Comparison of the Efficiency of Different Light Sources for the Generation of Hydroxyl Radicals Using TiO_2 and ZnO Photocatalysts

Máté Náfrádi, **Tamás Hlogyik, Tünde Alapi**
Department of Inorganic and Analytical Chemistry, University of Szeged, H-6720 Szeged, Dóm tér 7, Hungary

Advanced Oxidation Processes (AOPs) may offer a way to remove several non-biodegradable pollutants released to wastewaters, like pesticides, pharmaceuticals, and other organic or inorganic compounds. Heterogeneous photocatalysis is amongst the most researched AOPs thanks to its efficient transformation and mineralization of most organic pollutants, but its practical application has not yet been solved. Several studies work on the synthesis or modification of semiconductors to effectively utilize visible light, but the improvement of UV-sources for well-established photocatalysts may also help with reducing operating costs and increasing the efficiency of the method. UV-LED light sources can be an efficient solution for the excitation of semiconductors like TiO_2 and ZnO. This work aims to compare mercury vapor lamps (MVLs) to different UV-LEDs. Cheap, commercial LEDs emitting at 398(±10) nm (P=76 mW/LED), high power UV-LEDs emitting at 365(±10) nm (P=2.0 W/LED), and an MVL emitting in the 300-400 nm range (λ_{max}=365 nm, P=15.0 W) has been used.

The light sources were compared based on their photon flux emitted, in the case of the LEDs the electric power input was controlled, and different values were compared. The LED light sources proved to be significantly more efficient at similar electric power consumption compared to the MVL based on iron-oxalate actinometry. The efficiency of all three light sources was tested during heterogeneous photocatalysis employing the two most widespread photocatalysts, TiO_2 and ZnO. Coumarin was used as a model compound, as it allows us to compare the formation rate of hydroxyl radicals ($^{\bullet}OH$) based on the formation of its hydroxylated product, as generally $^{\bullet}OH$ is responsible for the high mineralization efficiency of the method. The different light sources and catalysts were also compared based on electric power consumption and photonic efficiencies.

The optimal conditions for the measurements (catalyst dosage, initial concentration) were determined. In the case of TiO_2, a significantly higher $^{\bullet}OH$ formation rate was calculated compared to ZnO. On the other hand, ZnO was slightly more effective at transforming coumarin, indicating a different primary reaction mechanism. The LEDs emitting at 398 nm were the least efficient during photocatalysis, but the UV-LEDs emitting at 365 nm were more effective, and consumed less electric power than the MVL, especially in the case of ZnO. During photocatalytic experiments with the LED light sources, the photonic efficiencies were reduced with increasing the light intensity, therefore their operation is much more cost-efficient at low electric power input.

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