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DECOLOURIZATION OF WOOD-ETHANOL STILLAGE
USING A GRANULAR ACTIVATED CARBON PACKED
ANAEROBIC EXPANDED-BED REACTOR

A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY
IN BIOTECHNOLOGY AT MASSEY UNIVERSITY

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1984

MASSEY UNIVERSITY AND NEW ZEALAND FOREST SERVICE
RESEARCH CONTRACT NO. 180. MARCH 1983-FEBRUARY 1984

ABSTRACT

The anaerobic treatment (including decolourization) of wood-ethanol stillage from the Forest Research Institute (FRI) wood-hydrolysis pilot plant at Rotorua has been investigated using granular activated carbon (GAC) packed expanded-bed reactors. Specifically, bioregeneration of the GAC in the reactors in terms of organic and colour removal has been considered.

Two 7.2 l anaerobic expanded bed (AEB) reactors were designed and built. Reactor One (R1) was used for the anaerobic digestion of raw wood-ethanol stillage and Reactor Two (R2) for the decolourization of anaerobic lagoon pretreated wood-ethanol stillage. For R1, a desulphated stillage feed (to 500 mg.l⁻¹ sulphate) was used. Depending on the organic loading rate (OLR), the additions of nitrogen (N), phosphorus (P) and alkalinity reagent ranged from 240-350 mg.l⁻¹, 80-250 mg.l⁻¹ and 2.5-4.5 ml 20% w/v NaOH per litre feed respectively. Only N and P feed supplements were used for R2 at 240 and 80 mg.l⁻¹ respectively. The reactors' performance and stability were closely monitored through analyses of volatile fatty acid's, pH, alkalinity, colour, chemical oxygen demand (COD), sulfide, biogas production rate and methane composition, solids concentrations, N and P.

After operating R1 for 227 days, it was demonstrated that this system, is superior to the previous systems reported for the treatment of a similar stillage. A non-maximal OLR of 29.0 kg tCOD.m⁻³.d⁻¹ at 0.85 d hydraulic retention time (HRT) with total and soluble COD (tCOD and sCOD) removals of 74.5 and 83.5% respectively were achieved. Digestion stability was excellent with acetate at 160 mg.l⁻¹, propionate at 490 mg.l⁻¹ and a gas methane composition of 61.0%. The colour loading rate was 4.7 kg chloroplatinate.m⁻³.d⁻¹ with a 75% colour removal. Higher colour and COD removals may be obtained by operating at a longer HRT (e.g. the percentage colour and sCOD removals were 90.6 and 91.8% respectively at a 2 d HRT). Previously, no significant colour removal for the anaerobic digestion of wood-ethanol stillage has been reported. In this study, only approximately 9% w/v of the chromophoric materials

present in the wood-ethanol stillage are particularly recalcitrant to anaerobic degradation. The methane gas yield was near to that predicted by theory (99.7% at 2 d HRT) with a very low sludge yield (2.8% based on 91.8% sCOD removal). Consequently, the AEB reactor had a very low nutrient requirement for effective treatment. In terms of reactor stability, it can accommodate very high hydraulic loading rates (less than 0.85 d) without problems of cell washout. The use of activated carbon medium also provides a toxicity sequestering potential against biological inhibitors present in the wood-ethanol stillage. Continuous bioregeneration of the GAC in R1 has also been demonstrated using sCOD and colour breakthrough curves for GAC adsorption with and without biological activity. Microbial degradation of the chromophoric species has been confirmed using UV-visible spectrophotometric scans.

Little methanogenic activity was observed in R2 in its 191 days of operation due to the recalcitrant nature of the anaerobic lagoon pre-treated stillage. Only approximately 20% bioregeneration of GAC in terms of colour removal was achieved at a colour loading rate of 1.2 kg chloroplatinate.m⁻³.d⁻¹.

This study has demonstrated that the GAC packed expanded-bed reactor (R1) provides a very effective treatment of wood-ethanol stillage (including decolourization) while recovering a very significant portion (89%) of the stillage energy. Considerable capital and operating cost savings are possible using the AEB system since effective treatment can be achieved in a single step utilizing a relatively small reactor with minimal nutrient, sludge disposal and GAC regeneration or replacement costs. The only disadvantages of the system are the carbon cost, a long start-up period of 5 months and a recycle energy cost to maintain an expanded-bed. It is believed that they can partly be reduced by using a GAC carrier with a smaller particle size.

Anaerobic digestion, utilizing a GAC packed expanded-bed reactor, thus represents a cost effective and commercially attractive option for the utilization/disposal of wood-ethanol stillage.

ACKNOWLEDGEMENTS

I am very grateful to a large number of people for their friendship, support and guidance in the course of my work at Massey University. I would especially wish to acknowledge the following:

Dr P.N. McFarlane for laying the groundwork and obtaining financial assistance for this study and, for providing enthusiastic support and eminent guidance as my dedicated supervisor.

The late Dr I.J. Callander for his invaluable advice and sharing of knowledge on the anaerobic treatment of wood-ethanol stillage.

Professor R.L. Earle for his kindness and support since my undergraduate years and for the provision of research facilities.

The Forest Research Institute at Rotorua for providing the wood-ethanol stillage and the technical support on gas chromatograph-mass spectrograph analyses and scanning electron photomicrographs of the carbon.

Those colleagues in all sections of the Biotechnology and Food Technology departments - whose friendly advice and support made the research possible. I would especially like to thank:

- Mr J.T. Alger and Mr P.D. Shaw for excellent technical assistance in all engineering aspect of this work.
- Dr R.H. Archer for his many original ideas on the design of the anaerobic expanded-bed reactor.
- Mr M.K. Stevens, Mr M. Lubbers and Mrs M.C. Bewley for their cooperation and promptness in providing laboratory materials.
- Mrs B.A. Hawthorn, Mrs P.D. Burton and Mr D.W. Couling for their cooperation and administrative support.
- Mrs V. Fieldsend for her patience and proficiency in typing this thesis.

This research study was generously funded by the New Zealand Forest Research Institute at Rotorua. This included a student emolument which is greatly appreciated.

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CHAPTER 1

PRELUDE