Chemical, Biological & Environmental Engineering

MICROBIAL CONVERSION OF METHANE TO METHANOL USING A TWO-PHASE FLOW REACTOR

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BACKGROUND

OPPORTUNITY

- Methane (CH₄), a landfill byproduct and greenhouse gas, has limited value as a fuel.
- Liquid methanol (CH₃OH) has a higher energy density than methane, making it more valuable and versatile.
- Biocatalysts, such as methanotrophic bacteria, provide an energy efficient means to convert methane to methanol.

BIOCATALYST

- Methylosinus trichosporium (OB3b) is a methanotrophic bacteria that:
  o Degrades methane via action of monoxygenase enzyme (MMO)
  o Produces methanol as intermediate in its metabolic conversion of CH₄ to CO₂
  o Can be inhibited with cyclopropanol, allowing methanol product to accumulate (Figure 1)

TWO-PHASE FLOW REACTOR OPPORTUNITY

- Methane's low solubility in water makes it difficult to contact with microbes.
- Interfacing gas and liquid feed streams using a silicone membrane passively supplies methane and oxygen to aqueous microbes.

OBJECTIVES

- Construct dynamic testing environment
- Characterize gas transfer across membrane
- Analyze microbial activity in membrane system
- Investigate formation of biofilm on membrane

EXPERIMENTAL DESIGN

PERMEABILITY INVESTIGATION

The permeability of silicone tubing was evaluated using a PermSelect hollow fiber module, which features 10 cm² of interfacial surface area. Confirming the transport properties of oxygen and methane across silicone membranes was necessary to gauge the capacity for microbial growth in a two-phase flow system. For 40 min, pure oxygen at ~2 psig flowing at 10 mL/min passed through the tube side of the unit, saturating ~200 mL of water recirculating through the shell side (Figure 4).

MATERIALS AND METHODS

- Membrane module, which features 10 cm² of interfacial area
- Oxygen concentration taken from liquid reservoir and analyzed for dissolved oxygen concentration
- Gas was fed through silicone tubing at ~2 psig and ~1 mL/min. Milliliter samples were taken daily to measure cellular activity. The microbes' ability to convert ethylene to ethylene oxide was used as an indicator reaction to quantify the relative activity of each sample (Figure 5).

RESULTS

OXYGEN ACCUMULATION VS. TIME

Figure 3. Semi-batch reactors growing MOT OB3b in stagnant media. Reactors were inoculated with 0.1 mg/L, 1 mg/L, and 10 mg/L cell concentration, and were ran for ~4 days.

Figure 4. Oxygen diffusion tests using the PermSelect membrane module. Pure oxygen was ran counter current to a recirculating liquid flow. Liquid samples were periodically taken from liquid reservoir and analyzed for dissolved oxygen concentration.

Figure 5. Relative ethylene oxide concentrations for 3 cell inoculum densities are compared over 4 days. Error bars represent 95% confidence intervals for each sample.

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FUTURE WORK

- Investigate conditions of biofilm formation
- Design a two-phase flow reactor based on previously collected permeability and activity data
- Evaluate economic and practical feasibility of reactor scale-up

ANALYSIS

- Oxygen transport tests show a permeability of 3.0x10⁻⁷ mmol-mm/cm²-psi-min, confirming silicone’s ability to sufficiently deliver necessary gases to microbes.
- Activity in semi-batch reactors indicates that a membrane system can sustain microbial growth and provides insight for future experimentation.
- Cells remained active for 3 days.
- All cell cultures showed little or no activity by day 4, potentially due to nutrient depletion.
- Cell inoculum of 1 mg/L exhibited the most stable activity over the duration of the experiment.

LOOKING FORWARD

- Evaluate economic and practical feasibility of reactor scale-up

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REFERENCES


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