Enhancing SODIS through Simplified Collectors for Cost-Affordable UV Radiation Disinfection

POSTER
Ph.D. Student: N
Journal: JECE

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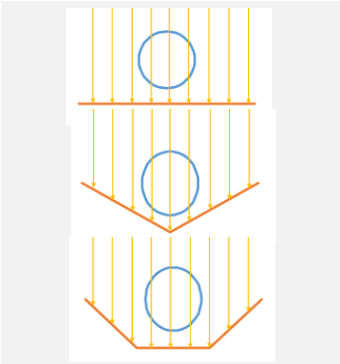

SODIS method has emerged as a low-cost alternative capable of mitigating the consumption of contaminated water and the transmission of waterborne diseases. However, for its effective implementation, it is necessary to increase the amount of UV radiation from the Sun reaching the water. The use of different solar collectors has been proposed for this purpose, but their complex shapes contribute to increasing the water treatment costs. This work proposes the use of simplified solar collectors that do not pose an unaffordable cost for the interested communities. A ray-tracing study was conducted to assess the efficiency of one, two, and three-sided collectors in different locations. The results showed that collectors with two and three flat plates were able to achieve concentration efficiencies similar to a CPC collector in three reference cities at a very reduced cost.

Introduction

SODIS (Solar Disinfection) method is a sustainable and low-cost alternative for the inactivation of pathogens present in water to produce safe water in communities with low economic resources. This method uses solar radiation to disinfect water, using transparent bottles exposed to the sun for a specific time. However, although SODIS offers an accessible solution, its traditional implementation has disadvantages that complicate its effectiveness. Some disadvantages are the long exposure times required (from 6 to 12 hours), the limitations of volume to be treated or the dependence on favorable weather conditions.

Most of these drawbacks can be mitigated by increasing the amount of UV radiation that reaches the water to be treated. For this purpose, reflective surfaces capable of concentrating solar radiation can be incorporated. Among the most common concentration systems, the compound parabolic collector (CPC) stands out. The CPC is a static collector whose reflecting surface is arranged in such a way that the normal at each point of the collector is tangent to the circumference that constitutes the tube section. The main characteristic of these collectors is that they can concentrate both direct radiation and diffuse radiation [1], so a solar tracking system is not required.

In both cases, the use of this type of system manages to increase the incident radiation captured for the process and, therefore, its efficiency. However, this improvement also represents a notable increase in the total cost of the process, since the collectors are usually built with aluminum and the manufacturing to obtain the parabolic shape required to achieve the correct reflection of the sun's rays is not simple. Consequently, the increase in the cost of water treatment may make it an unaffordable expense for low-income communities.

In this work, the possibility of using affordable simple solar collectors capable of achieving high concentration of solar radiation was studied. The concentration efficiency of one, two and three-sided collectors was studied, depending on their geographical location and solar position and the optimal configuration was chosen for different locations.

Material and Methods

Concentration efficiency simulations of thousands of one-, two-, and three-sided reactor configurations for different solar positions were carried out using a ray tracing tool [2]. For the flat plate collector, a constant value of *f* (distance from the center of the receiver tube to the collector) equivalent to the radius of the reactor tube was set, ensuring the collector remained consistently attached to the receiving tube. Various collector width (*w*) / receiving tube diameter (*D*) ratios ratios ranging from 2 to 10 were explored. In the case of the collector with two flat plates, the study included *w/D* ratios from 2 to 10 and *f* values ranging from *D*/2 to 2*D*. The same set of parameters was varied for the three flat plate collectors, including a variation of the angle of inclination of the side plates with respect to the horizontal one within the range of 90 to 170º. For all collectors, the angle of solar incidence was varied between 1 and 90º, the optical density between 0 and 10 and a reflectivity of 0.85 was set corresponding to anodized aluminum material. The total number of cases studied was 1800, 12960 and 131220 for collectors with one, two and three flat plates, respectively.

Once the corresponding concentration factors were obtained for all the purposed reactors, and knowing the position and solar radiation on each day of the year and location, the concentration efficiency that each of the reactors annually would have was calculated for different locations. The results obtained were compared with the concentration values that would be obtained with a standard CPC reactor.

On the other hand, to validate the simulations, the construction of the optimal reactor of each type was carried out for the facilities of the Rey Juan Carlos University in Móstoles, Spain, (40.33°N, 3.86°W). Once constructed, potassium ferrioxalate actinometry experiments were carried out following the procedure described elsewhere [3].

Results and Discussion

In the figure, the results obtained when evaluating collectors with one, two, and three flat plates in three representative cities located at different latitudes are presented (Móstoles, 0.33°N, 3.86°W; Goa 15.4°N 74.01°E, and Cape Town, 33.92°S 18.42°E). These results illustrate the concentration efficiency for the optimal collector of each type in each city, contrasting it with what would be achieved using a CPC. In Móstoles and Cape Town, it is highlighted that the simplified three-sided collectors predict higher concentration efficiencies than those obtained with a CPC. Regarding the two flat plate collectors, its efficiencies will be comparable to those of the CPC, while the use of a single plate collector would result in values of approximately 70% compared to the CPC. In the case of Goa, the calculated efficiencies for all simplified collectors were considerably lower, ranging between 60% and 80%, in comparison to the CPC. These findings emphasize the importance of considering the geographical location when designing a specific collector, as this variable will significantly impact its future efficiency.

On the other hand, the costs of the different collectors were estimated for comparative purposes. The costs of the CPC collector were determined using the Williams method, resulting in a value of 87.58 €. Additionally, the cost of simplified collectors was calculated using the following expression:

$$Cost = Tube\ cost + Reflector\ cost \times Collector\ area$$

The tube cost was set at 10.05€ per meter, while the collector cost was fixed at 22.55€ per square meter, as indicated elsewhere [2].

The obtained results demonstrated that in all cases, the simplified collectors reduced costs by more than 20% compared to the CPC collector, representing a significant cost reduction. It is noteworthy that these simplified collectors not only entail a considerable cost reduction but may also enhance the feasibility of their deployment in remote locations, given the absence of the need for special equipment in their fabrication.

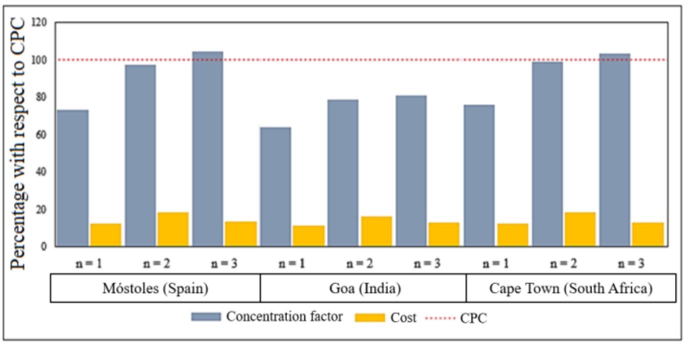

Figure 1. Comparison of the efficiency of simplified collectors with a CPC for different locations

Conclusions

The results showed that two and three side collectors achieved concentration efficiencies like a standard CPC at considerably reduced costs. Although the single-sided collector had slightly lower efficiency, it is still an attractive option due to its simplicity of construction. On the other hand, the calculations were correctly validated through experimental tests at the facilities of Rey Juan Carlos University.

Acknowledgments

The authors gratefully acknowledge the financial support of the Spanish State Research Agency (AEI) and the Spanish Ministry of Science and Innovation through the project AQUAENAGRI (PID2021-126400OB-C32).

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