

Solar disinfection of wild *Salmonella* sp. in natural water with a 18 L CPC photoreactor: Detrimental effect of non-sterile storage of treated water

Frédéric Sciacca^a, Julián A. Rengifo-Herrera^c, Joseph Wéthé^b, César Pulgarin^{a,*}

^a Ecole Polytechnique Fédérale de Lausanne (EPFL), Institute of Chemical Science and Engineering, GGEC, Station 6, CH-1015 Lausanne, Switzerland

^b Institut International d'Ingénierie de l'Eau et l'Environnement (2iE), Laboratoire Eau, Dépollution, Ecosystème et Santé, LEDES, 01 BP 594, Ouagadougou 01, Burkina Faso

^c Centro de Investigación y Desarrollo en Ciencias Aplicadas "Dr. J.J. Ronco" (CINDECA), Departamento de Química, Facultad de Ciencias Exactas, UNLP-CCT La Plata, CONICET, 47 No. 257, 1900 La Plata, Buenos Aires, Argentina

Received 15 November 2010; received in revised form 1 March 2011; accepted 26 March 2011

Available online 5 May 2011

Communicated by: Associate Editor Gion Calzaferri

Abstract

For the first time solar disinfection of liters of water containing wild *Salmonella* sp. and total coliforms was carried out in a compound parabolic collector (CPC) photoreactor at temperatures of almost 50 °C. Using surface water with high turbidity, this treatment was efficient in completely inactivating *Salmonella* sp. without regrowth during the subsequent 72 h of dark sterile storage. However if the solar treated water is poured in a non-sterile container, bacteria regrowth occurs even if 10 mg L⁻¹ of H₂O₂ is added before the storage. On the other hand, 30 mg L⁻¹ of H₂O₂ added when the irradiation started was completely depleted within 2 h and did not prevent bacterial regrowth during post-irradiation storage in non-sterile containers, demonstrating that storage of large volumes of water treated by solar irradiation was not optimal. Finally, total coliforms (*Escherichia coli* included) showed a far higher sensitivity than *Salmonella* sp. and demonstrated to be an inappropriate indicator for monitoring bacterial contamination in water during solar disinfection processes. © 2011 Elsevier Ltd. All rights reserved.

Keywords: Solar water disinfection; SODIS; CPC photoreactor; Post-irradiation events; *Salmonella* sp. inactivation

1. Introduction

Many Sahelian countries undergo drinking water supply problems. In Burkina Faso, surface water collection was developed through dam constructions. However, surface waters are often affected by human activities, which imply hazardous chemicals and especially bacteriological pollution. The socio-economical context, mainly in isolated and rural populations (Boyle et al., 2008), considerably reduces the applicable techniques for water disinfection. In addition, chlorination, which is a largely used technique

for surface water disinfection, is limited by the formation of toxic by-products such as trihalometanes (THMs), resulting from the reaction of chlorine with natural organic matters (NOM) often present in surface waters (Bond et al., 2009; Moncayo-Lasso et al., 2009; Mosteo et al., 2009).

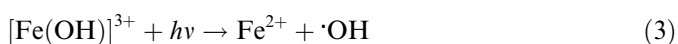
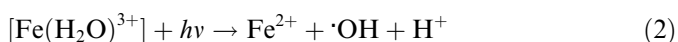
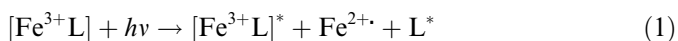
In the sunny regions of Burkina Faso, it is of interest to develop low cost disinfection methods such as SODIS. Solar water disinfection in bottles, known as the SODIS process, is a simple and widely used household technique constituting a small-scale way to improve water quality for drinking purposes at point-of-use (Du Preez et al., 2010; Wegelin et al., 1994). SODIS treatment for a whole household unit requires a large configuration (in terms of

* Corresponding author. Tel.: +41 21 693 47 20; fax: +41 21 693 56 90.
E-mail address: cesar.pulgarin@epfl.ch (C. Pulgarin).

bottles exposed and stored at the same time) and around 6 h of solar exposure, which can increase during cloudy days to up to 48 h, followed by storage to cool the water (Oates et al., 2003). Bacterial inactivation by SODIS treatment is the consequence of two synergistic factors: (i) the effect of UV-A (between 320 and 400 nm) and the visible irradiation between 400 and 490 nm, and (ii) a temperature increase which must reach at least 45 °C (McGuigan et al., 1998; Sommer et al., 1997; Wegelin et al., 1994). SODIS treatment for water disinfection has often been evaluated through the monitoring of *Escherichia coli* inactivation as the main bacterial indicator. However, Berney et al. (2006) have found that this microorganism is one of the most sensitive to the effect of solar irradiation and temperature with regard to other waterborne human pathogens. For this reason, it does not represent a suitable indicator of SODIS performance for drinking water production. In contrast, *Salmonella typhimurium* an extremely pathogenic microorganism, seems to be more resistant to SODIS treatment, making it a far more suitable indicator (Berney et al., 2006; Smith et al., 2000; Winfield and Groisman, 2003; Rincón and Pulgarin, 2003).

In natural surface waters, humic substances and organic chromophores (which are part of NOM), act as photosensitizers. Under UV–Vis irradiation, these substances induce O₂ reduction leading to reactive oxygen species (ROS) such as singlet oxygen (¹O₂), superoxide (HO₂[•]/O₂^{•-}), and [•]OH radicals very toxic to cells (Canonica, 2007; Moncayo-Lasso et al., 2008a; Paul et al., 2004). Hence, dissolved oxygen concentration in water is considered as a directly influencing parameter of the bactericidal action of SODIS treatment (Curtis et al., 1992; Gourmelon et al., 1994; Reed, 1997). As agitation can promote the release of dissolved oxygen, potential SODIS reactor configurations have to be evaluated individually with regard to this parameter (Kehoe et al., 2001).

Next to this, sunlight can also induce other ROS-producing reactions in natural waters containing transition metals such as iron, which is the case in Sahelian regions, where water flows on ferruginous substrates (Ben Yahmed, 2005). At a natural pH of 7.5, iron species in aqueous solution are principally present as organo- (and aqua-) complexes of ferric ions (Gallard et al., 1999; Moncayo-Lasso et al., 2008b; Pignatello et al., 2006). Under visible light, the photoreduction of dissolved ferric ions via ligand-to-metal-transfer (LMCT) reaction also leads to the production of [•]OH radicals (Goslan et al., 2006; Lee and Yoon, 2004; Malato et al., 2009; Vermilyea and Voelker, 2009):



Recently, some of us have reported that in synthetic or real waters at near neutral or neutral pH, photo-sensible iron species could directly interact with cell membranes (complexation with proteins and other membrane compo-

nents) avoiding its precipitation and playing an important role in photo-Fenton disinfection processes (Sciacca et al., 2010; Spuhler et al., 2010).

Despite its simplicity, SODIS point-of-use treatment has not been fully explored to disinfect larger volumes of drinking water. PET bottle exposition on a corrugated iron sheet implies treatment in series with different sets of bottles in order to obtain enough water for a household family. The SODIS principle has been improved through changes in its configuration, which could also allow the disinfection of larger water volumes than conventional PET bottles (Kehoe et al., 2001; Navntoft et al., 2008). Among the possibilities evaluated, reflection of solar irradiation around the exposed reactor pointed out the advantages of temperature increase on enhancement of bacterial inactivation (Martín Domínguez et al., 2005; Rijal and Fujioka, 2003). In this context, using of compound parabolic collector (CPC) photoreactor showed an evident capacity to enhance solar disinfection by photocatalysis reactions while non-TiO₂ photo-assisted treatment is not efficient (Fernández et al., 2005; Rincón and Pulgarin, 2005; Rincón and Pulgarin, 2007a,b).

Ubomba-Jaswa et al. (2010) have recently demonstrated that treating large water volumes (25 L) by CPC photoreactors under solar irradiation could efficiently inactivate *E. coli* K-12 cells without regrowth within 48 and 72 h following the solar disinfection. However, solar disinfection in a CPC reactor has still not been evaluated in areas with a constant solar irradiation and in natural waters containing wild bacteria strains. This study aims to evaluate the disinfection efficiency of the solar irradiation process (reproducing field conditions) in a CPC solar photoreactor with natural surface water sampled in urban dams containing wild *Salmonella* sp. of Ouagadougou, Burkina Faso. Experimentation was carried out during April–May 2009 when air temperature was of about 40 °C (see Fig. 1).

2. Experimental section

2.1. Reactors

2.1.1. Preliminary experiments at laboratory scale – solar simulator

Pirex-glass bottles of 50 mL were used as batch reactor and exposed under simulated solar light. A Hanau Suntest solar simulator (placed in laboratory facilities of the Institut International d'Ingénierie de l'Eau et l'Environnement (2iE) in Ouagadougou-Burkina Faso) is equipped with a Xenon lamp, which has a spectral distribution of about 0.5% of the emitted photons at wavelengths shorter than 300 nm (UV-C range) and about 7% between 300 and 400 nm (UV-B, -A range). Simulated solar spectrum between 400 and 800 nm follows solar spectrum. Experiments were carried out using a solar simulated irradiation with a light global intensity of about 660 W m⁻² (32 W m⁻² on the UV-A range).

Download English Version:

<https://daneshyari.com/en/article/1551446>

Download Persian Version:

<https://daneshyari.com/article/1551446>

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