirements, field tests confirmed the results from laboratory research, in which a 3 log reduction of faecal coliforms is achieved. **This means that under normal conditions SODIS shows an efficiency of about 99,9%.**

Results obtained from field research carried out in different countries highlight the efficiency of SODIS for different parameters.



The water used for SODIS needs to be clear

## Physical & chemical water quality

### *Turbidity*

Raw water used for SODIS should be as clear as possible. However, field tests reveal that **turbid water up to 30 NTU may be treated with SODIS** under normal climatic conditions. **Water of higher turbidity needs to be pretreated** [16,25].

### *Oxygen*

Laboratory research showed that inactivation of bacteria (*E. coli*, *Enterococcus faecalis*, *Streptococcus faecalis*, faecal coliforms) is much more efficient in aerobic than in anaerobic conditions. Field tests confirmed that the **shaking of bottles enhances SODIS efficiency**, but suggest that the effect is smaller than assumed by laboratory research.

It is recommended to **shake ¾-filled bottles for about 20 seconds** before filling them completely. Especially stagnant water of low oxygen content drawn from ponds, cisterns and wells should be aerated before sunlight exposure [20,25,17].

### *Colour*

Tests have shown that high levels of **colour in the water increase the time required** for inactivating the pathogens [25].

## Microbiological water quality

### *Faecal coliforms*

Most laboratory and field tests have been carried out with *Escherichia coli* bacteria or with faecal coliforms (a group of faecal bacteria that include *E. coli*). Under normal conditions, the disinfection process shows an **efficiency level of about 3 logarithms (99,9%)** [15,16,20].

### *Vibrio cholerae*

Inactivation rates for *V. cholerae* are similar to the ones for faecal coliforms with water temperature > 50°C. If the threshold temperature of 50°C is not reached, **V. cholerae shows higher inactivation rates than faecal coliforms** [16,23].

## Parasites

Laboratory tests suggest that *Giardia* (*G. lamblia*, *G muris*), a very common water-borne parasite, is susceptible to sunlight. Another parasite, *Cryptosporidium parvum*, seems to be more resistant. However, it is worth to note that *C. parvum* is also very resistant to chlorine [14,24]. Field tests are currently carried out with both parasites.

## Analysis of SODIS efficiency in demonstration workshops

Workshops offer a good opportunity to test SODIS efficiency under a wide range of conditions. Parameters like water, weather, exposure time are set by the local conditions. Often, different types of containers and bottle supports can be tested, so that the participants themselves can assess the most suitable conditions for SODIS and promote it accordingly.

Table 16 summarises all the available data from SODIS workshops held in Latin America in the last three years. **81% of the analysed samples showed a disinfection rate on faecal coliforms of more than 99,9 %**. The remaining 9% of the samples were in the range of 99-99,9%, and 4% of the samples in the range 90-99%. Only 5% of the analysed samples showed an efficiency of less than 90%.

An interesting detail: no difference between half-blackened and unpainted bottles was observed in these workshops. This is probably because most of the workshops had been conducted in high altitude regions, where water temperatures are low (<50°C) but UV radiation intensity is high.

## Water quality at user level

To measure the SODIS efficiency at user level is not as simple as during a demonstration workshop. In fact, the inactivation rate of bacteria cannot always be defined accurately, as data on the initial contamination often is not available. Due to operational, logistical or human limitations, a survey of SODIS efficiency at user level is difficult. Current SODIS dissemination projects focus on social and educational aspects, water quality is generally monitored occasionally, mainly with a didactic purpose, to demonstrate SODIS efficiency to the users.

Normally, SODIS treated water is analysed simultaneously with raw water. The raw water is taken from the same water source as the SODIS water was taken earlier, but it is not exactly the same water. Therefore, it is not possible to measure the exact SODIS inactivation rate, but the quality of SODIS water is compared with the general water quality of the user's drinking water taken directly from the source.

The best data available at user level comes from a SODIS implementation project realised in two rural communities of the Matagalpa region in Nicaragua [27]. Both communities do not have a water distribution system, and get their water from 5 different water sources (covered pump well, uncovered well, natural spring, etc.). The microbiological quality of the sources varies from 0 to >2'000 FCU/100ml. All samples taken from the household storage vessels showed faecal contamination due to primary pollution of the source or secondary contamination during transport and/or storage. After an intensive awareness raising and training phase, 63 of

Efficiency level	% of samples	Nr of samples
> 99,9 %	81.2	95
99-99,9%	9.4	11
90-99%	4.3	5
< 90%	5.1	6
Total	100	117

**Note.** The data has been collected during 25 workshops in Bolivia (22), Honduras (1), Ecuador (1) and Peru (1) between 1999-2001. A total of 117 SODIS water samples have been processed and compared with the raw water quality. All samples with a water turbidity of less than 30 NTU, initially contaminated with faecal coliforms and an exposure starting before 10 am have been included in the evaluation. It is worth to note that all samples with an efficiency lower than 90% were measured during a single workshop in Peru under very unfavourable climatic conditions.

Table 16: SODIS efficiency during demonstrative workshops



Testing the water quality of SODIS water and raw water with the DelAgua field-test-kit.

Efficiency	% of samples	Nr of samples*
> 99,9 %	64.6	31
99-99,9%	0.0	0
90-99%	20.8	10
< 90%	14.6	7
Total	100	48

Other statistical data:  
- average raw water quality: 154 FCU/100ml (median 56 FCU/100ml)  
- average treated water quality: 8 FCU/100ml (median 0 FCU/100ml)

\* From the 63 initial samples, 15 samples of the raw water had an uncountable faecal coliform concentration (> 2'000 FCU/100ml). As the efficiency may not be calculated from undefined initial concentrations, these 15 samples have not been included in the table.

Table 17: SODIS efficiency at user level (example from SODIS project in Nicaragua)

66 households adopted SODIS as a new treatment method for their drinking water.

During follow-up visits to each household, an adult was asked for two samples of untreated and SODIS water from the household storage recipient. In most cases, the SODIS treated water was taken directly from the plastic bottles, although some households stored it in a clay pot, with a potential risk for secondary contamination. Both samples of treated and untreated water were tested for faecal coliforms, allowing to indirectly calculate the SODIS efficiency. The results of these tests are presented in Table 17.

It is important to stress that the table shows data from a single project with its specific conditions, and may not be generalized for every SODIS project. These data integrate all possible sources of error or contamination at user level: not optimal positioning of bottles, too short exposure time, secondary contamination due to bad storage, etc. Therefore, it gives a very good idea of what can be achieved in terms of water quality improvement at user's level.

## Bottles and bottle support

### Plastic Bottles

Field tests show that **transparent PET bottles of 2 litres volume are very appropriate containers** for SODIS. Tests show good results for both returnable and one-way bottles, however one-way bottles are slightly better as they transmit more UV radiation. The effect of aging does not significantly affect the transmission coefficient of one-way bottles.

**Coloured bottles do not transmit enough UV radiation;** these bottles should not be used for SODIS [19,20].

### Glass bottles

Transparent glass bottles theoretically may also be used as an alternative to plastic bottles. However, **glass with a higher content of iron oxide transmits less UV-A radiation**. Field tests confirm that certain glass bottles show lower disinfection rates. Furthermore, glass bottles frequently break. Therefore, glass bottles are not recommended [14,16,21].

### SODIS bag

Especially developed SODIS plastic bags show higher efficiency due to a better surface-volume ratio, but they are not recommended as they are not available locally, are **difficult to handle, break faster than plastic bottles** ([16], SODIS News No.1, SODIS News No.3).

### Plastic bag

Locally available transparent polyethylene plastic bags have been tested and show a very high disinfection efficiency, but **are not recommended** for the same practical considerations as described for the SODIS bag [22].

### Bottle support

A similar temperature increase may be obtained with the **use of CGI-sheet as support for water bottles**. Other dark support are also suitable [16,20]

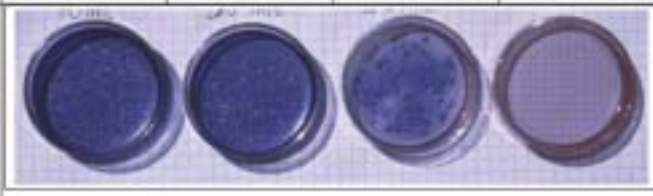


CGI-sheets reflect sunlight and therewith are an ideal bottle support for SODIS



### Example of analyses conducted at a workshop in Ecuador

SODIS is still a very new technology for many government officials and field staff. It is quite common that participants in workshops are very enthusiastic about the idea of Solar Water Disinfection, but still have doubts regarding the efficiency of the method, and hesitate to drink SODIS water ...

	Original Quality	After 1 hour	After 2 hours	After 3 hours
				
Faecal coliforms FC/ 100ml	18'200	2560	256	0

The best approach to fully convince the participants that SODIS really works, is to integrate practical training on the application of SODIS during the first day of the workshop, followed by microbiological analyses. After exposing the bottles to the sun, samples of raw and SODIS-treated water are analysed for faecal coliforms with a portable water quality testing kit (OXFAM-DELAGUA

Water Testing Kit). The water samples are filtered, and the filters containing bacteria are then incubated for 16-18 hours at a temperature of 44°C. The next day, colonies of bacteria can be counted and SODIS efficiency is evaluated.

The following table shows an example from a workshop held in Quito, Ecuador, in July 2001. The participants were divided into two groups: the first group used untreated tap water from the community of Amaguaña; group No. 2 used spring water mixed with polluted water from the San Pedro river. Turbidity of both waters was lower than 5 NTU.

Group 1 (tap water)			
Type of container	Initial conc. [FCU/100ml]	Final conc. [FCU/100ml]	Efficiency [%]
Returnable plastic bottle	51	0	100
Half-blackened returnable plastic bottle	51	0	100
Non-returnable plastic bottle	51	0	100
Half-blackened non-returnable plastic bottle	51	0	100
Group 2 (spring mixed with river water)			
Type of container	Initial conc. [FCU/100ml]	Final conc. [FCU/100ml]	Efficiency [%]
Returnable plastic bottle	284	1	99.6
Half-blackened returnable plastic bottle	284	0	100
Non-returnable plastic bottle	284	0	100
Half-blackened non-returnable plastic bottle	284	0	100
Control bottle (without exposure)	284	202	29

Bottles were exposed to the sun from 8:30 am to 4 pm in full sunshine in the morning, clouds around midday, and rain in the afternoon. None of the bottle reached the threshold temperature of 50°C, but the UV radiation during the day was sufficient to fully disinfect 7 of the 8 bottles. One bottle showed an efficiency of 99.6% (a returnable bottle). During previous experiments these bottles showed a lower UV-A transmittance and therewith a lower SODIS efficiency. No significant reduction was observed in the control bottle without exposure.

The workshop participants critically analysed the test results presented on the petri dishes, and thereafter were convinced of the microbiological efficiency. Conducting such tests therefore is a very good approach to overcome doubts on the effectiveness of the method. The event was concluded with what is now a tradition in the SODIS workshops: A toast with SODIS water!

## Influence of weather conditions

### *Cloudy sky*

With covered sky conditions, it is possible that the UV dose received during one day of exposure will not be sufficient to achieve a satisfactory water quality. Laboratory tests realised with viruses showed that the radiation dose is cumulative and **that two consecutive days of exposure may be sufficient to inactivate the pathogens.**

This data still needs to be confirmed under natural conditions and for other pathogens, especially bacteria [15,16].

### *Parameters affecting water temperature*

**Air temperature** and **wind** are the two climatic factors influencing the water temperature, which has a direct impact on the efficiency of the process.

However, field test carried out in the north-west plateau in China and in the highlands of Bolivia reveal that **countries with cold/temperate climates are also suitable for SODIS, provided sufficient solar radiation is available** [20,21].



*Exposure of SODIS bottles in Thailand*

## Users' handling of the SODIS application

**Users often make mistakes in the application of SODIS that significantly can reduce SODIS efficiency.** For example, bottles are exposed to the sun in the morning, but after a few hours the area is in the **shade**. Or some users expose the bottles with the black coloured side towards the **sun**, or put them **vertically**, or **do not remove the label...** **Intensive training and follow-up visits** are the only way to correct bad handling practices and improve the disinfection efficiency at user level, as shown by the following practical examples:

- Environmental Concern (EC) in Khon Kaen, Thailand, selected two villages using rainwater as raw water source. The rainwater is collected from the roof of the houses and stored in jars. During the handling while withdrawing the rainwater from the jars, the water is very likely to get contaminated. During the first phase of the project, SODIS could only increase the percentage of unpolluted samples from 59% (raw water samples without faecal contamination) to 78% (SODIS water samples without faecal contamination). Several SODIS water samples even showed a higher contamination level than the raw water. Secondary contamination caused by poor handling is the most likely cause for this rather surprising result. The villagers were advised **not to use contaminated containers** for drinking water storage when transferring the treated water. During the second test period, only 33% of the samples of the untreated water were free of faecal coliforms, the number of uncontaminated samples rose to 93% for the SODIS water (SODIS News No.1, SODIS News No.2).
- In the rural community of Melikan, Indonesia, 40% of the villagers have started to place their containers on chairs or concrete floors which, compared to exposure on corrugated zinc, tile roof or other black support, are not ideal locations. **The back part of the chair often shaded the bottles a few hours later.** Only 50% of the exposed water samples were free of faecal coliforms. After people

## ***Is it or is it not SODIS water?***

Extension workers making follow-up visits in the communities have developed a few tools to check if people really are using SODIS in their daily life, or if they only say they do in order to please the interviewer... Asking for a glass of SODIS water is of course the best way to see if safe drinking water is available at the moment of the visit. A quick visit to the place where the bottles are exposed may also be very instructive: cold bottles have been found at midday more than once ... a sign that the bottles had just been filled up at the arrival of the project staff! Or the bottles show a thin layer of dust... probably they haven't been removed from the roof since the last visit!

While monitoring the water quality at household level, it is sometimes very difficult to know if the given water sample really has been treated. To mention an example from the Matagalpa project in Nicaragua, the following question was asked during a baseline study: "What kind of treatment do you apply to your drinking water?" 22 of 52 households responded that they use chlorine. The water containers of the 22 households were tested, but residual chlorine was only detected in 2 containers...

Obviously, the same may occur when analysing SODIS water: is it really SODIS, or does it just look and taste like SODIS water, but actually rather looks like raw water from the microbiological point of view?

A survey of the microbiological water quality may be useful when evaluating the results of a project, but it also has some disadvantages:

- bacteriological analyses are relatively expensive,
- extension workers and users may feel that SODIS is not a safe technology if the water quality is not analysed,
- a SODIS project placing too much importance on analytical aspects would probably lose sight of the fact that the implementation of SODIS is not a technical problem but far more an education/ communication issue,
- periodic sampling may be perceived as too much external control.

Therefore, bacteriological analyses is a valuable didactic instrument for demonstration purposes, but not indispensable for the implementation of SODIS at community level. The SODIS Foundation in Bolivia provides us with a good example: in the last two years, the staff has conducted hundreds of tests during demonstration workshops, water quality monitorings in the communities, follow-up visits at household level, etc. But the SODIS water treated daily on the office roof and drunk by the staff has never been analysed, not even once, as nobody considered it as necessary!

received training and suitable corrugated zinc sheets, the number of inadequate applications dropped to 3% [26].

- In Indonesia, a comparison between a rural and peri-urban community showed that the number of **incorrect applications was significantly lower among the higher educated population** of the peri-urban community. However, both communities were able to further improve the treatment efficiency through additional training ([26] / SODIS News No.2).
- In Bolivia, during a demonstration project carried out in the community of Sacabamba, a few SODIS water samples contained high concentrations of faecal coliforms. **The very dirty screw tap of the bottle was most probably responsible for that contamination** [21].
- In China, field tests carried out with 2.5l glass bottles revealed that SODIS could increase the number of samples free of faecal coliform from 25 % (raw water) to only 72% (SODIS water). After **replacing the large glass bottles by more adequate 1.25l plastic bottles**, 99,2% of the tested SODIS samples showed 0 faecal coliforms (SODIS News No.2)

## Conclusions of SODIS efficiency in the field

The data collected during almost a decade of field research, demonstration workshops and monitoring at user level confirmed that **SODIS is a reliable method for drinking water disinfection at household level.**

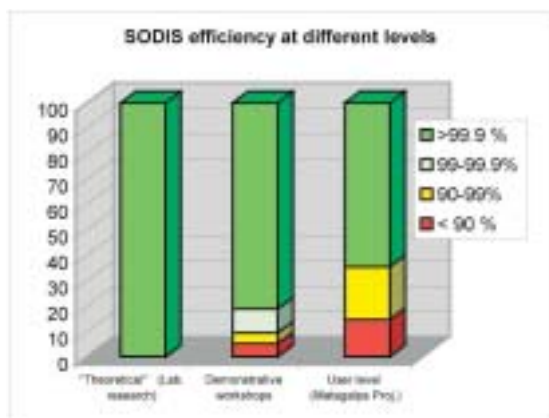


Figure 18: Comparison of SODIS efficiency at different levels

Figure 18 compares the SODIS efficiency for removing faecal coliforms in the laboratory with the SODIS efficiency under less optimal conditions such as a demonstration workshop in Latin America and at user level in Nicaragua.

We can conclude that **SODIS proved to be efficient not only under laboratory conditions, but also at user level**, provided that the basic technical requirements are fulfilled.

However, SODIS will probably never supply 100% safe water to the whole population. **Poor handling practices and inadequate application of the method lead to a reduced SODIS efficiency, or the treated drinking water is subject to secondary contamination. The objective of SODIS therefore is to significantly reduce the risk of microbiological infection.**

After years of research and field testing, the challenge of reducing the incidence of water-borne diseases through SODIS use is now lying in the hands of the institutions and field workers in charge of hygiene education and sanitation programs. Through appropriate diffusion of the information, intensive training of users and follow-up, people will have access to a simple and affordable alternative to improve the microbiological quality of their drinking water at household level.

### 3.3. Lessons learnt from the application in the field

- Appropriate containers are transparent PET-bottles of up to 2 litres volume.
- In warm climatic conditions, where water temperatures reach 50°C during exposure, half-blackened bottles may be used, as the water temperature increases quicker in such bottles.
- In high altitude regions, where the water temperature remains cold, fully transparent bottles should be used in order to optimise the effect of UV-A.
- The efficiency of SODIS will be increased if bottles are placed on a reflective surface such as for example aluminium or CGI-sheets.
- The bottle needs to be exposed to the sun for 6 hours if the sky is clear or up to 50% cloudy. The bottle needs to be exposed to the sun for 2 consecutive days if the sky is 100% cloudy. During days of continuous rainfall, SODIS does not perform satisfactorily. Rainwater harvesting is recommended during these days. If a water temperature of at least 50°C is reached, 1 hour exposure time is sufficient.
- Water with a turbidity of more than 30 NTU needs to be filtered before it is filled into the SODIS bottle.
- The SODIS efficiency is increased at higher levels of oxygen in the water. Aeration of the water can be achieved by shaking the 3/4 filled bottles for about 20 seconds before they are filled completely.

### 3.4. Health benefits of SODIS

Solar water disinfection (SODIS) provides an unusually simple, efficient and sustainable drinking water treatment option. Thus it reduces health risks associated with the consumption of contaminated drinking water.

#### Type of diseases reduced by SODIS

SODIS affects pathogens present in the drinking water and therewith reduces the occurrence of enteric diseases caused by these pathogens:

- **infectious diarrhoea**  
from bacterial infections with enteropathogenic *Escherichia coli*
- **dysentery**  
watery diarrhoea from bacterial infections with *Salmonella* or *Shigella*
- **dysentery**  
from parasitic infection with *Giardia lamblia* ("Giardiasis") or *Entamoeba histolytica* ("Amoebiasis")
- **cholera**  
from bacterial infection with *Vibrio cholera*

A number of viral agents such as rotavirus and adenovirus are responsible for a large burden of viral gastroenteritis, however, **routes of infection other than through drinking water dominate virus transmission and infection (person-to-person, droplets).**

Table 19 shows the infectious dose (number of organisms required for an infection) for different pathogens.

#### Indicators used to assess health benefits from SODIS use

Chapter 1.3 describes the **multiple and simultaneous transmission routes** of diarrhoea causing pathogens. **As pathogens are transmitted through different pathways, it is difficult to measure health benefits attributed to an improved quality of drinking water.**

Measuring the health impact of SODIS is also very difficult, as the multiple factors of disease transmission have to be considered in the evaluation. Thus, health impact assessments on SODIS are complex. So far, only a few studies have investigated the effect of SODIS on improving the users' health.

Four studies measured the effectiveness of SODIS on the health improvement of children of various ages.

How was the health impact of SODIS measured? The occurrence of different types of diarrhoea was compared between families that use solar water disinfection at home and those that do not use it.



4 billion cases of diarrhoea cause 2.2 million deaths, mainly among children under the age of five [2].

Infectious dose of enteric pathogens	
Pathogen	Infectious dose
<i>Shigella</i>	10 <sup>1-2</sup> organisms
<i>Campylobacter jejuni</i>	10 <sup>2-5</sup> organisms
<i>Salmonella</i>	10 <sup>5</sup> organisms
<i>Escherichia coli</i>	10 <sup>8</sup> organisms
<i>Vibrio cholerae</i>	10 <sup>8</sup> organisms
<i>Giardia lamblia</i>	10 <sup>2-3</sup> cysts
<i>Entamoeba histolytica</i>	10 <sup>2-5</sup> cysts

Table 19: Infectious dose of enteric pathogens [34].

Indicators to assess the impact of SODIS were ;

- “reported diarrhoea”: bowel movements more than “usual”. Generally measured as more than 3 movements per day.
- “severe diarrhoea”: affecting daily chores, school attendance and life

### Results from field studies on health benefits from SODIS

The results from these studies can be summarised as follows:

**- SODIS reduces the number of new cases of diarrhoea**  
In Kenya, a study among 206 ‘adolescents’ aged 5-16 years was conducted. During the four-month study period the number of **new cases of diarrhoea** in families using SODIS was **10% less than in families** that were not using the method [28].

Another study among Kenyan children under 5 years showed a similar reduction of 16 % of diarrhoeal illnesses among SODIS users over a one year observation period [29].

In Bangladesh, SODIS was introduced in 16 villages. The uptake of the method was promoted by local development committees. Child diarrhoea was significantly less frequent in villages with a strong committee, high level of village organisation and commitment for community development, which led to a better adaption of SODIS by the villagers [30].

**- SODIS reduces the number of severe cases of diarrhoea**

The same study [28] found a **24% reduction of severe diarrhoea** among children of families that used solar-disinfection of drinking water.

**- SODIS helps to prevent cholera**

A cholera outbreak occurred in the same study area in Kenya in 1997/98. The researchers were able to demonstrate the efficiency of solar water disinfection for **cholera prevention** in children below the age of 6. Among SODIS users, **children below 6 were 8 times less likely to contract a cholera-diarrhoea**. For older children, adolescents and adults no preventive effect was found [31]. This could be attributed to the fact, that mothers strictly controlled the type of drinking water consumed by their small children, while older people also drank water from contaminated, not treated water sources.

Further information on the effect of consuming SODIS treated water on human health is presently being collected during a health impact study in Bolivia. This public health research project will measure the impact of SODIS on reducing child diarrhoeal illness. This SODIS health evaluation project is conducted by the Swiss Tropical Institute (STI) in collaboration with Bolivian partner institutions: the Fundación SODIS, CASA at the University Mayor of San Simon in Cochabamba and UNICEF Bolivia.



*Exposure of SODIS bottles in Thailand*

### Can SODIS be used for babies?

Women who cannot breastfeed their babies may be forced to prepare food for their babies from powder milk. During project implementation at users' level the question may come up if SODIS treated water can be used for the preparation of powder milk for babies or for weaning food.

SODIS removes 99.9% of the bacteria and viruses and also removes parasites to a certain degree from contaminated water, but **the water is not sterilised through SODIS and a certain risk of contamination and consequential infection remains. As babies are fragile and very quickly dehydrated, they are subjected to a very high death risk due to diarrhoeal illnesses. The remaining infection risk from consumption of SODIS water therefore must be eliminated and only boiled water, which is sterile, should be used for the preparation of powder milk or weaning food for babies.**

When babies are about 6 months old, women successively start to complement breast-milk with other food. This is a very critical time for the children. Health statistics from the developing world show that this age group has a very high morbidity and death risk due to diarrhoeal diseases. Therefore, it is important that all food given to children of this age in addition to milk is carefully being prepared through boiling.

SODIS may be introduced to children at the moment when they actively move around and start to drink on their own at the age of about 18 months.

### Other limitations of SODIS use

Boiled water instead of SODIS water should also be used by persons with a considerably increased risk of infectious diarrhoeal diseases including:

- Severely ill children and adults
- Severely malnourished children and adults
- Patients with decreased immuno-deficiency (AIDS)
- Patients with gastro-intestinal abnormalities or chronic gastrointestinal illnesses



*Weaning food for children under 18 months should be prepared with boiled water*

### What adults can learn from children...

A promoter told the SODIS project team in Usbekistan the following story: A boy had heard about SODIS at school. He was thrilled about the idea and got himself some bottles. He painted them black and prepared SODIS water in them. When the promoter visited the family, he was served a watermelon, which they ate together with great delight. After the meal, the boy brought SODIS water, but his father remarked with defense: *"SODIS isn't necessary. I always drank directly from the tap and I never got sick!"* The boy tried to convince him that especially after eating a watermelon he shouldn't drink untreated water. The father, however, didn't listen and drank directly from the water tap. The boy and the promoter served themselves from the SODIS bottle.

A week later, the promoter visited the same family again. They told him that the father had come down with severe diarrhoea the next day and hadn't been able to go to work for three days. The promoter and the boy on the other hand had stayed healthy. Now the father drinks only SODIS water.



Beat Grimm, JDA Kokand





## 4. Training of Promoters

### 4.1. Training approaches and methods

#### Methods used to train the promoters

The methods used to train the promoters must be **simple and explanatory**, so that they themselves can use similar methods during their work in the community.

The knowledge on SODIS generally is transmitted to the future promoters in a series of sessions, using **participatory methods** like the ones explained in the following paragraphs.

**It can be difficult to address issues that are considered private subjects, especially for women who feel ashamed to speak about hygienic behaviour in the household.** To overcome such difficulties, it is very important to **work with positive messages**; such as for example that soap makes hands clean and gives them a good smell.

#### 1. Comparing SODIS with other water disinfection methods

This session introduces the promoters to different methods of water treatment which can be used at household level (boiling and chlorination) and compares the **advantages and disadvantages of all the methods**.

The promoters must receive written background documents covering the topics of this session, which will serve as reference material for their future work in the community.

#### 2. Exposing SODIS bottles to the sun

The promoters must have a sound knowledge of the SODIS application and **serve as an example for the users in the villages**. Therefore it is important that the **promoters use SODIS for the preparation of their own drinking water**.

When training the promoters in the application of SODIS, the conditions should match the real conditions in the field as far as possible. A SODIS demonstration should best be conducted in the area where SODIS will be introduced in the future (instead of demonstrating it in the distant city where the climatic conditions may be different).

The topic to be covered during the SODIS demonstration are: the **type of bottle** to be used, the **position of the bottles**, the **place of exposition**, the **duration of exposure**, the **washing and cleansing of the bottles**. These details are very important for the correct application of SODIS. Emphasising them while training the promoters may enhance the correct transfer of this knowledge to the community.

#### Who are the promoters?

The promoters are the contact persons between the local population and the institution that wishes to disseminate SODIS. The promoters transmit the knowledge on SODIS and they are the ones to verify the correct application of the method.

#### What do the promoters do?

The promoters teach the correct application of Solar Water Disinfection. By regularly making home visits, the promoters check the application of SODIS and correct possible mistakes made by the users.

#### What kind of knowledge must the promoters have?

As SODIS is a method to improve the quality of drinking water, it is important, that the promoters have good knowledge about all issues related with water and sanitation. They must be able to explain local communities the relation between the quality of drinking water, safe handling of water, contamination of water, disposal of excreta, and the effects on health.

The promoters must have knowledge on water sources and water distribution systems and the problems connected with maintenance. They must understand different methods and possibilities to disinfect drinking water at central or household level and know the advantages and disadvantages of the different water treatment methods.

#### What kind of qualifications are required from a promoter?

As the promoters are the ones who are in direct contact with the population, they must have a very good and clear understanding of SODIS and general hygiene practices. They must be able to transmit their knowledge to people with little or no school education. Therefore it is important that the promoters are familiar with the local community and have a good relation with the people. They must be able to speak the local language, have good communication skills and an active personality. The promoters have to be able to start and guide group discussions.



Training of promoters in Bolivia

3. Testing the water quality before and after the SODIS application

It is very useful to conduct a microbiological analysis of the water quality before and after the application of SODIS. Such an analysis is observed with much interest and convinces doubtful trainees of the effectiveness of SODIS.

The knowledge on the bacteriological transmission routes will help the promoters to identify possible sources of water contamination in the villages and give adequate instructions on water protection.

It is also important to explain the criteria water must have in order to be suitable for the SODIS application: It is necessary to **avoid very turbid and highly contaminated water**.

4. Audio-visual methods

During the presentation of video cassettes on SODIS followed by guided group discussions, the participants are presented examples of SODIS application in other regions and, thereafter, discuss and reinforce the main concepts of the method and its application.

5. Water and health

It is important to transmit sufficient knowledge on the **relation between health and the quality of water**. Generally, gastrointestinal diseases are a common problem in many households and people feel a strong need to solve this problem. Promoters therefore must be able to explain **why gastrointestinal illnesses are caused by the consumption of contaminated water and how the contamination of drinking water can be avoided**.

It is necessary that people with good medical knowledge explain health related issues, preferably nurses, health advisors or other people with medical qualifications.

6. Personal accounts of experiences with SODIS

Personal accounts of people who already worked as SODIS promoters, are very instructive. Experienced promoters can present details encountered during daily project work, which generally are not presented in texts. The **dialog** between the experienced and future promoters introducing SODIS on the basis of personal experiences yields very good results.

7. Group visits to a family of potential SODIS users

It is a good approach if trainees visit possible future SODIS users together with an experienced SODIS promoter. Under the supervision of the experienced promoter, the trainees identify the subjects to be explained to the users' family based on the issues they learned during the previous lessons, and **they do the training** on SODIS application accordingly. It is helpful if the experienced promoter prepares a list of questions, allowing the trainees to successfully conduct a training.



Training of promoters in Uzbekistan

*In Uzbekistan, the SODIS promoters were trained in technical details of the SODIS method as well as in teaching the community about the relation between clean water and health. An additional 1.5 days training on participatory approaches, such as the Participatory Community Appraisal were included in the training curriculum. The following methods were used during the training:*

- lectures
- working in groups
- role playing
- practical exercises

*The training consisted of one initial week of training, followed by three further training sessions each of two days duration, over the following six weeks.*

*After the training, the promoters received two complete outlines for training in the communities: one outline for SODIS training and one for hygiene. Each team was expected to adapt the outline to the particular local situation in the villages.*

*During their work in the villages, the promoters received regular support from the project office in Kokand. Every two weeks, the promotion team met with the technical resource person in the office to discuss the work progress, the experiences in the villages and difficulties encountered. In addition to these meetings the technical resource person regularly visited the promotion teams during their work in the villages.*

## **4.2. Training material**

Training material for promoters must be easy to understand, so that the promoters easily can use them during their work in the field. The following material can be used for training:

### **Flipchart Posters:**

A laminated series of coloured posters of appropriate size (40\*60cm) with pictures illustrating the subjects to be explained during the SODIS training. Such flipcharts can well be used when explaining SODIS to a small group of people. (see Annex A).

### **Explanatory technical sheets:**

Also explanatory technical sheets should be large enough, for them to be presented to an audience. The technical sheets must be simple and easy to understand. The trainees should also receive technical texts containing the references to scientific publications on SODIS.

### **Videos on Solar Disinfection**

The videos are shown to the trainees in order to generate questions when comparing the presented SODIS application with local conditions. The video presentation should be followed by a group discussion.



*Training material must be well designed and easy to understand*

### Example of a training workshop for SODIS promoters

#### Programme of the 19 June 2001

##### Preparation:

Around 8 o'clock in the morning, we expose the SODIS bottles containing contaminated water and thermometers, as well as a radiation meter to the sun. The participants are instructed to read the temperature in the bottle and the radiation intensity every hour.

A control set of bottles with contaminated water is kept in the shadow.

Time	Topic	Responsible person
14.00-14.30	Presentation of the SODIS method and presentation of the objective of the workshop	Ana
14.30-14.40	Working in groups, discussing water sources, sources of water contamination, water and health	Ana, Esteban
14.40-15.00	Presentation of group work	Participants
15.00-16.30	Different methods for water disinfection: Boiling, chlorination, SODIS Work in three groups 15 Min Explanation 60 Min Preparation 45 Min Presentation	Ana, Esteban
16.30-16.45	Tasting of water that has been prepared with three different methods	Participants
16.45-17.00	Preparation of conclusions – Advantages and disadvantages of each method in groups	Participants
17.15-17.30	General conclusion	Ana, Esteban
17.30-18.00	Reinforcing SODIS	Esteban
18.00-18.30	Presentation of the results of Water Analysis with the microbiological field test kit on the water exposed during the previous day	Esteban
18.30-19.00	Presentation of SODIS video	Ana

### 4.3. Lessons learnt during the training of promoters

- The promoters must have a sound knowledge of the correct application of SODIS, as such a person will be more convincing than an insecure person.
- The promoters must apply SODIS for the preparation of their own drinking water. In this way they are certain about the correct application of SODIS and they serve as an example for the target community.
- The promoters should be capable to answer questions from the community. Check on this before the promoters start working in the community.
- Advise the promoters to never lie in case they cannot answer a question from a user. In such a case they should contact the technical resource person
- The promoters must speak the local language.
- The optimal size of a promotion team is 2 persons.
- The NGO and the promoters have a very important role for the promotion. Their example serves to make SODIS credible.

- The technical resource person should develop a list of criteria to select the promoters.
- In the training sessions, the same methods should be used that later will be applied in the villages. In this way promoters have the opportunity to train and practice their future work.
- During the training, emphasis should be placed on good communication skills and confidence building.
- The training should build on previous experiences and existing knowledge of the promoters.
- The promoters should be carefully observed during the training to assess their motivation and capabilities.
- Inform the promoters that behavioural changes take time. And include a lesson on “resistance to changes” in the training curriculum.



*Experience has shown that training workshops carried out with non-participatory methods are not effective, but more likely to bore the participants.*



*Actively involving participants with participatory methods, requiring their active involvement in the sessions and allowing them to comment, is a better way to get the message across. . At the same time the participants learn and practise participatory approaches which they can apply themselves during their field work.*



## 5. Training of Users

### 5.1. Conducting a need assessment at community level

Prior to introducing to a community, it is important to **assess the local environmental situation, the existing water supply situation, water handling practices, and water treatment and consumption patterns. SODIS should only be introduced to the community after conducting and evaluating a need assessment and if the introduction of SODIS is found necessary.**

The following questions should form part of the need assessment:

#### Questions on the existing water supply and water consumption:

- Which raw water sources are used for drinking water?
- Are the water sources protected or open?
- Is the water polluted at the source?
- Do people consume microbiologically contaminated raw water?
- Do people use some methods for drinking water purification?
- Which methods are applied for water treatment?
- Are the treatment methods applied for all water consumed?
- Are the water treatment methods applied successfully or does the water still contain pathogens?
- How good is the drinking water quality after the application of treatment methods?
- Does the community suffer from waterborne infections?
- During which seasons can you observe a high incidence of water borne diseases?
- How does the higher incidence of diseases relate to behaviour and environmental conditions?

=> It is not necessary to introduce SODIS to:

- ✓ Persons successfully applying other water treatment methods.
- ✓ Persons with access to safe and clean drinking water.
- ✓ Persons free of waterborne infections.

#### Questions on the availability of local resources necessary for the application of SODIS:

- Are transparent plastic bottles available?

=> if bottles are not available locally, a supply scheme has to be initiated. The application of SODIS otherwise will not be sustainable.

- Is sufficient sunlight available throughout the year?

=> If the use of SODIS is only feasible during some months of the year, the community has to be instructed on water treatment methods they can use during months of low solar intensity, such as for example boiling, chlorination or collection of rainwater during the rainy season.

#### Who are the users?

On the basis of the experience and interest people show for the application of SODIS, the users can be classified as:

##### 1. Family using SODIS regularly

In such a family at least 50% of the family members use SODIS for at least 4 days a week. The following conditions have to be fulfilled:

- a) The family has a suitable number of bottles and the bottles are in good condition.
- b) The family exposes bottles to the sun, but also has bottles with water ready for consumption inside the house.
- c) SODIS is applied correctly.
- d) No turbid water is used for SODIS.

##### 2. Family using SODIS irregularly

In such a family less than 50% of the members use SODIS. They use it only 2-3 days a week. Other indicators are that SODIS is not applied correctly and the family does not have a sufficient number of plastic bottles to prepare the required amount of drinking water.

#### Which users should be trained in SODIS use?

SODIS should be introduced to:

- ✓ Persons without access to safe and clean drinking water,
- ✓ Persons in need of a cheap and simple water treatment method,
- ✓ Persons suffering from water borne diseases.

SODIS training preferably should be addressed to the person in charge of hygiene and household cleaning, as well as the person responsible for the preparation of food and drinks. Also children can be trained in SODIS.

#### What kind of knowledge must the users have?

Ideally the users should have enough understanding and knowledge to apply SODIS correctly and they must be aware of the dangers of consuming contaminated drinking water.

## 5.2. Training approaches and methods

**The most effective form of training is to personally explain SODIS to the user family.** This approach however, is very time consuming. **When addressing a single family, it is best to practically demonstrate the application of SODIS.**

Nevertheless, also the **transfer of knowledge to groups of people** is a valid approach. While addressing groups, it is very important to use participatory approaches stimulating the contribution of each participant.

### Training of individual families

This type of training is generally given to families with a close relation to the promoter. In such an atmosphere it is easy to practically demonstrate the different steps of the SODIS application to the family members and address different hygiene practices.



*Posters containing many pictures and graphical material are a good training tool*

#### 1. Addressing secondary contamination of the water

Secondary contamination of drinking water through inadequate handling of the water inside the home can be explained with examples from the user's own house. For example:

- Using the same container to transport water and other things.
- Dirty utensils used for the preparation of food.
- Drinking water directly from the vessel used for the transport of water
- Pools of dirty water around the house.
- The risk of contamination from open water storage containers.

#### 2. Permanent display of posters in the house

Posters containing much graphical material and little written text are well accepted by the users, children as well as adults, and can permanently be displayed in their home. In Bolivia posters containing general hygiene rules were accepted for display in the house (see Annex B).

The promoter explains the pictures on the poster to the family members during his visit. The poster then is left with the user's family for them to remember the explanations of the promoter or to explain SODIS to other people.

#### 3. Practical demonstrations

Direct instructions are given, if the application of SODIS is directly demonstrated to the potential new users. During such a demonstration good bottles are selected and each step of the SODIS application is carefully explained. During this occasion possible doubts expressed by the family on SODIS can be discussed and cleared.

Much credibility is generated if the promoter in the evening consumes from the SODIS water that has been prepared during the demonstration exercise on the same day.



## Training of community groups

The training of community groups is the most common form of SODIS training. Some recommendations before organizing such gatherings are:

- **The schedule of the meeting has to be established in agreement with the villagers**, so that also women, who generally are very busy and do not have much free time, can attend the gatherings. The gatherings should be proposed during general leisure times and **agricultural peak seasons should be avoided**.
- The meetings must be **initiated and directed by persons familiar to the community**, such as community leaders or representatives of respected institutions. Such local leaders are respected persons and the villagers are far more likely to follow advice and training supported by their leaders.
- For each gathering, **a programme has to be prepared with objectives and activities**. The program has to be evaluated at the end of the day.
- During the gathering, an atmosphere of trust has to be created, enhancing the exchange of ideas, questions and experiences.

Some of the methods used in Bolivia for the training of groups are summarized in the following paragraphs.

### 1. The use of flipchart posters

Flipchart posters are a good tool for an audience that cannot read or follow academic lectures. It can skillfully be used with a guide explaining or moderating each page. The flipcharts can be used in small gatherings of up to 30 people. This allows the gathered listeners to see the displayed poster. The flipchart is an instrument allowing the audience to discover the relation between water and health and the effect of Solar Water Disinfection. The illustrations can initiate the discussion between the participants and the moderator. The images on the flipchart posters must represent the environment and the cultural context of the audience (see an example in Annex A).

Another form of using the flipchart posters has proven effective in Bolivia: the participants themselves take up the role of the moderator and explain the situations on the pictures in groups of two or three people. Pages of the flipchart are given to groups of people. The groups are given 5 minutes to study the picture and later explain the content and idea of the picture to the audience. The trainer complements their presentations and clarifies issues that have not been understood. This is a very participative form of presenting the flipcharts, where the participants can contribute their own ideas related to the subject and their daily life.

### 2. Use of story tapes

The presentation of tape recorded stories followed by discussions are a useful tool. The dissemination of SODIS is accelerated and such presentations generally are better accepted than lessons. The stories need to be adapted to the environment and cultural context of the audience in order to attract interest. The recorded story should not be longer than 15 Minutes.

### 3. Practical demonstration of the SODIS application

It is very important to practically demonstrate the application



Community training in Thailand

## Mistakes often made by the users

The SODIS water treatment method is easy to apply. Nevertheless, people need to be trained carefully in its application. Trainers and resource persons should control the application procedure in the local communities regularly in order to ensure a correct and successful SODIS application, especially during the first months of applying SODIS. Repeated visits to communities that recently had been trained in SODIS revealed that the **users made a number of mistakes in the application of SODIS**:

- Bottles were exposed to the sun in the morning, but **after two hours the area was in the shade**.
- Some users put their bottles on a chair, not considering that the **back of the chair does shade the bottles** at some point in time.
- The **bottles were exposed with the wrong side to the sun, i.e. with the black part on top**.
- Some users put their bottles on wooden racks; but **wind moving underneath the rack cools down the temperature and reduces the effectiveness** of SODIS.
- Exposed **bottles were not closed tightly** or different elements were used to close the bottle, if bottle lids were unavailable, as consequence, the water leaked out.
- **Only partially filled bottles** were exposed to the sun. The air bubbles inside the bottle then reduced the UV-A radiation.
- **Turbid, not filtered water**, containing small particles such as for example insects, was exposed.

of SODIS during the community gathering. The demonstration must include the selection of the correct bottle, checking of the water turbidity, filling the bottle (including shaking it and making sure that the bottle is filled completely with water) and exposing the bottle in a suitable place. At the end of the day, the promoter and the gathered participants should drink the treated SODIS water.



Practical demonstration of SODIS in Bolivia

#### 4. Building a sense of prestige

People are more likely to adopt a new behaviour if the activity is prestigious and gives them a sense of pride. The use of plastic bottles to improve the drinking water quality is more sophisticated than to simply drink the water from the tap. Therefore, people drinking SODIS water have a higher prestige in the eyes of the simple community drinking raw water.

#### **Community training in Uzbekistan**

*Good health depends not only on access to clean drinking water, but also on the right hygiene behavior. For this reason, the SODIS team in Uzbekistan provided the promoters with two complete outlines for training sessions: one for SODIS and one for hygiene. Each team was expected to adjust these outlines to their particular village situation.*

*During community meetings the promoters introduced the SODIS method, explained the effect of sunrays and pointed out how diarrhea is transmitted. In some cases, hygiene rules were taught parallel to the SODIS method. During the agricultural peak season, cotton harvest in autumn, it was not possible to organize community meetings because the villagers were busy in the field.*

#### **Taking up contact with the community**

*Village leaders were first contacted and introduced the promotion teams to the interested families. Through the village health posts, the promoters received the information about families with members that recently suffered from diarrhoea or have small children. These families are the ones to be most interested in learning and applying the SODIS method. The promoters were able to build a good relationship with many of the interested people. They visited them once a week and discussed their questions and problems. During the later project evaluation it turned out, that these people applied SODIS most consistently.*

#### **Community training**

*About 20 to 40 adults, and often a substantial number of children, attended the meetings. The villagers followed the meetings with interest and were even willing to participate. For example, after the promoters had presented the SODIS method with the help of pictures, someone from the audience was asked to repeat the preparation of a SODIS bottle. As a reward for his participation he was given a painted SODIS bottle. Villagers who were already applying SODIS shared their experiences and encouraged the audience to follow their example.*

*The technical resource persons in Uzbekistan put emphasis on participatory teaching methods, including role games. The promoters, however, rejected the latter with the explanation that this would make SODIS look ridiculous. Instead, the promoters decided to design their own posters with hygiene rules.*



A good relation between the promoter and the users is important for SODIS promotion

Each team of promoters developed its own approach to explain SODIS to the community during the meetings:

**The mystical approach:** In the community meetings of this team, users related how they were healed of sore throats and stomach aches by drinking SODIS water. SODIS – a type of healing water!

**The rational approach:** This team emphasised strongly that by drinking SODIS water, diseases can be prevented, resulting in families needing less money for medicine. SODIS – a means to save money!

**The relational approach:** The third team put the main emphasis on good relations with decision-makers and key people to whom they introduced the method. SODIS – for your friends!

### SODIS in kindergartens

In the SODIS Project in Uzbekistan educators in kindergartens were trained in the application of SODIS. The educators were enthusiastic about the new method for water treatment, as they are responsible for the children's health. They prepared SODIS water in the kindergartens and gave it to the children.

In some kindergartens, the parents were invited to a meeting and SODIS was explained to them. The educators explained how their children can stay healthy by drinking SODIS. The parents were highly interested in this idea.

### SODIS in schools

SODIS training in Usbek schools was conducted in individual classes or even in big school meetings. The children were very open to the method and understood quickly. At the teachers' initiative, every second child brought a bottle of SODIS water to class. Two children then shared the water in the breaks or for lunch.

Because SODIS is easy, some of the children started using it at home. The most enthusiastic children were honoured with a special SODIS pass and declared promoters. Other schools used posters and brochures and set up SODIS corners in halls and classrooms.



Performance of a SODIS song in the Agua Clara primary school in Bolivia

### Raffles increase the interest in SODIS

Hans Haller tells us about his experiences with promoting SODIS in Igarassu, Brasil: On 21 February 2002 I trained 40 students of the 4<sup>th</sup> grade in the Joao Leite School in Igarassu in the application of SODIS. Each student received a sheet of paper with drawings illustrating how SODIS has to be done. I demonstrated the application in front of the students. Thereafter I asked one of the listeners to come to the front and repeat the important points of the application process. Like this I was sure that the students understood what I had explained to them.

To motivate the children to really use SODIS at home, I promised them to organise a SODIS raffle during the following week in which all those could participate that regularly applied SODIS at home. In this raffle they had the chance to win a bag of foodstuff. One week later 10 students participated in the raffle. The second time I organised the raffle, 12 students participated. After the contest, we accompany the winner to his or her home, to check that he or she really uses SODIS for the preparation of their drinking water.

On 25 March my partner Sandra introduced SODIS to another 25 students of the same school. One week later 7 of those students participated in the SODIS raffle and on 18 April 22 of 56 students took part in the SODIS raffle. Some of the students commented their experiences with SODIS. They said that the water had a very good taste, just like mineral water. 23 students participated in the 5<sup>th</sup> raffle. Eduarda, the winner of this raffle told us that at first she started SODIS using just one bottle, but in the meantime she already treats 5 bottles per day. When she told her mother what she had learned about SODIS in the school, her mother first thought that her daughter had gone crazy. But when we accompanied Eduarda home to hand over the bag of foodstuff she had won, her mother was very happy and convinced that SODIS is a good thing.

Hans Haller, Brasil



## ***Maxi is mini at home***

On the road to Ende I enjoyed the nice hilly landscape near Maumere. Petrus was driving the project car and with us was Pius, in charge of the SODIS project in Flores. We were heading towards the school of Kimang Buleng, where 2 months ago, the local NGO Yayasan Dian Desa (YDD) introduced SODIS to the teachers and to the 138 students. We left the main road near a large football field surrounded by 3 classroom buildings. We parked our car under the shade of a tree and noted that all the teachers were busy holding classes. We did not announce our visit but nevertheless, we soon were greeted by one of the teachers who took us to the office of the headmaster. After exchanging some formalities we were allowed to visit the school premises. Petrus discovered a small tap - the water source of the school. He opened the tap but no water was flowing. One of the teachers informed us that the water supply was not permanent but water usually was running late in the morning.

In the meantime, our group was surrounded by excited and curious school children. I asked a small boy in the front line, called Maxi, to bring a SODIS bottle from the headmaster's office. He proudly ran away and soon returned with a full bottle. Together with the teachers we drank some of the SODIS water which tasted good. However, my interest was not so much focussed on the treated water but rather on the results of the SODIS dissemination. Schools have the advantage of having clear organisational structures with headmaster, teachers and students and, therefore, YDD decided to use schools as entry point for their SODIS promotion campaign. Teachers and students are trained in the use of the new water treatment method in order for the children to introduce SODIS at home.

Therefore, I asked Maxi, my smart little boy to sit next to me on the floor and I offered him some SODIS water. He proudly accepted my offer and carefully filled a glass with water. He was aware that the attention of all his colleagues was now focused on him. We started our conversation and he told me that he is living with his parents and 4 sisters and brothers about half an hour's walk away from the school. When questioned if he also uses his two SODIS bottles at home he became embarrassed. He was the youngest in the family and was not taken too seriously. When he told his family about SODIS, they hardly understood why sunshine should improve the water quality. And they did not listen to Maxi's advice to use plastic bottles for preparing their drinking water. As a result, he did not insist on introducing the new idea, but put the bottles aside and hence, SODIS was not used at his home.



*Maxi, primary school boy, proudly filling a glass of SODIS treated water in Flores, Indonesia*

Maxi is mini at home. Usually, children have to obey their parents and have to defend their position in the family. Similar to Maxi, the youngest often have a difficult role in the family. However, the communication path from schools to families is also rather long. Not all the information might be forwarded correctly to the next level. As a result, such dissemination projects might not produce the expected results. However, YDD also observed that school girls are more successful in introducing SODIS at home. The society is attributing the gender roles already to children - and women as well as girls are the ones responsible for the collection and preparation of water at household level.

Martin Wegelin, SANDEC

### 5.3. Cultural aspects and local resources

#### Cultural aspects

Different ethnic groups have their own cultural beliefs, they use their individual ways of communicating, and perceive the world in their own manner. Each SODIS team intending to work with a specific group therefore has to **adapt their communication and training methods to the group addressed. The cultural context provides the basic framework for each SODIS project.**

Important elements in the case of solar water disinfection are the sun and water. These two elements can have different meanings and levels of importance in specific cultural groups. Another aspect is the fact that in certain cultures women do not speak in public meetings, or that villagers refuse to speak of certain issues without the authorisation of the community leader. It is therefore a good idea to have group meetings with potential SODIS users in order to understand their cultural thinking, their concepts and myths related to water, sun and hygiene practices before taking up SODIS activities.

The method of focal group discussions has been used in Bangladesh and Bolivia to obtain more information about local customs. Although it is not possible to know all the beliefs and myths surrounding water and hygiene, it is necessary to have some guidelines for the cultural adaptation of the SODIS introduction and render it acceptable to the local community.

In Uzbekistan for example, tea is the main beverage. People believe that drinking cold water can make you sick. Visiting guests are always served hot tea as it is impolite to offer the guest cold water. Despite of this belief, people do drink cold water directly from the tap, especially when they are thirsty in summer. The SODIS team in Uzbekistan therefore had to build upon the belief that hot water is good and introduce the concept that SODIS is a method for water purification, using the sun to boil the water. SODIS-water in Uzbekistan therefore is sun-boiled water and good for the health.

In Indonesia the promoters can also build on traditional behaviours based on the belief that sunshine is good for health and kills pathogens:

- People in Java regularly expose their mattresses to the sun as they believe that it is healthier to sleep on a mattress that frequently is exposed to the sun.
- Bathing water for babies is exposed to the sun as people believe that the baby will be healthier if bathed in water that had been exposed to the sun than boiled warm water.

#### Bottles

The availability of plastic bottles is of key importance for the sustainability of the SODIS activities. The SODIS promotion team has to **assess if people can afford to buy bottles and from where such bottles are available, possibly also secondhand bottles.**

If no plastic bottles are available locally, the project team has to **initiate a bottle supply scheme.** The best idea is to initiate a small-scale business where plastic bottles, possibly also secondhand bottles, are bought from the city and transported to the villages. Local shop owners might take up the supply of plastic bottles.

#### What to do with old PET-bottles?

During our field visits the SODIS users asked us what they should do with old and damaged PET-bottles. Can old and damaged SODIS-bottles be burnt?

**It is not recommended to burn the PET-bottles under the conditions generally encountered in the field.** Due to the lack of oxygen under such conditions, carbon monoxide (CO) is formed instead of carbon dioxide (CO<sub>2</sub>). In addition, PET contains aromatic substances which, when being burnt under suboptimal conditions (low temperatures and lack of oxygen), are transformed into the toxic PAHs (polycyclic aromatic hydrocarbons).

However, if PET is burnt at high temperatures and with sufficient oxygen, as it is the case in incineration plants, only carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) are produced. Therefore, old SODIS PET-bottles should be collected and burnt centrally.

Another option is to use the old bottles for other purposes, e.g. as pots for growing seedlings, or to centrally bury the old bottles together with the household waste.



*The availability of plastic bottles is of utmost importance for the sustainability of SODIS*

## 5.4. The role of hygiene education

Consuming water of pure quality helps to reduce the number of diarrhoeal illnesses. However, as the human pathogens can be transmitted through multiple routes from faeces via fingers, flies, food and fluids (see Figure 2 in Chapter 1.3 'Transmission of waterborne pathogens'), appropriate hygiene practices have a great influence on community health.

Esrey [35] and Hutley [33] reviewed relevant field studies and evaluated the effectiveness of different interventions on reducing diarrhoea morbidity. Their assessment revealed that an **improvement of the drinking water quality** ought to be the first intervention. It reduced the diarrhoea morbidity by approximately 20%. Another reduction of more than 30% could be achieved simply by **washing hands with soap**. The **safe disposal of excreta** also accounted for approximately 30% reduction of diarrhoea morbidity. Further improvements can be achieved by other practices of household hygiene such as washing vegetables, fruits and dishes with clean water, safe disposal of household waste etc.

This shows that training on water purification should always be combined with general hygiene training to achieve the best impact possible for community health. Thus, a very good approach is to **integrate SODIS training into ongoing projects for community health and hygiene education**.

The hygiene education/training should cover the following topics:

- general household and community hygiene
- water supply hygiene
- latrine use, hygiene and maintenance
- hygienic disposal of other waste
- use and maintenance of facilities.

**Hygiene education messages should be positive and build on the local cultural knowledge, beliefs and values.**

Before people adopt a new hygiene practice, they will ask themselves how the new practice fits into their ideas and affects their lives. They will adopt a new practice, if they believe that the practice has net benefits for health or other benefits, and if they consider these benefits to be important.

The following case story provides an example of the effect of hygiene education if positive messages are used within the local context.



*Hygiene education messages should be positive and build on local beliefs and values*

## ***Positive messages for hygiene education: Encounter with Doña Ricarda***

An hour before the SODIS presentation in Viña Perdida started, Doña Ricarda was already present in the community room. She wanted to see what this presentation would be about. I told her that the presentation would be about SODIS, preparation of drinking water with solar energy, but that it would only start an hour later.

“Well, then I have just enough time to get water for my pigs before the presentation starts,” she said. “Can I accompany you?” I asked. “Of course.”

Doña Ricardo brought a large and two smaller jerry cans, as well as a cloth for carrying the load. Together we went down to the irrigation canal running through Viña Perdida. The water was clear and cool. Downstream I saw people washing their clothes and children playing in the water. In the meantime Doña Ricarda had filled her jerry cans with water. She gave me the large jerry can of 25 litres to carry and took the two small ones. With an effort, I placed the jerry can on my back and followed Doña Ricarda who already was on her way to her house on top of the hill. I had difficulties following her fast steps and started to work up a sweat. As soon as we arrived, we filled the water into the feeder for her pigs. I asked Doña Ricardo, if she usually carries all this water by herself. “Of course”, she said “Every day, I carry the big jerry can on my back, and the two small ones with my hands. If the weather is very hot, I even go twice. I do not want the pigs to go to the irrigation canal and make everything dirty there. You have seen that women do their laundry there, and they also fetch water for the kitchen from the canal.” Secretly I admired Doña Ricarda for her commitment, I thought. Especially, as Doña Ricarda is not a young and vigorous woman, but a grandmother with many wrinkles in her face. Her husband had died many years ago and her children are now all grown up, married and live in Mizque.

Shortly later, my local partners started introducing SODIS to the people of Viña Perdida, now gathered in the community room. The first topic addressed were hygiene practices in the village. When answering the question what kind of hygiene practices would be common in Viña Perdida, unfortunately only negative answers were given: “We drink dirty water from the canal, we have no latrines, we do not wash our hands, we live together with animals, altogether we are totally unhygienic.” The general atmosphere in the room following this discussion was not really bad, but rather strange.

This prompted me to tell the people the experience I just had with Doña Ricarda. The steps Doña Ricarda takes to water her pigs, is nothing else than a hygiene practice. Every day she carries about 40 litres of water uphill, to prevent the pigs from messing around in the irrigation canal and make the water dirty, which is used by other people further downstream for washing and cooking. This is an enormous effort, Doña Ricarda is making every day, to prevent the water from being contaminated, to protect her neighbours and their children from possible diarrhoea illnesses. “We have to be grateful, that Doña Ricarda makes this great service, and I am convinced that every day all of you take many such hygienic measures, maybe even without being aware of it.”



Doña Ricarda was visibly touched when I told her story in the community gathering and the atmosphere in the room changed all of a sudden. The people from Viña Perdida were very motivated to try out new methods for improving hygiene and to apply SODIS.

I had learned that everywhere traditional hygienic practices can be detected. And when discussing and praising these positive behaviours, people are much more motivated to learn and adapt new strategies.

Stephan Indergand-Echeverria, STI

## 5.5. Training material

The training material for the users can be divided into material used during the training in the community and material remaining in the homes of the users.

### Material used during the training session

The training material must be **colourful and contain many pictures but little text**, as the people of rural communities generally feel more attracted to pictures than to text. The subjects and material presented to the community first should address issues on **health, water and hygiene**, such as safe water handling, frequent causes of diarrhoea, different uses of water in the home and possible sources of bacteriological infection. **Once the relation between water and health is presented, Solar Water Disinfection can be introduced.**

Educational videos, showing the application of SODIS in other regions, can be used as catalyst for initiating discussions between the public and the trainers.

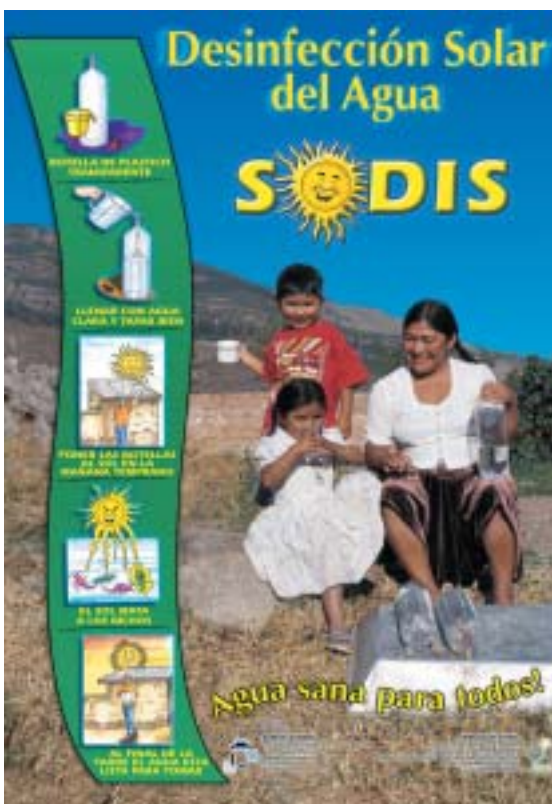
**Oral stories**, told in the local language in the style of tales, are also useful to incorporate solar disinfection. Especially children appreciate this training tool.

### Material left for display at home

**Colourful posters showing the application** of SODIS in steps are left with the users for display in their home. These posters are preferably printed in large size (40 x 60 cm) and should be fixed to the wall in a well visible place. It is important that the pictures and illustrations are adapted to the local conditions and culture so that the potential users identify themselves with the pictures presented.

The examples of training material presented in the Annex include:

- Annex A: Flipchart Posters from Bolivia
- Annex B: Posters for Display in the users' home
- Annex C: Posters for Display in the users home
- Annex D: Short stories for radio from Bolivia
- Annex E: SODIS pamphlets (Unicef) from Bolivia
- Annex F: SODIS game: The SODIS team in Usbekistan developed a simple board game into which the SODIS rules were integrated. It turned out to be an effective tool to introduce SODIS to children in schools.
- Annex G: Answers to frequently asked questions



SODIS poster

## 5.6. Lessons learnt during users' training

- Before SODIS is introduced in a village, the existing situation needs to be assessed: What is the quality of the drinking water? Do people already successfully apply other water treatment methods? Is the introduction of SODIS necessary?
- First contacts with the village should be made through local leaders and medical personnel (Village Health Posts). These people should be involved in SODIS activities and should take an active part in SODIS promotion.



- It is necessary to regularly visit the local community and support SODIS users with advice. This activity requires much time and resources.
- The language used in the training material should be well adapted to the target group. The terms used in the publications should be culturally appropriate. Different material should be developed for different target groups:
  - => Scientific background information should be included in material for technical project staff, government officials and medical staff from village health posts.
  - => Pictures and comics should be used for small children and illiterate people.
  - => Pamphlets using simple language and well illustrated with pictures, are suitable for literate villagers.
- The training should be active and participatory. This increases the villagers' ability to learn.
- Visual and audio-visual material should be used as much as possible during the training.
- Include practical demonstrations on how SODIS works in the training and if possible also demonstrate its effectiveness.
- The time planning for the community meetings has to be done in close consultation with the community. Farmers for example are not able to attend meetings during agricultural peak seasons.
- Depending on the cultural context, it might be necessary to hold separate meetings for men and women.
- Women often are the ones responsible for the preparation of food and water as well as for household hygiene. In addition, women are the caretakers of their children's health. It is therefore important to well integrate women into the SODIS training and focus the discussion and training tools on this role.
- It is better to introduce only one topic during one lesson or group gathering and to repeat the central thought several times instead of packing too much material into one session.
- SODIS should be introduced together with training on health and hygiene practices. The best approach is to integrate SODIS into on-going health education projects.
- Provide at least two SODIS bottles to each household immediately after the training. After the training users generally are curious to try out the new method for water purification. If no bottles are available immediately after the training, the initial interest may fade. Further bottles to supply the whole family with drinking water can then be organised by the users themselves.
- Influential people who are convinced of SODIS greatly will influence the way SODIS is accepted and adopted in the community.



*SODIS should be introduced together with training on health and hygiene practices*



*SODIS in schools in Bolivia*

*...and in Indonesia*



- The relation between the promoters and the community is a key aspect for the success of the project. The closer and stronger the relationship, the better are the chances for SODIS to successfully be adapted.

### **SODIS in schools**

- Parents can be reached through their children, as they are willing to invest time and money into the well-being of their children.
- Children generally are open to new ideas.
- Children should definitely be targeted in the dissemination of SODIS, as they are most susceptible to diarrhoea.
- Structures of schools and kindergartens can easily be used for disseminating the SODIS idea.
- Activities should be coordinated with the local education department. This is a precondition for good cooperation with the school principals.
- A SODIS day or teacher training could be used to reach entire schools with the SODIS idea.

## 6. Promotion of SODIS at national level

### 6.1. Different levels of promotion

Although SODIS is a simple technology to purify water for human consumption, its dissemination and promotion at different public levels require a dynamic and creative process. The final aim is that SODIS does not only remain theoretical knowledge, but that the idea is accepted and recommended by the local authorities and put into practice by those in need of a simple low-cost method for water treatment.

The SODIS promotion process in each country must focus mainly on three levels:

1. Authorities of different government institutions and international and local non-governmental organisations: the knowledge about SODIS has to be transmitted to these organisations through seminars, workshops or personal communication.
2. Technical staff and promoters of different institutions that show interest in SODIS: theoretical and practical knowledge about SODIS is transmitted during workshops of about 2 days duration. The aim is to instruct the technical staff about the technical details of SODIS, in order for them to recognize it as an alternative water treatment method and take up promotion work for SODIS after the workshop. It is important for the technicians to be convinced of SODIS as they have a close relation with the local communities and future SODIS users, and their commitment and enthusiasm for SODIS will influence the level of acceptance by the villagers.
3. Leaders at community level: the promotion at this level first addresses key people at community level, such as local leaders or other respected persons, as these people can influence the level of acceptance of SODIS. In the community, SODIS will be presented to the future users during group meetings or it can also be promoted by directly visiting the users in their home and by explaining and demonstrating the use of SODIS there.

### 6.2. Acceptance at village level

SODIS is a very simple method for water purification. This makes promotion very attractive, but also has an influence on the acceptance at village level. Future users often doubt whether such a simple method really works and can be trusted.

**The performance and demonstration of microbiological tests with a portable DelAgua field test kit is a tool to overcome such doubts.** Another possibility is to conduct simple presence/ absence tests. Such tests have been used in Nepal to demonstrate the SODIS efficiency in different communities. An advantage is, that people can perform the tests themselves, and the presence/ absence tests are cheaper than membrane filtration.

Another factor influencing acceptance is that SODIS should be connected with a process of change in hygiene behaviour. Such processes of changing behaviour require much time and results cannot quickly be achieved in a short period.



*SODIS water ready for consumption*

## The little SODIS ambassadors

SODIS was introduced in the rural area of Mizque in Bolivia during the last two years through the UNICEF water programme. Although the communities collect their water from highly polluted irrigation channels, the majority of the population did not use any household based water treatment before the introduction of SODIS.

In the first months after the introduction of SODIS, only a part of the villagers regularly used SODIS for the preparation of their drinking water, despite of the rather critical water quality and a high incidence of diarrhoeal diseases. However, over the following months many families who initially only occasionally had used SODIS for the preparation of their drinking water, turned into regular users. This success partly might be attributed to the intensive follow up and hygiene education campaign, but also due to other factors which contributed to the acceptance of SODIS by the villagers.

During a field evaluation in January 2002, the project staff visited the communities, including the Andia family. Doña Cecilia and Don Melquíades explained how they became convinced SODIS users:

*“One year ago, we learned about SODIS during a workshop at a community gathering”, explained Doña Cecilia. “Following the workshop, several times we received the visit of extension workers reminding us about the importance of treating our drinking water. Therefore I prepared SODIS from time to time, just when I remembered to put the bottles on the roof.”*

At that stage, the Andia family had not really adopted the SODIS method, as they only occasionally used it to treat their drinking water.

*“But at the end of last year”, told us Don Melquíades, “a group of children came to our community for a short visit. These children came from a rural school of the neighbouring department of Potosí, where SODIS had been promoted through the schools. When I saw these children explaining us why and how to do SODIS, I was a little bit ashamed by the fact that children from another community had to come and teach us, what we should do to improve our health.*

*Now, our daughter is in charge of filling the SODIS bottles every morning and for exposing them on the roof. If she forgets to prepare the SODIS water for some reasons, I always remind her to do it.”*

Bruno Gremion, Fundación SODIS



Promotion is only successful if the implementation strategy involves people's surrounding and environment, their customs, cultural beliefs and traditions. The promotion of SODIS in indigenous communities in Latin America for example, has a great advantage as the sun is given much importance in their culture and tradition.

## Factors contributing to the acceptance of SODIS in the communities

During SODIS promotion in the community, **promoters should emphasise that SODIS is a simple and attractive new method for water treatment that only requires sunlight and transparent plastic bottles as resources.** The message can be enforced if local community leaders and other respected persons, such as teachers, well known technical staff, government officials, doctors, etc., support the SODIS application.

The following key messages are important and will demonstrate the advantages of SODIS to the community:

- Compared to water that has been treated through boiling or chlorination, SODIS treated water tastes good.
- SODIS alleviates the household economy. While using SODIS, the family no longer has to buy fuel or gas to boil drinking water.
- The workload of women and children, who are the responsible for the collection of firewood as well as for the preparation of drinking water, is reduced.
- The application of SODIS is simple and easily understood by everybody.
- The family members will have less diarrhoea and thus will be healthier. Less money therefore has to be spent for medical treatment.

## Lessons learnt about acceptance at village level

- It is essential to gain the confidence of the people in the community where SODIS is promoted.
- The promoters must be totally convinced of the SODIS method they are promoting and use SODIS for the preparation of their own drinking water. They should use a simple and clear language in order to avoid confusion. The promoters also have to explain the limitations of Solar Water Disinfection.
- The promotion material used must be adapted to the reality, local culture and language of the people in each location.
- SODIS can be promoted during group gatherings in communities or during visits to individual user's homes.
- Promotion material should be left with the users for their future reference.
- Where plastic bottles are not available, a supply scheme for used plastic bottles should be initiated.
- It is useful to promote SODIS during special public events in the communities.
- The experience gained during SODIS promotion in rural school in Bolivia showed that the children with their enthusiasm and dynamism can turn into important SODIS promoters in their communities.

### 6.3. Cooperation with the authorities

Cooperation with government institutions at different levels of operation is a key aspect for a broad national dissemination of SODIS. During SODIS promotion high priority should be given to **obtain the institutional recognition of SODIS by the local authorities and international Organisations. Establishing an alliance for SODIS promotion and dissemination with the authorities of the government in each country proves very effective for the broad acceptance and dissemination of the method.** The SODIS promotion team should try to get SODIS integrated into the national extension plan and spread the method through the official extension channels.

The SODIS project team therefore should establish a good contact and information exchange with the officials of the concerned government institutions at central and local level. To organise an institutional workshop is a good method to introduce SODIS to the concerned decision-makers.

*In Uzbekistan for example, the head of the health department introduced SODIS to the leading doctors during a district meeting. Moreover, the doctors were told to instruct their medical staff at village health posts to pass the idea on to the village population.*

It is, however, not a simple task to introduce SODIS to the authorities, especially the Ministry of Health. For years these officials have promoted the disinfection of drinking water through chlorination or boiling and therefore, adding a new recommendation might take time. **The cooperation with the authorities for the promotion of SODIS however contributes to its credibility and therefore should form an integral part of the promotion programme.**

#### Activities to develop cooperation with authorities

Close cooperation with the government institutions requires a permanent dialogue. The following factors enhance the development of smooth cooperation:

1. A presentation of SODIS should focus on technical aspects and include all the advantages and limitations of solar water disinfection. Furthermore, the fact should be stressed that SODIS does not replace the traditional methods for water disinfection but that it is an alternative method for water treatment in situations where other methods are inadequate.
2. Once SODIS has attained credibility, government officials should be convinced to integrate SODIS into already existing health and hygiene education programmes.
3. The integration of the SODIS method into the plan of action, an extension manual or a similar working document of the government service, especially the Ministry of Health and Ministry of Education, should be suggested.
4. When organising SODIS promotion workshops at regional or national level, the cooperation with the government and local authorities always should be sought, in order for them to become patrons of the event.



*Water quality analysis using a DelAgua field test kit during the workshop to demonstrate SODIS efficiency.*



*Members of different NGOs and government institutions participating in the SODIS workshop in Central America*



*Puppet-show on SODIS*



*Students acting in SODIS play in Bolivia*

### Lessons learnt on cooperation with the authorities

- Cooperation with the government should form an integral part of the SODIS programme as promotion by the authorities increases the credibility of SODIS.
- It might take time until SODIS officially is accepted as introducing SODIS to the authorities means changing their paradigm.
- The frequent transfer of staff among different departments of the government or also international organisations often delays the establishment and implementation of action plans. In the worst case, smooth cooperation has to be rebuilt up from the scratch.

### 6.4. Networking activities

Organising activities to **establish a network of organisations involved in the dissemination of SODIS in each country is an important task to strengthen the promotion of SODIS**. A network of SODIS organisations at country level strengthens cooperation alliances between different institutions that have taken up the task of disseminating SODIS through their programmes and activities.

The **publication of a bulletin** is a good tool for the exchange of information. Through exchanging information, the existing network of SODIS organisations is strengthened and further contacts for dissemination may be made. The bulletin contains technical information about the method as well as accounts of the experiences made during project implementation by different institutions.

The establishment of a SODIS network in each country largely contributes to a sustainable dissemination of the method because:

1. A process of learning is initiated when the different organisations share their experiences on SODIS dissemination.
2. The network enhances the constant commitment of the different institutions to promote SODIS in their working areas.
3. A multiplying effect is initiated as further organisations with a potential to disseminate SODIS are attracted.

In addition to the publication of a bulletin, it is also important to create tools for reflection, for example **institutional workshops, where experiences and lessons learnt during the implementation of SODIS projects are exchanged, discussed and new strategies are developed**. Ideally, a workshop for all the organisations actively involved in the SODIS promotion is organised once a year.

## Network of institutions promoting SODIS in different countries

In view of the fact that the exchange of experiences and information is not only important at national level, but also needed between institutions of different countries, a SODIS network in Latin America has been established. So far, the network SODIS Latin America comprises about 100 institutions from Nicaragua, Guatemala, Honduras, Ecuador, Peru, El Salvador and Bolivia. Also at the level of the international network the exchange of experiences is a dynamic process. A SODIS News bulletin for Latin America is published quarterly.

Potential partners for the dissemination of SODIS are:

- Government institutions and official extension workers, including village health posts
- Local non-government organisations
- International non-government organisations
- Community based organisations
- Schools and kindergartens
- Media, etc.

## 6.5. Promotion material

Promotion material is an important tool to be used during the dissemination process. Various materials, tools and methods may be used to reach a great number of people and transmit the knowledge about SODIS:

- Television: TV is a very suitable tool to reach a wide audience. Short 'commercial' spots broadcasted several times during the day, also during prime time, are more effective than long reports.
- Radio spots, radio programmes, stories on SODIS being broadcasted through the radio
- Articles in newspapers and journals
- Flyers, posters, stickers, calendars
- Dances, songs, plays, puppet-shows

**The promotion material has to be especially designed to reach each section of the target audience.** Articles in newspapers as well as documentaries on television are a good tool to reach the educated upper class. Flyers, posters and calendars are adequate communication tools to address the population in need of improved water quality.

An important group are the people without access to safe drinking water. As this is mostly the poorest and least educated section of a population, it is important that people with no or little schooling can understand the promotion material and tools designed for them. Good experiences have been made with the use of recorded stories on SODIS broadcasted through the radio, and with posters containing colourful pictures and illustrations explaining the use of SODIS, which are then left in the homes of the users. Short stories on the experiences with SODIS shown on the Television could also be useful, but it has to be kept in mind that the poorest often only have limited access to TV-programmes.

SODIS also successfully has been promoted in schools through puppets-shows, plays, dances and songs.

## SODIS promotion through radio programmes

During 6 months, 5 radio stations in the Andean region of Bolivia broadcasted programmes about SODIS. The programmes were both in Spanish and Quechua, a widely spoken native language. In Cochabamba, Radio Pio XII was one of the radio stations broadcasting the SODIS programmes. Radio Pio XII is run by a catholic congregation and has a wide coverage in the periurban outskirts of the city and the neighbouring rural areas. The message about SODIS also reached the ears of many members of the clergy. Father Guillermo Siles, Director of radio Pio XII, explained that the SODIS programmes had a big impact within their own congregation of priests:

*"One of the priests living in our congregation, Father Amado, who is also chaplain of the nearby prison, has become a very enthusiastic SODIS user since he heard about this new method on the radio. Soon after that, he made his first trials with using sunlight to prepare his own drinking water. Now, the congregation every day exposes 3 bottles of water on the roof and 3 bottles with water ready for consumption are kept inside the house of priests."* tells us Father Guillermo. *"In fact, SODIS water really tastes better than bottled mineral water. Like us, also other members of the clergy living in rural areas have adopted SODIS, for example Father Oscar and Brother Hugo living in Pojo. I think that the radio programmes motivate people to try SODIS, as the message is quite clear and easy to understand. In the future, I think that it would be better to frequently broadcast short SODIS messages, as people are informed now, but constant reminders are required until a change of behaviour takes place."*

Father Guillermo does not only disseminate SODIS messages through the radio, but he also promotes SODIS in his own family: *"Once I visited my mother and sister and brought them SODIS water instead of a soft drink. I let them try SODIS water and explained how to prepare it. Since that day, my mother has also started to drink SODIS water."*

Ana Choque, Fundación SODIS



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### **Annexes**

Annex A Flipchart Posters

Annex B Posters for display in the users home (Bolivia)

Annex C Posters for Display in the users home (Indonesia)

Annex D Short stories for radio

Annex E SODIS pamphlets (Unicef)

Annex F SODIS Game

Annex G Answers to frequently asked questions

## Annex A Flipchart Posters

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### Poster 1: The water and the environment

#### Objective of the Poster

To reflect about different types of water sources, being used for people's daily water supply (rivers, streams waterfalls, wells, ponds, springs etc)

#### Possible Questions

What can you see on this poster?  
What kind of water sources do you know?

#### Content

We can divide the sources of water into two kinds of groups:

Surface water  
Underground water

Surface water is found in rivers, streams, waterfalls, lakes, ponds etc.  
Underground water is found in wells and springs.

The water sources are formed through the hydrological cycle of water. This means, water first evaporates from the lakes and seas and it falls as rain to the earth. Part of the rainwater infiltrates the ground to form ground water. The other part flows as surface runoff over the soil to form rivers, streams and lakes.

1

The origin of water



### Poster 3: The use of water

#### Objective of the Poster

To think about the different uses of water at household level and to discuss about the water quality required for the different activities.

#### Possible Questions

What do you see on the poster?  
For what purpose do we need water?  
For what other purposes do we need water?  
For which of the activities on the picture can we use water of minor quality?

#### Content

We use the water for:  
Drinking, cooking, washing ourselves, washing the dishes, giving water to the animals, watering the plants etc.  
We also need the water for recreational purpose, for example to swim in ponds or rivers.  
It is important, that the water that is consumed during meals or in between is clean and safe. This can be achieved by disinfecting the water.

To take care of and protect the water is a task for girls and boys as well as for adult women and men, then without water life would not be possible. It is therefore important that the whole family has a profound knowledge about water.  
Let us remember that women and the children are always the ones in charge to carry the water from the sources to their houses.

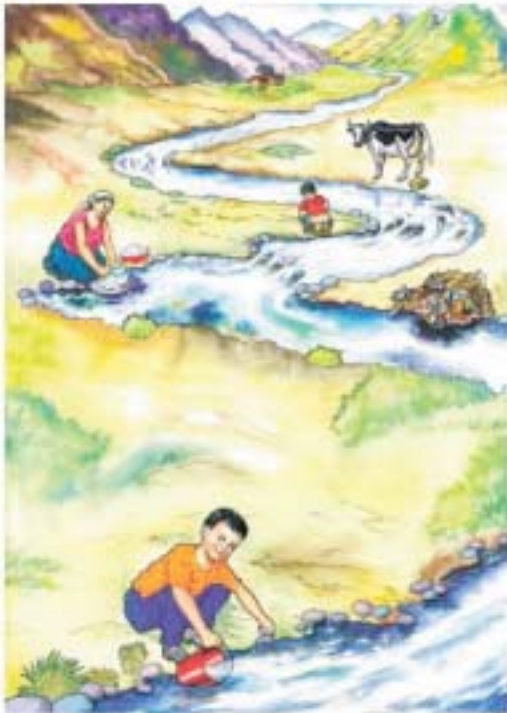
3

Use of water



4

Contamination of water



### Poster 4: Contamination of the water

#### Objective of the Poster

To think about the little attention we generally give to the protection of our water sources, causing its contamination as a consequence and creating the risk for people to consume contaminated water and get ill.

#### Possible Questions

What can we see on the poster?

What are other possible sources for water contamination?

Are humans the only ones contaminating the water?

What happens when we consume dirty water?

#### Content

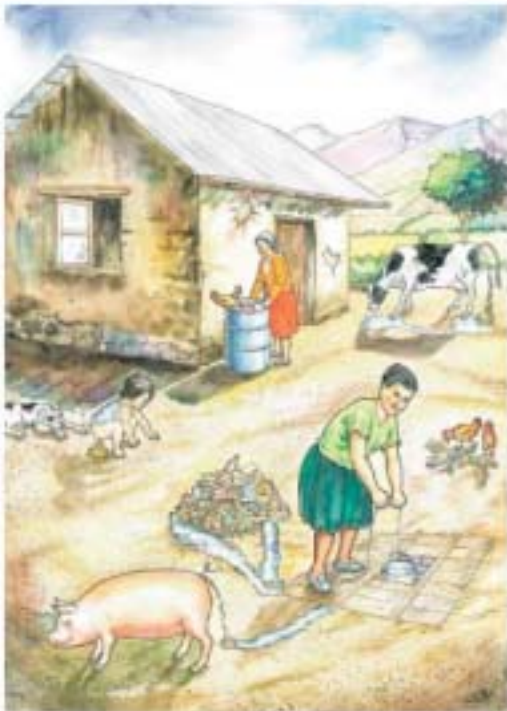
We almost always contaminate our water source because we do not take enough care. Our faeces are the primary source of contamination, especially when people and animals defecate into the open field or near to a water source.

Also the industries and other waste producers contaminate the water and make it unsuitable for human consumption.

If we see clear water, we believe that it is clean, but also clear water can be contaminated.

5

Hygiene practices which influence the contamination of water



### Poster 5: Habits influencing the contamination of water

#### Objective of the Poster

To think about hygiene habits people practice around their house and reflect about the little care that is given to the protection of water sources.

#### Possible Questions

What can we see on the poster?

What is the source of water of this family?

Where do they disperse their faeces?

What are the animals doing? Do they stay in their appropriate place?

Is it correct to defecate in just any place?

What is the child doing?

How can we protect the water we use for our daily consumption?

#### Content

We contaminate the water not only at its sources but also in the house, when not having well taken care of the cleaning of the containers where we keep the water or when our tank of water storage is not protected against contamination.

Under inadequate hygienic conditions around the house, a major contamination of the water can occur, for example:

If the rope we use to pull out water from the well was in contact with something dirty.

If the birds stay on the water barrel and shit into the water.

If people or animals defecate near the house or near the family's water source.

## Poster 6: Transmission cycle of faecal microbes

### Objective of the Poster

To show transmission cycle of gastrointestinal illnesses through the contamination of water and food items.

### Possible Questions

What can we see on the poster?

Can the foods get contaminated if we leave them without protection, as is shown on this poster?

What happens if we leave our plates and cups with foods on them standing around, as is shown on this poster?

How do the microbes arrive into our body?

From where comes the contamination of water?

### Content

The hygienic practices determine whether the water is clean or contaminated. Faeces are the principal source of contamination for water as well as for foods.

The first picture shows a defecating child. Every one of us (adults or children) whether we are healthy or ill, has microbes in our intestines that could cause diarrhoea in other people. Through the faeces these microbes arrive into the environment.

The faeces we saw in the first picture have been dispersed with the rain, wind or through animals, for example mosquitoes, flies etc. The water as well as the food on the table are now contaminated with faeces.

In the last picture a healthy person consumes contaminated water and contaminated foods. The microbes can produce stomach pain and diarrhoea in that person. When this person defecates, the microbes in the intestines are again discharged to the environment. In this way the transmission cycle of faecal microbes is being produced.

6

Transmission cycle of faecal microbes



## Poster 7: Consequences of consuming contaminated water

### Objective of the Poster

To show the microorganisms present in contaminated water and the consequences of consuming such water.

### Possible Questions

What can we see on the poster?

What can you see inside the water?

What is the woman doing?

What can happen if she drinks contaminated water?

What are the illnesses she gets when drinking contaminated water?

### Content

If we do not clean the vessels used for keeping the water, the water will be contaminated even if it was clean originally.

Inside the water there are very small microorganisms. These microbes are so tiny that we cannot see them with our eyes. When we see clear water, we therefore believe that the water is clean, but it is not always the case.

If somebody drinks the contaminated water, the person can get ill through a gastrointestinal infection, with the following symptoms:

vomiting  
stomach pain  
diarrhoea

7

Consequences of the consumption of contaminated water



8

Behaviours which protect the water



### Poster 8: Habits which contribute to the protection of water

#### Objective of the Poster

To show what kind of protection measures are to be taken for the water sources as well as for the vessels used for storing the water.

#### Possible Questions

What can we see on the poster?  
 How can we protect the water sources?  
 How is the water vessel where the water is stored?  
 Where do the animals have to stay?  
 How is the environment of the house?  
 What is the difference between this and poster Nr. 5?

#### Content

We have to protect our water sources from contamination: Take care that the animals keep enough distance to the water source, that they stay inside a fence and that they have a separate water source. Take care of the environment around the house, each thing should have its specific place. Keep the place for defecation far away from the house and from the water source. And especially keep:

- Covered wells
- A clean rope and clean vessel to pull out the water from the well
- Covered barrel for stored water
- Waste in a covered vessel

In this way a better water quality for the daily consumption can be guaranteed.

9

Personal hygiene:  
wash the hands

### Poster 9: Personal hygiene, washing the hands

#### Objective of the Poster

To show the importance of personal hygiene in addition to the protection of water and the cleanliness of the living place.

#### Possible Questions

What can we see on the poster?  
 When is it necessary to wash the hands?  
 What do you have to do after going to the bath/ latrine?  
 Why is it important to wash the hands before cooking and eating?

#### Content

It is very important to have adequate habits of personal hygiene. This contributes to an improvement of the family health. Some important hygiene practices are:

- To wash the hands with soap before cooking and eating
- To wash the hands after defecating and cleaning the bottom of the babies.

## Poster 10: Common methods for water disinfection

### Objective of the Poster

To explain different methods commonly used for disinfecting drinking water such as boiling, chlorination and solar water disinfection.

### Possible Questions

What can we see on the poster?  
What other forms of water disinfection do we know?  
Have you already heard about SODIS?

### Content

The most common forms of water disinfection at household level are:

boiling the water  
chlorination  
using SODIS

10

Methods used for the disinfection of water



## Poster 11: How does SODIS work?

### Objective of the Poster

To clearly explain the effect of sunlight on human pathogens present in the water.

### Possible Questions

What can we see on the poster?  
What do you think happens with the pathogens contaminating the water when the sunlight hits them directly?  
How can the sunlight touch the microorganisms in the water?  
Do you think that the sunlight can destroy them?

### Content

SODIS is a method for the disinfection of water that works in the following way:

When the direct sunrays, and especially the ultraviolet radiation present in them, penetrate the water, they completely destroy the human pathogens. Also, the sunlight increases the water temperature, which also contributes to killing the microbes.

In this way, the combination of the two effects caused through ultraviolet radiation and increased temperature produce disinfected water, suitable for human consumption. It is important to know that ultraviolet radiation is a strong disinfectant that is also used in water treatment plants in industrialized countries.

Other effects of the ultraviolet radiation are that they can cause burns of the skin, damage the eyes or even cause skin cancer. The human pathogens present in the water are very sensitive to solar radiation because they are used to live in our stomach and intestines. Therefore they do not have any protection mechanisms against sunlight. For this reason the UV-radiation can burn and kill the pathogens.

11

How does SODIS work?



12

Influence of turbidity and bottle depth



### Poster 12: Influence of turbidity and depth of the bottle

#### Objective of the Poster

To show the adequate level of turbidity and depth of the water bottle required for an optimal efficiency of solar water disinfection.

#### Possible Questions

What can we see on the poster?

What do you think happens if the water exposed to the sun is very turbid?

What do you think will happen if the water bottle is too big?

#### Content

In order to achieve a proper effect of the solar radiation, two conditions need to be fulfilled:

#### The Water needs to be clear

If the water we are exposing is very turbid, the sunrays cannot penetrate through all the water because they are absorbed by the particles found in the water. In other words, the particles present in turbid water protect the pathogenic microorganisms and the sunrays then cannot kill them.

The size of the bottle needs to be adequate

It is scientifically shown that SODIS is a method for disinfecting small quantities of water. For large volumes of water SODIS will not work. Therefore it is recommended to use bottles with a volume of up to 2 litres for the application of SODIS. The depth of a vessel for applying SODIS should be less than 10cm. If we use vessels with more depth, the sunrays cannot penetrate the profound areas of the vessel with the same intensity. This makes the disinfection process incomplete.

13

For the correct application of SODIS choose good bottles:



### Poster 13: Choose good bottles for SODIS

#### Objective of the Poster

To present to best bottles for the SODIS application.

#### Possible Questions

What can we see on the poster?

How do the bottles have to be?

#### Content

For an effective SODIS process it is necessary to choose good bottles. It is important that the bottles have a lid and close tightly.

The bottles are made from transparent and not coloured plastic, as the sunrays cannot penetrate coloured plastic.

The bottles need to be intact without breaks, nor splits.

The bottles need to be clean. Before you use them the first time, wash to bottles with clean water and a bit of soap.

The bottles should have a volume of up to 2 litres.



## Poster 14: If the water is turbid

### Objective of the Poster

To show what has to be done if the water is turbid.

### Possible Questions

What can we see on the poster?

What can we do if the water we are going to use for SODIS is turbid?

### Content

If the water we are going to use for SODIS is turbid, it is recommended to:

Let the water stand for a while (let the particles sediment and decant the water afterwards)

Filtrate the water with a fine cloth. In this way, the water will be clearer afterwards.

If you have no possibility to filtrate or decant the water, it is also possible to use coagulants (for example lime). The coagulants group the particles together and let them settle more quickly.



## Poster 15: Fill the bottles completely with water

### Objective of the Poster

To show that the bottles need to be filled with water and well closed afterwards.

### Possible Questions

What can we see on the poster?

How do we have to fill the bottles?

### Content

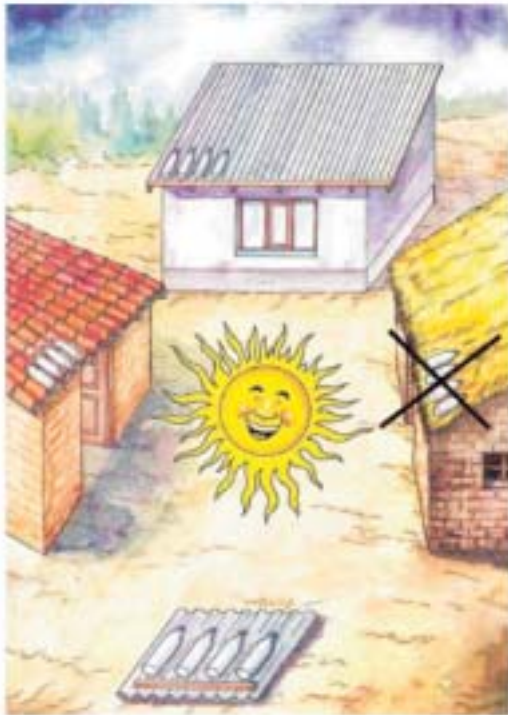
When the water is ready for SODIS, we have to fill the bottles completely without leaving air bubbles inside the bottle. Then close the bottle tightly so that no water is spilled out. It is important not to leave any air in the bottle, as the air bubbles reflect the sunrays.

The lid of the bottle needs to be clean.



16

Expose the bottles to the sun



### Poster 16: Expose the bottles to the sun

#### Objective of the Poster

To indicate the place of exposition of the bottles and the orientation they must have.

#### Possible Questions

- What can we see on the poster?
- Where are the bottles?
- Where can the bottles be put?

#### Content

The bottles have to be exposed to the sun on the metal roof of the house, on a piece of corrugated zinc sheet put on the floor or on a tile roof if no corrugated zinc sheet is available.

The bottles are exposed to the sun in horizontal position, facing towards the sun.

It is important that the place of exposition receives sun during the whole time, this means from at least 9 o'clock in the morning until 3 o'clock in the afternoon.

17

Expose the bottles to the sun from the morning until the evening (for at least 6 hours)



### Poster 17: Expose the bottles from the morning until the evening (for at least 6 hours)

#### Objective of the Poster

To show the exposition time required for the sun to disinfect the water in the bottles.

#### Possible Questions

- What can we see on the poster?
- How much exposition time is required for the sun to kill the microorganisms in the water?
- Why is it important to expose the bottles for at least 6 hours?

#### Content

In order to guarantee the disinfection of the water, the bottles need to be exposed to the sun from the morning until the evening for at least 6 hours. It is better if the bottles are exposed during the whole day. If the exposure time is less, it is possible that the disinfection will not be complete.

It is important to know that the bottles need to be exposed to the sun during the hours of the biggest sun intensity, around midday. It is not enough to expose the bottles at 6 o'clock in the morning and take them in again for lunch. The bottles need to be exposed from 9 o'clock in the morning until 3 o'clock in the afternoon. There will be no problem if the bottles remain exposed for longer than that, also not if the bottles remain on the roof over night.

## Poster 18: Additional recommendations

### Objective of the Poster

To analyse the climatic conditions influencing the performance of SODIS.

### Possible Questions

What happens if the day is cloudy?

### Content

During very cloudy days it is important to expose the bottles during two consecutive days. If it is raining during the whole day, it is however recommended to use a different method for water disinfection such as boiling the water or using rainwater.

## Poster 19: The water is clean and safe for consumption

### Objective of the Poster

After all the steps of the SODIS method are applied, the water is ready for consumption.

### Possible Questions

What can we see on the poster?

Do you believe that the water is disinfected and ready for consumption after all the steps of the SODIS method have been applied properly?

### Content

If all the indicated steps of SODIS are done in a correct manner, the water is clean, disinfected and safe for consumption.

### Final Recommendations

It is recommended to use double the amount of SODIS bottles required for preparing the daily drinking water. While one bottle is being exposed to the sun, the other bottle stays ready for consumption in the house. The SODIS bottle is a clean and safe container, protecting the water against recontamination. Therefore it is the best to store the disinfected water in the SODIS bottle itself and not in a different container which could be contaminated. Use a clean glass to drink the disinfected water.

It is recommended to consume the SODIS water within two days after exposing the water to the sun.

Finally, it is of advantage for the facilitators using this Posters' guide to study additional literature and information about SODIS in order to deepen their understanding of technical aspects of the solar water disinfection method. Also, it is a requirement for facilitators to collect their own experiences with the application of SODIS through personal use before they start teaching the application procedure of SODIS to others.

18

Additional recommendations

### Clouded days

During very cloudy days it is recommended to expose the bottles during 2 consecutive days or cook the water



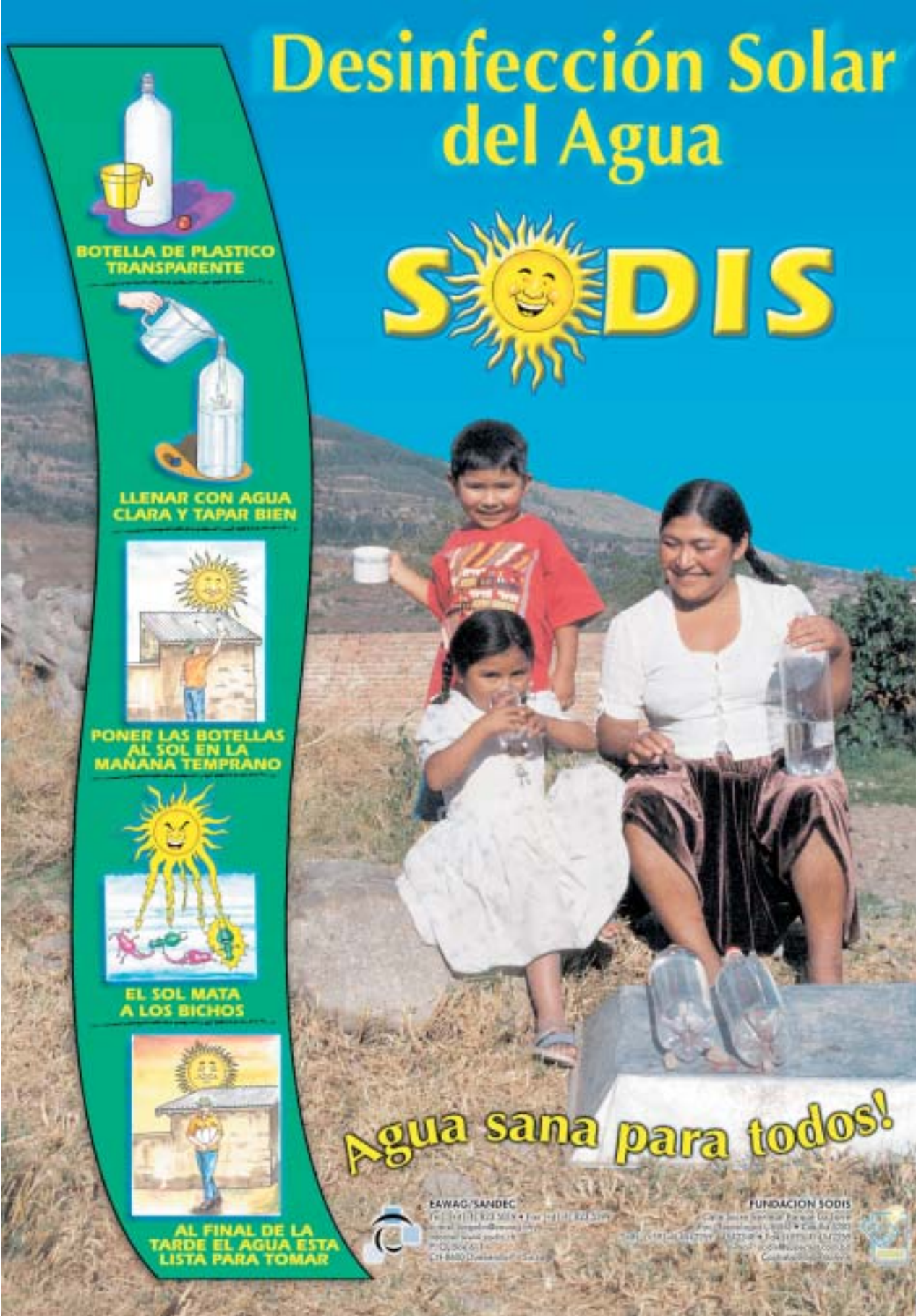
19

The water is now clean and safe for consumption



# Desinfección Solar del Agua

## SODIS



**BOTELLA DE PLASTICO TRANSPARENTE**

**LLENAR CON AGUA CLARA Y TAPAR BIEN**

**PONER LAS BOTELLAS AL SOL EN LA MAÑANA TEMPRANO**

**EL SOL MATA A LOS BICHOS**

**AL FINAL DE LA TARDE EL AGUA ESTA LISTA PARA TOMAR**


**Agua sana para todos!**

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**Annex C Posters for display at home**  
**Examples from Indonesia**  
 © Yayasan Dian Desa, Indonesia

## Healthy Life Needs Healthy Water



Is the water safe to drink?

**SODIS PROGRAM**  
 Yayasan Dian Desa

## What is SODIS ?



Sodis is a simple and low cost water treatment method that can provide safe drinking water

- A treatment method to eliminate pathogens that cause water borne diseases
- Ideal to disinfect small quantities of water used for consumption
- A water treatment process using solar energy only
- An old but so far hardly applied water purification method



**SODIS PROGRAM**  
 Yayasan Dian Desa

## Getting Healthy Water With Sodis



Prepare transparent container, such as used mineral water bottle. The size of the bottle should not be more than 1.5 litres.

Turn half of the outer part body of the bottle with black part horizontally.

Once closed, fill the bottle with water and screw the cap tightly. Make sure that the water is clear enough for Sodis treatment.

Expose the transparent bottle to sun shine. The length of exposure depends upon the weather condition, 4-5 hours in clear sunny day, 6-7 hours if the weather is overcast, or 2 days continuously if raining with occasional clear spells.

The water in the bottle is safe to drink

**SODIS PROGRAM**  
 Yayasan Dian Desa


## Who Benefit from Sodis

**WOMEN**

- Save cooking time
- Save fuel
- Save time and the drudgery in collecting fuel
- Reduce family health risk
- Improve self-esteem through being involved in development activities and contribution to family

**CHILDREN**

- Drinking safe water
- More efficient studying



**SODIS PROGRAM**  
 Yayasan Dian Desa

## Annex D Short stories for radio

### SCRIPT

#### Radio short story Nr. 1, Example from Bolivia

##### 1. CONTROL: CORTINA MUSICAL, SOUNDS OF THE ENVIRONMENT

2. Juanita: Hooo, it is so hot, I am really thirsty. Doña Mercedes, please offer me some water to drink
3. Mercedes: How are you, Doña Juanita?... Yes, you're right, it is really so hot today. Please serve yourself, Juanita, drink from my water.
4. Juanita: Umm, your water tastes so nice... But tell me, why are you keeping your water in these soft drink bottles?
5. Mercedes: Ah, what happens is that I am using the strong sunshine to purify the water in these bottles.
6. Juanita: What? How is this possible? Please explain it to me...

##### 7. CONTROL: RAFAGA MUSICAL

8. Mercedes: Look, first we have to fill transparent plastic bottles with clear water. Then we expose the bottles filled with water to the full sunshine, best on the roof or on a corrugated zinc sheet  
The bottles have to be put horizontally. You need to put the bottles to the sun from the early morning till the late afternoon. The sun rays go through the water in the bottles and thereby kill the microbes that cause diarrhoea, vomits and stomach aches. In the evening the SODIS water in the bottles is ready to drink.
9. Juanita Wow! So good, it is almost like a possibility to "sunboil" the water, isn't it? In this way we can prepare water, which is better for health!
10. Mercedes Yes, Juanita, and SODIS is so simple to do: we can find plastic bottles everywhere and also the sunlight is available everywhere. Everybody easily can do SODIS at home.

##### 11. CONTROL: CORTINA MUSICAL

## **SCRIPT**

### **Radio short story No. 2**

#### 1. CONTROL: CORTINA MUSICAL, SOUNDS OF THE ENVIRONMENT

2. Child:       Daddy, what kind of water shall I drink to grow strong ?

3. Daddy:       To grow strong, you need to drink safe water which is good for your health This water will protect you against diarrhoea, and you will grow healthy.

4. Child:       But how can we make this “healthy” water at home?

5. Daddy:       It is easy, my son! For example we can boil the water! Or when the weather is as nice as today, we can also do SODIS!

6. Child:       SODIS? What is that, Daddy?

7. Daddy:       SODIS means Solar Water Disinfection. You just need to do three things:

Firstly: fill transparent plastic bottles with clear water and close them well.

Secondly you put the bottles horizontally on the roof or on a corrugated zinc sheet in a place that is fully exposed to the sunlight.

Thirdly: The bottles must be in the sun from the early morning until the late afternoon. In the evening the SODIS water in the bottle is ready for consumption. Is safe and healthy water to drink.

#### 8. CONTROL: CORTINA MUSICAL

9. Child:       Daddy, why is it so important that the bottles must be transparent?

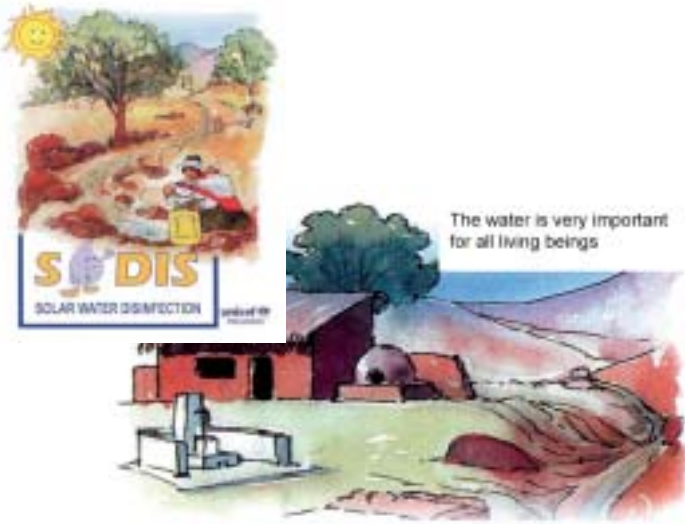
10. Daddy:      My son, only if the bottles are transparent, the rays of the sun can go through the water and kill the microbes that will cause you diarrhea.

#### 8. CONTROL: CORTINA MUSICAL

11. Child:       Wouah, Daddy! I drank SODIS water and it tastes really nice! So good, that from now on I will not get diarrhoea anymore! And each of us, we can clean our water with the sun, it is so easy. You know what, Daddy, I will tell this to all my school friends, how easy it is to purify the water with the help of the sun rays.

#### 12. CONTROL: CORTINA MUSICAL

**Annex E SODIS pamphlets**  
 © Fundación SODIS Boliva

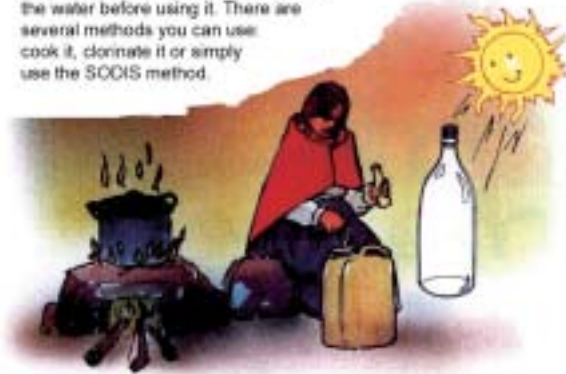


But the water can be of very bad quality and it can contain contaminations. Such water is dangerous, it can cause many health problems.



1 [www.sodis.ch](http://www.sodis.ch)

This is why it is very important to purify the water before using it. There are several methods you can use: cook it, chlorinate it or simply use the SODIS method.



SODIS is a method for water purification. The sunrays and the water temperature kill the microorganisms which are present in the water.



2 [www.sodis.ch](http://www.sodis.ch)

The steps to use SODIS are very simple:  
 First we select a good plastic bottle with a lid:



3 [www.sodis.ch](http://www.sodis.ch)

If the water is turbid....



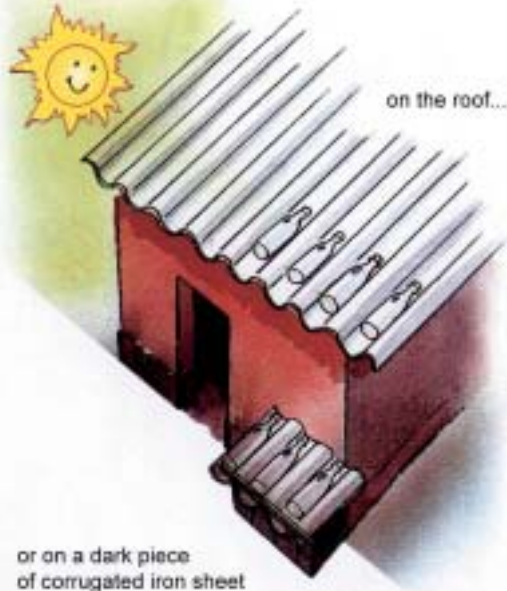
After filtering fill the plastic bottle with clear water



4 [www.sodis.ch](http://www.sodis.ch)

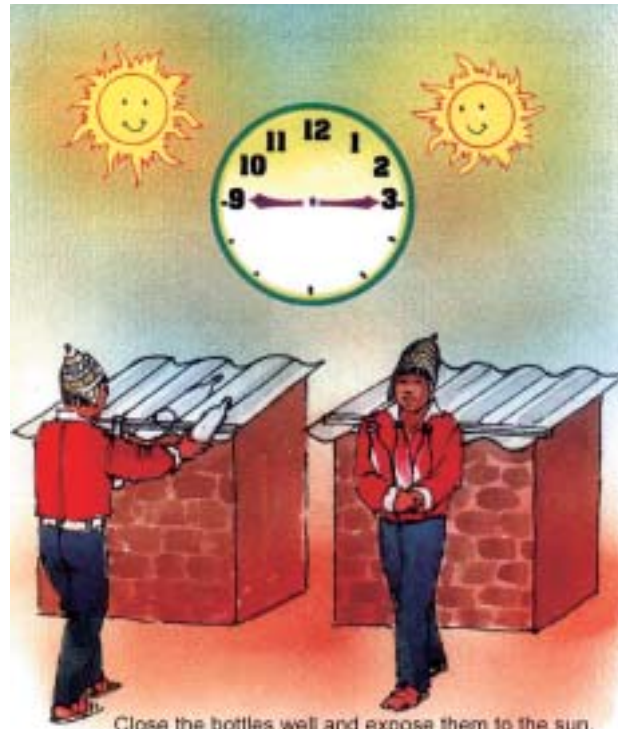


Expose the bottles to the sun...



5

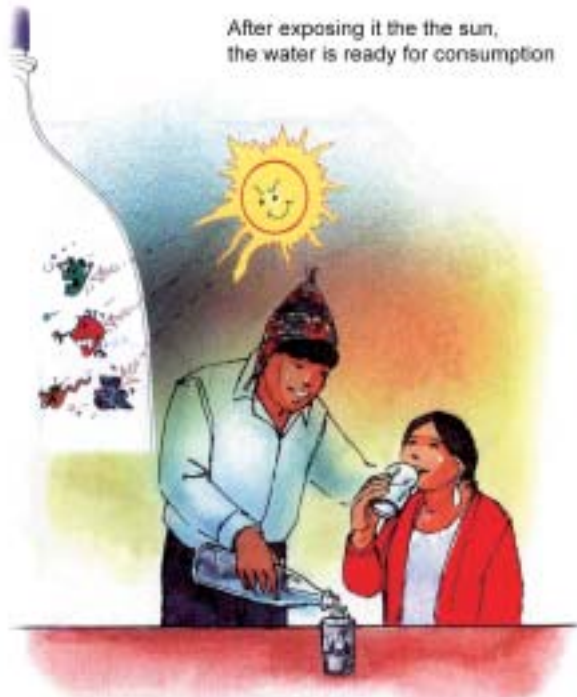
www.sodis.ch



6

www.sodis.ch

After exposing it the the sun, the water is ready for consumption



7

www.sodis.ch

Choose a bottle:



8

www.sodis.ch

Annex F SODIS Game  
© JDA, Uzbekistan

# SODIS

**Rules of the game:**

1. Each player in turn, one after the other throws the dice.
2. The game can be started and finished with a „1“ only.
3. If the player happens to reach a picture, he must always move from a black number to a white number. Never the other way round.

**Explanation of the pictures:**

- 2 You have got a PET-bottle and cleaned it well. Move on to number 3!
- 5 You did not remove the label. Go back to 4!
- 7 You run out of black paint. Miss one turn.
- 9 Well done! Water was cleaned first and then poured into the bottles. Move on to number 13!
- 12 You were not careful and stained your clothes. Go back to number 1!
- 14 You told somebody about the SODIS method. Move on to number 27!
- 15 While shaking the bottle you spilled half of the water. Go back to 11!
- 18 The sun is shining. You can change your position with someone else's.
- 21 You placed the bottles on corrugated sheet metal. Move on to 34!
- 24 The sky is overcast. Wait until another player has overtaken you.
- 28 The water is still hot and cannot be drunk yet. Miss one turn.
- 30 Shade fell on the bottles. Go back to 26!
- 32 Well done! You prepared and stored enough bottles. Move on two numbers.
- 35 We all know that SODIS water is sun-boiled water. All players may move on the next number.
- 37 What a shame! You drank from a dirty cup. Change your position with the last player!
- 38 You washed your hands after using the bathroom. Move on to 40!

FINISH	40	39	38	37	36	SODIS Sun-boiled water!	35
	29	30	31	32	33		34
	28	27	26	25	24		23
	14	15	16	17	18		20
	13	12	11	10	9		8
	1	2	3	4	5		6
START	1	2	3	4	5		6

## Annex G Answers to frequently asked Questions

	Page
◆ Does SODIS “inactivate” or kill all the bacteria?	XVII
◆ Which microorganisms in the water are destroyed by SODIS?	XVIII
◆ What kind of indicator should be used for testing the effectiveness of SODIS?	XVIII
◆ Up to which level of contamination with faecal coliforms does SODIS work?	XIX
◆ What kind of containers should best be used for SODIS?	XIX
◆ Is it possible to use SODIS when it is cloudy?	XIX
◆ Can I increase the efficiency of SODIS?	XX
◆ Which water can I use for SODIS?	XX
◆ Which water should not be used for SODIS?	XX
◆ How can the turbidity of water be measured?	XX
◆ Why should I shake the bottle after I filled 3/4 of it with water?	XX
◆ What are the mistakes often made by new SODIS users?	XXI
◆ Do additives from plastic bottles migrate into the water and cause a possible health risk?	XXI
◆ How can I distinguish a PET- from a PVC-bottle?	XXI
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◆ How do deal with waste generated by old and damaged SODIS bottles?	XXII
◆ How is SODIS stored at home to avoid secondary contamination of the water?	XXII
◆ What to do against growth of Algae in bottles exposed to the sun?	XXII

### Does SODIS “inactivate” or kill all the bacteria?

SODIS is used to inactivate the pathogenic microorganisms, predominantly those causing diarrhea. Most pathogens cannot grow outside the human body apart from a few exceptions such as salmonella, which however require favorable environmental conditions (e.g. appropriate supply of nutrients). During the exposure of the SODIS bottle to the sun, other harmless organisms present in the water might grow well. Therefore, it is very important to use adequate parameters to assess the efficiency of SODIS, such as for example faecal coliforms, E.coli.

## Which microorganisms in the water are destroyed by using SODIS?

Research has shown that pathogenic bacteria and viruses are destroyed by SODIS. The inactivation of the following microorganisms has been observed:

- ◆ Bacteria: *Escherichia coli* (E.coli), *Vibrio cholerae*, *Streptococcus faecalis*, *Pseudomonas aeruginosa*, *Shigella flexneri*, *Salmonella typhi*, *Salmonella enteritidis*, *Salmonella paratyphi*
- ◆ Viruses: bacteriophage f2, rotavirus, encephalomyocarditis virus
- ◆ Yeast and Mold: *Aspergillus niger*, *Aspergillus flavus*, *Candida*, *Geotrichum*

The inactivation of spore and cyst forming organisms such as protozoa and helminths by solar water disinfection has not systematically been assessed yet.

However, the thermal death point of amoebic cysts for example is about 50°C. If contaminated water reaches a temperature of at least 50°C during an hour, this would ensure the destruction of the amoebic cysts as well as other microorganisms. (Compare with table)

Microorganisms	Temperature for 100% Destruction		
	1 Min.	5 Min.	60 Min.
Enteroviruses			62 °C
Rotaviruses			85 °C for 30 Min
Faecal Coliforms	at 80 °C complete destruction		
Salmonellae		62 °C	58 °C
Shigella		61 °C	54 °C
Vibrio Cholera			45 °C
Entamoeba Histolytica Cysts	57 °C	54 °C	50 °C
Giardia Cysts	57 °C	54 °C	50 °C
Hookworm Egg and Larvae		62 °C	51 °C
Ascari Eggs	60 °C	62 °C	57 °C
Schistosoma Eggs	60 °C	55 °C	50 °C
Taenia Eggs	65 °C	51 °C	51 °C

Table 6: Thermoresistance of micro-organisms (adapted from [32])

## What kind of indicators should be used for testing the effectiveness of SODIS?

Many waterborne pathogens can be detected directly but require complicated and expensive analytical methods. Instead of directly measuring pathogens, it is easier to use indicator organisms indicating faecal pollution in the water. A faecal indicator organism has to fulfil the following criteria:

- ◆ it is present in high number in the human faeces,
- ◆ it is detectable by simple methods,
- ◆ it does not grow in natural water,
- ◆ its persistence in water and the degree of removal through the water treatment method is similar to those of the waterborne pathogens.

Many of these criteria are fulfilled by *Escherichia coli* (E.coli, faecal coliform). E.coli is therefore the best indicator organism for assessing faecal contamination of drinking water when the resources for microbiological examination are limited (WHO, Guidelines for drinking water quality, 1993). An important point is that the testing for E.coli is also possible under the difficult field conditions in a developing country, for example by using the portable DelAgua field-test-kit.

Some organisms however such as Enteroviruses, *Cryptosporidium*, *Giardia* and *Amoebae* are more resistant than E.coli. The absence of E.coli therefore does not necessarily indicate their removal. Spores of sulfite-reducing clostridia can be used as an indicator for these organisms (WHO, Guidelines for drinking water quality, 1993). But the analytical methods cannot be used for routine tests as they are time-consuming and expensive.

Total coliform bacteria cannot be used as an indicator for the sanitary quality of untreated raw water, because they are naturally abundant in the environment.

Neither is the total count of bacteria an adequate parameter for the assessment of SODIS efficiency, as harmless bacteria might grow during sunlight exposure. The purpose of SODIS is not to produce sterile water free of microorganisms, but the inactivation of pathogenic, diarrhoea causing microorganisms.

### Up to which level of contamination with faecal coliforms does SODIS work?

The laboratory experiments showed an efficient reduction of the faecal coliforms through SODIS also with initial concentration of 10'000/100ml up to more than one million/100ml. This is much more than normally encountered in common river and ponds ( a few thousand/100ml or less).

However it has to be considered, that the conditions during the experiments are different from practical situations, where the process might not be applied in a strictly controlled way, materials are not optimal and the handling of the treated water often is inadequate.

Important for an efficient inactivation of faecal coliforms is sufficient exposure of the contaminated water to the sun (500 W/m<sup>2</sup> during at least 6 hours) in an appropriate container and clear water (water turbidity should be less than 30 NTU).

### What kind of containers should best be used for SODIS?

We recommend to use PET-bottles, with a volume up to 2 litres for SODIS because they:

- ◆ show a good transmittance for UV-A-radiation
- ◆ are locally available in many places
- ◆ are cheap and durable
- ◆ contain fewer additives than PVC bottles

Also glass bottles can be used for SODIS, but user's experiences with glass bottles have shown that SODIS is less efficient in these bottles because it takes more time to increase the water temperature. The users also found the handling of glass bottles less practical: they are not convenient to carry (heavy), bottles are easily smashed, and they are more expensive to buy than plastic bottles.

### Is it possible to use SODIS when it is cloudy?

The SODIS efficiency is dependent on the amount of solar energy available:

- ◆ Expose the bottle to the sun for 6 hours if the sky is cloudless or up to 50% cloudy.
- ◆ During completely overcast days the UV-A radiation intensity is only 30% of the radiation present on a cloudless day. On cloudy days it is therefore necessary to expose the bottles for two consecutive days.
- ◆ At a water temperature of at least 50°C, 1 hour exposure time is sufficient.
- ◆ During days of continuous rainfall, SODIS does not perform satisfactorily. Rainwater harvesting or boiling is recommended during these days.

### Can I increase the efficiency of SODIS?

There are a number of methods to enhance the efficiency of SODIS:

- ◆ place the plastic bottles on a metal sheet,
- ◆ use raw water with low turbidity,
- ◆ expose the bottle for two consecutive days on cloudy days,
- ◆ replace old and scratched bottles.

### Which water can I use for SODIS?

- ◆ Clear water; i.e. water free of solid matter and of low turbidity (<30 NTU)
- ◆ Water free from chemical contamination
- ◆ Microbiologically contaminated water: water that might have been in contact with faeces (the purpose of SODIS is to improve the microbiological quality of the water)

### Which water should not be used for SODIS?

- ◆ As turbidity reduces solar radiation intensity and protects microorganisms from being irradiated, the raw water used for SODIS should be as clear as possible and it should not exceed a turbidity of 30NTU.
- ◆ SODIS does not change the chemical quality of water. Chemically contaminated water should therefore not be used for SODIS (nor should it be consumed without treatment).

### How can the turbidity of water be measured?

There is a very simple test: Fill the SODIS bottle with the water and place the bottle on top of a paper with the SODIS-Logo (the letters should have a size of about 1.5cm). Open the lid of the bottle and watch through the bottle to the bottom of the bottle. If you still can read the letters of the SODIS-Logo on the paper, you can use the water for SODIS.

If you cannot read the letters, the water is too turbid for SODIS and needs to be filtered before the water is filled into the SODIS bottle.

### Why should I shake the bottle for 20 seconds after I filled 3/4 of it with water?

Oxygen helps to kill the microorganisms as has been shown by the research work carried out by Reed. Filling the bottle to 3/4 and closing it, shaking it for approx. 20 seconds and filling it then completely with water would be the best procedure for SODIS. Especially when people treat standing water (e.g. as it is the case in Thailand for stored rainwater), it would be very good to shake the bottle first and therewith increase the level of oxygen in the water.

After shaking, the bottle should be filled completely in order

to avoid any air pocket which partly would reflect sunlight radiation (interference at the free water surface).

### What are the mistakes often made by new SODIS users?

Green or brown plastic bottles are used for SODIS.

=> such bottles do not transmit the UV-A light. Therefore use clear transparent bottles only.

The containers chosen are too big.

=> optimally plastic bottles of 1-2 litres volumes are used (better surface/volume ratio).

Bottles are placed upright.

=> Instead of this: laying the bottles horizontally increases the area for sunlight exposure and reduces water depth. (At a water depth of 10cm and moderate turbidity level of 26 NTU, UV-A radiation is reduced to 50%)

After SODIS treatment, the clean water is filled into contaminated containers and the water is recontaminated.

=> Instead of this: consume the treated water directly from the bottle using a clean glass or a cup.

### Do additives from plastic bottles migrate into the water and cause a possible health risk?

Sunlight transforms plastic material into photoproducts. Laboratory and field tests however revealed that these photoproducts are generated at the outer surface of the bottles. No migration of these photoproducts from the PET bottles into the water was observed with the applied analytical methods.

### How can I distinguish a PET- from a PVC-bottle?

- ◆ PVC is difficult to inflame. The material doesn't burn outside the flame. The smell of the smoke is pungent.
- ◆ PET burns easily when held into a flame. The fire goes out slowly or not at all outside the flame. The smell of the smoke is sweet. You should use the PET bottles for SODIS.

### How long can a PET-bottle be used for the SODIS application?

The UV-A transmittance of the bottle is very important for the efficiency of SODIS. Clear and unused PET-bottles usually have a transmission of >60% above 340nm (UV-A: 320-400nm). The experiments however have shown, that the ageing of the bottle decreases UV-A transmission.

In addition to the aging of the bottle due to sunlight, bottles are being scratched during the daily handling. We do recommend to replace scratched and dull bottles after about one year of regular daily SODIS application.

### How to deal with waste generated by old and damaged SODIS bottles?

It is not recommended to burn the PET-bottles under the conditions generally encountered in the field. Due to the lack of oxygen under such conditions, carbon monoxide (CO) is formed instead of carbon dioxide (CO<sub>2</sub>). In addition, PET contains aromatic substances which, when being burnt under suboptimal conditions (low temperatures and lack of oxygen), are transformed into the toxic PAHs (polycyclic aromatic hydrocarbons).

However, if PET is burnt at high temperatures and with sufficient oxygen, as it is the case in incineration plants, only carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) are produced. Therefore, old SODIS PET-bottles should be collected and recycled, or burnt centrally. Another option is to use the old bottles for other purposes, e.g. as pots for growing seedlings, or to centrally bury the old bottles together with the household waste.

### How is SODIS stored at home to avoid secondary contamination of the water?

The best solution to avoid secondary contamination of SODIS-treated water is to store the water in the same bottle and drink it directly from the bottle (best by using a cup). This handling is very effective in preventing secondary contamination of the treated water. Therefore, a double set of SODIS bottles is required: One for exposure during the day, the other containing the water treated during the previous day ready for consumption.

### What to do against growth of Algae in bottles exposed to the sun?

Depending on the local water quality, algae can grow inside the SODIS bottles after some days of solar exposure. The algae do not pose a health problem, but their layer on the inner wall of the bottle may reduce UV-A transmission. Bottles can be cleaned by putting some sand into the bottles and shaking them. This procedure however scratches the inner surface of the bottle and reduces its lifetime.

However, instead of cleaning bottles with algae it would be better to avoid the growth of algae. Water could be filtered before solar exposure to remove as much solid matter as possible - and it should be drunk before algae can grow. Usually the growth of algae is only observed after several days of exposure.