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DOCTOR OF ENGINEERING SCIENCES

of **Gille Wittevrongel**

The public defense will take place on **Monday 20th October 2025 at 5 pm** in room **D.0.02** (Building D, VUB Main Campus)

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**DEVELOPMENT AND APPLICATION OF STRUCTURED ACTIVATED
CARBON ADSORBENTS FOR BIOBUTANOL RECOVERY**

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Abstract of the PhD research

The increasing global demand for energy, coupled with concerns about greenhouse gas emissions, necessitates the development of sustainable processes for producing renewable fuels and chemicals. Biobutanol, produced via fermentation from various biomass feedstocks, presents a promising alternative fuel due to its compatibility with existing infrastructure. However, its low fermentation yields and concentrations require efficient downstream separation and purification. Conventional techniques like distillation face limitations, necessitating the exploration of alternative methods. Adsorption, particularly using structured adsorbents, offers a potential solution for intensifying biorefinery processes and achieving efficient butanol recovery. This thesis investigates the adsorptive recovery of biobutanol using structured activated carbon adsorbents, specifically focusing on monoliths.

A first part of the study focuses on the evaluation and application of zeolites and activated carbons, both commercially available and newly developed, for biobutanol adsorption. A range of activated carbons were incorporated into structured monoliths. The materials were characterized, and their performance was compared against traditional packed beds. Adsorption studies, including isotherm measurements and breakthrough experiments, were conducted to assess their efficacy for butanol separation. A key finding was the stark difference in breakthrough behavior between liquid and vapor phases. Liquid-phase breakthrough experiments on the monolith exhibited rapid adsorbate elution and broad tailing, indicative of significant mass transfer resistance, while vapor-phase breakthroughs were sharp and characterized by much shorter contact times.

A second part explores novel heating methods and the recovery of biobutanol from the adsorbents. Steam regeneration is investigated as a desorption method in a Rapid Temperature Swing Adsorption (RTSA) process on an activated carbon monolith. Cyclic adsorption-desorption experiments revealed the effectiveness of steam regeneration in removing biobutanol and increasing its concentration in the recovered product by up to 18-fold compared to the inlet concentration. Optimization of steam flow rate and duration highlighted the trade-off between recovery capacity and product concentration. The total amount of steam used during regeneration was identified as a key factor influencing recovery and product concentration. An analysis of the energy requirements for the steam regeneration process was also conducted. Further, different heating methods, including microwave and joule heating, were also investigated for their potential in heating activated carbon monoliths.

Finally, a last part addresses the modeling of biobutanol separations. This work demonstrates the successful application of Ideal Adsorbed Solution Theory (IAST), coupled with appropriate isotherm models, to simulate and predict breakthrough curves for binary and ternary alcohol/water mixtures on an all-silica beta zeolite.