Insights into the fate of key elements and prediction of products yields along the hydrothermal liquefaction of civil sludge via kinetic modelling and mass balances

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Hydrothermal liquefaction (HTL) stands out as a highly promising thermochemical route for transforming wet biomass, such as sewage sludge, into valuable bio-crude oil. HTL offers several benefits, including waste volume reduction, recovery of energy and resources, and a decrease in GHG emissions. Understanding the reaction kinetics of HTL is crucial for process optimization and efficient resource recovery.
In this work, a lumped kinetic model based on experimental data for HTL of sewage sludge in a 500 mL batch apparatus, at a heating rate of ~8°C/min and temperatures of 150–370°C, was developed to predict the yields of bio-crude, solid residue, aqueous phase and gas, as a function of reaction time and temperature. The inclusion of a first-order ash dissolution dynamic model allowed to predict the ash distribution in the solid residue and aqueous phase. The developed model was very accurate in the interpretation of products yields retrieved during the heating ramp and isothermal stages at 300 and 350°C (Figure 1). In addition, a semi-empirical modelling approach was developed on the basis of elemental analyses results, to predict CNHSO elemental composition in different product lumps along the HTL process. The carbon content in the solid residue decreased with the HTL time, whereas for the bio-crude C wt% monotonically increased in time approaching a 70 wt% asymptotic value at set point temperature of 300 and 350°C. This research highlights the relevance of combing kinetic modelling and elemental analysis to build up predictive models able of augmenting the efficiency and sustainability of sewage sludge treatment via hydrothermal liquefaction.

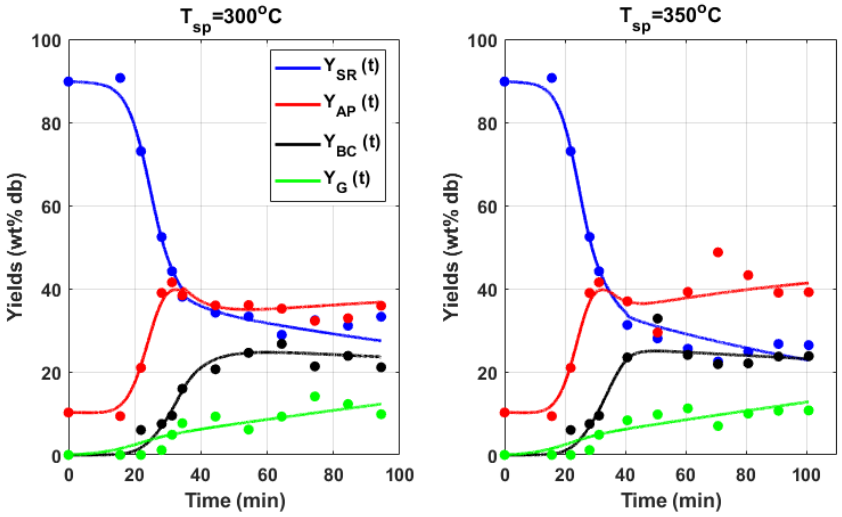

Figure 1: Curve-fitting of the developed kinetic model during the heating ramp and isothermal stages at set point temperatures T_{sp} of 300 and 350°C. Filled circles are experimental data. SR=solid residue, AP=aqueous phase, BC=bio-crude, G=gas phase.