IWA 17th SWWS AND 9th ROS
10th–14th November, 2024
Curitiba-Brazil

Improving the natural disinfection (SODIS) of surface water samples on using a sunlight-driven photocatalyst (g-C_3N_4/SiO_2)

Medeiros, G. R.*, Lima, L. B.*, Polakiewicz, H. M.*, Hoffmann, M. T.*, and Sabogal-Paz, L. P.*

*Department of Hydraulics and Sanitation, São Carlos School of Engineering, University of São Paulo, São Carlos, São Paulo, Brazil.

Highlights:

- Microbial communities pose challenges to conventional SODIS.
- Combined treatment of SODIS/Photocatalysis was the most effective.
- SODIS and g-C_3N_4/SiO_2 exhibited comparatively lower effectiveness individually.

Keywords: Bacteria; Drinking water; Inactivation.

INTRODUCTION

SODIS is a household water treatment method designed for developing countries. Small volumes of water are placed in transparent containers and exposed to sunlight to inactivate pathogens. While the UV-B radiation causes direct damage to microorganisms DNA, the UV-A range promotes the formation of reactive oxygen species in water, which damages cell constituents. Furthermore, infrared radiation causes heating and pasteurization of water (Luzi et al., 2016).

Due to the accessibility of this method, SODIS has been used in more than 50 countries, reducing the risk of diarrhea in children worldwide (McGuigan et al., 2012). However, for efficient water disinfection, sun exposure of at least 6 hours is necessary. On cloudy days, the recommended exposure increases to 48 hours (Luzi et al., 2016). To overcome these limitations, some techniques have been developed to improve SODIS performance, such as the combination with photocatalysts (Afitiri et al., 2024).

Photocatalysis process uses materials that are photoactive at certain wavelengths, forming free radicals that can damage microorganism molecules (Chaúque and Rott, 2021). Among these materials, graphitic carbon nitride (g-C_3N_4) is a metal-free photocatalyst that has been widely proposed for the inactivation of bacteria, viruses, and microalgae under visible light (Minella et al., 2021). Therefore, this work aimed to test the effect of g-C_3N_4/SiO_2 on the efficiency of SODIS, by analyzing the inactivation of total coliforms (TC) and *Escherichia coli* (EC) in surface water samples.

METHODOLOGY

The g-C_3N_4/SiO_2 was synthesized through a single-step thermal treatment. The method involved mixing melamine and silica gel in a 1:1 ratio in a mortar, and then the mixture was placed in a muffle for 2 h at 520 °C and 2 h at 550 ºC. Finally, a finely divided yellow bulk was obtained.

The water used in the study was collected from the Santa Maria do Leme stream, in the city of São Carlos (Brazil, -22.0094, -47.8960). It presented a pH of 5.52, turbidity of 34.2 NTU, apparent color of

94 HU, true color of 26.7 HU, transmittance at 254 nm of 70.9%. In addition, the initial concentrations of EC and TC were 1.38×10^3 CFU/mL and 6.39×10^3 CFU/mL.

The experiment involved placing four Petri dishes outdoors, parallel to the solar trajectory with 50 mL of surface water each. Two of them were exposed to sunlight to test the treatments: (1) SODIS + g-C_3N_4/SiO_2, and (2) SODIS, while two were packaged as dark controls: (3) g-C_3N_4/SiO_2, to assess toxicity of the photocatalyst, and (4) blank assay with just surface water. The concentration of g-C_3N_4/SiO_2 was 4 mg/mL. The assays were conducted from 10 a.m. to 4 p.m. on a cloudy day (542 KJ/m² obtained by National Meteorological Institute, station A711).

Aliquots of 20 µL were collected every 2 h and microdiluted in buffered saline solution for microbiological analysis. TC and EC were detected using Chromocult® and quantified in CFU/mL.

RESULTS AND CONCLUSIONS

Figure 1 shows the microorganism inactivation when exposed to SODIS and/or g-C_3N_4/SiO_2. EC removal was more pronounced than TC inactivation in both treatments, attributing to the fact that EC originates from fecal matter, consequently more vulnerable to disinfection processes, and indicating that diverse microbial communities pose challenges to conventional SODIS.

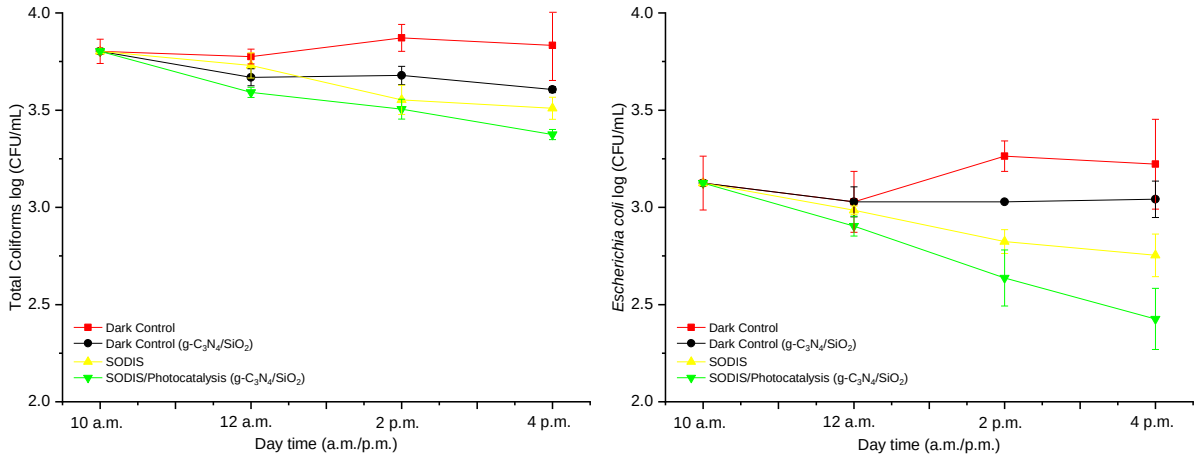

Figure 1 - Inactivation of (a) total coliforms and (b) *Escherichia coli* by SODIS and/or g-C_3N_4/SiO_2 photocatalysis methods.

The combined treatment of SODIS/photocatalysis was the most effective, whereas SODIS and g-C_3N_4/SiO_2 exhibited comparatively lower effectiveness individually. In the toxicity test, there was a decrease in the level of TC and stability of EC, suggesting the possibility of adsorption and/or inhibition of bacterial growth in the presence of g-C_3N_4/SiO_2. No external interference was noticed in the blank, just natural variations.

Regarding the catalyst, no detachment of the photocatalyst into the water samples was observed, demonstrating that the synthesis was successful for this application and the g-C_3N_4/SiO_2 was stable. Moreover, the impregnation of g-C_3N_4 into SiO_2 increases the activity of hydroxyl radicals, enhancing the photodegradation efficiency and bacteria DNA damage (Hao, 2016). Given these preliminary

results, we invite further research on g-C_3N_4/SiO_2 as a photocatalyst to assess optimal conditions for enhanced SODIS.

ACKNOWLEDGMENTS

The authors acknowledge The Royal Society (ICA\R1\201373 - International Collaboration Awards 2020), Brazilian National Council for Scientific and Technological Development - CNPq (Proc. 442074/2023-9 and 308070/2021-6) and Coordination for the Improvement of Higher Education Personnel (Proc. 88887.951426/2024-00, 88887.683999/2022-00, 88887.683608/2022-00 CAPES-PROEX).

REFERENCES

Afitiri, A.R., Aram, S.A. & Martienssen, M. 2024 Systematic review of the effects of advanced oxidation processes integration with solar water disinfection for improved drinking water production. Waste Management Bulletin, 1(4), 52–59.

Chaúque, B.J.M. & Rott, M.B. 2021 Solar disinfection (SODIS) technologies as alternative for large-scale public drinking water supply: Advances and challenges. Chemosphere, 281, 130754.

Luzi, S., Tobler, M., Suter, F. & Meierhofer, R. 2016 SODIS manual: Guidance on solar water disinfection. Dübendorf: EAWAG/SANDEC, p.56.

McGuigan, K.G., Conroy, R.M., Mosler, H.-J., Preez, M. du, Ubomba-Jaswa, E. &Fernandez-Ibañez, P. 2012 Solar water disinfection (SODIS): A review from bench-top to roof-top. Journal of Hazardous Materials, 235-236, 29–46.

Minella, M., Sordello, F. & Minero, C. 2021 Graphitic carbon nitride-based metal-free photocatalyst, in García-López, E.I. and Palmisano, L. (ed.) Materials Science in Photocatalysis. 449-484.

Hao, Q., Niu, X., Nie, C., Hao, S., Zou, W., Ge, J., Chen D., Yao, W. 2016 A highly efficient g-C3N4/SiO2 heterojunction: the role of SiO2 in the enhancement of visible light photocatalytic activity. Physical Chemistry Chemical Physics, 18, 31410-31418.