Popular science summary of the PhD thesis

PhD student	Sambit Dutta
Title of the PhD thesis	Trickle bed reactors for syngas biomethanation: A comprehensive study on modeling, scale-up, and sustainability
PhD school/Department	Chemical and Biochemical Engineering

Science summary

In light of the increasing need for renewable energy worldwide, this PhD thesis investigates cutting-edge technology: employing a trickle bed reactor (TBR) to convert syngas into biomethane, a renewable substitute for natural gas. Syngas, a mixture of CO, CO_2, and H_2, is produced from the gasification of agricultural residues or wood. In this process, syngas is biologically converted to biomethane by anaerobic mixed microbial consortia , producing a renewable fuel that can be easily incorporated into the existing natural gas grid. The design of the TBR allows for efficient gas-liquid interaction over the packed bed, where the microbial biofilm grows. This biofilm provide a stable environment for the microbes to conduct syngas biomethanation efficiently, thereby improving methane production.

This thesis addresses the critical challenges of optimizing and scaling up TBR. A dynamic model was developed to estimate the variable volumetric mass transfer coefficient (k_La) and how factors like gas and liquid flow rates, reactor size and properties, and operating temperature influence k_La. Experiments and modeling demonstrated that at thermophilic temperatures (60°C) and optimized liquid flow rate, k_La is improved significantly under higher gas flow rates and smaller packing material, further enhancing microbial activity. Another novel aspect of this research is modeling microbial growth and biofilm formation along with reactor hydraulics and mass transfer kinetics. The research specifically studied two microbial groups: carboxydotrophs and methanogens, that convert CO, CO_2, and H_2 to CH_4.

In addition to the technological development and through life cycle assessment, this thesis also evaluated the environmental benefits of syngas biomethanation. The findings revealed that combining this process with a Power-to-gas system and using renewable energy systems can reduce greenhouse gas emissions, convert waste into valuable energy, and promote a circular economy.

In summary, this research provides a foundation for optimizing and scaling up TBR technology, paving the way for industrial scale biomethane production. This work lessens the dependency on fossil fuels and promotes a sustainable future by converting waste into renewable energy.

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