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Research Article

Seawater utilization through hybrid photocatalysis-electrocoagulation process using pumice-supported g-C₃N₄/BiOBr for hydrogen production and methylene blue decolorization

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Abstract. This study investigated the simultaneous photocatalysis-electrocoagulation process using pumice-supported g-C₃N₄/BiOBr nanocomposites in seawater treatment to remove organic pollutants and generate hydrogen gas. The photocatalyst nanocomposite was synthesized via coprecipitation and immobilized on the pumice surface to enhance light exposure and facilitate catalyst recovery. The performance of the hybrid system was evaluated under various operational parameters, including applied voltage, seawater concentration, and pH. The results showed that the combined process outperformed the individual photocatalysis and electrocoagulation systems. Optimal performance was achieved at pH 3 and 15% seawater concentration, resulting in 99.37% methylene blue decolorization and 211 mL of hydrogen within 2 hours. At higher salinities and lower pH, increased coagulant formation caused a shadowing effect, limiting photocatalytic efficiency despite continued hydrogen evolution. The XPS (X-Ray Photoelectron Spectroscopy) characterization of the photocatalyst material, demonstrated the successful formation of a nanocomposite with a stable surface chemistry. Photoluminescence analysis confirmed that the charge separation mechanism could be enhanced, suppressing the recombination rate and being the primary reason for the enhanced photocatalysis process, although interfacial electronic interactions remained limited. Overall, this study demonstrates that the pumice-supported g-C₃N₄/BiOBr photocatalyst integrated with electrocoagulation provides an effective and stable platform for seawater-based hydrogen production and organic pollutant removal.

Keywords: Hydrogen, Photocatalysis, Electrocoagulation, Seawater, Renewable Energy



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1. Introduction

The increasing demand for clean energy and the urgent need to mitigate climate change are driving the search for sustainable and resource-efficient renewable energy technologies. In this context, hydrogen has been recognized as a promising carrier in the world energy transition due to the high-energy content and lack of carbon emission throughout combustion (Cheekatamarla, 2024; Roy and Pramanik, 2024; L. Zhang *et al.*, 2024). Among the various hydrogen production methods, water splitting fueled by solar energy is considered one of the most attractive renewable energy sources (Badruzzaman *et al.*, 2025; Imran and Hussain, 2024; Jia *et al.*, 2016). However, there is a scarcity of freshwater resources, which are often used in agriculture or for household purposes. This has led to a rise in the use of seawater as a rich and naturally conducting substance to produce hydrogen. Despite the abundant access to seawater, the large-scale use in green hydrogen infrastructure is still limited. This is due to the complexity of the ionic composition, as well as the inability to develop stable and effective catalysts operating in saline environments.

In this regard, solar and electrical energy can be used in a complementary pattern by relying on the hybrid processes of photocatalysis and electrochemical methods (Muttuqin *et al.*, 2022; Pratiwi *et al.*, 2025; Surjo *et al.*, 2024). Photocatalysis uses semiconductor materials to absorb light and produce electron-hole pairs for the production of redox reactions to split water and eliminate pollutants (Ali *et al.*, 2024; Hosseini *et al.*, 2023; R. Li and Li, 2017; Yusuf *et al.*, 2025). Meanwhile, electrocoagulation includes the application of direct current to sacrificial electrodes, made of aluminum/iron, which dissolves to create hydroxide flocs capturing dissolved contaminants (Al-Ajmi *et al.*, 2025; Boinpally *et al.*, 2023). These two systems are by-products of cathodic reduction to generate hydrogen gas, and the mechanisms of operation suggest a strong potential for synergistic interaction when implemented simultaneously.

Recent studies have shown that the combination of photocatalysis and electrocoagulation produces a significantly higher operational efficiency compared to the use of a single method (Muttuqin *et al.*, 2022; Pratiwi *et al.*, 2025; Surjo *et al.*, 2024). This enhanced performance is attributed to the interaction between these mechanisms. In terms of mechanisms of operation, the external electric field facilitates the extraction

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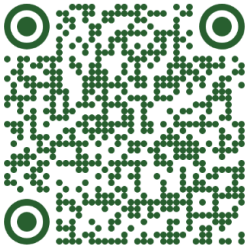
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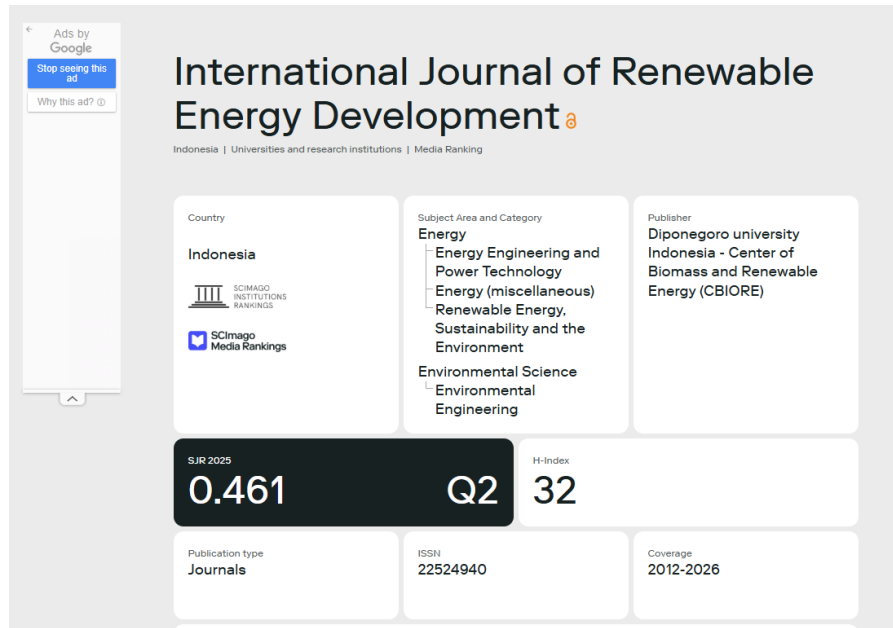
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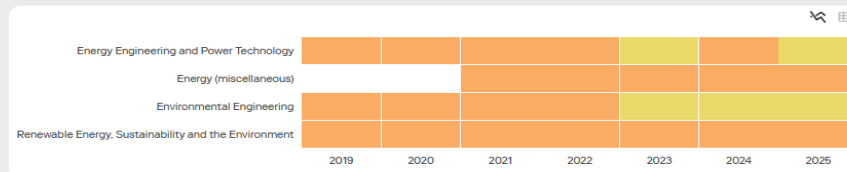
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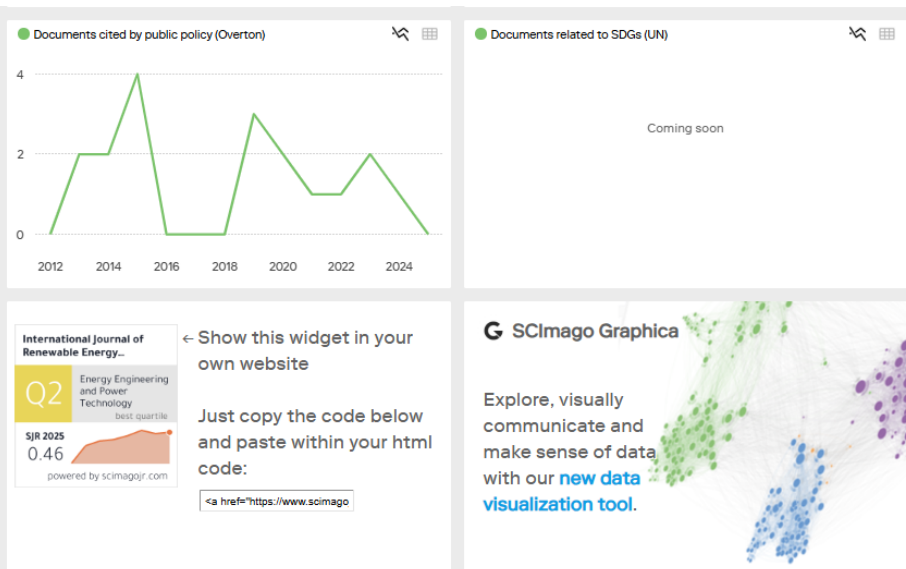
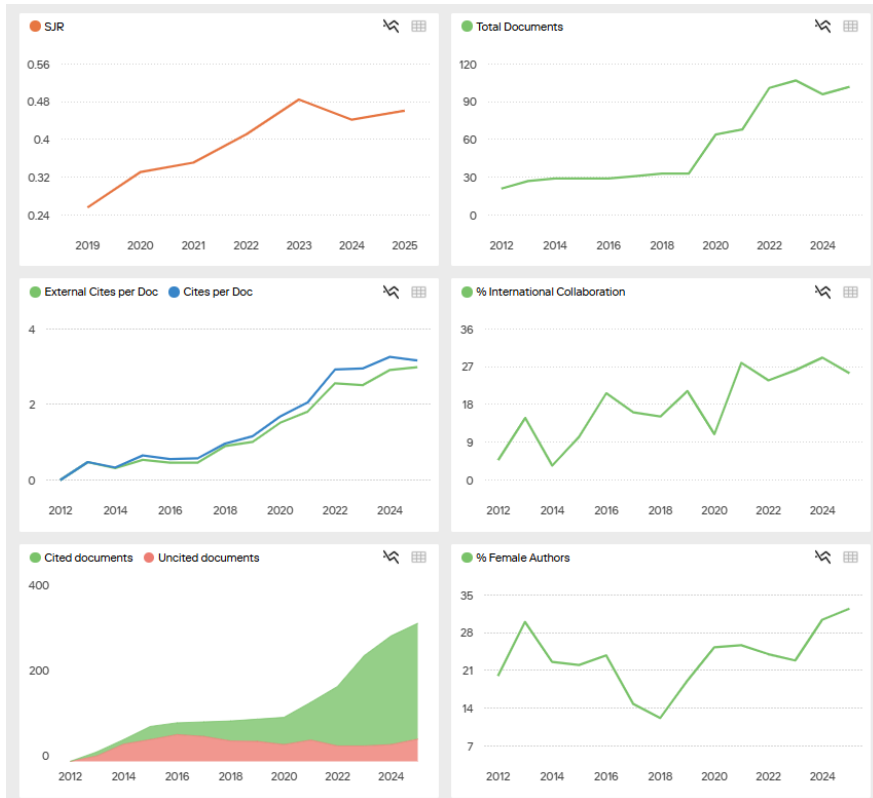
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