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Optimization and performance improvement of Anaerobic Membrane Bioreactor (AnMBR) for volatile fatty acid and biohydrogen production

By

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A Dissertation

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Mohd Atiqueuzzaman Khan, declare that this thesis is submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering, Faculty of Engineering and IT at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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Abbreviations

Symbol	Description
AD	Anaerobic Digestion
ADBA	Anaerobic Digestion and Bioresource Association
AeMBR	Aerobic Membrane Bioreactor
AnMBR	Anaerobic Membrane Bioreactors
APBR	Anaerobic Packed Bed Reactors
BES	Bio Electrochemical Systems
COD	Chemical Oxygen Demand
CSTR	Continuous Stirred Tank Reactor
DO	Dissolved Oxygen
EPS	Extracellular Polymeric Substance
ERR	External Rate of Return
ES	Excess Sludge
EV	Electric Vehicle
FAME	Fatty Acid Methyl Esters
FCV	Fuel Cell Vehicles
GC-MS	Gas Chromatogram Mass Spectrometry
GWP	Global Warming Potential
HHPB	Halophilic Hydrogen Producing Bacterium
HPLC	High Performance Liquid Chromatography
HRT	Hydraulic Retention Time
IBR	Induced Bed Reactor
ICE	Internal Combustion Engine
IRR	Internal Rate of Return
LCA	Life Cycle Assessment
MBR	Membrane Bioreactor
MLVSS	Mixed Liquor Volatile Suspended Solids
MS	Mass Spectrometer
MTBE	Methyl Tert-Butyl Ether

OEB	Overall Energy Balance
OFMSW	Organic Fraction of Municipal Solid Waste
OLR	Organic Loading Rate
PHA	Polyhydroxyalkanoate
PMC	Photosynthetic Mixed Culture
PVDF	Polyvinylidene Difluoride
SAnMBR	Submerged Anaerobic Membrane Bioreactors
SCFA	Short-Chain Fatty Acid
SDBS	Sodium Dodecylbenzenesulfonate
SDS	Sodium Dodecyl Sulfate
SHPR	Specific Hydrogen Production Rate
SMP	Soluble Microbial Products
SMR	Steam Methane Reforming
SRT	Solid Retention Time
TAN	Total Ammonia Nitrogen
TMP	Trans Membrane Pressure
UASB	Upflow Anaerobic Sludge Blanket reactor
VFA	Volatile Fatty Acid
VOC	Volatile Organic Components
VSS	Volatile Suspended solids

Ph.D. DISSERTATION ABSTRACT

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Thesis title: Optimization and performance improvement of Anaerobic Membrane Bioreactor (AnMBR) for volatile fatty acid and biohydrogen production

Faculty: Engineering and Information Technology

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Abstract

Anaerobic Membrane Bioreactors (AnMBRs) have been widely used for source recovery from municipal and industrial wastewater treatment. Most of the research initiatives are inclined to optimize the production of methane-containing biogas from the anaerobic process. Volatile Fatty Acids (VFAs) and biohydrogen are two major intermediate products of AnMBR that can be recovered to improve the energy efficiency and product revenue from AnMBR.Research studies have investigated the technical feasibility of the production of VFA and biohydrogen using anaerobic digestion. The optimisation of VFA and biohydrogen production has been carried out through reducing their consumption by methanogens. This research study aims the optimisation of VFA and biohydrogen production through process optimisation so that the findings can be applied in a generic AnMBR model producing multiple products. Production of VFA has been investigated by reducing the Hydraulic Retention Time (HRT) and increase Organic Loading Rate (OLR) of the AnMBR. The solvent extraction method was used for VFA extraction and individual concentrations were measured using Gas Chromatogram-Mass Spectrometry. At 8 hrs HRT the concentration of major VFA components were maximum

whereas at 550 mg/L COD_{feed} showed the optimum nutrient and COD removal efficiency of AnMBR. Selective production of major VFA components has been investigated by altering the pH of the bioreactor. At pH 7.0 the percentage of acetic acid was highest indicating acetate type fermentation was predominant at that condition. However, a major alteration in the percentage of VFA components were observed at pH 12.0 indicating isobutyric acid as the major VFA components. The result implies that butyrate type fermentation was predominant at pH 12.0. Production of VFA and biohydrogen both were investigated during a stepwise reduction of HRT. Without inhibiting methanogenic activity, the highest VFA and hydrogen yields were 37.08g VFA / 100 g $COD_{feed,}$ and 24.6 mL H_2/ g $COD_{feed,}$ observed at 8 and 6 hr HRT respectively. Optimization AnMBR operating pH was carried out to maximize the production of biohydrogen. The highest yield and production rate were observed to be 122.21 ± 39.05 mL H_2 / L. d and 65.38 ± 3.2 mL H_2 /g COD_{added} respectively and at pH 5.0 at an HRT of 6 hrs.

Keywords

Anaerobic Membrane Bioreactor (AnMBR), biohydrogen, membrane fouling, nutrient removal, inhibition, wastewater, energy recovery, volatile fatty acid, solvent extraction, optimization