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Sustainable Sewage Sludge Management: Risks, Challenges, and Opportunities in the Circular Economy

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Abstract

Sewage sludge management is an increasingly important challenge in environmental and resource management as wastewater treatment capacity expands and regulatory requirements become more stringent. While sewage sludge contains valuable organic matter, nutrients, carbon, and recoverable energy, its complex composition also raises significant environmental and health concerns. In addition to conventional contaminants such as heavy metals and pathogens, emerging contaminants—including pharmaceuticals, microplastics, and per- and polyfluoroalkyl substances (PFAS)—are reshaping how sludge treatment, reuse, and disposal strategies are evaluated.

In the transition toward a circular economy, sewage sludge is increasingly viewed not merely as a waste to be disposed of, but as a potential secondary resource. This shift creates opportunities for integrated management approaches that combine environmental risk reduction with resource and energy recovery. Anaerobic digestion, nutrient recovery, pyrolysis, gasification, and biochar production provide different pathways for recovering energy and valuable materials while reducing sludge volumes and reliance on conventional disposal routes. However, sustainable sludge management cannot be defined solely by treatment efficiency or resource recovery potential. The fate of contaminants, greenhouse gas emissions, energy requirements, economic feasibility, regulatory constraints, and the environmental safety and quality of recovered products must also be considered.

This keynote presentation will address the evolving risks and challenges associated with sewage sludge management while exploring emerging opportunities within a circular economy framework. Particular attention will be given to resource and energy recovery, thermochemical conversion, the development of sludge-derived products, and the role of life-cycle thinking in evaluating alternative management pathways. The presentation will emphasize the importance of integrated, low-carbon, resource-efficient, and environmentally safe strategies to support the transition from conventional sewage sludge management toward sustainable resource recovery.

Keywords: Sewage sludge, Circular economy, Resource recovery, Energy recovery, Thermochemical conversion, Life-cycle thinking