

THE AEROBIC TREATMENT OF REVERSE OSMOSIS

PERMEATE FOR REUSE

128
6139

A thesis submitted in partial fulfilment

of the requirements for the degree

of

MASTER OF TECHNOLOGY

in

ENVIRONMENTAL ENGINEERING

by

PAUL OLIVER BICKERS

Department of Process and Environmental Technology

Massey University

1995

ABSTRACT

The reduction of effluent streams and the demand for freshwater intake in the dairy industry, may be accomplished by the segregation and reuse of streams that can be readily treated. This study assessed the biodegradability and suitability for reuse of reverse osmosis (R/O) permeate from Kiwi Dairies Ltd processing factory (Hawera), using aerobic treatment.

Analysis of the permeate showed that there was a direct relationship between chemical oxygen and lactose concentration. The chemical oxygen demand of R/O permeate from two reverse osmosis membrane plants operating in parallel varied widely during the period of study. This wide variation in permeate chemical oxygen was directly related to the membrane efficiency.

Elemental analysis of the R/O permeate showed that iron and phosphorous would need to be supplemented to ensure balanced microbial growth.

The biodegradability was characterised by a series of batch tests to determine the biokinetic constants μ_m , K_s , $q_{s,m}$ and Y_t . These tests showed that the biodegradability of reverse osmosis permeate is comparable to general dairy wastes. Batch tests were also performed on permeate from R/O membranes of varying performance efficiency, with different lactose and mineral concentrations. There were no conclusive variations in biokinetic constants between permeates from R/O membranes of varying performance efficiency.

Operation of a model activated sludge pilot plant showed that soluble COD removal

efficiencies of over 90% could be achieved at hydraulic retention times of 10 and 20 hours. The sludge settling characteristics were more favourable at a 10 hour hydraulic retention time. Sudden fluctuations in membrane efficiency caused shock loads resulting in a deterioration in treatment efficiency and sludge settling characteristics. Although the pilot plant achieved satisfactory reductions, soluble COD levels were not decreased to the level of 10 to 15 mg l⁻¹ required to enable the reuse of the permeate.

In order to determine if low substrate levels could be achieved when aerobically treating R/O permeate from an efficient membrane plant, a laboratory scale reactor was used to treat permeate with a COD of 200 mg l⁻¹. It was established that R/O permeate could be aerobically treated to levels suitable for reuse, provided the previous membrane processes performed efficiently.

ACKNOWLEDGEMENTS

I am grateful for the support of many people in the completion of this thesis and would like to thank the following:

Firstly to my supervisor Professor Rao Bhamidimarri of Massey University, for his invaluable guidance, patience and positiveness during this process.

I must also gratefully acknowledge the cooperation of Kiwi Dairies Ltd, especially Andrew M^cGregor, Howard Waters and Peter Walker of Peter Walker Consultants, for their practical and financial support as well as their patience.

Thanks also must go to the Department of Process and Environmental Technology as a whole for providing a platform for, and supporting the most important science of Environmental Engineering.

Thanks to friends, flatmates and fellow postgrads who helped me maintain my balance throughout the course of this work.

Thanks to all of my family, especially my mother Margaret, for their complete support and belief in me and my endeavours.

Thanks also go to my "wantoks" for providing an example of a world, different, but most likely, more real. Tank iu tu mas alketa.

TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES.....	viii
LIST OF TABLES.....	x
1 INTRODUCTION.....	1
2 LITERATURE REVIEW.....	4
2.1 DAIRY INDUSTRY WASTES.....	4
2.1.1 Characteristics of Dairy Industry Wastes.....	4
2.1.2 Sources of Dairy Industry Wastes.....	5
2.1.3 Waste Minimization in the Dairy Industry.....	6
2.1.4 Waste Stream Recovery in the Dairy Industry.....	7
2.1.5 Water Quality.....	13
2.2. REVERSE OSMOSIS IN THE DAIRY INDUSTRY.....	14
2.2.1. Principles of Reverse Osmosis.....	14
2.2.2. Reverse Osmosis in the Processing of Whey.....	15
2.3. AEROBIC WASTE TREATMENT.....	16
2.3.1 The Aerobic Process.....	16
2.3.2 Nutrient Requirements for the Aerobic Process.....	17
2.3.3 Growth Characteristics and Kinetic Constants.....	18
2.3.4 Kinetic Determination using Oxygen Uptake Rates.....	21
2.3.5 The Activated Sludge Process.....	22
2.3.6 The Aerobic Treatment of Dairy Waste.....	28
3 MATERIALS AND METHODS.....	30
3.1 ACTIVATED SLUDGE PILOT PLANT.....	30
3.2 LABORATORY SCALE ACTIVATED SLUDGE SYSTEM.....	32
3.3 BATCH REACTOR TESTS.....	32
3.3.1 Substrate Removal Rate and Yield Coefficient Determination.....	32
3.3.2 Specific Growth Rate Determination.....	33

3.3.3	Oxygen Uptake Rate Test.....	33
3.4	ANALYTICAL METHODS.....	34
3.4.1	Biomass Concentration.....	34
3.4.2	Chemical Oxygen Demand (COD).....	34
3.4.3	Sludge Volume Index (SVI).....	34
3.4.4	Lactose Determination.....	35
4	RESULTS AND DISCUSSION.....	37
4.1	REVERSE OSMOSIS PERMEATE CHARACTERISTICS.....	37
4.1.1	Permeate Elemental Analysis.....	37
4.1.2	Permeate Nitrogen Analysis.....	40
4.1.3	Permeate Lactose Concentration.....	41
4.1.4	Permeate Conductivity.....	42
4.2	BATCH TESTS.....	45
4.2.1	Biokinetic Constants using Optical Density.....	45
4.2.2	Substrate Removal Rates.....	49
4.2.3	Batch Tests using R/O Permeate from Different Sources.....	52
4.2.4	Biokinetic Constants using Oxygen Uptake Rates.....	57
4.2.5	Summary.....	59
4.3	ACTIVATED SLUDGE PILOT PLANT STUDIES.....	60
4.3.1	Introduction.....	60
4.3.2	Hydraulic Retention Time (HRT).....	60
4.3.3	Substrate Removal Efficiency.....	60
4.3.4	Feed Total Suspended Solids.....	64
4.3.5	Effluent Total Suspended Solids.....	64
4.3.6	Mixed Liquor Suspended Solids (MLSS).....	65
4.3.7	Sludge Volume Index (SVI).....	66
4.3.8	Sludge Age.....	66
4.3.9	Physical Variables.....	67
4.3.10	Summary.....	67
4.4	LABORATORY SCALE ACTIVATED SLUDGE SYSTEM.....	68
4.4.1	Introduction.....	68
4.4.2	Soluble Substrate Reduction.....	68

4.4.3	Mixed Liquor Suspended Solids (MLSS).....	70
4.4.2	Summary.....	70
4.5	FULL SCALE APPLICATION OF AEROBIC TREATMENT.....	71
4.5.1	Activated Sludge Model.....	71
4.5.2	Options.....	72
5	CONCLUSIONS AND RECOMMENDATIONS.....	74
5.1	CONCLUSIONS.....	74
5.2	RECOMMENDATIONS FOR FURTHER WORK.....	76
	REFERENCES.....	77
	APPENDIX.....	81

LIST OF FIGURES

Figures	Page
1.1 Block diagram of Kiwi Dairy Company whey membrane processing plant.....	2
2.1 Dairy wastewater aerobic treatment plant for water reuse.....	11
2.2 Distinguishable portions of biomass growth and decay curve.....	18
2.3 Plot of Monod equation, showing effect of substrate concentration on the specific growth rate (μ).....	20
2.4 Flow diagram used to develop equations for complete-mix activated sludge process.....	23
3.1 Process flow diagram of activated sludge pilot plant.....	31
4.1 Relationship between R/O permeate lactose concentration and COD.....	41
4.2 Variation of R/O permeate conductivity for membrane plants 1 and 2.....	42
4.3 Semi-log plot of relationship between permeate conductivity and COD.....	43
4.4 Semi-log plot of relationship between permeate conductivity and lactose concentration.....	44
4.5 Plot for determination of biokinetic constants for permeate from plant 1.....	46
4.6 Hyperbolic plot of specific growth rate and substrate concentration for permeate from plant 1.....	47
4.7 Plot for determination of biokinetic constants for permeate from plant 2.....	47
4.8 Hyperbolic plot of specific growth rate and substrate concentration for permeate from plant 2.....	48
4.9 Substrate removal curves for R/O permeate.....	50
4.10 Specific growth rates from direct biomass measurement.....	55
4.11 Specific growth rates determined from substrate removal rates.....	55
4.12 COD removal rates for different permeates.....	56
4.13 Maximum yield coefficients for permeates from varying sources.....	56
4.14 Hyperbolic plot using oxygen uptake rates.....	58
4.15 Monod type hyperbolic plot using oxygen uptake rates.....	58
4.16 Plot of feed, soluble effluent and effluent COD and treatment efficiency achieved.....	61
4.17 Total solids of feed, clarifier outlet and effluent after sand filter.....	62

4.18	Total solids of reactor biomass and recycle sludge.....	62
4.19	Plot of SVI and sludge age variation.....	63
4.20	Plot of DO, pH and temperature variation.....	63
4.21	Plot of feed COD, effluent soluble COD, and substrate reductions achieved with a laboratory reactor.....	69
4.22	Plot of reactor MLSS, recycle TSS and effluent TSS during laboratory reactor operation.....	69
4.23	Predicted curves for effluent quality and biomass concentration using Gaudy and Rozich model.....	71

LIST OF TABLES

Tables

	Page
2.1 Characteristics of dairy plant wastes in New Zealand.....	4
2.2 Defining various waste streams.....	9
4.1 Reverse Osmosis permeate elemental analysis.....	38
4.2 Biokinetic constants determined from substrate removal curves.....	51
4.3 Initial substrate concentrations for permeate batch tests.....	53
4.4 Comparison of biokinetic constants from this study with literature values for other dairy wastes.....	59