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RESEARCH ARTICLE

Feasibility and Applicability of Solar Disinfection (SODIS) for Point-of-use Water Treatment in Bandar Abbas, South of Iran

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Abstract

Today, drinking water supplies for most of the developing countries which mainly includes the remote villages are at stake. Therefore, using of low-cost and available methods, for the treatment of surface water for drinking in the areas without safe water system or emergency conditions was approved by international healthcare organizations. Solar disinfection technology (SODIS), is one of the most important technologies. In this study, the effect of UV-A radiation of sunlight in surface water disinfection in Bandar Abbas was studied. In a cross-sectional study, the samples have been exposed to sunlight for 1 to 7 hours in two types of PET and glass containers. Using of HPC method was measured number of remaining bacteria in the samples. Then, by using a statistical analysis, the relationship between reduce of microbial load and turbidity, contact time, weather conditions and type of containers was investigated. The results showed that removal efficiency of bacteria increased by increasing contact time from 1h to 7h. Also there was a direct and inverse relationship respectively between environmental temperature and turbidity with disinfection efficiency. Also results showed that in glass containers was observed more microbial load reduction. Noticed to significant impact of turbidity on SODIS, it is recommended, a filtration step performed prior to disinfection to reduce water turbidity. Based on the findings, the use of SODIS as a simple and practicable method is recommended to guarantee the drinking water safety.

Keywords: *Solar disinfection, SODIS, poInt-of-use, Water treatment, Bandar Abbas.*

Introduction

Supply of safe drinking water always has been raised as a serious problem to many human societies, especially developing countries and arid regions, so that more than a billion of the world's population still have not access to safe water (1-5).

In developing countries, especially in far area, due to lack of safe potable water supply systems, non-safe water from surface resources as rivers, streams and lakes may be used. Meanwhile, contaminated water sources, poor management and lack of adequate planning guidelines intensify this crisis (6, 7). This challenge will be more serious in emergencies and crisis (8).

Such adverse situations, people and especially children and sensitive people are at risk of water-borne diseases; even these diseases can cause death in susceptible people, infants and children (9-13).

Therefore, attention to safe water supply options is necessary in crisis management plans. One of these options can be using of in place simple filtration systems and other simple available methods. Simple procedures such as boiling or adding chlorine to water are conventional methods to Purification of water which in both methods, there are limitations because of lack of access to energy sources and chlorine in crisis situations and in remote areas. Numerous studies have shown that the solar disinfection (SODIS) is a reliable method to improve the quality of drinking water using solar radiation to disable the causes of diarrheal disease (14-17).

Protocols in this way is using a 1-2 L PET clear container and put it in the sun exposure for 6 hours or 48 hours respectively for sunny and cloudy conditions (8). The area located between latitudes 15 degrees north for to 35 degrees south has good condition for SODIS. In the SODIS method of UV-A radiation (wavelength of 400-320 nm) is used because it reacts with oxygen dissolved in water; thus leading to the formation of free oxygen radicals and hydrogen peroxide in water, which leads to the sterile water (18).

In other words, UV-A destroying microorganisms in the water by using two mechanisms: (a) absorption in microorganism DNA (b) absorption in microorganisms in water-soluble organic compounds and production of oxidizing compounds such as superoxide, hydrogen peroxide and hydroxyl radicals (19-20). SODIS is a simple procedure, environmental stability, non-specialty chemicals, inexpensive and effective drinking water purification which usually is use in small quantities and home scale. This method is recommended by the World Health Organization as ah household water treatment and safe storage (9, 21).

Solar ultraviolet (UV) radiation is the most effective factor in the SODIS; three wavelength ranges of UV are: (UV-A 400–315 nm), (UV-B 315–280 nm) and (UV-C 280–100 nm). The mechanism of UV radiation is effect on the microorganism DNA. When DNA exposed by UV radiation in sunlight, pyrimidine rings of thymine and cytosine bases in the DNA absorbs a part of UV radiation, so the energy is taken by DNA; the received energy can lead to the formation of new bonds between adjacent pyrimidine bases, so pyrimidine dimers are formed thereby (22). Pyrimidine dimers avoid of base pairing with purine on the other strand of DNA that changes the shape of the DNA molecule in the dimer area (23). In some cases, visible wavelength UV-A has not enough energy to cause DNA base change directly, so creates reactive oxygen species (ROS) such as singlet oxygen, superoxide, hydrogen peroxide, and hydroxyl radical in water (24-25). In addition, sunlight can be produce more ROS by photosynthesis of photosensitizers present in surface waters (humic acids and chlorophyls), so concentration of ROS is increased, which is a good disinfectant (26).

Since strong synergistic effect between passive optical and thermal processes there, due to rising temperatures in SODIS process, disinfection done more efficiently (23). Several past studies have shown that during the SODIS process, temperature arise to more than 45 and even 65 degrees

Celsius (27-30). Bandar Abbas capital of Hormozgan province, with a low-latitude arid hot climate (Köppen-Geiger classification: BWh) located in Persian Gulf shore at (27°12'N, 56°22'E, 10 m), south of Iran, The average temperature is 27.2 degrees Celsius that ranging from 18.1°C in the winter to 34.3°C in the summer. In the province and neighboring provinces, there are outlying areas that in some cases, there is not possible to provide clean safe drinking water; moreover, in crisis and disasters due to the loss of infrastructure, drinking water supply problems will increase.

Therefore, this study aimed to investigate the effect of parameters of turbidity, exposure time, and weather conditions and bottles material on efficiency of SODIS technology in disinfection of surface water, and to determine the optimal conditions to provide the best efficiency. The applicable purpose was to find a reliable, effective, simple method and independent to chemicals and energy method that can be used in communities without water treatment systems as well as in cases of disaster.

Materials and Methods

In this cross-sectional study, the water samples were poured in polyethylene three phthalate (PET) bottles and after involving SODIS, the output were sampled in different situations.

In order to enhance the interaction effects of ultraviolet radiation and heat from the sun, a half side of bottle was colored dark vertically from the outer side. To calculate the sample size, parameters such as turbidity, contact time, weather conditions and type of bottles, were studied at certain levels as variables.

On this basis and to estimate the number of samples, 4 levels for turbidity (3, 16, 24 and 33 NTU), 4 levels for retention time (1, 3, 5 and 7 hours), two types of glass and PET bottles on atmospheric conditions quite sunny, semi-sunny and mostly cloudy were evaluated. Given that 15 samples of waters, the sample size, 195 samples were obtained.

To provide the required turbidity, the (0.55-6.4 mg) clay soil was added to 1 L distilled water, after 30 minutes shaking followed by1 hour settling, the supernatants were collected, and the turbidity was adjusted to achieving the turbidity levels of 3 to 33 NTU.

Turbidity was measured by using a Hatch 2100N Laboratory Turbidity meter (Hatch Ltd., USA). The samples were contaminated manually using sanitary wastewater (3 mL in1 L distilled water). HPC test as an indicator of microbial quality, in accordance with the standard method were performed (31).

The bottles were placed in a slope surface horizontally in exposure the sun for 6 hours, so the dark side contacted to the surface. After the 6 hr exposure, the samples were collected and tested for HPC counting.

In the second test, which aims to evaluate the effect of contact time, the samples were initially infected samples and four times of 1, 3, 5 and 7 hours for sun exposure were evaluated to HPC reduction. In the next part of experiments, effect of climate conditions in three situations of sunny, semi cloudy and quite cloudy were studied in a certain turbidity and exposure time.

At the end of experiments, in a quite sunny climate, in optimum exposure time and certain turbidity, 15 samples poured in glass bottles and 15 samples in PET bottles; so the effect of bottles type was studied by measuring the HPC reduction. Eventually, the collected data from four stages were entered to SPSS software of version 19 for windows.

Results

Figure 1 describes the effect of exposure time on efficiency of the SODIS process. As the figure shows by increasing the exposure time from 1 to 7 hours, the efficiency of HPC reduction has been increase from28.92 to 99.25 percent.

Figure 2 shows the relationship between opacity and HPC reduction in the water samples.

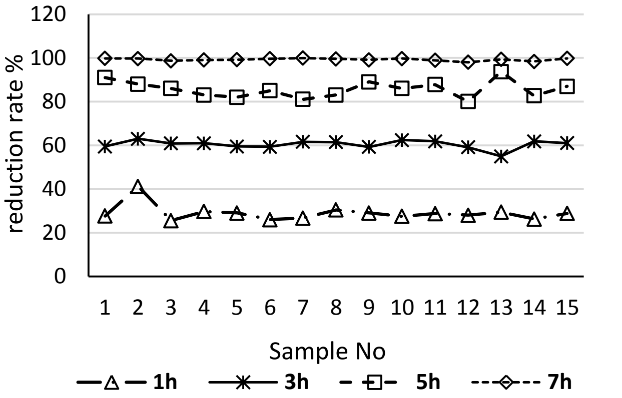

Figure 1: Effect of exposure time on microbial removal efficiency of water using the SODIS (initial turbidity = 3 NTU, the weather is quite sunny)

The results show that by increasing the water turbidity, germicidal effect of sunlight has been decreased. So in turbidity of 3 NTU, HPC reduction was 98.04% while this rate was reduced to 28.03 percent in turbidity of 33 NTU.

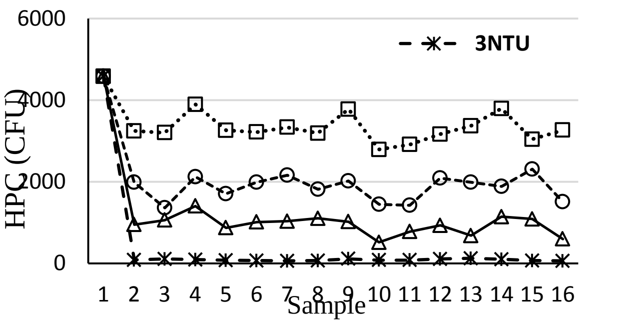

Figure 2: Effect of initial turbidity on microbial removal efficiency of water using the SODIS (exposure time=6 hour. the weather is quite sunny)

Figure 3 shows the effect of weather conditions on the performance of SODIS process. As is known from the figure, germicidal efficiency of SODIS in a perfectly sunny, semi-sunny and mostly cloudy weather conditions were as 98.13, 85.38 and 63.33 percent respectively.

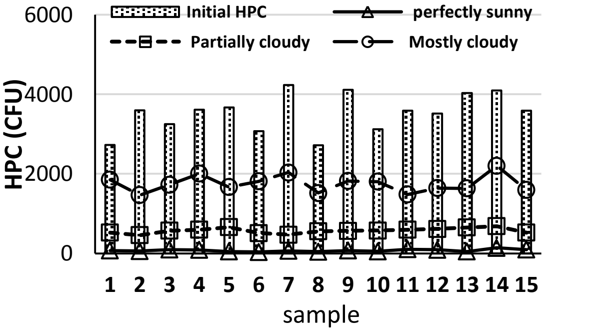

Figure 3: Effect of weather conditions on microbial removal efficiency of water using the SODIS (exposure time=7 hour. Initial turbidity= 3NTU)

Figure 4 shows the effect of bottle material on the performance of SODIS process. As it cleared from this figure, the PET and glass bottles had similar function I reduction of microbial load.

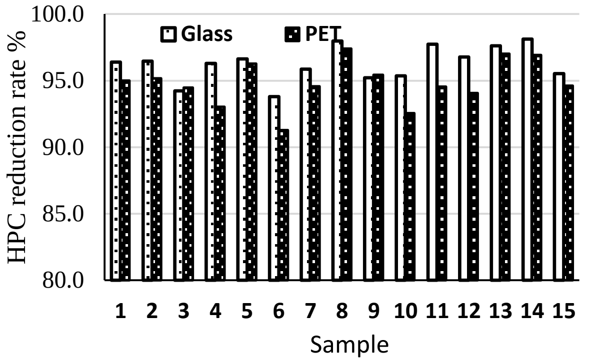

Figure 4: Effect of bottle material on microbial removal efficiency of water using the SODIS (Turbidity NTU 3, Exposure time 7 h, and the weather is quite sunny)

Discussion

As the results show the inactivation of microbes is inversely relationship to the turbidity. The water turbidity leads to colored water; as water colors may absorb specific wavelengths, thus reduce the potential for disinfection (32). So that the highly colored samples may not be germicidal effect of sunlight. the maximum allowable turbidity in drinking water is equal to 5 NTU, the results of this study showed that up to the allowable turbidity it can be reduced the microbial load safely in a reasonable time.

Hence it is recommended to enhance the performance of this process, using operations such as settling or using fabric filters and so on, the turbidity of water be reduced. By increasing exposure time, intake of ultraviolet radiation will increase, that this situation causes a rise in temperature as well. As stated in the introduction, this situation creates a synergy resulting in improved disinfection property. In Bandar Abbas weather, at least a 6-hour exposure time is required to ensure disinfection. The results of the study are corresponded to Mahvi el al., study which conducted in Iran (33), and Gómez et al., in Spain (34).

In order to evaluate the effect of weather conditions, monthly mean daily global solar radiation incident on a horizontal surface for Bandar Abbas. In quite cloudy weather the intensity of UV-A reduces to one third of full shiny days, so during the cloudy days, it need to expose bottles more time (35). As it cleared from the table 1, the mean of intensity of radiation is 5.40±1.37 kW/m2.day, which is a high rate of radiation intensity. The averages of reduction values of HPC were identified by analysis of variance test which confirmed the significant difference among the different weather conditions (p=0.009).

Table 1:Monthly mean daily global solar radiation incident on a horizontal surface (kW/m2.day) for Bandar Abbas

Months	kW/m^2.day	Months	kW/m^2.day
Jan	3.71	Jul	6.88
Feb	4.61	Aug	6.45
Mar	4.91	Sep	5.72
Apr	6.21	Oct	4.80
May	7.01	Nov	3.93
Jun	7.26	Dec	3.32

As it mentioned in the past research that in case of *C. parvum* oocysts, the infectivity began to decrease when samples were exposed to radiation of intensity equal to or higher than 600W/m^2 (36). It emphases that the intensity of radiation is very effective factor in the SODIS process.

The bottles material (PET or Glass) showed the least effect on reduction of bacterial load of the water studied samples; however, HPC reduction was more a bit in glass containers. T-test was conducted on data of bottles material and it showed that there was not significant different between two averages of HPC reduction related to PET and glass bottles (p=0.056).

Conclusion

SODIS was identified as an efficient and simple disinfection method of water using the solar radiation. An exposure time of 1 to 6 hours is required to provide the safe level of HPC reduction. By increasing the water turbidity, germicidal effect of sunlight has been decreased. In turbidity more than 30 NTU, the efficiency of SODIS is not reliable.

The intensity of radiation is very effective factor in the SODIS process, so efficiency of SODIS was variant from 98.13 to 63.33 percent in a perfectly sunny to mostly cloudy weather conditions respectively. Noticed to significant impact of turbidity on SODIS, it is recommended, a filtration step performed prior to disinfection to reduce water turbidity. Based on the findings, the use of SODIS as a simple and practicable method is recommended to guarantee the drinking water safety.

References

1. Meera V, Ahammed MM. Solar disinfection for household treatment of roof-harvested rainwater. Water Science and Technology: Water Supply. 2008 Jul 1;8(2):153-60.
2. Bazrafshan E, Biglari H, Mahvi AH. Phenol removal by electrocoagulation process from aqueous solutions. Fresenius Environmental Bulletin. 2012;21(2):364-71.
3. Bazrafshan E, Biglari H, Mahvi AH. Humic acid removal from aqueous environments by electrocoagulation process using iron electrodes. Journal of Chemistry. 2012;9(4):2453-61.
4. Biglari H, Saeidi M, Alipour V, Rahdar S, Sohrabi Y, Khaksefidi R, et al. Review on hydrochemical and health effects of it in Sistan and Baluchistan groundwater's,Iran. International Journal of Pharmacy and Technology. 2016;8(3):17900-20.
5. Biglari H, Chavoshani A, Javan N, Hossein Mahvi A. Geochemical study of groundwater conditions with special emphasis on fluoride concentration, Iran. Desalination and Water Treatment. 2016;57(47):22392-9
6. Alipour V, Mahvi AH, Rezaei L. Quantitative and qualitative characteristics of condensate water of home air-conditioning system in Iran. Desalination and Water Treatment. 2015 Feb 13;53(7):1834-9.
7. Biglari H, Saeidi M, Alipour V, Rahdar S, Sohrabi Y, Khaksefidi R, et al. Prospect of disinfection byproducts in water resources of Zabol. International Journal of Pharmacy and Technology. 2016;8(3):17856-65.
8. Khakzada, S., G.R. Goudarzib, and M. khakzadc, Solar Disinfection: An Empirical Study on Karoon River, Khuzestan, Iran. Computational Research Progress in Applied Science & Engineering, 2015. 1(3): p. 83-92.
9. Dejung S, Fuentes I, Almanza G, Jarro R, Navarro L, Arias G, Urquieta E, Torrico A, Fenandez W, Iriarte M, Birrer C. Effect of solar water disinfection (SODIS) on model microorganisms under improved and field

SODIS conditions. Journal of Water Supply: Research and Technology-Aqua. 2007 Jun 1;56(4):245-56.

10. Kehoe SC, Joyce TM, Ibrahim P, Gillespie JB, Shahar RA, McGuigan KG. Effect of agitation, turbidity, aluminium foil reflectors and container volume on the inactivation efficiency of batch-process solar disinfectors. Water Research. 2001 Mar 31;35(4):1061-5.

11. Meierhofer R, Wegelin M. Solar water disinfection: a guide for the application of SODIS. Intermediate Technology Development Group Publishing; 2002.

12. Biglari H, Sohrabi Y, Charganeh SS, Dabirian M, Javan N. Surveying the geographical distribution of aluminium concentration in groundwater resources of sistan and baluchistan, Iran. Research Journal of Medical Sciences. 2016;10(4):351-4.

13. Mohammadi S, Zamani E, Mohadeth Z, Mogtahedi F, Chopan H, Moghimi F, et al. Effects of different doses of simvastatin on lead-induced kidney damage in Balb/c male mice. Pharmaceutical Sciences. 2015;20(4):157-62.

14. Martín-Domínguez A, Alarcón-Herrera MT, Martín-Domínguez IR, González-Herrera A. Efficiency in the disinfection of water for human consumption in rural communities using solar radiation. Solar Energy. 2005 Jan 31;78(1):31-40.

15. Harding AS, Schwab KJ. Using limes and synthetic psoralens to enhance solar disinfection of water (SODIS): a laboratory evaluation with norovirus, Escherichia coli, and MS2. The American journal of tropical medicine and hygiene. 2012 Apr 1;86(4):566-72.

16. Sajjadi SA, Asgari G, Biglari H, Chavoshani A. Pentachlorophenol removal by persulfate and microwave processes coupled from aqueous environments. Journal of Engineering and Applied Sciences. 2016;11(5):1058-64

17. Aghdasi H, Gholami F. A survey on the application of solar disinfection (sodis) technology on water microbial reduction. Journal of Urmia Nursing And Midwifery Faculty. 2014 Oct 15;12(7):522-31.

18. Rai BB, Pal R, Kar S, Tsering DC. Solar disinfection improves drinking water quality to prevent diarrhea in under-five children in Sikkim, India. Journal of global infectious diseases. 2010 Sep;2(3):221.

19. Stumm W, Morgan JJ. Aquatic chemistry: chemical equilibria and rates in natural waters. John Wiley & Sons; 2012 Dec 18.

20. Oates PM, Shanahan P, Polz MF. Solar disinfection (SODIS): simulation of solar radiation for global assessment and application for point-of-use water treatment in Haiti. Water Research. 2003 Jan 31;37(1):47-54.

21. Robertson PK, Bahnemann DW, Robertson JM, Wood F. Photocatalytic detoxification of water and air. InEnvironmental Photochemistry Part II 2005 (pp. 367-423). Springer Berlin Heidelberg.

22. Goodsell DS. The molecular perspective: ultraviolet light and pyrimidine dimers. The Oncologist. 2001 Jun 1;6(3):298-9.

23. McGuigan KG, Conroy RM, Mosler HJ, du Preez M, Ubomba-Jaswa E, Fernandez-Ibanez P. Solar water disinfection (SODIS): a review from bench-top to roof-top. Journal of hazardous materials. 2012 Oct 15; 235:29-46.

24. Rinkerberger JL, Hung BA, Tuveson RW. Growing Escherichia coli mutants deficient in riboflavin biosynthesis with non-limiting riboflavin results in sensitization to inactivation by broad spectrum nea-ultraviolet light (32 0–400 nm). Photochem. Photobiol. 1990; 47:897-901.

25. Reed RH, Mani SK, Meyer V. Solar photo-oxidative disinfection of drinking water: preliminary field observations. Letters in applied microbiology. 2000 Jun 1;30(6):432-6.

26. Bosshard F, Bucheli M, Meur Y, Egli T. The respiratory chain is the cell's Achilles' heel during UVA inactivation in Escherichia coli. Microbiology. 2010 Jul 1;156(7):2006-15.

27. Matlack C, Chizeck H, Davis TB, Linnes J. A low-cost solar disinfection indicator for safe water. InGlobal Humanitarian Technology Conference (GHTC), 2011 IEEE 2011 Oct 30 (pp. 283-286). IEEE.

28. Waithaka P N, Maingi J M, Anthony, Microbial KN., contamination of environmental, food and treated water samples in Nakuru North Sub-county, Kenya, International Journal of Microbiology and Allied Sciences, 2014, 1(2):78-91.

29. Kendricks MR, David JL, Sisco TE, Surbeck CQ. Solar Disinfection Water Treatment for a Community-Scale System: An Analysis of Design Parameters for Humanitarian Engineering Projects. International Journal for Service Learning in Engineering. 2013 Mar 1;8(1).

30. Ndounla J, Kenfack S, Wéthé J, Pulgarin C. Relevant impact of irradiance (vs. dose) and evolution of pH and mineral nitrogen compounds during natural water disinfection by photo-Fenton in a solar CPC reactor. Applied Catalysis B: Environmental. 2014 Apr 27; 148:144-53.

31. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Water Environment Federation. Standard methods for the examination of water and wastewater. American Public Health Association.; 1915.

32. Mirzabeygi M, Naji M, Yousefi N, Shams M, Biglari H, Mahvi AH. Evaluation of corrosion and scaling tendency indices in water distribution system: a case study of Torbat Heydariye, Iran. Desalination and Water Treatment. 2016;57(54):25918-26.

33. Mahvi AH. Feasibility of solar energy in disinfection of drinking water in Iran. American-Eurasian J Agric Environ Sci. 2007;2(4):407-10.

34. Gómez-Couso H, Fontán-Sainz M, McGuigan KG, Ares-Mazás E. Effect of the radiation intensity, water turbidity and exposure time on the survival of Cryptosporidium during simulated solar disinfection of drinking water. Acta tropica. 2009 Oct 31;112(1):43-8.

35. Caslake LF, Connolly DJ, Menon V, Duncanson CM, Rojas R, Tavakoli J. Disinfection of contaminated water by using solar irradiation. Applied and Environmental Microbiology. 2004 Feb 1;70(2):1145-51.

36. Fisher MB, Iriarte M, Nelson KL. Solar water disinfection (SODIS) of Escherichia coli, Enterococcus spp., and MS2 coliphage: effects of additives and alternative container materials. Water research. 2012 Apr 15;46(6):1745-54.

