Contribution ID: **25216** Type: **Extended Abstract**

Process Intensification for Radioactive Wastewater Treatment: Efficient Pb^{2+} and Cu^{2+} Removal Using an Agitated Tubular Reactor

Tuesday, 4 November 2025 15:15 (15 minutes)

Efficient treatment of radioactive wastewater containing toxic heavy metals such as Pb^{2+} and Cu^{2+} remains a pressing environmental challenge. This study explores the application of an Agitated Tubular Reactor (ATR) as an intensified process alternative to conventional batch systems. Using a pilot-scale Coflore® ATR, the performance of clinoptilolite and co-precipitation agents under varying agitation conditions (0–5 Hz) for simultaneous removal of Pb^{2+} and Cu^{2+} at 200 ppm concentrations was evaluated. Comparative experiments demonstrated that the ATR achieved removal efficiencies of 98% for Pb^{2+} and 97% for Cu^{2+}, outperforming natural clinoptilolite alone (58% Pb^{2+}, 67% Cu^{2+}) and matching or exceeding batch systems. Enhanced lateral mixing through the ATR's sinusoidal agitation promoted superior mass transfer, dispersion, and floc formation, resulting in compact sediment structures with compressive yield stress comparable to those from batch processes. Dye tracing confirmed efficient pseudo-plug flow behavior and shear-driven mixing, particularly at a frequency of 5 Hz. Unlike batch reactors, which are limited by operational intermittency and clogging, the ATR offers continuous operation, reduced fouling, and higher space-time yields. Moreover, its modular, compact design enables scalability and mobile deployment, making it highly suitable for on-site applications at nuclear facilities. Given its superior performance, process intensification capabilities, and operational flexibility, the ATR represents a viable and promising future solution for treating radioactive effluents containing heavy metals in both industrial and environmental remediation contexts.

Technical Track

Fuel Cycle and Waste Management

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Session Classification: Fuel Cycle and Waste Management