American-Eurasian J. Agric. & Environ. Sci., 2 (4): 407-410, 2007
ISSN 1818-6769

Feasibility of Solar Energy in Disinfection of Drinking Water in Iran

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Abstract: The solar disinfection of water (SODIS) is a simple technique used to destroy pathogenic microorganisms and so it can improve microbiological quality of drinking water. Many countries are in good positions with respect to receiving solar radiation and Iran ranks first in this regard. Thus, it is important for health authorities to prefer this simple method for use in rural areas of the Country and at abnormal conditions instead of other complicated techniques. The main objective of this study was to determine the efficiency of locally available bottles (not transparent to UVC and semi-transparent to UVA) for use in solar disinfection of water in non-urban areas of Iran. For this purpose normal plastic bottles were used and the solar disinfection efficiency was evaluated in terms of fecal coliform reduction of contaminated surface water samples. Two types of locally available normal plastic bottles with UV transmittance values of 0.1 and 0.8 percent were selected and used according to WHO guidelines about SODIS in the disinfection process of water samples from a surface water resource. Examinations of microbiological quality of all water samples have been performed by determination of fecal coliform group (5 tube fermentation technique) according to the procedure outlined in Standard Methods. Water sampling had been accomplished in the fall of 2006. Results indicate that SODIS is also possible even if available plastic bottles with less transparency are used instead of standard bottles. According to the results obtained by use of these bottles, about 99.9% disinfection of water (up to 3 log reduction in fecal coliforms) is possible at the temperature of 39.6 degree centigrade. Also, it should be noted that by substituting the bottle with less UVT with the more transparent one, it would be possible to decrease the required contact time for 3 $\log_{10}$ reduction of microbial indicator from 8 to about 6 hours. Results of this study clearly indicate that utilizing of both locally available bottles used in this study may have enough justification for SODIS process in non-urban areas and communities of Iran which mostly have warm climates.

Key words: Drinking water % disinfection % solar radiation % plastic bottles % non-urban areas

INTRODUCTION

No resource is as universally necessary to sustain life as is safe drinking water. But water used for drinking and food preparation has also been responsible for transmission of numerous infections agents. Diarrhea diseases which mainly result from drinking water that has been contaminated through unsafe disposal of sewage are among the top 3 causes of death world wild and the leading cause of death among children under 5 in most developing countries. Thereupon, all governments should promote equitable access to safe water supplies and strengthen their programs to improve water quality.

Solar disinfection, or SODIS as it is known, is one of the simplest methods for providing acceptable quality drinking water. The SODIS technique involves storing contaminated drinking water in transparent containers (plastic bags, plastic bottles or glass bottles) that are placed in direct sunlight for periods of up to 8 h before consumption[1,2]. Pathogenic microorganisms are vulnerable to two effects of the sunlight: radiation in the spectrum of UV-A light (wavelength of 320-400 nm) 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 [3].

SODIS is ideal to disinfect small quantities of water of low turbidity. If cloudiness of pathogens is greater than 50%, the plastic bottles need to be exposed for 2 consecutive days in order to produce

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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 [7, 8].

The other important factors include latitude of location, turbidity of water and dissolved oxygen of water and bottle type which all affect the disinfection efficiency of SODIS [3, 6].

The effectiveness of SODIS in reduction of various microorganisms was studied in the recent years. The results of the investigations show that this technique is highly effective against a broad range of bacterial fungal and free-living protozoan pathogens such as *Vibrio cholerae* [2, 7], *Salmonella typhimurium* [8], *Shigella dysenteriae* type I [7], *Pseudomonas aeruginosa*, *Candida albicans*, *Fusarium solani* and the trophozoite stage of *Acanthamoeba polyphaga* [9] and *Cryptosporidium parvum* [6, 7, 10, 11]. Previous studies have reported a reduction in incidence of diarrhea among those children who drank water exposed to direct sunlight compared with another group that drank water not exposed to sunlight [2].

There are a few criteria that must be applied in selecting the appropriate type of containers to be used for the proper disinfection of contaminated drinking water by sunlight. The important rule to be followed is to base the selection not only on availability and size, but also on the need to use containers that would permit the penetration of sun rays. However, for many regions and under abnormal conditions, accessible containers are often used without attention to this subject.

The objective of this research was to study the feasibility of SODIS application in the rural areas of Iran. In our study, two types of locally available normal plastic bottles were used as the possible containers and the efficiency of SODIS was investigated in terms of reduction in fecal coliforms indicator of contaminated surface water samples.

METHODS

Water sampling had been performed from a surface water canal in Tehran. The experiments were done in fall season, the average air temperature was about 17°C and the sky was relatively clear. Aeration of the water was achieved by shaking the three fourth filled bottles for about 20 seconds before the bottle was filled completely and exposed to the sun. Fecal coliforms indicator was examined for determination of SODIS efficiency. Therefore, the number of fecal coliforms in the water samples was measured before and after solar exposure. The number of fecal coliforms was determined as most probable number per 100mL (MPN/100 mL) using 15-tube fermentation technique according to the procedure outlined in "Standard Methods for the Examination of Water and Wastewater"[12]. The initial turbidity and fecal coliforms of water samples were about 1 NTU (Nephelometric Turbidity Units) and 2000-3000 MPN/100 mL, respectively.

The volume of normal plastic bottles used in the research was 1.5 L. The effect of solar radiation time on SODIS efficiency was investigated at 3, 6 and 8 h exposure times. Also, the effect of transparency of bottles for UV radiation was studied using two types of normal plastic bottles with 0.1 and 0.8 percent UV transmittance at the wavelength of 254 nm. All of the experiments were performed in triplicate and the average values were presented.

RESULTS

The effect of solar radiation time on SODIS disinfection efficiency is presented in Fig. 1. For those experiments the normal plastic bottles with 0.1 percent UV transmittance (at the wavelength of 254 nm) had been used. The average water temperature was 19°C at the beginning of the experiments; also the average water temperature was obtained to be 39, 40 and 38°C after 3, 6 and 8 h radiation time, respectively. As Fig. 1 illustrates, SODIS efficiency in fecal coliforms reduction was determined to be 93, 99.8 and 99.9 percent at 3, 6 and 8 h radiation time, respectively. Therefore, this means that for 3 $\log_{10}$ reduction of fecal coliforms a relatively long radiation time (8 hours) was required.

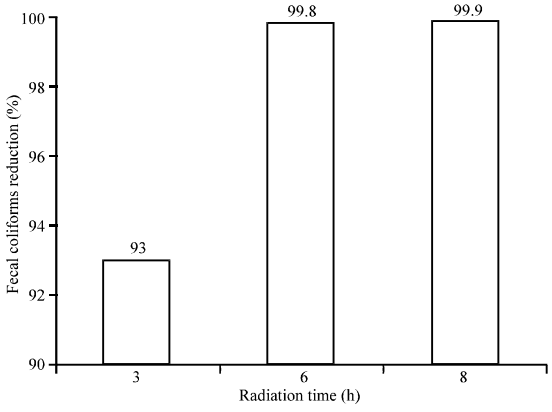

Fig. 1: Effect of solar radiation time on SODIS disinfection efficiency

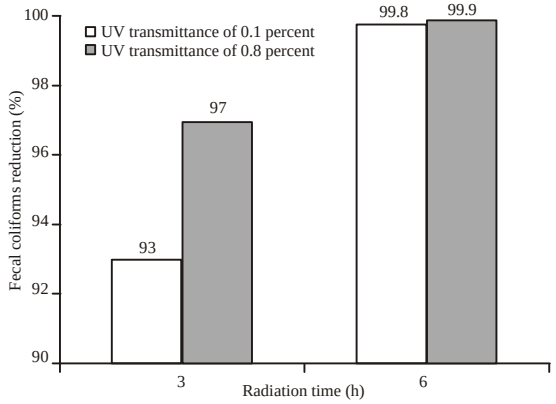

Fig. 2: Effect of UV transmittance of bottles on SODIS disinfection efficiency

Figure 2 illustrates the effect of UV transmittance of bottles on SODIS efficiency. The average water temperature was 20°C at the beginning of the experiments; also the average water temperature was obtained to be 41 and 40 degrees centigrade after 3 and 6 h radiation time, respectively. According to Fig. 2, the required radiation time for 3-log reduction of fecal coliforms had been decreased to 6 h by using more transparent bottle.

DISCUSSION

The disinfection efficiency of SODIS was considerable, such that 3-log reduction of fecal coliforms was achieved at 6 to 8 h radiation time by using normal plastic bottles with 0.1 and 0.8 percent UV transmittance. It is also anticipated that by application of more transparent bottles, the required exposure time would be less than 8 hours. However, for household applications of the technique, the environmental factors affecting SODIS should be studied.

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 [13, 14]. Iran is located between latitude of 25°N and 40°N. This means that the country is in a good position. Besides, sunshine duration is also suitable for SODIS, especially in the central and southern parts of Iran, so over 90% of the sunlight directly touches the earth due to the limited cloud cover and rainfall (less than 250mm rain and usually more than 3000 hours of sunshine annually).

It is obvious that the negative effect of using containers with less UVT would be in producing water with less quality. However, at contact times equal or more than 6 hours this effect would not be a problem and as Fig. 2 shows water disinfection is accomplished quite well by both containers.

Turbidity of water decreases the penetration of solar radiation into water and protects microorganisms from being irradiated. Therefore, the disinfection efficiency of SODIS is reduced in turbid water [4, 15]. In the rural areas of Iran, drinking water is usually provided from groundwater resources such as qanats, springs and wells. Generally, turbidity of the groundwater resources is low. Therefore, the water quality most parts of the country is suitable for SODIS application.

The study on SODIS efficiency and environmental factors affecting SODIS including climate and turbidity of water indicated that SODIS technique is an appropriate method for household water disinfection in rural areas of Iran. Consequently, it is recommended that training of SODIS application is set in health education program in the rural areas without access to safe water.

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