Contribution ID: **111** Type: **Študenti fyzika**

Rapid Degradation of Coumarin via In Situ Hydroxyl Radical Generation Induced by Recycled Gas from a DBD Plasma Bubble Reactor

Wednesday, November 26, 2025 11:14 AM (1 minute)

Coumarin, a fluorescent aromatic compound widely used in dyes, pharmaceuticals, and optical brighteners, is frequently detected in industrial effluents and poses ecological risks due to its persistence, phototoxicity, and potential bioaccumulation in aquatic environments 1. This study presents a novel approach for the rapid degradation of coumarin using recycled gas from a dielectric barrier discharge (DBD) plasma bubble reactor. The DBD plasma device consists of a coaxial geometry (150 mm length, 15 mm outer diameter) with two quartz tubes forming a 1.5 mm discharge gap where plasma is generated. The complete experimental setup is shown in Fig. 1(a). The reactor is immersed in water, allowing reactive oxygen and nitrogen species (RONS) to be transferred into the liquid phase via plasma bubbles, while gas-phase species such as ozone are recycled to a secondary reactor containing the pollutant solution. These recycled oxidants, mainly ozone and hydrogen peroxide, react to generate hydroxyl radicals in situ, accelerating coumarin degradation.

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Fig. 1. (a) Complete experimental setup for coumarin degradation, (b) Degradation profile of coumarin under three different treatment conditions.

The performance was evaluated under three conditions: (i) plasma bubbling, (ii) recycled gas treatment, and (iii) ozonation alone. Hydroxyl radicals were quantified in all cases using a terephthalic acid fluorescence probe, revealing that the secondary reactor with recycled gas diffusion produced the highest radical concentration, correlating with the maximum degradation. Among these, the recycled gas system achieved 99% degradation within 25 minutes, demonstrating superior efficiency, as shown in Fig 1(b). The presence of excess nitrogen species in the primary plasma zone reduced degradation efficiency compared to ozone alone, emphasizing the role of optimized gas recycling in enhancing plasma-based oxidation.

This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V03-00033 EnvAdwice.

1. Aspatwar A, Berrino E, Bua S, Carta F, Capasso C, Parkkila S, Supuran CT. Toxicity evaluation of sulfamides and coumarins that efficiently inhibit human carbonic anhydrases. J Enzyme Inhib Med Chem. 2020 Dec;35(1):1765-1772. doi: 10.1080/14756366.2020.1822829.

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Session Classification: Poster session + káva: prezentácie študentov Fyzika

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