Research Journal of Recent Sciences ISSN 2277-2502
Vol. **6(6),** 29-34, June **(2017)** *Res. J. Recent Sci.*

SODIS: A potent technology for sustainable drinking water management in tropics

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Available online at: www.isca.in, www.isca.me
Received 30th April 2017, revised 30th May 2017, accepted 1st June 2017

Abstract

Obtaining clean drinking water is a constant challenge in many communities in developing countries. The contaminated water causes many gastrointestinal illnesses. The vast majority of such diseases are recorded in rural areas of developing countries where there is lack of adequate sanitation facilities and the water supply is contaminated with a variety pathogenic and nonpathogenic organisms. The present research work attempts to identify and characterize the inactivation process in operation when contaminated drinking water is stored in transparent PET bottles and exposed to sunlight. The role of solar radiations in activation mechanisms were studied in detail by measuring water temperature, light intensity, pH, turbidity and MPN which were recorded during a series of solar disinfection procedures carried out at Nashik city. The highest light intensity and temperature are responsible for the change in physicochemical property of water as well as MPN and MPN reduction efficiency. The results showed the maximum MPN reduction efficiency of 71.43%, at the temperature of 48.7^{0}C and 5 hours' exposure to solar radiations.

Keywords: Solar radiation, Most probable number, Turbidity, Water disinfection, Solar water disinfection (SODIS).

Introduction

Water is not only essential for life but is also predominant in the organic constituents of living matter[1]. Due to the rapid growth of population, agriculture and industry, the demand for fresh water is on the rise and is expected to increase even more in the future. In a previous study we found the presence of pathogenic as well as nonpathogenic organisms in the water used for human consumption from certain regions of Nashik city. Ground water constitutes the most important source of drinking water in Maharashtra. However numerous man made source of pollutants such as land disposal of sewage effluents, sludge & solid waste, septic tank effluents, and urban runoffs have resulted in contamination of ground water. WHO has reported that in developing countries, approximately three out of five people do not have access to safe drinking water. Further, it has been emphasized that good quality drinking water and sanitation must be made available to all because 80% of all sickness and disease in the third world is attributable to contaminated water. Infact, an estimated 15 million children succumb to water borne diseases every year and 50% of the worlds' hospital beds are occupied by persons affected by such diseases[2,3]. The most commonly used technique to disinfect water in a large number of countries is chlorination, as this technique remains functionally more advantageous than any existing alternatives. However treated water remains out of reach for many poor communities due to its high cost and the Environmental Protection Agency, has reported a direct link between chlorine and cancer appearance.

The solar energy utilization to disinfect water is practical only if the intensity of solar radiation reaches sufficient levels. On exposure to sunlight, photo sensitizers present in the organisms absorb photons of light from the UV-A and early visible light wavelengths (320 to 450 nm). The activated photo sensitizers then react with oxygen molecules to generate highly reactive oxygen species. These in turn react with DNA and cause the DNA strands to break or alter the bases which can cause death or mutagenesis (due to replication blocks) respectively. In bacteria, this damage can be reversed if the conditions become favorable, however viruses do not possess the ability to repair DNA damage and are hence sensitive to optical inactivation[4].

A newer water treatment technique in accordance with the proposed methodology by SODIS (Solar Water Disinfection Project) involves the use of disposable materials such as PET (polyethylene terephthalate) bottles. In this technique, a synergetic effect of solar radiation and temperature leads to the death or inactivation of water borne pathogenic bacteria (such as those responsible for dysentery, typhoid and cholera). The current study was initiated with an aim to quantify the efficiency of solar energy in decontaminating water.

Materials and methods

The experiments were carried out in K.T.H.M. College Environmental Research laboratory, located in Nashik city (MS, India). It receives an average light intensity about 580 Cd. Water samples were collected in sterile containers from 11 different locations in Nashik City viz. Dindori Road, Satpur Colony, Shivaji Nagar, Mahatma Nagar, Indira Nagar, Panchavati, Nashik Road, Cidco, Ambad, Hirawadi, and Gopal nagar designated as L1 to L11.

Identical sterile PET bottles of one liter capacity were used for each experiment. In assay 1, the sample water bottles were incubated in a controlled state i.e. in dark at ambient temperature. In assay 2, another set of sample water bottles were incubated by placing them on roof in direct sunlight. Regular adjustments in the position of the bottles were made to ensure that sunlight fell on the container surface at an angle of 90 ± 2^o. Water samples from the assay1 and assay 2 were analyzed in the laboratory over the time to check for the presence of pathogenic and non-pathogenic microorganisms along with the other physiological parameters using techniques in accordance to those mentioned in the standard methods for examination of water and wastewater, APHA, USA, 21st edition.

The bottles used in the experiment were rinsed with distilled water and irradiated with UV light, to prevent contamination prior to the solar treatment. Then the bottles containing the samples were exposed to solar radiation for a period of five hours, from 11:00 a.m. to 04:00 p.m. The collected samples were analyzed for pH, turbidity and most probable number before and after exposure in the solar radiation. The physiochemical properties, MPN and percent efficiency of MPN reductions were also estimated for the samples incubated in the controlled state.

Results and discussion

The change in MPN reduction efficiency, light intensity and turbidity indifferent water samples collected in month of January, May and September as representative samples of each season from Nashik city, are represented in the Figures-1 to 9.

The maximum light intensity and maximum temperature was recorded in the month of May, and were 580±06 cd and 48.9± 0.1^0C at the location of Shivaji Nagar and Mahatma Nagar respectively. Whereas the lowest light-intensity was 332±0.7 cd and temperature was 40.8 ± 0.3^0C recorded in the month of September. The light intensity and temperature caused a significant change in pH and turbidity and MPN. The summer season where the bright sunlight and high temperature was responsible for the change in pH, turbidity and the MPN, where the MPN reduction was noted considerably.

The control bottles did not show any significant reduction in any of the analyzed parameters. According to Berney et al the main factor responsible for determining the efficiency of this method in eliminating bacteria is solar radiation and not the temperature[5]. The generally accepted cause of the optical inactivation is as a result of the solar UV radiation. However, it has been reported that a synergistic action of both optical and thermal effects, are responsible for inactivating the pathogens at a faster rate than would be possible from the effect of each factor in isolation[6,7].

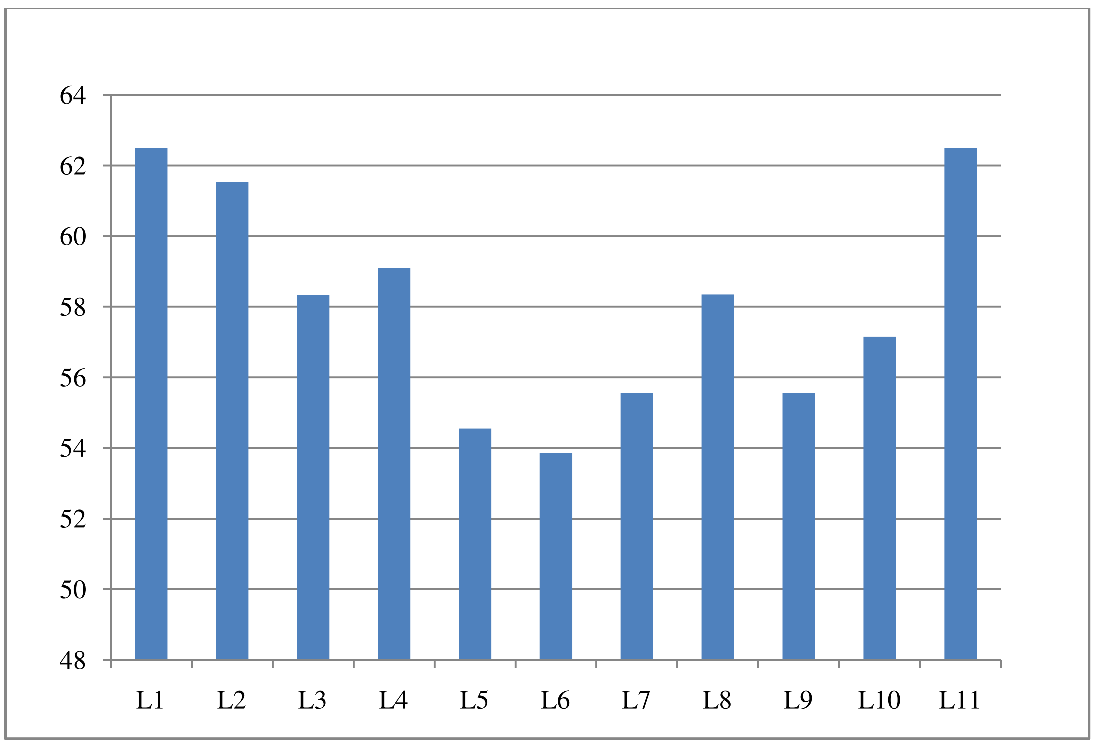

Figure-1: The MPN reduction efficiency for the month of January.

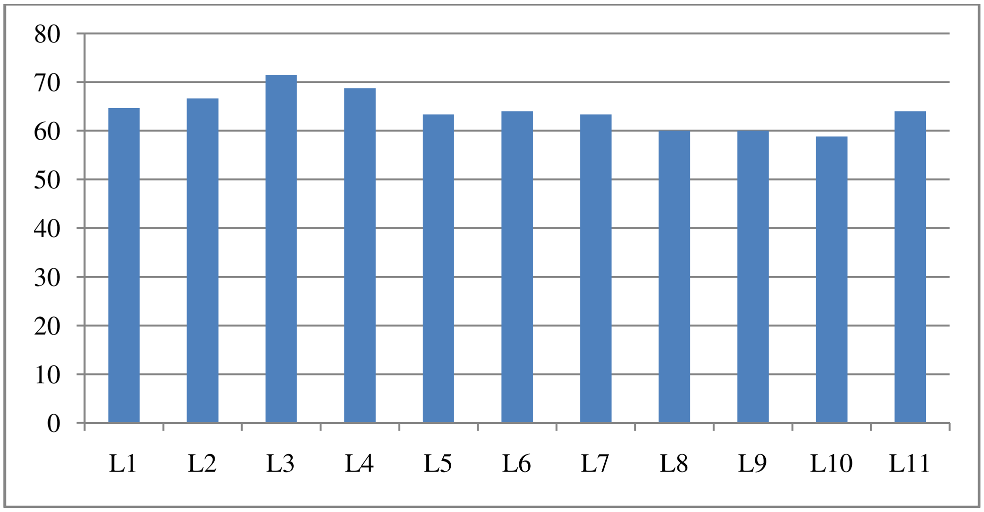

Figure-2: The MPN reduction efficiency for the month of May.

Figure-3: The MPN reduction efficiency for the month of September.

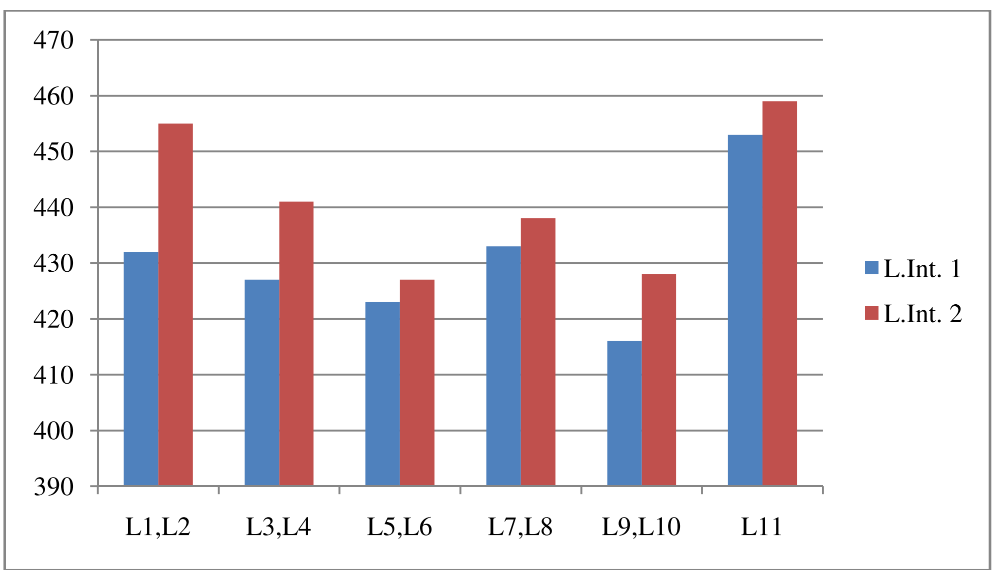

Figure-4: The light intensity in the month of January.

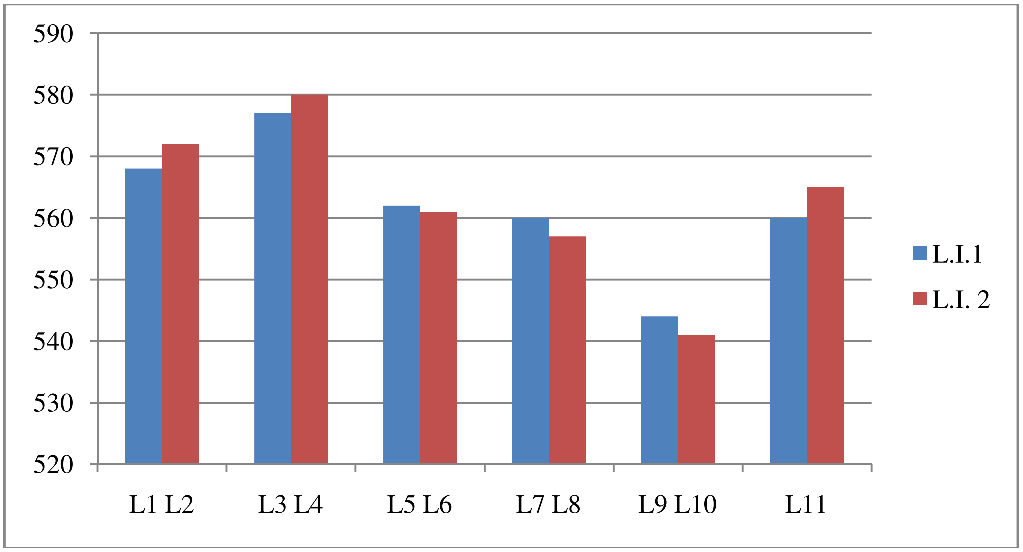

Figure-5: The light intensity in the month of May.

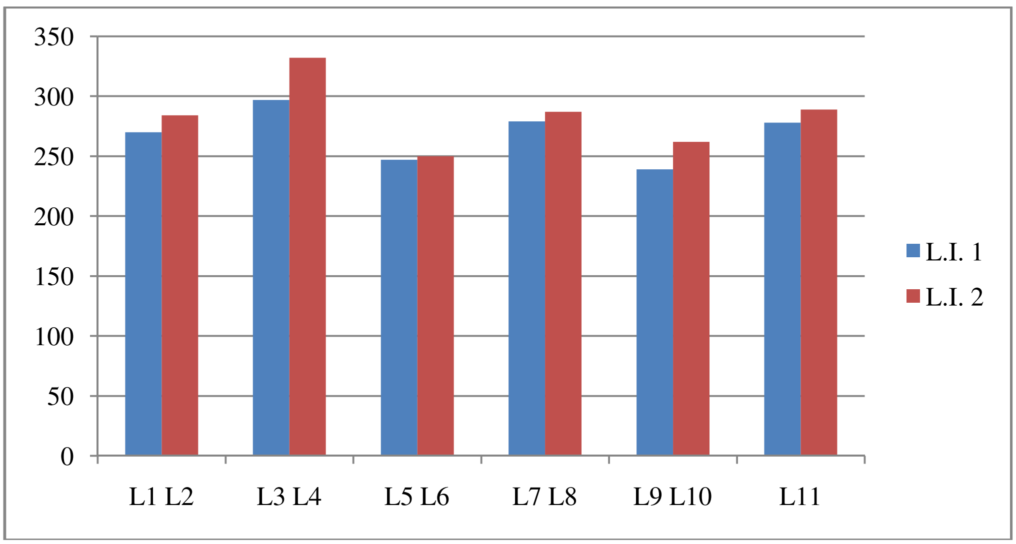

Figure-6: The light intensity in the month of September.

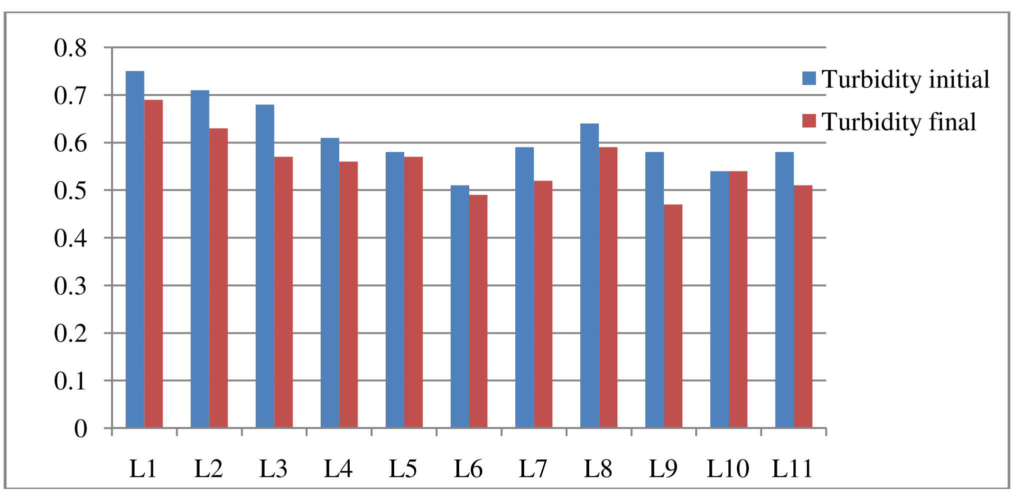

Figure-7: The turbidity recorded in the month of January.

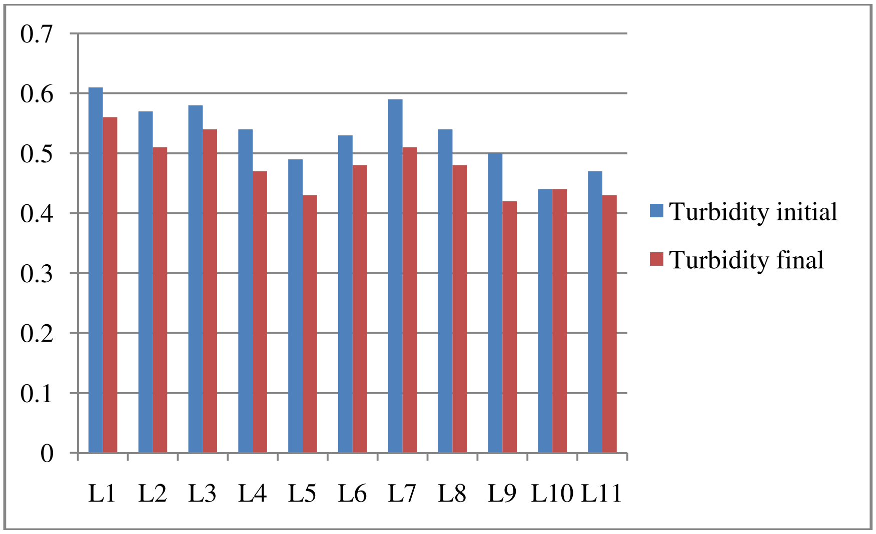

Figure-8: The turbidity recorded in the month of May.

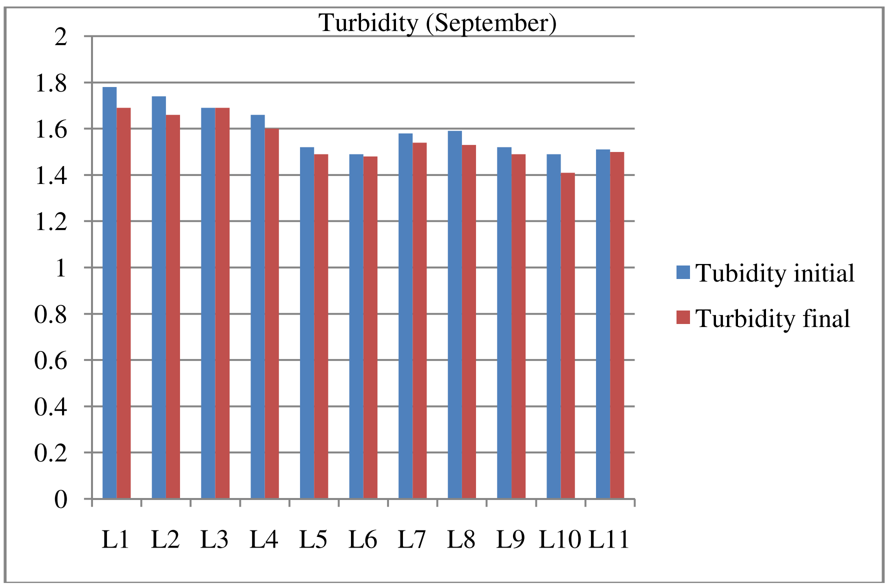

Figure-9: The turbidity recorded in the month of September.

The data generated in the present study is in concordance with the findings of Acra et al[8], and Wegelin et al[9]. They found that using solar disinfection (SODIS) to treat water, by exposing drinking water in polyethylene terephthalate (PET) bottle to sunlight for 6 hours resulted in the inactivation of the enteric bacteria present in the water. Solar disinfection of water is a simple and cheap method which can be used to improve the water quality, especially in developing countries. This method is effective and acceptable for increasing water safety in resource limited environment and can reduces mortality rate in children's due to water borne diseases[10]. The solar disinfection process not only useful for destroying diarrheal infection but also efficient in, inactivating total coliforms as well as fecal coliforms[11]. In case the water is turbid beyond the ability of this technique to clear, then adding other simple steps to this process can help in clearing out the turbidity[12]. These steps include techniques such as pre-filtration, or use of locally available coagulation or flocculation agents to reduce the turbidity which have shown to increase the inactivation levels and thus suggest that periodic agitation of the bottle during exposure would speed up the disinfection process[13].

Conclusion

A variety of organic chemicals and pathogenic organism are destroyed or killed by direct exposure to solar radiation[14]. Using solar radiation to achieve this purpose is relatively inexpensive and is an environment friendly method as it does not generate harmful by products as is the case in technologies dependent on the use of chemicals.

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