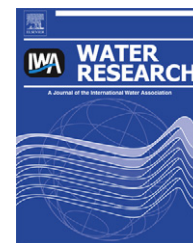


Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Solar disinfection of wastewater to reduce contamination of lettuce crops by *Escherichia coli* in reclaimed water irrigation

Françoise Bichai*, M. Inmaculada Polo-López, Pilar Fernández Ibañez

Plataforma Solar de Almería-CIEMAT, Carretera Senés km 4, 04200 Tabernas (Almería), Spain

ARTICLE INFO

Article history:

Received 20 June 2012

Received in revised form

16 August 2012

Accepted 17 August 2012

Available online 30 August 2012

Keywords:

Escherichia coli

Hydrogen peroxide

Irrigation

Lettuce

Solar disinfection

Wastewater reuse

ABSTRACT

Low-cost disinfection methods to allow safe use of recycled wastewater for irrigation can have important beneficial implications in the developing world. This study aims to assess the efficiency of solar disinfection to reduce microbial contamination of lettuce crops when solar-treated wastewater effluents are used for irrigation. The irrigation study was designed as a complete experimental loop, including (i) the production of irrigation water through solar disinfection of real municipal wastewater treatment plant effluents (WWTPE), (ii) the watering of cultivated lettuce crops at the end of solar treatment, and (iii) the detection of microbial contamination on the irrigated crops 24 h after irrigation. Solar disinfection was performed using two types of reactors: (i) 20-L batch borosilicate glass reactors equipped with CPC to optimize solar irradiation, and (ii) 1.5-L PET bottles, i.e. the traditional SODIS recipients commonly used for disinfection of drinking water in developing communities. Both solar and H₂O₂-aided solar disinfection processes were tested during ≤5 h exposure of WWTPE, and *Escherichia coli* inactivation was analysed. A presence/absence detection method was developed to analyse lettuce leaves sampled 24 h after watering for the detection of *E. coli*. Results of inactivation assays show that solar disinfection processes can bring down bacterial concentrations of >10³–10⁴ *E. coli* CFU mL^{−1} in real WWTPE to <2 CFU/mL (detection limit). The absence of *E. coli* on most lettuce samples after irrigation with solar-disinfected effluents (26 negative samples/28) confirmed an improved safety of irrigation practices due to solar treatment, while crops irrigated with raw WWTPE showed contamination.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

The world's population living in water-stressed areas is projected to reach 44% by 2050 (Scheierling et al., 2011). As the world faces increasing freshwater scarcity, wastewater use is gaining attention as an option for augmenting available water supplies. Agriculture irrigation is by far the most established application of wastewater reuse in the world (Scheierling et al., 2011). Yet, agriculture still accounts for over 70

percent of the world's total freshwater withdrawal (FAO, 2012). Recycled domestic wastewater has beneficial properties for agriculture use, such as nutrients which have a natural fertilizer value for crops, leading to higher crop yields while reducing demand for chemical fertilizers (Dreschel et al., 2010). It also provides a climate-independent source of water allowing year-round crop production. Wastewater recycling for agriculture irrigation is particularly cost-effective in low-income arid and semi-arid countries (Dreschel et al., 2010).

* Corresponding author. Tel.: +1 617 496 5961; fax: +1 617 496 1457.

E-mail addresses: fbichai@seas.harvard.edu (F. Bichai), mpolo@psa.es (M.I. Polo-López), pilar.fernandez@psa.es (P. Fernández Ibañez).
0043-1354/\$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
<http://dx.doi.org/10.1016/j.watres.2012.08.024>

Moreover, land application of wastewater can be viewed as a low-cost wastewater treatment reducing pollution to water bodies.

Unplanned use of wastewater in agriculture, involving direct or indirect use of untreated wastewater, is by an order of magnitude more commonly found than planned use globally (Scheierling et al., 2011). The use of inadequately treated domestic wastewater effluents for irrigation raises public health concerns arising from the presence of pathogens in the wastewater. Such risk is especially critical in the case of vegetables eaten raw, such as leafy greens (Beuchat, 2002). Secondary treatment is standard practice as an environmental management strategy for a majority of domestic wastewater systems worldwide. The typical quality of such wastewater effluents is estimated to 10^5 total coliforms/100 mL (Moulin et al., 2010; Levatensi et al., 2010). The WHO guidelines for the use of wastewater for unrestricted irrigation (including irrigation of salad crops and vegetables eaten uncooked) require a water quality of <1000 faecal coliforms per 100 mL (WHO, 2006).

Many arid and semi-arid countries facing water scarcity are well positioned to receive sufficient UV radiation from natural sunlight yearly, enhancing the potential for solar disinfection applications (UNDP, 2006). While solar and solar photo-catalytic disinfection processes have been proven to efficiently inactivate various pathogens in drinking water (Boyle et al., 2008; Sichel et al., 2009; Gómez-Couso et al., 2009) or in simulated water effluent (Polo-López et al., 2010), the use of solar radiation had never been assessed for enhancing the microbial quality of real wastewater effluents for crop irrigation. The addition of low amounts of hydrogen peroxide in water was previously demonstrated to increase the inactivation rate of microorganisms exposed to sunlight at a low cost (Polo-López et al., 2010). Hydrogen peroxide decomposes into water and oxygen in the disinfection process. Therefore the reagent is consumed without producing toxic by-products nor requiring pH correction, as it is the case in other advanced photo-oxidation processes (using titanium dioxide or photo-Fenton catalysis) which require a post-treatment (Polo-López et al., 2010). While wastewater effluents are spontaneously used in developing countries when other sources for irrigation are scarce (Dreschel et al., 2010), low-cost solar disinfection processes could help reducing health risk for consumers of wastewater-irrigated crops.

The objective of this study is to assess the performance of solar disinfection processes, with or without the addition of a low hydrogen peroxide dose (5 and 10 mg L⁻¹), as a low cost wastewater treatment to enhance microbial safety of secondary-treated wastewater effluents used for irrigation. This study aims at (i) measuring *Escherichia coli* inactivation in wastewater effluents freshly collected from a municipal wastewater treatment plant with a standard secondary treatment, during exposure to natural sunlight with or without hydrogen peroxide addition, and (ii) comparing *E. coli* contamination (presence/absence) on lettuce crops irrigated with the fresh wastewater effluent vs. the solar-disinfected effluent on the day after irrigation was practiced.

Indigenous *E. coli* was chosen as a target microorganism in this study because it is naturally present in municipal secondary-treated wastewater effluents in sufficient

concentrations to likely allow measurements of (i) a significant reduction during disinfection assays, and of (ii) a detectable contamination on lettuce leaves watered with the untreated wastewater effluent. *E. coli* is also the most commonly used bacterial indicator of faecal contamination in water.

This study is, to our knowledge, the first to present a direct assessment of microbial contamination on crops irrigated with solar-treated vs. untreated real wastewater effluents, through an innovative complete experimental loop design.

2. Material and methods

2.1. Experimental design

To emulate the transport of *E. coli* in a cycle of wastewater reuse for irrigation of edible crops, the following experimental study was designed (Fig. 1): (i) The efficiency of solar disinfection processes was evaluated in standard water matrixes (distilled water, natural well water, and simulated wastewater effluent) inoculated with *E. coli* K-12, and in real municipal wastewater treatment plant effluents (WWTPE) contaminated with naturally occurring *E. coli*. Two types of solar static batch reactors, i.e. 20-L CPC reactors and 1.5-L PET bottles, were used. The disinfection effects of natural sunlight with and without the addition of a low dose of H₂O₂ were evaluated. (ii) Cultivated lettuce crops were watered with solar-treated real WWTPE and (iii) *E. coli* was detected on lettuce leaves 24 h after irrigation. For this purpose, a presence/absence detection method of *E. coli* on lettuce leaves was developed.

2.2. *E. coli* detection and enumeration

E. coli K-12 (ATCC 23631) was used in solar disinfection processes for characterizing inactivation kinetics of the solar reactors. This strain was also used to contaminate the synthetic irrigation water as a positive control in lettuce irrigation tests. Cultures of *E. coli* K-12 were generated from frozen stocks by streaking onto Luria Bertani (LB) (Sigma–Aldrich, USA) agar and were incubated at 37 °C for 18–24 h. A single colony from the plate was inoculated into 14 mL sterile LB-broth (Sigma–Aldrich, USA) and incubated at 37 °C for 18 h on a rotary shaker to obtain a stationary phase culture. Cells were harvested by centrifugation at 800 × *g* for 10 min and the pellet was re-suspended in 14 mL Phosphate Buffer Solution (PBS, Oxoid), yielding a final concentration of ~10⁹ CFU mL⁻¹. Appropriate volumes were diluted to reach a starting concentration of ~10⁶ CFU mL⁻¹ in the reactors.

The samples collected during solar disinfection experiment were enumerated using the standard plated counting method through serial 10-fold dilutions in PBS, and volumes of 20 µL were plated in triplicate on Endo Agar (Sigma–Aldrich, USA) plates. Colonies were counted after incubation of 24 h at 37 °C. When very low concentrations of *E. coli* were expected to be found in solar-disinfected samples, 500 µL-samples were spread over a plate to decrease the detection limit down to 2 CFU mL⁻¹ (DL). Data obtained in the studies were analysed using the one-way ANOVA analysis tool (Origin v7.0300, OriginLab Corp., Northampton, USA).

Download English Version:

<https://daneshyari.com/en/article/4482048>

Download Persian Version:

<https://daneshyari.com/article/4482048>

[Daneshyari.com](https://daneshyari.com)