Dose-Driven Degradation of Azole Emerging Contaminants in Water by Electron Beam Irradiation

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Purpose: Azole compounds such as benzotriazole, 5-methyl-benzotriazole, 1,2,4-triazole, and pyrazole are widely used in industrial and consumer applications such as corrosion inhibitors, synthetic antifungal agents and de-icing formulations. They are emerging contaminants increasingly detected in aquatic environments due to their persistence and resistance to conventional water and wastewater treatment. This resistance to conventional treatment highlights the need for alternative remediation technologies. Ionizing radiation technologies, particularly electron beam (e-beam) irradiation, offer a chemical-free advanced oxidation approach capable of generating reactive species (•OH, e^-_{aq}, H•) for contaminant degradation. This study investigates the effectiveness of electron beam irradiation for the degradation of selected azoles in aqueous systems and aims to evaluate its potential as a sustainable treatment strategy for emerging contaminants.

Methods: Dose-dependent degradation experiments were performed using aqueous solutions of analytical grade pyrazole, 1,2,4-triazole, benzotriazole, and 5-methyl-benzotriazole prepared in ultra-pure Milli-Q water (10 mg/L). Samples were subjected to controlled electron beam irradiation over a dose range of 0 – 20 kGy. Post-irradiation concentrations of parent compounds were quantified by UPLC–MS/MS using externally calibrated standards. Irradiated samples were compared with non-irradiated controls, and degradation behavior was evaluated using dose-based pseudo first-order kinetic modelling to derive apparent rate constants and assess degradation efficiency.

Results: Experiments are currently ongoing, and UPLC–MS/MS analysis is being conducted to quantify residual concentrations of irradiated azoles. Data processing focuses on establishing dose – response relationships in evaluating degradation efficiency at each dose and through dose-based pseudo first-order kinetic modelling. Final results will provide comparative degradation profiles and degradation efficiencies for the investigated azole compounds.

Conclusions: This work aims to provide quantitative insight into the effectiveness of electron beam irradiation for the degradation of persistent azole contaminants in water. The findings are expected to contribute to the development of irradiation-based advanced treatment strategies for emerging contaminants and to improve understanding of dose-dependent degradation efficiency of azoles.