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Review on Solar Energy for Purification of Water

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Abstract

This paper discusses on the Purification of Water which would be considered the Solar Energy as the methods for purifying the water using sunlight and PET plastic bottles, the SODIS (solar disinfection) method uses a combination of UV sunlight and increased temperature to kill pathogens in the water. Therefore the UV water disinfection technology, the UV light disinfects by penetrating microorganisms such as Bacteria, E coli, Cholera, Salmonella, Shigella, Campylobacter jejuni, Yersinia, Enterocolitica, Parasites, Giardia, Crytosporidium, Entamoeba, worms, Viruses and Rotovirus and destroying their DNA. UV lamp has a limited life and must be replaced once it is exhausted. In the unlikely event of premature failure of the lamp, the monitoring circuit will provide the signal to advise replacement.

Keywords: *Review, Solar, Energy, Purification, Water*

Introduction

Fresh clean pure water is the most precious commodity on earth. It has a worth more than gold and silver. Water is the very essence of life. Without water, we cannot live. Without water, we perish. But in many parts of the world, clean drinking water is becoming more and more difficult to find. And even in developed countries, there are situations where we might find our drinking water contaminated. There are many ways in which to purify water for drinking. Here is a little known method that might come in handy some day.

Water does not need to be boiled to be made safe for drinking. Most microbes and pathogens will be killed at 150°F (65°C) for just five minutes. Solar radiation can purify water and make it safe to drink. Solar energy from the sun can disinfect water from lakes and rivers. The UV rays from the sun can kill harmful bacteria, parasites, and viruses, given enough exposure.

Diseases destroys by UV Solar rays

In the UV water disinfection technology, the UV light disinfects by penetrating microorganisms such as Bacteria, E coli, Cholera, Salmonella, Shigella, Campylobacter jejuni, Yersinia, Enterocolitica, Parasites, Giardia, Crytosporidium, Entamoeba, worms, Viruses and Rotovirus and destroying their DNA. DNA plays an important role in organisms' functions and reproduction hence destroying the DNA prevents the organism from being active and multiplying. This UV energy (wavelength of 240-280 nm) is also naturally found in sunlight in very small quantities. The same energy is produced in stronger intensities with help of high mercury discharge lamps, commonly known as UV lamps.

No bacteria, viruses, molds or their spores can survive when exposed to the correct dose of UV light. Therefore UV is considered as the best solution for water sterilization.

The World Health Organization (WHO) recommends the following low tech method of disinfecting water. Using only sunlight and PET plastic bottles, the SODIS (solar disinfection) method uses a combination of UV sunlight and increased temperature to kill pathogens in the water.

How to Purify Water Using the Sun

- The water should be from a clean, well known water source, such as a lake or stream. Running water is best. Avoid standing water; smelly water; water with an oily look; and water near latrines and sewers.
- The water must not be chemically polluted. This method can kill bacteria not chemical, it will not remove chemicals.
- If the water has visible contaminants, such as dirt, mud, or debris, filter the water by pouring it through several layers of cloth to catch as much sediment and debris as possible. Then any remaining sediment settles to the bottom and filter until the water is as clear as possible. The UV rays will not be able to penetrate through cloudy, dirty water.

- Use clean, clear soda or water bottles no larger than 2 liters. The bottles need to be in good condition with no scratches or other visible signs of wear.
- Colored plastic and glass bottles will block too much of the UV rays. Indeed, some glass will block the UV rays completely
- Fill the bottles 2/3 full of water and shake for 20 -30 seconds. This will saturate the water with oxygen, which will help to kill the germs. Then finish filling the bottles to the brim with water. Lay them down in the sun. Do not stand them up. Laying them down allows the UV rays to penetrate to maximum depth.
- Although not necessary, if possible lay the bottles on a reflective surface to optimize the UV exposure.
- If the sky is mostly sunny with only a few clouds, then 6 hours of sunlight will be enough. However, if the sky is more than 50% cloudy, then it will take 2 days to purify the water. The ambient air temperature is not a factor, it is the strength of the UV sunlight that is significant. If there is a question about the proper length of time because of the sky conditions, it is best to err on the side of caution and allow the full 2 days of exposure.
- While there is some concern that toxins may leach out of the plastic bottle during the process, the *Swiss Federal Laboratories For Materials Testing and Research(2006)* have examined this process and found that the levels of toxins from the bottles is far below the WHO guidelines. Figure 1 below shows how PETE plastics containing water are arranged for purification.

Figure 1 clear PETE plastic beverage bottles

Solar water disinfection, in short **sodis**, is a type of portable water purification that uses solar energy to make biologically-contaminated (e.g. bacteria, viruses, protozoa and worms) water safe to drink. Water contaminated with non-biological agents such as toxic chemicals or heavy metals require additional steps to make the water safe to drink.

Solar water disinfection is usually accomplished using some mix of electricity generated by photovoltaics panels (solar PV), heat (solar thermal), and solar ultraviolet light collection.

Solar disinfection using the effects of electricity generated by photovoltaics typically uses an electric current to deliver electrolytic processes which disinfect water, for example by generating oxidative free radicals which kill pathogens by damaging their chemical structure. A second approach uses stored solar electricity from a battery, and operates at night or at low light levels to power an ultraviolet lamp to perform secondary solar ultraviolet water disinfection.

Solar thermal water disinfection uses heat from the sun to heat water to 70–100 °C for a short period of time. A number of approaches exist here. Solar heat collectors can have lenses in front of them, or use reflectors. They may also use varying levels of insulation or glazing. In addition, some solar thermal water disinfection processes are batch-based, while others (through-flow solar thermal disinfection) operate almost continuously while the sun shines. Water heated to temperatures below 100 °C is generally referred to as pasteurized water.

The ultraviolet part of sunlight can also kill pathogens in water. The sodis method uses a combination of UV light and increased temperature (solar thermal) for disinfecting water using only sunlight and repurposed PET plastic bottles. Sodis is a free and effective method for decentralized water treatment, usually applied at the household level and is recommended by the World Health Organization as a viable method for household water treatment and safe storage WHO (2010). Sodis is already applied in numerous developing countries. Educational pamphlets on the method are available in many languages, Majerhofer and Wegelin (2002) each equivalent to the English-language version(WHO,2006). Exposure to sunlight has been shown to deactivate diarrhea-causing organisms in polluted drinking water. The in activation of pathogenic organisms is attributed to: the UV-A (wavelength 320–400 nm) part of the sunlight, which reacts with oxygen dissolved in the water and produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides) that damage pathogens, while it also interferes with metabolism and destroys bacterial cell structures; and simultaneously the full band of solar energy (from infrared to UV) heats the water Clasen T (2009). At a water temperature of about 30 °C (86 °F), a threshold solar irradiance of at least 500 W/m^2 (all spectral light) is required for about 5 hours for sodis to be efficiency. This dose contains energy of 555 Wh/m^2 in the range of UV-A and violet light, 350–450 nm, corresponding to about 6 hours of mid-latitude (European) midday summer sunshine. At water temperatures higher than 45 °C (113 °F), synergistic effects of UV radiation and temperature further enhance the disinfection efficiency. Above 50 °C (122 °F), the bacterial count drops three times faster

Process for household application

SODIS instructions for using solar water disinfection

Guides for the household use of SODIS describe the process.

Colourless, transparent PET water or soda bottles of 2 litre or smaller size with few surface scratches are selected for use. Glass bottles are also suitable. Any labels are removed and the bottles are washed before the first use. Water from possibly-contaminated sources is filled into the bottles, using the clearest water possible. Where the turbidity is higher than 30 NTU it is necessary to filter or precipitate outparticulates prior to exposure to the sunlight. Filters are locally made from clo th stretched over inverted bottles with the bottoms cut off. In order to improve oxygen saturation, the guides recommend that bottles be filled three-quarters, shaken for 20 seconds (with the cap on), then filled completely, recapped, and checked for clarity.

Aluminum reflects ultraviolet well

The filled bottles are then exposed to the fullest sunlight possible. Bottles will heat faster and hotter if they are placed on a sloped Sun-facing reflective metal surface. A corrugated metal roof (as compared to thatched roof) or a slightly curved sheet of aluminum foil increases the light inside the bottle. Overhanging structures or plants that shade the bottles must be avoided, as they reduce both illumination and heating. After sufficient time, the treated water can be consumed directly from the bottle or poured into clean drinking cups. The risk of re-contamination is minimized if the water is stored in the bottles. Refilling and storage in other containers increases the risk of contamination. The table 1 shows the number of hours required for purification of water depending of the weather condition of a place.

Table 1 Suggested treatment schedule (EAWAG and SANDEC,2010)

Weather conditions	Minimum treatment duration
Sunny (less than 50% cloud cover)	6 hours
Cloudy (50–100% cloudy, little to no rain)	2 days
Continuous rainfall	Unsatisfactory performance; use rainwater harvesting

The most favorable regions for application of the SODIS method are located between latitude 15°N and 35°N, and also 15°S and 35°S WHO (2016)
. These regions have high levels of solar radiation, with limited cloud cover and rainfall, and with over 90% of sunlight reaching the earth's surface as direct radiation. WHO (2016)
The second most favorable region lies between latitudes 15°N and 15°S. these regions have high levels of scattered radiation, with about 2500 hours of sunshine annually, due to high humidity and frequent cloud cover WHO (2016)
. Local education in the use of SODIS is important to avoid confusion between PET and other bottle materials. Applying SODIS without proper assessment (or with false assessment) of existing hygienic practices & diarrhea incidence may not address other routes of infection. Community trainers must themselves be trained first WHO (2016)
.

Applications

SODIS is an effective method for treating water where fuel or cookers are unavailable or prohibitively expensive. Even where fuel is available, SODIS is a more economical and environmentally friendly option. The application of SODIS is limited if enough bottles are not available, or if the water is highly turbid. In fact, if the water is highly turbid, SODIS cannot be used alone; additional filtering is then necessary(Nelson and Fisher ,2014).
A basic field test to determine if the water is too turbid for the SODIS method to work properly is the newspaper test Majerhofer and Wegelin (2002)
. For the newspaper test the user has to place the filled bottle upright on top of a newspaper headline and look down through the bottle opening. If the letters

of the headline are readable, the water can be used for the SODIS method. If the letters are not readable then the turbidity of the water high and must be pretreated.

In theory, the method could be used in disaster relief or refugee camps. However, supplying bottles may be more difficult than providing equivalent disinfecting tablets containing chlorine, bromine, or iodine. In addition, in some circumstances, it may be difficult to guarantee that the water will be left in the sun for the necessary time.

Other methods for household water treatment and safe storage exist (e.g., chlorination) different filtration procedures or flocculation/disinfection. The selection of the adequate method should be based on the criteria of effectiveness, the co-occurrence of other types of pollution (turbidity, chemical pollutants), treatment costs, labor input and convenience, and the user's preference.

When the water is highly turbid, SODIS cannot be used alone; additional filtering or flocculation is then necessary to clarify the water prior to SODIS treatment (Dawney and Pearce, 2012; Dawney *et al,*. 2014)

Recent work has shown that common table salt (NaCl) is an effective flocculation agent for decreasing turbidity for the SODIS method in some types of soil (University of British Columbia 2011).

This method could be used to increase the geographic areas for which the SODIS method could be used as regions with highly turbid water could be treated for low costs (Mintz E *et al.,* 2001).

SODIS may alternatively be implemented using plastic bags. SODIS bags have been found to yield as much as 74% higher treatment efficiencies than SODIS bottles, which may be because the bags are able to reach elevated temperatures that cause accelerated treatment (Kohler,2007).

SODIS bags with a water layer of approximately 1 cm to 6 cm reach higher temperatures more easily than SODIS bottles, and treat Vibrio cholerae more effectively (Kohler, 2007). It is assumed this is because of the improved surface area to volume ratio in SODIS bags. In remote regions plastic bottles are not locally available and need to be shipped in from urban centers which may be expensive and inefficient since bottles cannot be packed very tightly. Bags can be packed more densely than bottles, and can be shipped at lower cost, representing an economically preferable alternative to SODIS bottles in remote communities. The disadvantages of using bags are that they can give the water a plastic smell, they are more difficult to handle when filled with water, and they typically require that the water be transferred to a second container for drinking.

Another important benefit in using the SODIS bottles as opposed to the bags or other methods requiring the water to be transferred to a smaller container for consumption is that the bottles are a point-of-use household water treatment method (William *et al.,* 2006).

Point-of-use means that the water is treated in the same easy to handle container it will be served from, thus decreasing the risk of secondary water contamination. The figure 2 below shows the type of plastic material that is suitable for disinfection of water.

Cautions

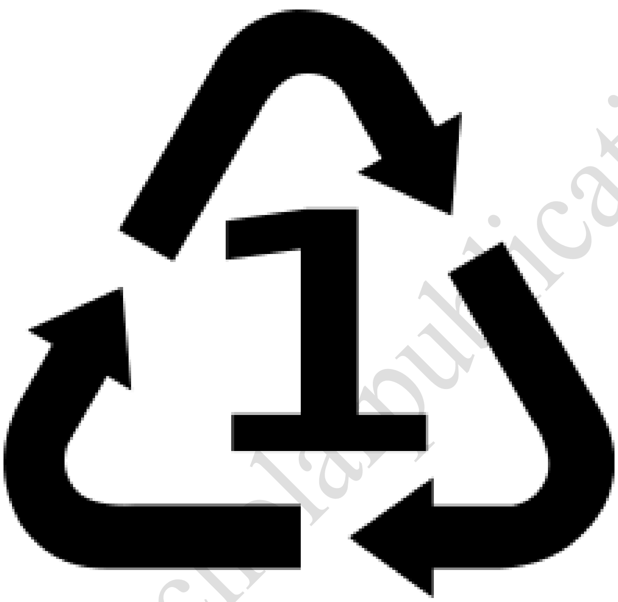

Figure 2 PET plastic suitable for disinfection of water

The PET recycling mark shows that a bottle is made from polyethylene terephthalate, making it suitable for solar water disinfection (University of Heidelberg, 2006).

If the water bottles are not left in the Sun for the proper length of time, the water may not be safe to drink and could cause illness. If the sunlight is less strong, due to overcast weather or a less sunny climate, a longer exposure time in the Sun is necessary.

The following issues should also be considered:

Bottle material

- It is best to use a "**PET**"

(PolyEthylene Terephthalate) bottle. Look for the recycle code #1 on the bottom.

Some glass or PVC materials may prevent ultraviolet light from reaching the water (Sciacca *et al.*, 2010).

Commercially available bottles made of PET are recommended. The handling is much more convenient in the case of PET bottles. Polycarbonate(resin identification code 7) blocks all UVA and UVB rays, and therefore should not be used. Bottles that are clear are to be preferred over bottles that have been colored, for example green lemon/lime soda pop bottles.

Aging of plastic bottles

SODIS efficiency depends on the physical condition of the plastic bottles, with scratches and other signs of wear reducing the efficiency of SODIS. Heavily scratched or old, blind bottles should be replaced.

Shape of containers

The intensity of the UV radiation decreases rapidly with increasing water depth. At a water depth of 10 cm (4 inches) and moderate turbidity of 26 NTU, UV-A radiation is reduced to 50%. PET soft drink bottles are often easily available and thus most practical for the SODIS application.

Oxygen

Sunlight produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides) in the water. These reactive molecules contribute in the destruction process of the microorganisms. Under normal conditions (rivers, creeks, wells, ponds, tap) water contains sufficient oxygen (more than 3 mg/L of oxygen) and does not have to be aerated before the application of SODIS.

Leaching of bottle material

There has been some concern over the question of whether plastic drinking containers can release chemicals or toxic components into water, a process possibly accelerated by heat. The Swiss Federal Laboratories for Materials Testing and Research(2010) have examined the diffusion of adipates and phthalates (DEHA and DEHP) from new and reused PET-bottles in the water during solar exposure. The levels of concentrations found in the water after a solar exposure of 17 hours in 60 °C (140 °F) water were far below WHO(2010) guidelines for drinking water and in the same magnitude as the concentrations of phthalate and adipate generally found in high-quality tap water. Concerns about the general use of PET-bottles were also expressed after a report published by researchers from the University of Heidelberg(2006) on the release of antimony from PET-bottles for soft drinks and mineral water stored over several months in supermarkets. However, the antimony concentrations found in the bottles are orders of magnitude below WHO (2010) and national guidelines for antimony concentrations in drinking water (Conroy *et al.*,1996; Conroy *et al.*, 1999; Conroy *et al.*, 2001). Furthermore, SODIS water is not stored over such extended periods in the bottles.

Regrowth of bacteria

Once removed from sunlight, remaining bacteria may again reproduce in the dark. A 2010 study showed that adding just 10 parts per million of hydrogen peroxide is effective in preventing the regrowth of wild Salmonella(Rose *et al.*, 2006).

Does a UV Disinfection System need periodic maintenance?

There can be some cases where the water is not adequately pre-treated and turbidity levels are low. In such cases, routine inspection and cleaning can be carried out every 6 months. In the case of high turbidity and hardness, the cleaning frequency might need to be increased. Finally, the UV lamp has a limited life and must be replaced once it is exhausted. In the unlikely event of premature failure of the lamp, the monitoring circuit will provide the signal to advise replacement. The table 3 below shows the contrast between UV method, chlorination and ozonation. Uv method is by far better than the other two methods because it is more safer and cheaper to use.

Table 2 Comparison of UV Disinfection System, Chlorination and Ozonation

	Ultra Violet	**Chlorination**	**Ozonation**
Capital Cost	Low	Lowest	High
Operating Cost	Lowest	Low	High
Ease of Installation	Excellent	Good	Complex
Ease of Maintenance	Excellent	Good	Poor
Contact Time Required	<10 seconds	20-30 minutes	10-20 minutes

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