https://doi.org/10.7250/CONECT.2026.110

MUNICIPAL WASTEWATER SLUDGE HYDROTHERMAL CARBONISATION AS A TOOL FOR REMOVAL OF EMERGING POLLUTANTS

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Abstract – Municipal wastewater sludge is a challenging residue due to high moisture content, heterogeneous composition, presence of nutrients, potentially toxic elements and emerging pollutants like pharmaceutically active substances. Current solutions in handling this waste are by composting, which is time consuming and generates greenhouse gases in the process; pyrolysis, which requires energy-intensive pre-drying; used in agriculture as fertilizer, which raises concerns of potential pollutant leaching in the soil. Hydrothermal carbonization (HTC) offers a route to convert wet sludge into a carbon-rich solid hydrochar under moderate temperatures of 160–250 °C and pressures up to 10 bar, supporting circular-economy solutions for sludge management. In this work, the influence of HTC temperature and residence time on hydrochar yield, process water chemistry, hydrochar thermal stability, element partitioning assessment in both hydrochar and process water using municipal sludge from Latvia. Dewatered sludge was collected in autumn 2025 from SIA "Ūdeka" wastewater treatment facilities (Ventspils, Latvia), dried at 105 °C. HTC was carried out in 100 mL PTFE autoclaves using dried sludge and deionized water at 170, 200 and 230 °C for 0.5, 1, 3 and 6 h as process optimization matrix parameters. After cooling and filtration, hydrochar yield was assessed, liquid-phase pH and electrical conductivity were measured, hydrochars were characterized by TGA/DTG, element concentrations were quantified by ICP-OES in both solid and liquid fractions. Residual pharmaceuticals (ibuprofen, progesterone) were quantified in the liquid phase and hydrochar extracts using UHPLC equipped with photodiode array (PDA) and fluorescence (FLR) detectors, enabling temperature-dependent degradation profiles. Increasing process severity decreased hydrochar yield, indicating intensified hydrolysis/solubilization: the maximum yield (87 %) was obtained at 170 °C/0.5 h, while yield dropped to 58 % within the 170 °C series at 6 h and to 52 % across the full experimental matrix at the most severe conditions. TGA-based proximate indicators showed progressive solid-phase stabilization, while volatile matter decreased from 67.90 % (raw sludge) to 42.19 % (230 °C/3 h), while ash increased from 22.06 % to 46.87 %. Element analysis demonstrated strong retention in hydrochar and limited transfer to process water; phosphorus reached 36,118 µg/g in hydrochar at 200 °C/3 h, highlighting nutrient-recovery potential, while several metals in the liquid phase were below quantification limits. Pharmaceutical degradation parameters were assessed.

Keywords – HTC; hormones; pharmaceuticals; phosphorus; valorisation

ACKNOWLEDGEMENT

This work has been supported by European Regional Development Fund Project No. 1.1.1.8/1/24/I/003 "Strengthening the Research and Development Capacity of Doctoral Studies at the University of Latvia in the Fields of Smart Specialisation".