Wastewater disinfection applying solar energy

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Abstract
Solar Water Disinfection Process (SODIS) is a simple technology using solar UV-A radiation (wavelength 320-400 nm) and elevated water temperature to inactivate pathogens. In the present survey, the effect of solar radiation on the disinfection of domestic secondary treated wastewater from the Wastewater Treatment Plant (WWTP) of the Municipality of Chania (Crete, Greece) was investigated during the day hours in summer. The used secondary treated wastewater samples had initial turbidity of 6 NTU, BOD_5 of 23 mgO_2/L, and concentration of 4.6×10^4 and 2.6×10^4 CFU/100ml for the total heterotrophic bacteria cultivated at 37°C and at 22°C respectively, 5.5×10^5 CFU/100ml for the total coliforms, 1.5×10^5 CFU/100ml for the fecal coliforms, and 2×10^4 CFU/100ml for the fecal Enterococcus. The experiments were carried out in transparent Polyethylene Terephthalate plastic bottles during the months July, August and September. An average reduction of 97-99% of the concentration of the total heterotrophic bacteria, and of 99.5-99.9% of the total and fecal coliforms, as well as of the fecal Enterococcus was obtained after 6 hours of exposition in solar radiation with intensity ranging from 500 to 1,280 W/m^2 and temperature from 33°C to 49°C in the wastewater. The results showed that solar disinfection of secondary treated domestic wastewater with turbidity less than 6 NTU could be applied during the period of sunlight in WWTPs of settlements ≤15,000 equivalent population, of at least 6 hours in tanks with deepness of 10cm or tubes with a diameter of 10cm.
Keywords: Wastewater, Solar Water Disinfection (SODIS), Total Coliforms, Fecal Coliforms

1. Introduction

The solar water disinfection method SODIS is a method of improving the quality of drinking water (with regard to microbial load) approved by the World Health Organization (WHO) (Figueredo-Fernández et al. 2017, McGuigan et al. 2012, Sommer et al. 1997, Wegelin et al. 1994).
The method is based on the inactivation of pathogenic micro-organisms due to the influence of UV-A (at 320-400 nm wavelengths) and the rise in water temperature, and is already successfully implemented in countries not technologically developed with a latitude between 15th B / N and 35th B / N (Figueredo-Fernández et al. 2017, McGuigan et al. 2012, SODIS website)
In the present study, the effect of solar radiation on the decontamination of secondary treated urban wastewater (from WWTP) was examined during the summer day hours in Chania (latitude 35° 31' north and latitude 24° 03' east).

2. Materials and Methods

The SODIS method was applied to secondary treated wastewater after secondary sedimentation, which came from the Wastewater Treatment Plant of the Municipality of Chania (Crete, Greece). The experiments were conducted in transparent plastic Polyethylene Terephthalate (PET) bottles of water (1.5 L volume), which were placed horizontally on a black metal surface.
The tested wastewater samples were exposed to sunlight for a total of 6 hours. Sampling of wastewater exposed to sunlight and measurements were performed every 1 hour. Control samples contained secondary treated wastewater placed in a dark chamber at ambient temperature were also used.
Viable bacteria were determined using the standard membrane filter method by filtration of the wastewater samples on sterile filters (internal diameter 47 mm) and subsequent culture growth on solid nutrient media.
The used growth media for the cultivated microorganism were: Membrane Lauryl Sulfate Broth (Lab M) with 1.5% Agar (Fluka) for total coliforms, and fecal heat-resistant coliforms, Slanetz and Bartley Medium (Lab M) supplemented with 1.5% Agar (Fluka) for fecal Enterococcus, and Plate Count Agar (Oxoid) for the total heterotrophic bacteria (cultivated at 37°C, as well as at 22°C).
Incubation of total coliforms and enterococci was carried out at 37 °C, while fecal heat-resistant coliforms at 44.5 °C. The counting of bacteria cultures was conducted after 48 hours with the standard plate count method. Total heterotrophic bacteria were determined after 48 and 72 hours at 37 °C or at 22 °C, respectively. Solar radiation intensity was measured using a pyranometer (Mavolux digital, Gossen).

3. Results

The monitoring of solar radiation intensity, sample bottle temperature during the experiment, and ambient temperature in the sunlight are shown in figure1.
The used secondary treated wastewater possessed an initial concentration of 4.6×10^4 cfu/100ml for the total

heterotrophic bacteria cultivated at 37°C, 2.6 × 10^4 cfu/100ml for the total heterotrophic bacteria cultivated at 22°C, 5.5 × 10^5 cfu/100ml for the total coliforms, 1.5 × 10^5 cfu/100ml for the fecal coliforms and 2 × 10^4 cfu/100ml for the fecal Enterococcus. The wastewater samples had the following initial average physicochemical characteristics turbidity of 6 NTU, BOD_5 of 23 mg O_2/L, COD of 15 mg O_2/L, TSS of 5 mg/L, pH of 7,2 – 7,6, electrical conductivity (E.C.) of 810 µS/cm, and initial ion concentrations of NO_3^- 5 mg/L, NO_2^- 0,05 mg/L, NH_4^+ 0,2 mg/L, and PO_4^{3-} 7,5 mg/L.

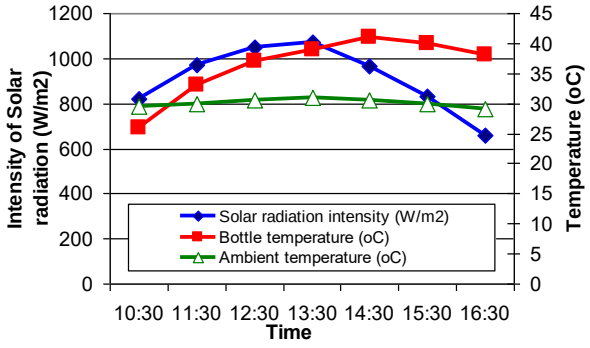

Figure 1. Monitoring of solar radiation intensity, sample bottle temperature, and ambient temperature in the sunlight during the experiment.

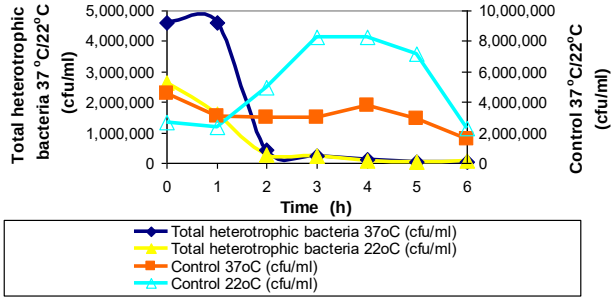

Figure 2. Effect of solar radiation on total heterotrophic bacteria grown at 22°C, and 37°C respectively in colony forming units per ml of sample.

The final concentration of bacteria in wastewater six hours after the solar disinfection treatment was 0 cfu/100 ml for total coliforms, 0 cfu/100 ml for fecal heat-resistant coliforms, 10 cfu/100 ml for fecal Enterococcus, 4.2 × 10^4 cfu/ml for total heterotrophic bacteria grown at 37 °C, and 6.5 × 10^4 cfu/ml for total heterotrophic bacteria grown at 22 °C (figures 2 and 3). During the experiments BOD, pH and E.C. values were stable.

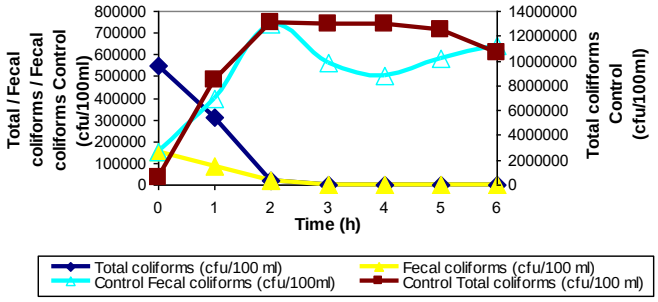

Figure 3. Effect of solar radiation on total coliforms, and fecal heat-resistant coliforms in colony forming units per ml of sample.

4. Conclusions

An average reduction of 97-99% of the concentration of the total heterotrophic bacteria (cultivated at 22°C, and at 37°C, respectively) and of 99.5 -99.9 % of the total and fecal coliforms as well as of the fecal Enterococcus was obtained after 6 hours of exposition in solar radiation with an intensity ranging from 500 to 1,280 W/m^2, and temperature in the wastewater from 33°C to 49°C. The results showed that solar disinfection of secondary treated domestic wastewater with turbidity less than 6 NTU could be applied during the period of sunlight in Wastewater Treatment Plants of settlements with less than 15,000 equivalent population that do not possess disinfection treatment of the wastewater before discharge to the final recipient. Essential requirement for the solar disinfection is the exposition of at least 6 hours in tanks with deepness of 10cm or tubes with a diameter of 10cm.

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