Clean Techn Environ Policy
DOI 10.1007/s10098-013-0689-0

ORIGINAL PAPER

# Heat-transfer modeling as a design tool for improving solar water disinfection (SODIS) containers

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Received: 29 August 2013 / Accepted: 11 November 2013


**Abstract** A simplified heat-transfer model has been developed to effectively simulate thermal performance of water containers used in solar water disinfection (SODIS) applications. The purpose of the model is to facilitate accurate, fast, and uncomplicated prediction of thermal performance of different SODIS-container designs and configurations, enabling developers to analyze new design ideas without the needs for field experiments, which are typically cumbersome and difficult to compare. The model utilizes electromagnetic absorption coefficients and other thermal properties of container materials, and water to establish control-volume heat-transfer equations that can predict the water temperature. The model's simulated results of basic container designs agreed reasonably well with experimental results. Preliminary enhancements to the water container design were implemented—namely painting the container's underside black and covering the container with a clear plastic bag—with the aim to achieve higher disinfection efficacy through higher water temperatures, in accordance with the fundamentals of SODIS mechanisms. The heat-transfer model predicted that both design enhancements would significantly increase the water temperature, with the black coating being more effective. Subsequent field experiments confirmed the model's predictions.

**Keywords** Solar water disinfection · Heat transfer modeling · Container design

## Introduction

Every human being needs safe drinking water to survive, but despite efforts from governments and international organizations to provide safe water to everybody worldwide, about one billion people, especially those in under-resourced areas, still lack access to safe water supply (Jain 2012). While there have been many novel technologies that effectively treat and make water safe for drinking (Heidarpour et al. 2011), most of them are still too expensive or complicated for use in remote areas. Simple and affordable methods for point-of-use drinking water treatment methods are needed. Solar water disinfection (SODIS) is one of the methods that are promising (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2005). In this method, the users fill water into a clear container and expose it to the sun for 6–48 h, depending on the intensity of the available sunlight (McGuigan et al. 2011; Sommer et al. 1997) (And add: Sommer et al. 1997); Ultraviolet (UV) radiation and thermal heating of the sunlight inactivates pathogens in the water, through optical and thermal inactivation, respectively (Sommer et al. 1997; Smith et al. 2000; Khaengraeng and Reed 2005). Furthermore, studies have shown that at water temperatures above 45 °C, strong synergy between the optical and thermal inactivation processes occurs and results in much more effective overall disinfection (Wegelin et al. 1994). With respect to overall sustainability, UV water treatment has the potential to have more environmental, health, and economic benefits than other conventional methods, such as chlorination (Das 2002).

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Published online: 23 November 2013