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Solar Water Disinfection Using Pet Bottles

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***Abstract*: Water disinfection processes in the presence of titanium dioxide as a photo-catalyst material provide an interesting route to destroy contaminants, being operational in the UV-A domain with a potential use of solar radiation. In recent years, advanced oxidation processes (AOP) have been developed to meet the increasing need of an effective wastewater treatment. AOP generates powerful oxidizing agent hydroxyl radicals which completely destroy the pollutants in waste water. Solar disinfection of drinking water with polyethylene terephthalate (PET) bottles has been shown to be very effective. Solar water disinfection (SODIS) is a simple, effective and inexpensive water treatment procedure suitable for application in developing countries. Microbially contaminated water is filled into transparent polyethylene terephthalate (PET) plastic bottles and exposed to full sunlight for at least 6 h. Solar radiation and elevated temperature destroy pathogenic germs efficiently. Recently, concerns have been raised insinuating a health risk by chemicals released from the bottle material polyethylene terephthalate (PET). Whereas the safety of PET for food packaging has been assessed in detail, similar investigations for PET bottles used under conditions of the SODIS treatment were lacking until now. In the present study, the transfer of organic substances from PET to water was investigated under SODIS conditions using used colourless transparent beverage bottles of different origin. The bottles were exposed to sunlight for 17 h at a geographical latitude of 47° N. In a general screening of SODIS treated water, only food flavour constituents of previous bottle contents could be identified above a detection limit of 1 μg/L. Quantitative determination of plasticisers di (2-ethylhexyl) adipate (DEHA) and di(2-ethylhexyl) phthalate (DEHP) revealed maximum concentrations of 0.046 and 0.71 μg/L, respectively, being in the same range as levels of these plasticisers reported in studies on commercial bottled water. Generally, only minor differences in plasticiser concentrations could be observed in different experimental setups. The most decisive factor was the country of origin of bottles, while the impact of storage conditions (sunlight exposure and temperature) was less distinct. Toxicological risk assessment of maximum concentrations revealed a minimum safety factor of 8.5 and a negligible carcinogenic risk of 2.8×10^{-7} for the more critical DEHP. This data demonstrates that the SODIS procedure is safe with respect to human exposure to DEHA and DEHP.**

***Keywords*: SODIS, disinfection.**

1. Introduction

A. Distribution of the water on earth

- Ocean water: 97.2 percent
- Glaciers and other ice: 2.15 percent
- Groundwater,: 0.61 percent
- Inland seas: 0.008 percent
- Soil Moisture: 0.005 percent
- Atmosphere: 0.001 percent
- Rivers: 0.0001 percent.
- Fresh water lakes: 0.009 percent

The effectiveness of the SODIS was first discovered by Aftim Acra, of the American University of Beirut in the early 1980s. Follow-up was conducted by the research groups of Martin Wegelin at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) and Kevin McGuigan at the Royal College of Surgeons in Ireland. Clinical control trials were pioneered by Ronan Conroy of the RCSI team in collaboration with Michael Elmore-Meegan. ICROSS. 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. 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. SODIS is already applied in numerous developing countries. 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.

2. Proposed Work

Colorless, 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

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necessary to filter or precipitate out particulates prior to exposure to the sunlight. Filters are locally made from cloth 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 thecap on), then filled completely, recapped, and checked for clarity. 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 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. 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. 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. 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.

3. Suggested Treatment Schedule

A. Result Analysis

Water temperatures in SODIS bottles should ideally be 45degrees Celsius or greater so that heat and UV light can act synergistically to kill pathogenic microbes 100% within a relatively short time. Temperatures above 30 degrees Celsius are reported to disinfect water, but usually this requires exposure to the sun over most of a sunny day (e.g., with a cloudless sky), or over the course of two days if clouds partially obscure the sunlight. Temperatures around 55 degrees, on the other hand, can generally result in effective disinfection in as little as one hour by thermal means alone. In general, regardless of the method, the higher the temperature achieved, the better the disinfection rate is Because it is difficult for water temperatures to reach ideal temperatures under a variety of conditions (e.g., during winter or early spring or late fall, on days with cloud cover, etc.), any modification of the SODIS bottles that permits the temperature of the water in the bottles to be raised even extra several degrees may increase the effectiveness of the SODIS disinfection process and decrease overall treatment time. This may improve the ability of people in developing nations to have potable water that will not make them sick. Data from experiments described in Chapter 3 was collected over a four and a half month period in 2010 from the outdoor College of Technology and Innovation water-treatment research facility yard on the Polytechnic campus at Arizona State University in Mesa, Arizona.

Table 1

Sunny (less than 50% cloud cover)	6 hours
Cloudy (50–100% cloudy, little to no rain)	2days
Continuous rainfall	Unsatisfactory performance

4. Conclusion

SODIS is a simple and low-cost technique used to disinfect contaminated drinking water. Transparent bottles (preferably PET) are filled with contaminated water and placed in direct sunlight for a minimum of 6 hours. Following exposure, the water is safe to drink as the viable pathogen load can be significantly decreased. The process has approximately 4.5 million regular users, predominately in Africa, Latin America, and Asia and is recognized and promoted by the WHO. However, there are several drawbacks with “conventional” SODIS technology. The use of PET bottles allows for only small volumes to be treated (2-3 L) and the process efficiency is dependent on a range of environmental parameters including the solar irradiance (which depends on the latitude, time of day, and atmospheric conditions), the initial water quality for example, organic loading, turbidity, and level and nature of the bacterial contamination. There are a number of ways to improve or enhance the conventional SODIS process and these include the design of SODIS bags where the solar dose per volume is increased, the use of UV dosimetry indicators which measure the UV dose and indicate to the user when the desired dose has been received by the water, design of customized SODIS treatment systems which maximize the solar dose and the inclusion of UV feedback sensors for automated control, and the use of semiconductor photo catalysis to enhance the treatment efficacy.

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