SUMMARY

SODIS is a water treatment method which uses solar energy to improve the microbiological water quality. It is used at household level to treat small quantities of drinking water.

BACKGROUND INFORMATION

What is SODIS?

- A treatment method to eliminate the pathogens which cause water-borne diseases
- Ideal to disinfect small quantities of water used for consumption
- A water treatment process depending on solar energy only
- An alternative water treatment option for use mainly at household level
- An old but so far hardly applied water purification method

The drinking water situation is precarious in numerous developing countries as more than one third of the rural population has no access to sufficient and clean water. Diarrhoeal diseases may be transmitted through contaminated drinking water and cause the death of over three million people annually. Solar water disinfection (SODIS) can contribute to improve this precarious situation.

SODIS does not

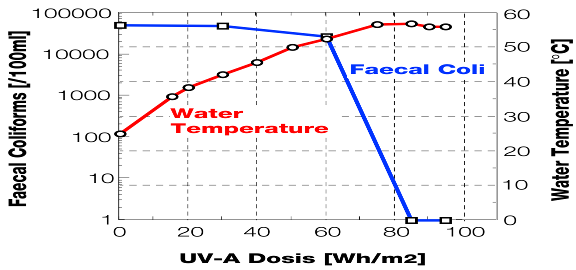
- change the chemical water quality
- change the odour nor the taste of the water
- increase the water quantity or reduce water shortages

Limitations of SODIS

- SODIS is not useful to treat large volumes of water
- SODIS requires relatively clear water (turbidity less than 30 NTU)
- SODIS needs solar radiation
  (exposure time: 5 hours under bright or up to 50% cloudy sky, or 2 consecutive days under 100% cloudy sky)

How does SODIS work?

The treatment process is a simple technology using solar radiation to inactivate and destroy pathogenic microorganisms present in the water. The treatment basically consists in filling transparent containers with water and exposing them to full sunlight for about five hours.



Inactivation of Faecal coliforms with half-coloured PET-bottle

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EAWAG SANDEC

Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland

Phone +41-1-823 50 19 Fax: +41-1-823 53 99

http://www.sodis.ch

http://www.sandec.ch

SUMMARY

Plastic bottles made from PET are recommended for SODIS use as they should not contain substances hazardous to health. Good transmittance of UV-A light is required when glass bottles are to be used for SODIS.

BACKGROUND INFORMATION

Plastic: Preference for PET

Plastic mineral-water and soft-drinks bottles are gradually replacing glass. Plastic bottles are made of either PET (polyethylene terephtalate), or PVC (polyvinyl chloride), both containing additives like UV-stabilisators to increase their stability or to protect them and their content from oxidation and UV radiation. Additives are large molecules which hardly imigrate through the PET material. Still, they are a potential health risk. In PET, additives are much less used than in PVC (less than 1% for PET), making PET the preferred material for SODIS treatment. Various types of transparent plastic materials are good transmitters in the UV and visible range of solar spectrum.

PET or PVC? A simple Test

There are several simple methods to determine wether a bottle is made of PVC or PET. One is the appearance. Bottles made of PVC have often a bluish gleam. This bluish hue 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.

Glass: UV-A Transmission

The transmission for ultraviolet radiation is largely determined by the content of iron oxide in the glass. Ordinary window glass in thicknesses of 2 mm or more is practically opaque to UV-radiation. Certain specific glasses (Pyrex, Corex, Vycor, Quartz Glasses) transmit significantly more ultraviolet radiation than the ordinary window glass. However, for an appropriate technology like SODIS large scale utilization of these special glasses may not be very attractive due to their high costs and rare availability in the developing areas of the world.

The advantages of PET are

- ☺ Low weight
- ☺ Relatively unbreakable
- ☺ Transparent
- ☺ Taste-neutral
- ☺ Chemical stable

The disadvantages of PET are

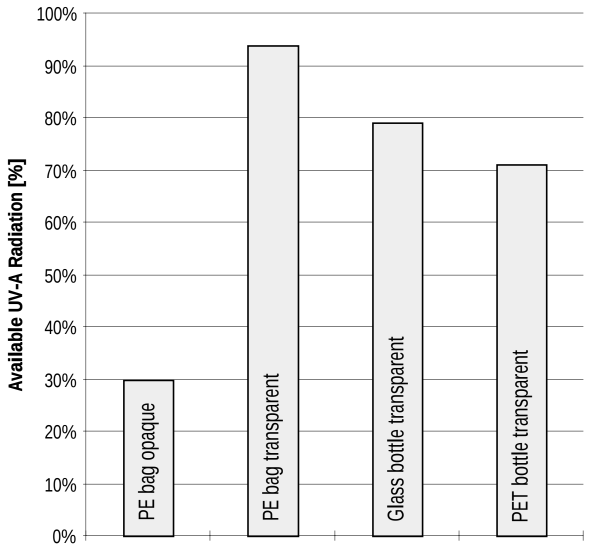
- ☹ Limited heat resistance (deformations above 65 °C)
- ☹ Scratches and other ageing effects

Advantages of Glass

- ☺ No scratches
- ☺ No photoproducts
- ☺ Heat resistance

Disadvantages of Glass

- ☹ Easily smashed
- ☹ High costs
- ☹ Weight



UV-transmission of PE, Glass and PET (examples)

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SODIS News No. 2, August 1997

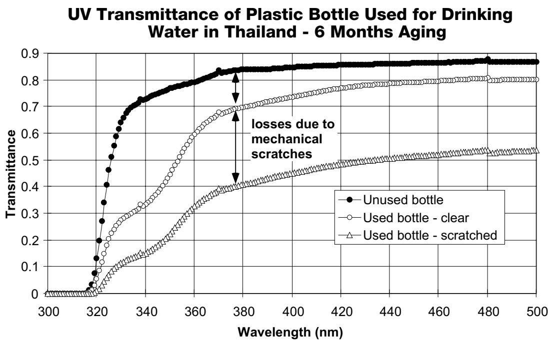
SUMMARY

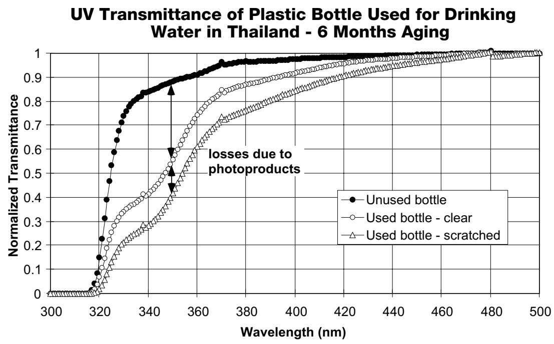
SODIS bottles are used daily and for a long period of time. Ageing of the PET-bottles leads to a reduction of UV-transmittance which, in turn, can result in a less efficient inactivation of microorganisms. The additives in the PET material, which are used to protect it from degradation by sunlight, have no influence on the water quality, since at the inside of the bottle no photoproducts are generated.

BACKGROUND INFORMATION

Transmittance Losses

Ageing of the bottles leads to a reduction of UV-transmittance which, in turn, can result in a less efficient inactivation of microorganisms. The figure below illustrates the UV transmittance for used and unused bottles. The figure on the left shows the transmittance losses due to mechanical scratches whereas the figure on the right illustrates the losses due to photoproducts. Smooth and careful cleaning is necessary to avoid mechanical scratches.

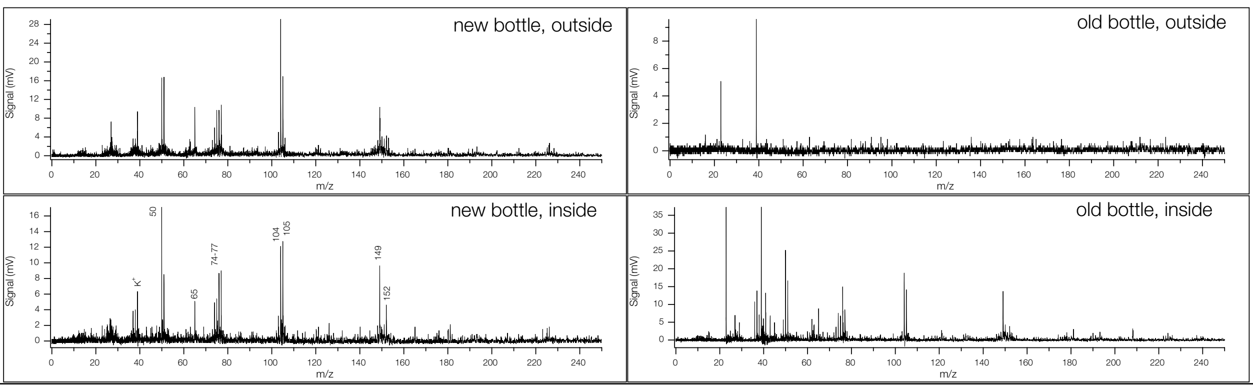




Photoproducts

PET, like all polymeric materials, undergoes reactions with oxygen or degradation under sunlight. The UV A and B components of sunlight in the 290-400 nm wavelength range lead to photochemical reactions resulting in optical and mechanical property changes.

To improve their stability, additives are widely used to protect them from oxidation, UV radiation effects, weathering etc. In the course of the polymer's life, the additives will be depleted from the host material by photochemical reaction or diffusion. This can greatly influence the properties of the material. The figure below illustrates the difference between new and old bottles exposed to sunlight for 6 months. The outer surface of the bottles clearly indicates the difference between a new and an old bottle. Hardly a difference is, however, visible between the inner surface of the old and the new bottle in the mass spectrum. Since the inner surface of the bottle does not seem to be affected by UV radiation, it is very unlikely that photoproducts of polymer additives will pollute the treated drinking water and cause health problems.



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EAWAG
SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99
http://www.sodis.ch
http://www.sandec.ch

SUMMARY

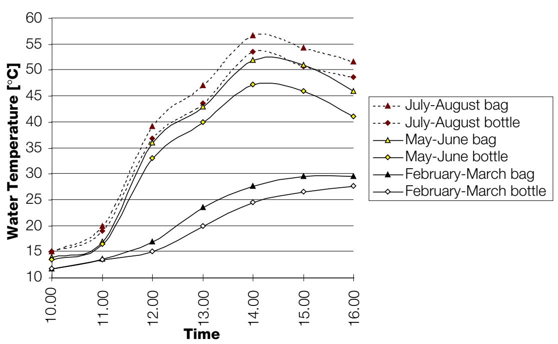
Plastic bottles made from PET are suitable containers for SODIS application. Higher treatment efficiencies can be achieved with plastic bags due to their larger area exposed to sunlight and smaller water depth. However, handling of plastic bottles is easier and more convenient to the users.

BACKGROUND INFORMATION

The SODIS treatment method bases on the synergetic effect of both water temperature and UV-A radiation (wavelength: 320-400 nm). Radiation with longer wavelength (> 400 nm) does not eliminate the bacteria efficiently enough and UV-B (280-320 nm) is only transmitted through special Pyrex glass and does reach the ground level at low intensity only. PET (Polyethyleneterephtalate) shows a good UV-A transmittance and therefore readily available PET-bottles are used for the SODIS-treatment.

On the technical side, PET-bottles are not the most efficient containers as they show a small area for sunlight exposure and have a water depth of 6-10 cm. As a consequence, the exposed area/water volume ratio is quite low which means that water is not heaten up to maximum possible temperatures and the UV-A radiation intensitiy on the lower side of the bottle is reduced.

As an alternative, bags made out of a transparent and a black PET-sheet have been produced (SODIS-bags) with a larger area for sunlight exposure and water depth of less than 6 cm. This increases the exposed area/ water volume ratio and therefore enhances the inactivation process.



Wter temperature curves in bottles and bags. The average temperature difference is about 2-3 °C.

Advantages of SODIS bags

- ☺ Faster heating up and to higher temperatures compared to the bottle
- ☺ More efficient inactivation of bacterias and viruses than with SODIS bottles

Disadvantages of SODIS bags

- ☹ The water out of SODIS plastic bags smells plastic
- ☹ Difficult to handle (filling and taking the water)
- ☹ The SODIS plastic bag is not durable (3-6 months only)
- ☹ A container is necessary to consume the water
- ☹ SODIS bags are not readily available
- ☹ Plastic is a problem for the environment

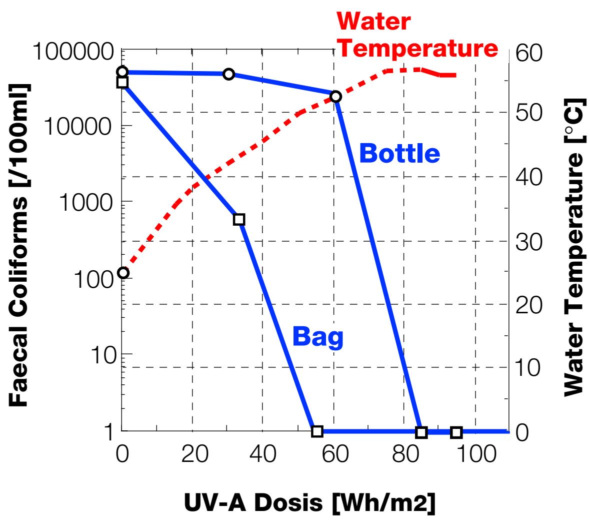
Advantages of SODIS bottles

- ☺ It is practical as it can be used directly at the table, no need for other container.
- ☺ Easy to handle (filling, carrying, taking the water)
- ☺ It is more prestigious
- ☺ The bottle is more durable. Even after several months, the bottle is still in good condition
- ☺ The bottle is easy available at low cost

Disadvantages of SODIS bottles

- ☹ Plastic is a problem for the environment
- ☹ Several bottles are needed to treat the water for the whole family.

Inactivation curves of SODIS bags and bottles



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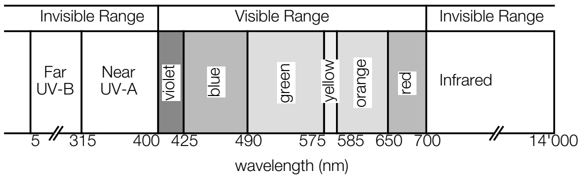
SUMMARY

Solar radiation reaching earth is composed of UV-B, UV-A, visible and infrared light. High radiation intensities are generally available in most developing countries, especially in those around the equator. UV-A is the most important spectrum for SODIS.

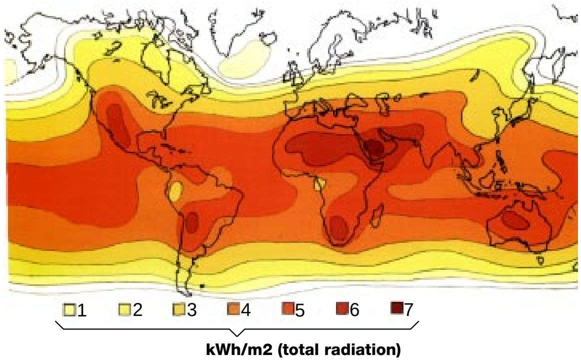
BACKGROUND INFORMATION

Solar radiation spectrum

The sun continuously radiates enormous amounts of solar energy at wavelengths that cover the ultraviolet,



visible, and infrared bands. Not all of the solar radiation received at the periphery of the atmosphere reaches the surfaces of the earth. This is because the earth atmosphere plays an important role in selectively controlling the passage towards the earth's surface of the various components of solar radiation. Radiations with short wavelengths are selectively scattered much more extensively than those with longer wavelengths by atmospheric gases or particles that are smaller in dimension than the wavelength of a particular radiation. Most of the radiation with a range of wavelengths from 200 to 300 nm is absorbed by the ozone (O_3) layer in the upper atmosphere.



Global Solar Energy Distribution

Solar radiation is unevenly distributed and varies in intensity from one geographic location to another depending upon the latitutde, season, and time of day.

The most favourable region for SODIS lies between latitudes 15°N and 35°N and embraces the regions that are naturally endowed with the most favourable conditions for solar energy applications. These semi-arid regions are characterized by having the greatest amount of solar radiation, more than 90% of which comes as direct radiation because of the limited cloud coverage and rainfall (less than 250 mm per year and usually more than 3000 hours of sunshine per year).

The second most favourable region lies between the equator and latitude 15°N. Because humidity is high and cloud cover is frequent, the proportion of scattered radiation is quite high. There is a total of about 2500 hours of sunshine per year.

It is important to note that the majority of developing countries fall within the more favourable regions between latitudes 35°N and 35°S. For this reason they can count on solar radiation as a steadfast source of energy that can be readily exploited cheaply by both rural and urban households for a multitude of purposes, including solar disinfection of drinking water.

UV-A is important for SODIS

The inactivation rate of micro-organisms increases with decreasing wavelength: Visible light → UV-A → UV-B → UV-C (260 nm). The maximum DNA absorbtion corresponds to the wavelength of UV-C. Comparing UV-A radiation and with visible light for example, more than the double amount of light is needed when using visible light only for the inactivation of microorganisms.

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Climatic Conditions: Seasonal Effects and Weather Changes

SUMMARY

Solar radiation intensity varies over time and geographical location. During completely overcasted days the UV-A radiation intensity is reduced to one third of that recorded during a cloudless day.

BACKGROUND INFORMATION

Solar radiation received at ground level has been measured at meteorological stations for many years in most western countries. This has not been the case in the developing world, where the potential and need for the development of sunlight as an alternative source of energy are even greater.

Seasonal variation

Solar UV-A intensity shows both seasonal (because of changes in the earth's angle of tilt) and daily variation. This variation is depens on the latitude and is mainly responsible for the climate in that region. Regions near the aequator encounter lower variance of light intensity during the year than those in the northern or southern hemisphere. In Beirut for example (Latitude: 56°N), a horizontal surface (Figure 1), the intensity reaches a peak level of some 18 W/m² in June and decreases to its lowest level close to 5 W/m² in December. The difference between these two levels (13 W/m²) is appreciable and important.

Daily variation (weather changes)

Figure 2 below shows the variation in received solar UV-A radiation intensity throughout the day under clear and cloudy weather conditions in Beirut (April and October 1985). With increasing cloudiness, less radiation energy is available. The reduction is depending on the wavelength as shown in Figure 3.

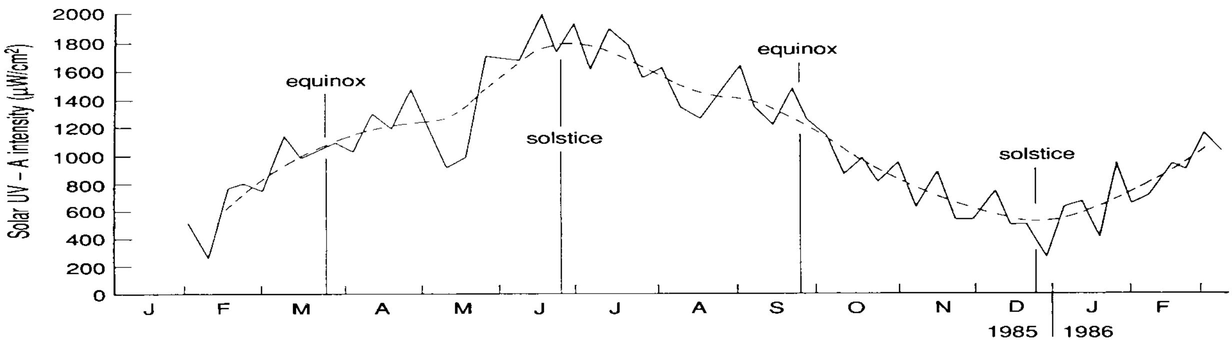

Figure 1: Mean weekly values (solid line) and moving averages (broken line) for solar UVA-A radiation intensity (horizontal surface)

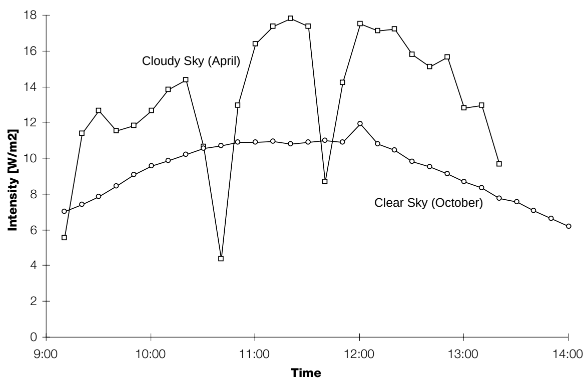

Figure 2: Variation of UV-A intensity during daytime under different weather conditions

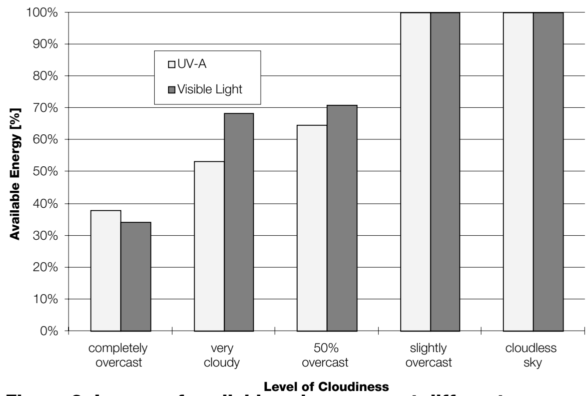

Figure 3: Losses of available solar energy at different weather conditions

REFERENCES

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EAWAG
SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99
http://www.sodis.ch
http://www.sandec.ch

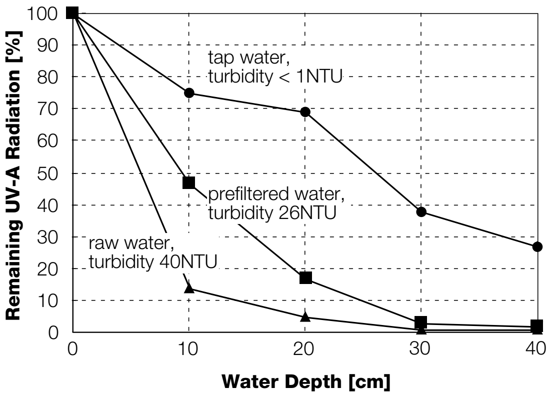
SUMMARY

Radiation intensity is reduced by increasing turbidity and water depth. Raw water of low turbidity (< 30 NTU) should be used for SODIS. Similarly, the water depth should be small and not exceed 10 cm in order to allow sufficient radiation of the water.

BACKGROUND INFORMATION

Water Turbidity

Turbidity is used as a parameter to characterise the optical properties of liquids containing absorbers and scatterers; i.e. suspended particles. As shown in Figure1, high turbidity substantially reduces the light penetration in water and therefore reduces the disinfection efficiency of the SODIS treatment process. To ensure safe water disinfection, the raw water should have a low turbidity (less than 30 NTU=Nephelometric Turbidity Units).



Water depth

UV-radiation is reduced by increasing water depth. At a water depth of 10 cm and moderate turbidity level of 26 NTU, UV-A radiation is reduced to 50%. The black lower surface of SODIS bags and bottles induces a temperature gradient which causes the water to circulate within the container thereby improving the inactivation efficiency. In any case, containers used for SODIS should be as flat as possible, with a water depth less than 10 cm.

Water Turbidity Test

To decide whether the water needs filtering, place the filled bottle on the SODIS Logo (see Figure below) on top of a table in the shade (to avoid light interference) and look through the bottle from top to bottom. If you can read the letters through the water, water turbidity is less than 30 NTU. If you can still see the sun rays of the Logo, turbidity is less than 20 NTU.

If water turbidity is higher than 30 NTU, coarse and settleable solids can be separated by storing the raw water for one day, and turbidity can be reduced possibly by flocculation / sedimentation (using alum sulphate or crushed Moringa oleifera seeds) or by filtration.

SODIS Logo for Turbidity Test. If one can read the letters, the turbidity is less than 30 NTU. If one can see the sun rays of the Logo, turbidity is less than 20 NTU.

REFERENCES

Wegelin, M. et al. (1994). Solar water disinfection: scope of the process and analysis of radiation experiments. *J Water SRT-Aqua*, 1994, **43**, No. 3, 154-169. [P1]

SODIS News No. 3, August 1998

EAWAG SANDEC

Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99

http://www.sodis.ch
http://www.sandec.ch

SUMMARY

The efficiency of SODIS can be increased by exposing oxygen saturated water to sunlight. Photoreaction will produce reactive forms of oxygen which will contribute to kill the microorganisms.

BACKGROUND INFORMATION

Role of Oxygen

Sunlight has a direct impact on microorganisms. The UV-A radiation is directly absorbed by the organic material. Besides this, the sunlight radiation produces highly reactive forms of oxygen which in term kill the microorganisms. Reactive forms of oxygen include oxygen free radicals and hydrogen peroxides. These intermediates are a temporary product for the action of sunlight on microbes in oxygenated water, with no significant residual effect once the sample is removed from the sunlight. The process has been termed ‘solar photo-oxidative disinfection’. The microbes exposed to the reactive oxygen intermediates are being oxidised during the treatment. Figure 1 shows representative results for faecal coliform bacteria in sewage-contaminated water. It is worth noting that the vertical axis is a logarithmic one, with a decrease in the number of bacteria of more than one thousand fold in less than five hours under oxygen-saturated conditions and a reduction of approximately tenfold over the same time period under deoxygenated conditions.

Bacteria regrowth

The possibility that the bacteria were sub-lethally injured, rather than killed, by the combination of sunlight and oxygen was assessed by performing further counts on samples 24 hours after they had been illuminated: no increases were observed, indicating that the bacteria had been irreversibliy inactivated.

Improving SODIS efficiency: shaking the bottle

On a practical level, aeration can be achieved by stirring the raw water vigorously before filling the SODIS containers or by shaking the half-filled containers thoroughly and filling them completely before sunlight exposure. Especially stagnant water drawn from ponds, cisterns and possibly wells should be aerated to enhance the inactivation of microorganisms by SODIS.

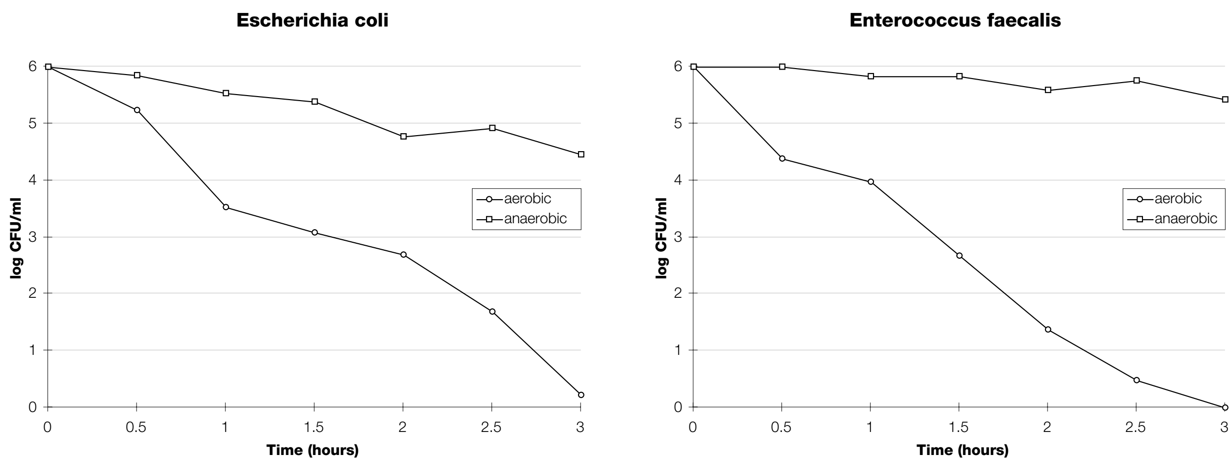


Figure 1: Inactivation under aerobic and anaerobic conditions

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EAWAG SANDEC

Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland http://www.sodis.ch

Phone +41-1-823 50 19 Fax: +41-1-823 53 99 http://www.sandec.ch

SODIS Technical Note # 9

SODIS Efficiency: The Process

SUMMARY

SODIS uses two components of sunlight: The UV-A light for irradiation of the microorganisms and the infrared light for water heating. This combined use has synergetic effects which enhances the inactivation efficiency of the process. A 3-log reduction of E. coli requires a fluence of 555 W·h/m² (dose of solar radiation integrated in the 350-450 nm wavelength range), which correspond to ~ 5h of mid-latitude midday summer sunshine. At a threshold water temperature of 50 °C the required fluence is reduced to 140 W·h/m² and hence, requires an exposure time of approx. 1 hour only.

BACKGROUND INFORMATION

Radiation effects

Radiation an short wavelengths induces lethal effects in bacteria and viruses. The shorter the wavelength, the more efficient microorgansims are eliminated. The radiation affects DNA, nucleic acids and enzymes. Table 1 shows the UV-A resistance of some microorganisms.

Table 1: UV-A resistance of some microorganisms (Acra, 1989)

Test organism	Fluence (W·h/m2) required to inactivate:		
	90%	99%	99.90%
Streptococcus faecalis	8.90	17.80	26.72
Coliforms	8.24	16.59	24.74
Escherichia coli	6.36	12.72	19.08

Temperature effects

Microorganisms are heat sensitive. Table 2 lists up the required temperature to eliminate microorganisms within 1, 6 or 60 minutes. It can be seen that it is not required to boil the water in order to kill 99.9% of the microorganisms. Heating up water to 50-60 °C for one hour has the same effect.

Table 2: Thermoresistance of microorganisms

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

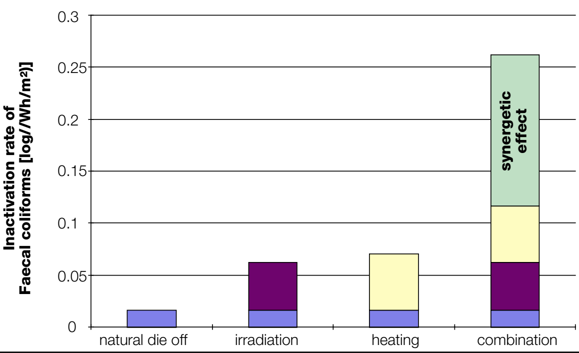
SODIS process: Synergetic effect

The SODIS treatment process is based on the synergetic effect of radiation and temperature. The die rates of Faecal coliforms exposed to irradiation heating increases substantially, when both stress factors occur. Table 3 and Figure 1 both show the synergetic effect of UV-radiation and water temperature on viruses and bacteria.

Table 3: Inactivation by artificial sunlight of coliphage f2 and the animal viruses EMCV and rotavirus. Time and fluence required for a 99.9% reduction at different temperatures are shown.

f2	Time (h)	Fluence (Wh/m²)
20 °C	3.3	2502
50 °C	1.3	973
EMCV		
20 °C	12.5	9535
50 °C	1.8	1390
Rotavirus		
20 °C	2.5	1890
40 °C	0.7	528

Figure 1: Synergetic effect of UV-radiation and temperature on Faecal coliforms in raw water.



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SODIS Efficiency: Influence of Turbidity

SUMMARY

Turbid water protects the microorganisms from being irradiated. The microorganisms will therefore only be exposed to thermal effects. Hence, the raw water used for SODIS application should be as clear as possible and not exceed a turbidity of 30 NTU.

BACKGROUND INFORMATION

Turbidity effects

Suspended particles in water cause radiation scattering by deflection from their surfaces in all directions. Turbidity is used as a parameter to characterise the optical properties of liquids containing absorbers and scatterers.

In short, turbidity

- reduces solar radiation intensity (Figure 1)
- protects microorganisms from being irradiated (being either under floating solids or in settleable solids)
- reduces the efficiency of the SODIS process (Figure 2)

Influence of temperature

UV-A radiation intensity is more reduced in turbid than in clear water, therefore reducing the SODIS-efficiency. However, the water temperature almost reaches the same level as in non-turbid water. The microorganisms are therefore inactivated by the temperature rather than by UV-A radiation. Table 1 shows some test results with bottles and bags at different levels of turbidity. With very high turbidity, not all pathogens could be eliminated in the bottle, because of the influence of the water depth (8 cm with bottle compared to 4 cm with bag).

Nevertheless turbidity has only a moderate effect on the efficiency of SODIS, the raw water used should be as clear as possible and not exceed a turbidity of 30 NTU.

Figure 1: Reduction of UV-A radiation as a function of water depth and turbidity

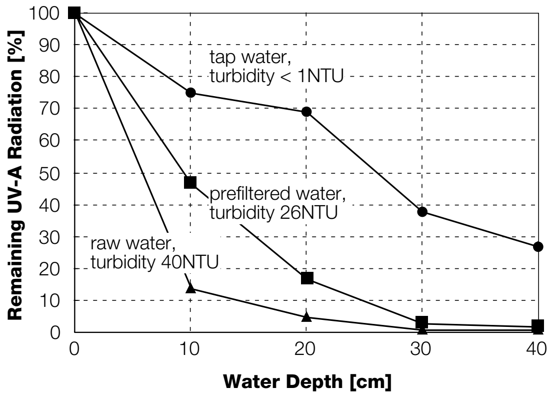

Figure 2: Inactivation of Faecal coliforms in 15 minutes under different test conditions

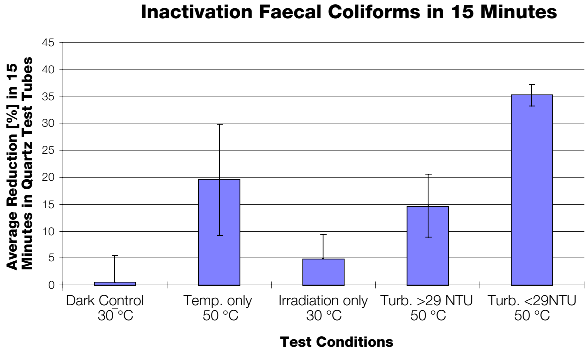

Table 1: Inactivation of Faecal coliforms in bags and bottles at different turbidity levels

	Faecal coliforms [CFU/100ml]		
Turbidity (NTU)	Begin	End (Bag)	End (Bottle)
5-10	290	0	0
10-20	16	0	0
30-40	1950	0	0
250	9050	0	116

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SUMMARY

Suboptimal climatic conditions - as it is the case for covered sky - might require to expose the SODIS bottles during two consecutive days. Sunlight exposure induces lethal effects to the microorganisms and hence, revival or regrowth has not been recorded.

BACKGROUND INFORMATION

Suboptimal conditions in the field

In the field, optimal conditions can often not be found, i.e. covered sky instead of full sunshine (see also Technical Notes 6). To encounter these problems, it is important to know that the die-off of microorganisms and pathogens is caused by several factors:

- Light
- Temperature
- Nutrition
- Humidity
- Time

Pathogens cannot grow outside the human body, apart from some exceptions like salmonella.

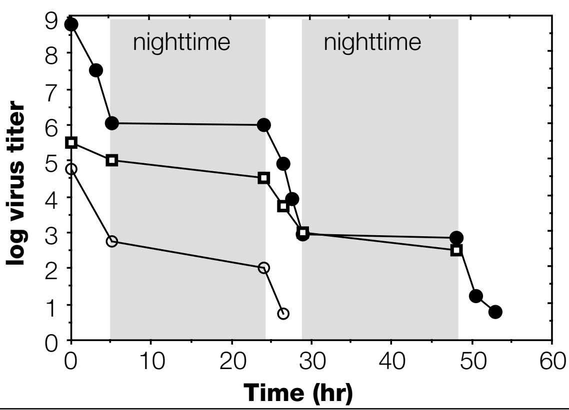
Prolonged SODIS operation

With covered sky, exposure for two consecutive days is needed to reach the required radiation dose and to ensure complete inactivation of the pathogens (see Figure 1 as an example).

Regrowth of microorganisms

Bacterial suspensions exposed to artificial UV-C radiation are inactivated within a few seconds only.

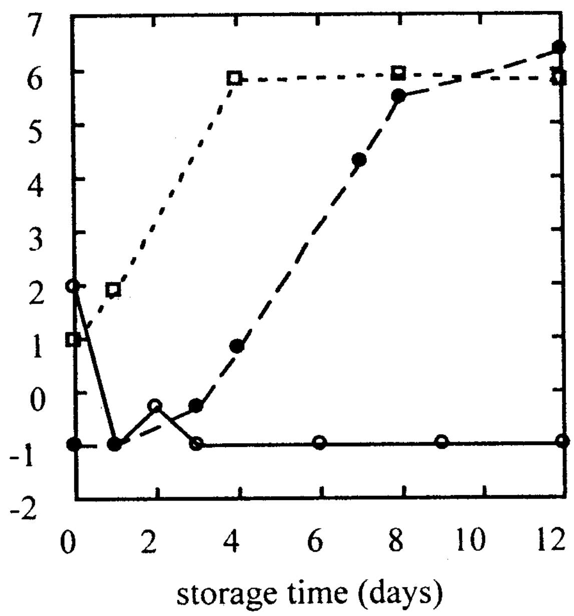
Figure 1: Prolonged SODIS operation (3 days) of ● coliphage f2 and the animal viruses ❑ EMCV and ❍ rotavirus.



However, it is observed that bacterial regrowth occurs which reaches the original cell density within a 1-week period (Figure 2). In comparison, suspensions exposed to normal sunlight and for a longer period of time (several hours) did not result in a revival or regrowth of E. coli even after prolonged storage periods of over two weeks.

However, the SODIS bottle exposed to sunlight is also a bioreactor in which harmless bacteria mixtures can multiply (Figure 2) as they would also do in the environment. Killing the pathogenic microorganisms is the target of SODIS and not the production of a sterile water.

Figure 2: Regrowth of E. coli and bacterial mixtures during increasing storage time of the irradiated supensions.



● **E. coli irradiated using the undoped lamp and 320 nm cut-off filter**
❍ **E. coli irradiated with sunlight**
❑ **bacterial mixtures irradiated with sunlight**

REFERENCES

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EAWAG
SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99
http://www.sodis.ch
http://www.sandec.ch

SUMMARY

The SODIS water treatment method is simple and easy to apply. Nevertheless, people will have to be introduced carefully to the process and trained. to handle it adequately.

BACKGROUND INFORMATION

Laboratory tests and practical use

The conditions in practical SODIS application differ from the ones in laboratory and field test experiments. The process is not applied under strictly controlled conditions, the material and methods used are often not optimal and the handling of the treated water freqently inadequate.

Furthermore, the inital Faecal coliform concentration used in the experiments was often much higher (> 10'000/100 ml up to more than one million/100 ml) than commonly encountered in polluted rivers and ponds (some 100 or 1000/100ml).

Handling and training

The SODIS water-treatment method is simple to apply. Nevertheless, people will have to be introduced carefully and get guidance about day-to-day application if they are to benefit fully.

There are different ways exposing the bottles of water to the sun. The users are oftenis not aware that the place used to expose the water to the sun should have full exposure for about 4-5 hours.

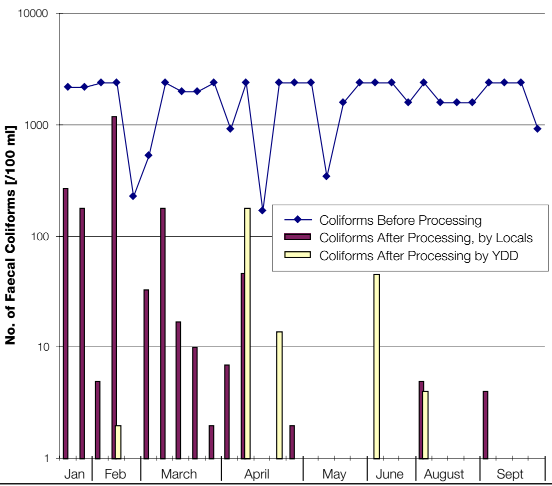
Mistakes made

- ☹ It is observed that some bottles are exposed to sunshine in the morning. But after two hours the area is shaded by trees or the house.
- ☹ It is also observed that many people like to put their bottles on a chair. At a certain point, the back part of the chair shades the bottles.
- ☹ Some users expose the bottle with the wrong side to the sun, with the black part on top.

In the rural Melikan, 40% of the villagers have started to place their containers on chairs or concrete floors which, compared to exposure on black rocks, corrugated zinc or tile roofs, are not ideal conditions: The disinfection efficiency is lower, and only 50% of the exposed water samples were free of Faecal coliforms. After people received training and suitable, corrugated zinc sheets, the number of inadequate applications was reduced to 3%.

The YDD (Yayasan Dian Desa) staff as SODIS project team treated in parallel to the users the same raw water and achieved far better results. This experience illustrates the importance of proper and continuous training of the users.

Progress of SODIS handling in Indonesia. The bars show the remaining Faecal coliforms in the treated water. By training, the users became as successful in treating water as the YDD team.



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SODIS **Technical Note # 13**

SODIS Use: Application Procedure

SUMMARY

SODIS works with the synergetic effect of water temperature and UV-radiation. The prescription given here mainly have the effect that sunlight and temperature are optimized. High water temperature is reached by using black surfaces or black paint and not too large volumes of water per exposure area. Radiation dose is depending on the choice of the material for the container, location and orientation of the container, water depth, turbidity and exposure time.

BACKGROUND INFORMATION

Containers

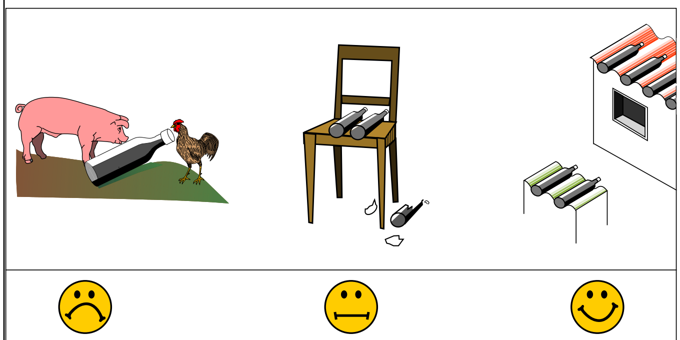
- Collect plastic bottles of 1-2 litre volume (preferably PET bottles) generally available as soft drink bottles
- Measure the light transmittance of the material with a photospectormeter (important is a good transmittance of the UV-A light, 320 - 400 nm spectrum)
- Check the water tightness of the bottles inclusive condition of the screw cap
- Clean the bottles thoroughly in- and outside
- Paint the bottles half-side black when black paint is available

Exposing Procedure

- Fill the bottles completely with raw water
- Screw the plug tightly
- Expose the bottles in the morning hours to sunlight on a place which is irradiated the full day
- Place the bottles in horizontal position on a firm blackened support, preferably on a corrugated iron sheet/roof or on a tile roof
- Collect the bottles in the late afternoon and bring them to a safe place for cooling
- Consume the treated water directly from the bottle using a clean glass or a cup, store it possibly overnight for additional cooling

Additional Prescriptions

- Use clean water free of settleable solids and of a low turbidity (max. turbidity > 30 NTU, see Technical Note #10, Influence of Turbidity, for more details). Separate coarse and settleable solids by storing the raw water for one day and reduce turbidity possibly by flocculation / sedimentation using alum sulphate or crushed Moringa oleifera seeds or by filtration.
- Use aerated water. Standing water with a low dissolved oxygen concentration should be aerated by shaking the containers or swirling the water with a stick before filling the containers.
- Observe a minimum exposure time to sunlight of one hour once the water temperature has reached 50 °C. At high ambient temperatures and intensive sun radiation one might be able to use the containers two times a day.
- Expose the water for five hours during a sunny day in case the water temperature has not reached the required 50 °C. Should the sky be covered with clouds expose the water for two consecutive days before consuming it.
- Collect rain water from a clean area (e.g. from a corrugated or tile roof) during rainy days to cover your drinking water demand.



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EAWAG SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland http://www.sodis.ch
Phone +41-1-823 50 19 Fax: +41-1-823 53 99 http://www.sandec.ch

SODIS **Technical Note # 14**

SODIS Use: Guidelines to Increase Efficiency

SUMMARY

Treatment efficiency can be increased by a sound application of SODIS. One important method is to enhance water heating through the use of half-blackened bottles and black zinc sheets as support of the bottles

BACKGROUND INFORMATION

In the field, the process is not applied under strictly controlled conditions, the material and methods used are often not optimal, the raw water pollution is generally much lower and the handling of the treated water frequently inadequate.

Optimizing water heating

The treatment efficiency can be increased by applying simple methods as listed below. Our method is to use half-blackened plastic bottles which achieve approx. 5°C higher water temperature as compared to unpainted bottles (see Figure 1). Another method is to place the plastic bottles on a black zinc sheet instead of laying them on a floor. This arrangement will also increase the temperature by approx. 5°C (see Figure 2). Both methods have the effect that the microorganisms are longer exposed to a period of increased temperature by a faster heating up of the water. This will enhance the inactivation effects.

Factors that reduce the efficiency

- Turbid water
- Bottles with low UV-A transmittance
- Low air temperature
- Cloudy sky
- Bottle placed upright instead of horizontal

Methods to enhance the efficency

- Use raw water with low turbidity
- Use half-side black painted plastic bottles
- Place container to a place which is exposed to the sun the full day
- Place the container on a corrugated zinc sheet
- Expose containers for two consecutive days on cloudy days
- Replace old and scratched bottles

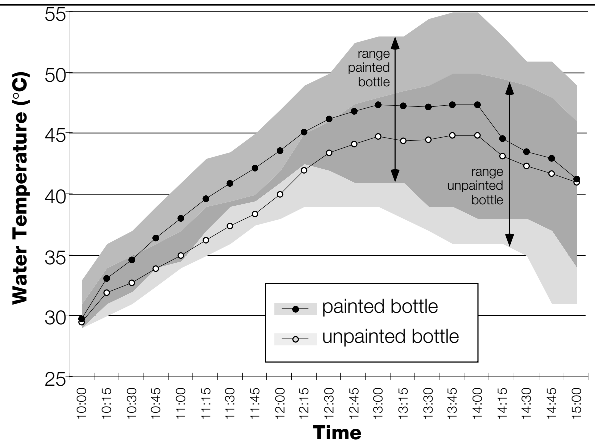

Figure 1. Comparison of water temperature in half-blackened SODIS bottles and clear bottles (cement floor, no black zinc sheet, no wind protection).

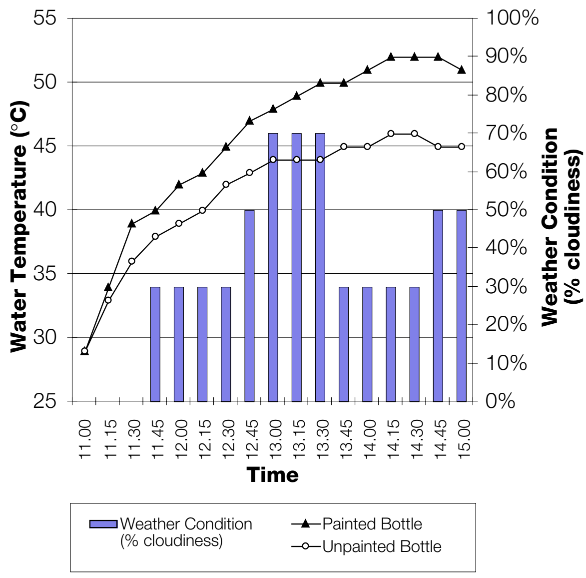

Figure 2. Water temperature in painted and unpainted SODIS bottles placed on a black zinc sheet. The bars illustrate the cloudiness.

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EAWAG
SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99
http://www.sodis.ch
http://www.sandec.ch

SUMMARY

High acceptance of SODIS is recorded as the useres appreciate the sustainable and simple water treatment method. Nevertheless, careful introduction of the process best through community participation is required to achieve good respond.

BACKGROUND INFORMATION

Introducing new equipment and facilities

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

Field Experience

The objective of the SODIS demonstration projects, conducted by local institutions in seven different countries, was to study the socio-cultural acceptance and affordability of this treatment option. The recently carried out survey revealed that an average of 84 % of the users will certainly continue to use SODIS after conclusion of the project, and about 13 % consider (maybe) using it in the future. Only 3 % refuse to use SODIS as their health is allegedly not affected by the present water quality. The figures obtained from two countries differ from the overall survey results inasmuch as the percentage of "maybes" was comparatively high in Burkina Faso (30 %) and China (45%). Involvement of the users in the projects was hardly observed in these two countries. In China, around half of the people interviewed said they still drink untreated water even though they are aware that the quality is poor.

Reasons stated by those who accept and continue practising SODIS

- Easy and practical
- It provides good and clean drinking water
- Less working time and burden for daily activities (no boiling means no starting fire, no fuel, no washing up the kettle)
- No pathogens anymore, less sickness, less diarrhea, no stomachaches
- It saves costs (firewood, fuel)
- It saves time
- Status
- Improves villagers quality of life

Table 1: Results of the SODIS acceptance evaluation

	I will continue to use SODIS			
Country	**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**

Reasons given by those who don't continue using SODIS

- Not trust in the results that bacteria can be killed just by exposure to sunshine
- Too long, not patience
- Water taste and smell plastic (especially those using plastic bags)
- Lack of materials

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Environmental Concern (EC) Khon Kaen (1997). SODIS Demonstration Projects. Khon Kaen, Thailand. Final evaluation. [FTha3]

EAWAG SANDEC

Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99

http://www.sodis.ch
http://www.sandec.ch

SUMMARY

SODIS is a low-cost technology. The required annual capital costs amount to a approx. 2-5 $ per household, the operation consts are practically zero. Saving due to reduced energy and medical care expenditures are expected benefits.

BACKGROUND INFORMATION

Willingness to pay

The factors influencing willingness to pay are rather complex and manifold. However, willingness to pay for a service or commodity is essentially demand-driven. The ability to pay is dependent on the level of income and costs of the provided service or commodity. Acces to good quality water, especially in terms of bacteriological quality, is often not a felt need, particularly not under "normal" pulic health conditions when several diarrhoeal incidences per year are regarded as normal. Hence, willingness to pay for water quality improvement may generally be low.

Economic considerations

The costs are divided into investment (cost of bottles) and operating & maintenance costs. The latter ones are neglectable, since solar energy is free of charge. The costs for PET bottles vary from country to country and usually amount less to than 0.5 US$/bottle:

China	0.14 US$
Thailand	0.3 US$
Colombia	0.4-0.6 US$
Indonesia	0.07 US$ (Rp. 500)

The annual costs for a household of 5 persons would amount 3 US$ only. (2 bottles per person at a price of 0.3 $ per bottle). The full costs for the bottles should be beared by the user of SODIS in order to achieve a real economic sustainability.

Project Costs

SODIS has to be introduced and disseminated by local institutions (NGO, government). These costs cannot be paid by the private users, but by public funds (grant of donors, governmental services).

Savings

Health benefits are difficult to quantify. Higher productivity through improved health and reduced costs required for medical treatment are the expected benefits. Reduced energy costs are a second benefit.

In Melikan (Indoniesia) for example, about 50% of the firewood consumption is used for water treatment (boiling). In average, each household spends more than Rp. 600 every day for the necessary firewood, whereas the price for a SODIS bottle (that can be used for a long time) amounts to only Rp. 500. Although water is purchased from a well owned by the government or from a private company, the water still has to be boiled for domestic purpose.

REFERENCES

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SODIS News No. 2, August 1997. [R12]

SODIS Use: SODIS Bags and Temperature Sensors

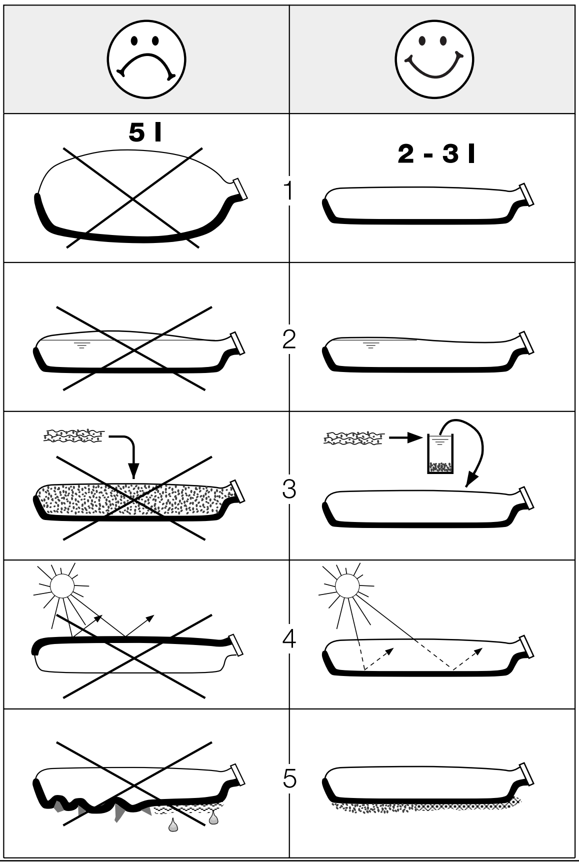
SUMMARY

SANDEC developed different prototype material which has been field tested in the SODIS demonstration projects. SODIS plastic bags were used to attract the interest of the people on the new water treatment method. Temperature sensors have been distributed to record whether the threshold water temperature of 50 °C has been attained or not.

BACKGROUND INFORMATION

Use of SODIS Bags

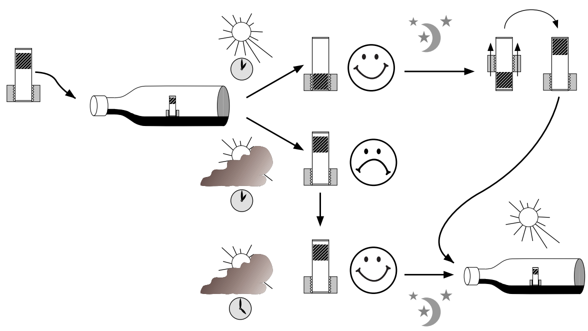
- Fill half of the bags with raw water
- Drive the air out of the bags and close them
- Place the bags in the morning hours on a spot receiving full sunlight throughout the day
- Place the bags in horizontal position on a firm blackened suport, preferably on a corrugated iron sheet/roof or tile roof
- Collect the bags in the late afternoon and store them in a safe place for cooling
- Consume the treated water directly from the bag using a clean glass or cup, store it possibly overnight for additional cooling



Use of Temperature Sensor

The SODIS Temperature Sensor (TS) is an aid for the user. It does not influence the SODIS process but is an indicator for the expected efficiency. When the temperature of 50°C is reached, the paraffine inside the TS melts and drops to the bottom. At this temperature, SODIS needs just one hour to inactivate the pathogens. The following day, the TS can be reused by pulling the screw to the opposite side of the paraffine and placing the TS inside the bag or bottle again (see Figure below).

When 50°C are not reached, the paraffine doesn't melt. If that's the case, the SODIS bag or bottle must be exposed for at least five hours to ensure inactivation. On very cloudy days and/or low temperature, an exposure for two consecutive days should be considered (see also Technical Note #11, Covered Sky Conditions).



Use of the Temperature Sensor. After the paraffine has melted down, the screw is pulled up, making the sensor ready for use again.

REFERENCES

EAWAG SANDEC
Ueberlandstr. 133, CH-8600 Duebendorf / Switzerland
Phone +41-1-823 50 19 Fax: +41-1-823 53 99
http://www.sodis.ch
http://www.sandec.ch