Thermal Treatment (Pyrolysis) for PFAS Removal and Degradation in Contaminated Sediments and Landfill Leachate-Derived Materials

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Introduction: The contamination of complex matrices, such as dredged sediments and materials derived from landfill leachate, by per- and polyfluoroalkyl substances (PFAS) presents significant environmental and health challenges. The development of effective treatment technologies is essential to achieve zero-pollution goals and support a circular economy by enabling material recovery and valorisation. This study examines the efficacy of thermal treatment, specifically pyrolysis, as a method for the destruction of PFAS in these challenging matrices.

Objectives: The primary aim was to assess the efficacy of pyrolysis in the removal and degradation of PFAS from contaminated sediments and materials derived from landfill leachate treatment, including dried sludge and Reverse Osmosis (RO) dried concentrate salts.

Methods: Laboratory-scale pyrolysis experiments were conducted utilizing a fixed bed reactor under anaerobic conditions, with control over temperature and residence time. The study focused on two complex matrices: dredged sediments sourced from Ancona, Italy, and the Netherlands, exhibiting varying levels of contamination, as well as dried sludge and RO dried concentrate salts derived from landfill leachate treatment. Sediment pyrolysis was performed at temperatures ranging from 400°C to 800°C, whereas leachate-derived materials were subjected to temperatures between 400°C and 600°C, with varying proportions of mixed dried concentrate and sludge. PFAS concentrations in the solid products (treated sediments, biochar), bio-oil, and syngas were quantified using LC-MS/MS, employing methods specifically adapted for complex matrices. The fate of PFAS in bio-oil and syngas from these materials was also investigated using specialized collection and analytical techniques. Additionally, analyses for heavy metals and dioxins/furans were conducted on the biochar and bio-oil products derived from the landfill leachate materials.

Results: Pyrolysis is highly effective in eliminating detectable PFAS from treated sediment solids, achieving concentrations below the limit of quantification (LOQ) across all tested temperatures and initial contamination levels. Notably, only one instance of 6:2 FTS detection was observed in the bio-oil derived from Netherlands sediments treated at 600°C. In the case of landfill leachate derivatives, pyrolysis resulted in the complete removal of PFAS from biochar at the temperature of 600°C. The fate and concentrations of PFAS in bio-oil and syngas from these materials were also examined across various temperatures and feed compositions. Analysis of biochar from the co-pyrolysis of landfill leachate derivatives revealed significant concentrations of heavy metals, which could restrict its application in agriculture, although dioxins and furans were not detected.

Conclusion: Pyrolysis emerges as a highly effective thermal treatment method for the substantial destruction and removal of PFAS from complex solid matrices, including contaminated dredged sediments and dried materials derived from landfill leachate treatment. The technology aligns with circular economy objectives by potentially facilitating the safe management and valorisation of pyrolysis products from waste streams, contributing to zero-pollution strategies.

Keywords: PFAS, Pyrolysis, Dredged Sediments, Landfill Leachate