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Energy-Efficient Storage of Methane Using Biosurfactant in the Form of Clathrate Hydrate

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Abstract : The utilization of solidified gas technology based on hydrates exhibits considerable promise for carbon capture, storage, and natural gas transportation applications. The pivotal factor impeding the industrial implementation of hydrates lies in the need for efficient and non-foaming promoters. In this study, a biosurfactant with sulfonate, amide, and carboxyl groups (BS) was synthesized as a methane hydrate formation promoter, replicating the chemical characteristics of amino acids and sodium dodecyl sulfate (SDS). The synthesis of BS follows a simple, three-step process that is amenable to industrial scale production. The first two steps of the process are solvent-free, which helps reduce potential environmental impacts and makes scaling up more feasible. Additionally, the final step utilizes a water-isopropanol mixture, which is an easily accessible and cost-effective solvent system for large-scale production. High-pressure autoclave experiments demonstrated a significant enhancement in methane hydrate formation kinetics with low BS concentrations. 50 ppm of BS yielded a maximum water-to-hydrate conversion of 66.9%, equivalent to a storage capacity of 119.9 v/v in distilled water. With increasing BS concentration to 500 ppm, the conversion degree and storage capacity reached 97% and 162.6 v/v, respectively. Molecular dynamic simulation revealed that BS molecules acted as collectors for methane molecules, augmenting hydrate growth rate and increasing the number of hydrate cavities. Additionally, BS demonstrated a biodegradability exceeding 60% within 28 days. Toxicity assessments confirmed BS's biocompatibility, with cell viability above 70% for skin and lung cells at concentrations up to 160 and 80 µg/mL, respectively. BS showed significant potential as an environmentally friendly alternative to synthetic surfactants like SDS for methane storage. These findings suggest that the synthesis of effective, such as BS, holds promise for diverse applications, including seawater desalination, carbon capture, and gas storage. Acknowledgments This study was funded by Russian Science Foundation according to the research project № 24-73-10069.

Keywords : solidified methane, gas storage, gas hydrates, green surfactant, gas hydrate promoter, computational simulation, sustainability
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