ASEC 2025 Conference

The 6th International Electronic Conference on Applied Sciences

09–11 December 2025 | Online

MDPI

Scaling and Environmental Analysis of a Heterogeneous Photocatalytic Rotary Photoreactor for Cyanide Treatment.

Omar Tirado-Muñoz[1], Jorge L. Gallego[2], Fernando Aricapa-Palacio[3], Alejandra Balaguera-Quintero[4], Alejandro Silva-C. [5] and Irina Tirado-B.[6]

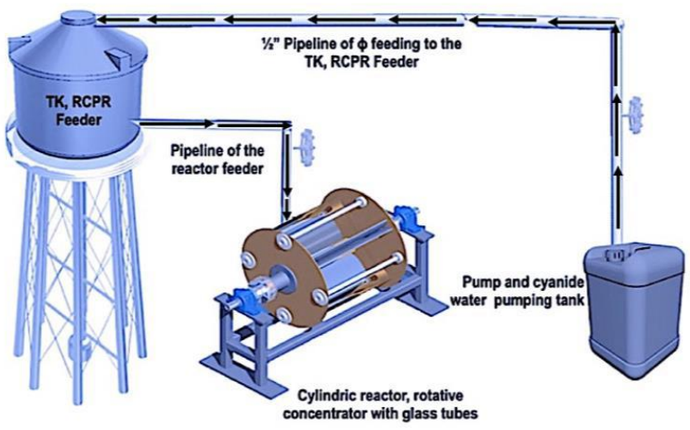
[1]Universidad Tecnológica de Bolivar Campus Tecnológico km 1 vía Turbaco Cartagena, Cartagena de Indias, Colombia.
[2] Biodiversity, Biotechnology and Bioengineering Research Group GRINBIO, Department of Engineering, University of Medellin, 050026, Medellín, Colombia.
[3] GISAH Research Group, Environmental Engineering Program, Universidad Tecnológica de Bolívar Campus Tecnológico km 1 vía Turbaco Cartagena, Cartagena de Indias, Colombia.
[4] Department of Engineering, University of Medellin, 050026, Medellín, Colombia.
[5] Department of Management Sciences, Instituto Tecnológico Metropolitano, 050034, Medellín, Colombia.
[6] GENOMA Group, Health Sciences Faculty, Universidad del Sinu, Elias Bechara Zainúm, 130015, Car-tagena de Indias, Colombia; irina.tirado@unisinu.edu.co

INTRODUCTION

Cyanide contamination from mining and industrial activities represents a severe environmental hazard due to its acute toxicity and persistence in aquatic ecosystems. Effective removal technologies are required to safeguard water resources and ecological health.

This study addresses this challenge by evaluating the scale-up of a TiO_2-based rotary concentrator photoreactor (RCPR) specifically engineered for the photocatalytic degradation of cyanide in contaminated water.

METHODS



Building on a previously developed pilot-scale reactor, the system was assessed through integrated modeling and simulation approaches to enhance design efficiency (Tirado-M. 2022).

Reactor design features

Features	Specification
Number of tubes	4
Total/irradiated tubes length	500/465 mm
Tube's material	Borosilicate glass
Tube OD	25.4 mm
Tube wall thickness	3 mm
Tube transmittance	0.880 ≤ τ ≤ 890 (λ ≥380nm)
Total irradiated area of the reactor	0.148 m^2
Total irradiated/treated volume	0.55/20 L
Reactor footprint	0.61 m^2
Flowrate (feeding and recycle)	20 L / min
Sun tracking system power	1 HP
Rotation speed	5 rpm
Pump power (axial drive)	0.5 HP

The methodology combined geometric sizing, a one-dimensional thermal energy balance, and optical simulations conducted in SolTRACE 3.0, under site-specific environmental conditions from the Colombian Caribbean.

CONCLUSION

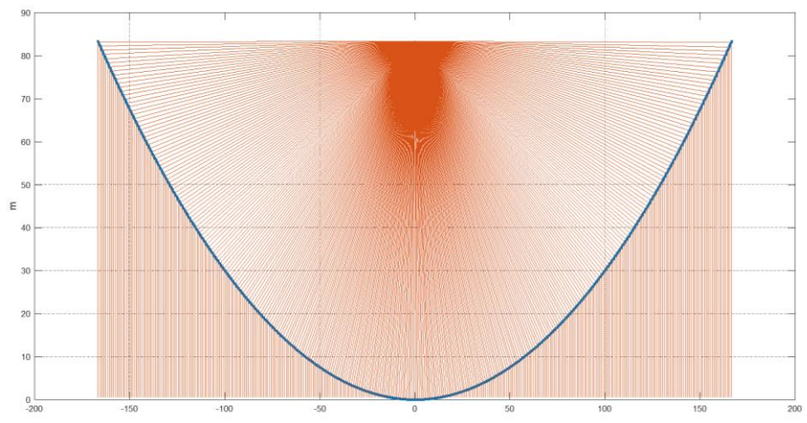
The SolTrace modeling results demonstrate that the geometric configuration, optical concentration, and surface reflectivity of the rotary photocatalytic reactor significantly influence the distribution of solar flux and the efficiency of light delivery to the focal region. The simulations confirm that optimized collector geometry enhances solar concentration, improves uniform heat distribution, and supports effective photocatalytic activation for cyanide degradation. Ongoing work includes integrating environmental impact assessment and cost–benefit analysis to evaluate the sustainability of full-scale deployment.

REFERENCES

Durán, J. M. Monteagudo, I. San Martín, & M. Aguirre, "Decontamination of industrial cyanide-containing water in a solar CPC pilot plant," Solar Energy, vol. 84, no. 7, pp. 1193–1200, 2010, doi: https://doi.org/10.1016/j.solener.2010.03.025.

Tirado-Muñoz, O., Tirado-Ballestas, I., Barbosa Lopez, A. L., & Colina-Marquez, J. (2022). Heterogeneous Photocatalytic Pilot Plant for Cyanide decontamination: A novel solar rotary photoreactor. Journal of Solar Energy Engineering, 144(5), 051005.

RESULTS & DISCUSSION

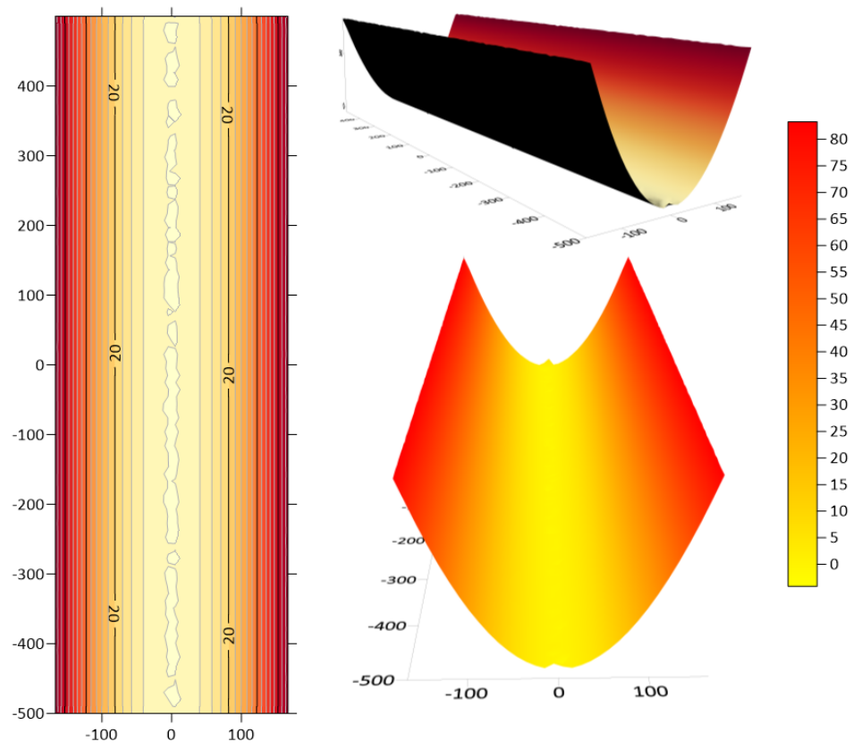


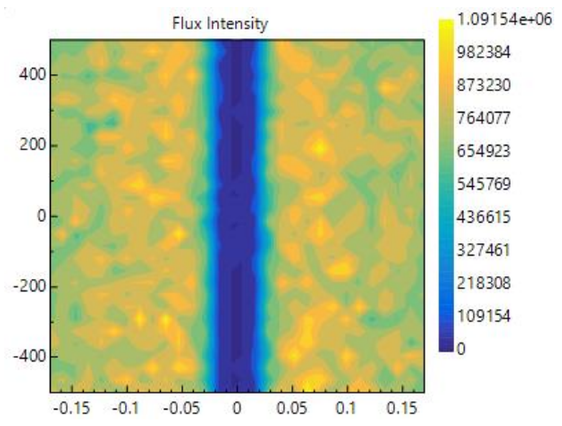
Capture Area and Collector Geometry

The reflection and shading areas on the collector surface are represented by simulating radiation perpendicularly, allowing the validation of solar ray concentration at the focal point.

Heat Distribution on the Collector Surface

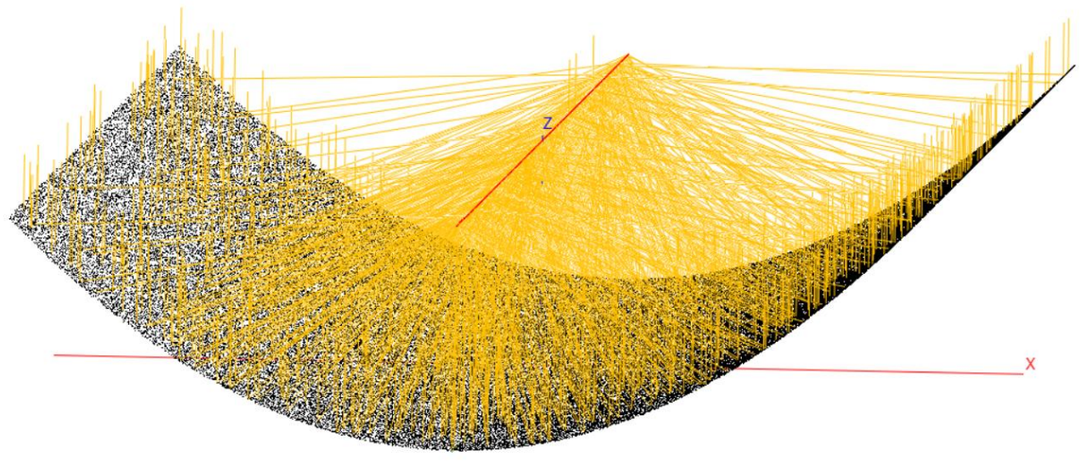
The heat distribution on the collector surface is identified, highlighting zones of higher temperature along the edge of the surface and a homogeneous distribution in the focal region of the collector.





Solar Radiation Flux Intensity on the Collector Surface in SolTrace 3.4

After simulating the solar rays in SolTrace, the intensity of the radiation flux on the prototype collector surface is represented. Heat-intense areas and shaded areas are identified, particularly in the region where the proposed collector's receiver is located.



Raytrace on the Collector Surface

The incidence of solar rays on the collector surface is identified; some rays are reflected toward the focal point where the receiver is located, while others strike the surface and are only absorbed or reflected in the same direction, especially near the edges of the collector surface.