Methodology for lighting optimization applied to photocatalytic reactors

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Abstract— **Replacement of conventional UV-lamps used in photocatalytic reactors by UV-LED sources with lower energy consumption and larger versatility has been proposed recently; However, the implementation of these types of sources in these reactors has not been studied in detail. In this article a methodology is proposed to find different LED arrays, whose distributions use the least amount of elements and optimum distance between them, using uniform irradiance models that satisfy the optical needs of photocatalytic processes. Experimental results presented show that it is possible to replace sources of high-energy consumption by LED arrays adapted to the specific needs of the photocatalytic reactor obtaining excellent oxidation results.**

I. Introduction

Water treatment is one of the actual technologies where the implementation of lightning techniques can report significant improvements. Heterogeneous photocatalysis is a process where a selection of the proper lightning source is crucial for the consecution of the desired effects owing to a proper illumination is directly related to photocatalytic activity[1].

The substitution of conventional sources of illumination in photocatalytic reactors is increasingly necessary, due to its disadvantages (i.e. fragility and toxicity) and some of the sources chosen for this substitution are LEDs, because they characteristics (i.e. cost, compact size, lightweight, lower operating temperature and long lifetime). In the last years some authors [2]–[5] proposed the use of UV-LEDs to carry out the photocatalysis, most of the current articles focusing on the direct replacement of the conventional ultraviolet lamp by LED arrays without any discussion regarding which is its most optimal distribution, in fact, the number of LEDs changes considerably for the different proposals. Hence, finding a way to determine the minimum number of LEDs and its geometrical distribution needed to replace effectively the conventional UV lamp source is a topic of potential interest.

This study focuses in the generation of a general methodology based on uniform irradiance models to obtain the optimal characteristics of LED arrays that allow the effective replacement of conventional ultraviolet lamps used in photocatalytic reactors. In addition, feasibility is demonstrated by comparing the results obtained from decolorization processes using lamps and LEDs.

II. Methodology for replacement of UV-lamps

In order to perform the replacement of conventional lamps in photocatalytic reactors, different factors were considered, such as the location and angle of position of the light source, the distance between it and the reactor and, mainly, the generation of a uniform irradiance pattern to photoactivate the catalyst.

The geometry of the photocatalytic reactors (with external lighting) offers the possibility of using models of uniform irradiance[6] to adapt the characteristics of the LEDs and generate uniform illumination. Applying these models allows a) to find the least number of LEDs needed to replace pre-existing UV lamps, b) generate specific arrangements to take advantage of the reactor geometry, since it is not mandatory that they have a defined structure or distribution.

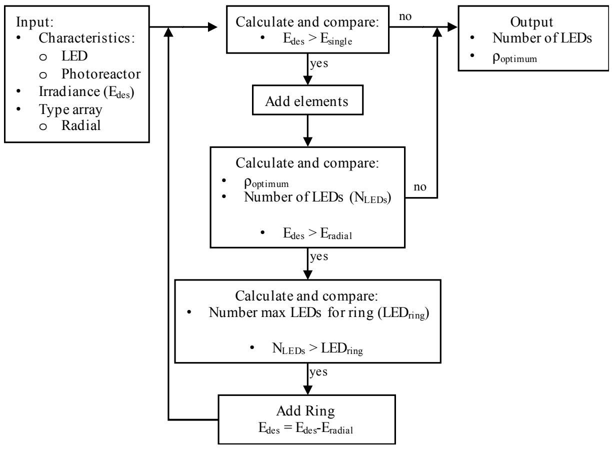

Fig. 1. Flowchart: Radial Array.

The algorithm created for this methodology has as input variables the dimensions of the reactor, the optical characteristics of the LED and the necessary Irradiance (E_{des}) to photoactivate the catalyst. The algorithm was a applied to find the minimum number of LEDs (Roithner LaserTechnik LED385-33 UVA) to replace three conventional lamps

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(Philips PLL 18W/10/4P UVA) in a reactor used for the treatment of textile wastewater, as well as a LED distribution that decreases the process time.

Fig. 1 shows the flowchart of the routine for the creation of a radial LED array, used the calculation of the array with the least amount of LEDs. With the aim to create a decrease in the reaction time, the algorithm for hexagonal arrays was used.

The calculation of the optimal number of LEDs is as important as the separation distance between each element. Fig. 2 shows the irradiance distribution of two LED arrays with the same number of elements created for a cylindrical photoreactor with dimensions 9 cm in height and diameter of 6 cm; whose geometry requires that the maximum irradiance value be in its central zone. As can be seen in Fig. 2a, when the array has an adequate distribution of LEDs the irradiance pattern is homogeneous, and if this distribution is not optimal, there may be a case of the decrease in irradiance, as well as not providing its maximum intensity in the desired zone (Fig. 2b).

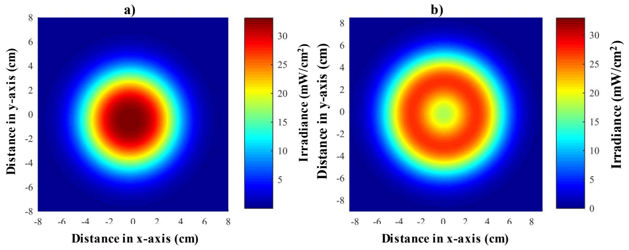

Fig. 2. Irradiance distribution LED radial Array. a)Optimal distance between elements b)Distance between elements higher than the optimum.

III. Experimental Results

The array with the minimum amount of elements consists of 30 LEDs placed in a circular shape, with a radius of 2.1 cm with respect to the center of the reactor, located in the upper part of the reactor at 10 cm from its bottom.

To reduce the time of the process, the arrangement of radial LEDs was placed in the upper part of the reactor as well as three hexagonal arrays placed at 120° around the reactor. Each hexagonal array has 12 LEDs placed at a distance of 1.2 cm.

Fig. 3 shows the results of discoloration carried out with three different types of illumination: conventional lamps, Radial LED Array and Multi array.

The results indicate that using the minimum number of LEDs (radial LED array), the process requires 10 % more time (45 min) of the usual process time, but 85 % of the total energy required for decolorization with conventional lamps is saved; However, if the geometry of the reactor is considered (multi-array), the decolorization time decreases 87 min, which means a reduction of the usual process time of 20 %, and 75 % of the typically required energy is saved.

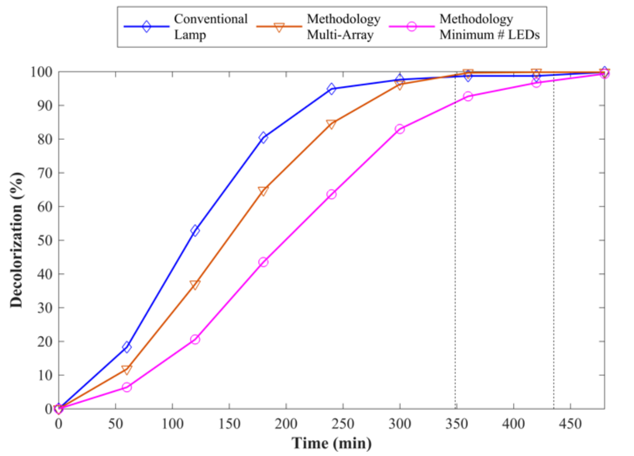

Fig. 3. Decolorization for the Reactive Orange 13 dye with different types of UV-sources, with a same initial concentration of dye and photocatalyst.

IV. Conclussion

It was found that it is possible to create a methodology to calculate the minimum number of LEDs and obtain discoloration results similar to conventional lamps. It was also shown that it is possible to optimize the reaction time of the photocatalytic processes by adapting the lighting sources to the geometrical characteristics of the reactors. And generate significant energy savings.

Although this methodology was developed and tested for the optimization of photocatalytic reactors, it can be used for any other application that requires uniform illumination.

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