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Sustainable Nuclear Decontamination strategies for carbon neutrality

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As nations accelerate efforts toward carbon neutrality, the decontamination phase of nuclear power plant decommissioning must transition to sustainable and low-emission strategies to minimize environmental impact. Traditional decontamination methods rely on high-energy, chemical-intensive processes, which contribute to carbon emissions, secondary waste generation, and excessive resource consumption. This study explores the use of inorganic decontamination reagents as an alternative to conventional methods, aiming to eliminate greenhouse gas emissions while maintaining effective decontamination performance. The objective is to enhance sustainability in nuclear decontamination by emphasizing low-carbon chemical processes, optimized waste handling, and energy-efficient dismantling techniques.

A comparative analysis is conducted between the inorganic SP-HyBRID (Sulfuric acid Permanganate - Hydrazine-Based Reduction Metal Ion Decontamination) process and the organic CORD (Chemical Oxidizing Reduction Decontamination) method, which utilizes oxalic acid. The study evaluates their environmental impacts, including waste generation, energy consumption, and carbon emissions, providing a data-driven assessment of their carbon footprint. Additionally, the research extends to analyzing the carbon footprint of immobilization processes, comparing conventional waste stabilization matrices such as cement, bitumen, and geopolymers to determine their relative sustainability in long-term waste containment.

Findings indicate that integrating Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) analysis into decommissioning decision-making optimizes cost efficiency, environmental sustainability, and resource utilization. The adoption of low-emission decontamination processes and circular economy principles enables the nuclear sector to transition toward greener decommissioning practices that align with climate action goals while ensuring radiological safety and regulatory compliance.