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# ABSTRACT:

## Innovative Photocatalysts for Hydrogen Production from Aqueous Solution

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Photocatalytic hydrogen production from aqueous solutions containing organic compounds represents a promising strategy for coupling clean energy generation with wastewater remediation, in line with the principles of the circular economy.

Recent advances in this field focus on optimizing both catalyst design and process configuration to enhance overall efficiency, scalability, and sustainability. Two complementary approaches have been investigated. The first involves the effective immobilization of $TiO_2$ on lightweight, reusable polystyrene pellets. In this configuration, $TiO_2$ serves as the active phase, enabling hydrogen evolution under reducing conditions and promoting the complete degradation of organic pollutants—such as phenols and other recalcitrant compounds—under oxidative conditions. This dual functionality allows for the sequential use of the same catalyst in distinct operational environments, facilitating both energy recovery and pollutant removal. When applied to real olive mill wastewater, the system achieved hydrogen production up to 16,954 μmol/L while maintaining catalyst stability over at least ten reuse cycles.

The second approach is based on the development of $RuO_2$-ZnO composite photocatalysts, with particular attention to optimizing the interfacial interaction between the two phases. This was achieved through a supercritical $CO_2$-assisted micronization process, which ensures homogeneous dispersion and high interfacial contact. The resulting materials exhibit improved charge separation and enhanced photocatalytic performance. In tests using aqueous gallic acid solutions under UV irradiation, the optimized catalyst (1 wt% $RuO_2$, 1 g/L dosage) achieved hydrogen production of up to 4,461 μmol/L after 180 minutes. These findings demonstrate how targeted advancements in catalyst formulation—either via innovative immobilization techniques or advanced synthesis methods—can significantly enhance the performance of photocatalytic hydrogen production systems.

The proposed strategies offer viable solutions for converting organic-laden wastewater streams into valuable energy carriers, contributing to the development of sustainable and integrated chemical engineering technologies.