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Effects of Carbon Dioxide Addition on Algae and Treatment Performance of High Rate Algal Ponds

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Abstract

Waste stabilisation ponds have been used for treating a great variety of wastewaters around the world for many decades. More advanced systems combine anaerobic or advanced facultative ponds with high rate algal ponds (HRAP) followed by a number of algae settling ponds and maturation ponds to achieve enhanced and more reliable removal of wastewater pollutants, while yielding possibly valuable by-products such as biogas and algal biomass. In recent years a growing number of scientists and engineers have proposed the use of HRAP treating domestic wastewater for carbon dioxide (CO₂) scrubbing from biogas and CO₂ sequestration. The experiments presented in this thesis sought to determine if the treatment performance of HRAP is affected by the addition of CO₂ and subsequent reduction of pond pH.

Experiments with algae cultures grown on domestic wastewater in laboratory microcosms, outside mesocosms and outside pilot-scale HRAP were conducted. Carbon dioxide addition to algae wastewater cultures restricted the maximum pH level to ~8. Key wastewater quality parameters of CO₂ added cultures, were compared to control cultures without CO₂ addition. The wastewater quality parameters monitored include temperature, pH, and concentrations of total suspended solids (TSS), ammoniacal-nitrogen (NH₄-N), dissolved reactive phosphorus (DRP), filtered biochemical oxygen demand (fBOD₅) and the faecal indicator *Escherichia coli* (*E. coli*).

Carbon dioxide addition to algae wastewater cultures was found to promote algal growth and increased the TSS concentrations. Over 8 day culture length CO₂ addition in laboratory and outside batch experiments increased algal growth (indicated by TSS) by up to 76% and 53%, respectively. During semi-continuous outside experiments CO₂ addition increased algal growth by ~20% in comparison to the control cultures. Despite enhancing algal growth (TSS), CO₂ addition appeared to have little effect on algae cell morphology, species composition and zooplankton activity in the algae wastewater cultures.

Monitoring of the key nutrients NH₄-N and DRP in cultures with and without CO₂ addition indicated that CO₂ addition can lead to an increase or a decrease in nutrient removal. Under culture conditions which allowed the control cultures to achieve high day-time pH levels CO₂ addition, and subsequent pH restriction, appeared to reduce overall nutrient removal. Only

slight changes or an increase in nutrient removal as a result of CO₂ addition were observed under culture conditions which allowed only for a moderate or small elevation of the control culture pH. However, the increases in algal biomass, observed in all CO₂ added cultures indicate a greater potential for the reclamation of potentially valuable wastewater nutrients in the form of algal biomass.

Monitoring of fBOD₅ levels during several outside experiments showed that CO₂ addition had no effect on the fBOD₅ removal by the algae wastewater cultures under those conditions.

During several outside batch experiments (of up to 8 day culture length) the removal of the faecal indicator bacteria *E. coli* was monitored. It was shown that CO₂ addition reduced *E. coli* removal by 1.4 to 4.9 log units compared to control cultures.

Basic modelling of carbon flows indicated that under New Zealand conditions the CO₂ volumes required for the changes described above would be available from the biogas produced in a wastewater pond system treating wastewater with a volatile solids (VS) concentration of ~ 500 mg/L. In systems treating weaker wastewaters additional CO₂ could be made available through the onsite combustion of biogas.

In summary, the obtained results suggest that CO₂ addition to a field-scale HRAP could increase algal biomass growth year-round and slightly enhance nutrient removal during winter, but might reduce nutrient removal during summer, and reduce *E. coli* removal year-round, while having no effect on fBOD₅ removal. The reduction in nutrient treatment performance during summer, and especially the losses in *E. coli* removal resulting from CO₂ addition may require more sophisticated downstream processing of the HRAP effluent, like increase retention times in maturation ponds. Such remedial measures have to be evaluated on a case by case basis, and are dependent on the given regulations and discharge regimes of the system.

This study indicates that in general HRAP can be employed for biogas purification and provide a useful sink for CO₂ rich waste streams. The beneficial effects of CO₂ addition to HRAP do not appear to allow for any design or management changes within the system, while it was indicated that most detrimental effects of CO₂ addition could be accommodated without major alternations, although in some cases significant remedial measures may be required for correcting the losses in disinfection and nutrient removal performance.

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Table of Contents

Abstract	ii
Acknowledgements	iv
List of Figures	viii
List of Tables	xii
1. Introduction	1
1.1 Waste Stabilization Ponds	2
1.1.1 Anaerobic Ponds	2
1.1.2 Aerobic Maturation Ponds	3
1.1.3 Facultative Ponds	3
1.2 Advanced Systems	5
1.2.1 Advanced Facultative Ponds	5
1.2.2 High Rate Algal Ponds	7
1.3. Processes in High Rate Algal Ponds	9
1.3.1 Photosynthetic Oxygenation and Algal Nutrient Uptake	9
1.3.2 Ammonia Volatilisation	12
1.3.3 Phosphate Precipitation	13
1.3.4 Disinfection	14
1.3.5 Ammonia Toxicity	14
1.3.6 pH Inhibition of Bacterial Growth	15
1.3.7 pH Inhibition and Carbon Limitation of Algae	15
1.4 Combining Ponds	16
1.5 Biogas Scrubbing	18
1.5.1 The Need for Biogas Purification	18
1.5.2 Conventional Biogas Purification Systems	19
1.5.3 Biogas Purification Using Algal Wastewater Cultures	19
1.6 Benefits of Carbon Addition for Algae Cultures	20
1.6.1 Carbon Dioxide and Wastewater Algae Cultures	20
1.6.2 Carbon Dioxide Addition in Algae Farming Operations	20
1.7 Theoretical Calculation of HRAP CO₂ Assimilation Potential	23
1.7.1 Simple Model of the Carbon Mass Balance in a Wastewater HRAP	23
1.7.2 Estimation of Carbon Assimilation	24
1.7.3 Estimation of Biogas Production	26
1.7.4 Estimation of Biogas Scrubbing Potential	26
1.7.5 Maximum Wastewater Strength	27
1.8 Objectives	29

2. Materials and Methods	30
2.1 Analytical Methods	31
2.1.1 Chemical Parameters	31
2.1.1.1 Total Suspended Solids (TSS).....	31
2.1.1.2 Ammoniacal-Nitrogen (NH ₄ -N).....	31
2.1.1.3 Dissolved Reactive Phosphorus (DRP)	32
2.1.1.4 Biochemical Oxygen Demand (fBOD ₅)	32
2.1.2 Biological Parameters	33
2.1.2.1. Faecal Indicator Bacteria - <i>Escherichia coli</i>	33
2.1.2.2 Algae and Zooplankton Abundance.....	33
2.1.3 Physical Parameters	34
2.2 Experimental Methods	35
2.2.1 Laboratory Experiments	35
2.2.1.1 Laboratory Microcosms	35
2.2.1.2 Wastewater Source	35
2.2.1.3 Algal Inoculum	36
2.2.1.4 Culture Conditions	36
2.2.1.5 pH Controller.....	36
2.2.1.6 Carbon Dioxide Addition Assembly.....	37
2.2.1.7 First Laboratory Batch Experiment	38
2.2.1.8 Second Laboratory Batch Experiment	39
2.2.1.9 Third Laboratory Batch Experiment	40
2.2.2 Outside Mesocosm Experiments	41
2.2.2.1 Site	41
2.2.2.2. Outside Mesocosms	42
2.2.2.3 pH Controllers.....	42
2.2.2.4 Local Weather Data	42
2.2.2.5 Winter Outside Mesocosm Experiment.....	43
2.2.2.6. Summer Outside Mesocosm Experiment.....	44
2.2.2.7 High fBOD ₅ Experiment with Glucose.....	45
2.2.2.8 High fBOD ₅ Experiment with Egg Material.....	45
2.2.3 Carbon Dioxide Addition to Outside Pilot-Scale High Rate Algal Ponds	46
2.2.3.1 Ruakura Pilot-Scale High Rate Algal Ponds	46
2.2.3.2 Carbon Dioxide Addition	48

3. Results	52
3.1. Laboratory Batch Experiments	53
3.1.1. First Laboratory Batch Experiment	53
3.1.2. Second Laboratory Batch Experiment.....	58
3.1.3 Third Laboratory Batch Experiment.....	63
3.2 Outside Mesocosms Experiments	67
3.2.1 Winter Outside Mesocosm Experiment	67
3.1.2 Summer Outside Mesocosm Experiment	71
3.2.3 High fBOD ₅ Experiment with Glucose.....	78
3.2.4 High fBOD ₅ Experiment with Egg Material.....	84
3.3 Ruakura Pilot-scale High Rate Algal Ponds	91
4. Discussion	99
4.1 Effects of CO ₂ Addition on Algae Growth (measured as TSS).....	100
4.2 Effects of CO ₂ Addition on Algae and Zooplankton Species Composition	104
4.3 Effects of CO ₂ Addition on Ammoniacal-nitrogen	106
4.4 Effects of CO ₂ Addition on DRP Removal.....	109
4.5 Effects of CO ₂ Addition on fBOD ₅ Removal.....	113
4.6 Effects of CO ₂ Addition on Faecal Indicator Bacteria Removal.....	115
4.7 Effects of CO ₂ Addition on Culture Physical/Chemical Parameters.....	117
5. Conclusions and Recommendations	118
5.1 Conclusions	119
5.2 Further Research	121
Appendix A: Calculations of the carbon flows in a wastewater pond system	122
Appendix B: Raw Data Tables	127
References	136

List of Figures

Introduction

Figure 1.1: Degradation and transformation processes occurring in a facultative pond.....	4
Figure 1.2: Schematic drawing of an advanced facultative pond (AFP)	5
Figure 1.3: Schematic drawing of a high rate algal pond (HRAP).	7
Figure 1.4: A high rate algal pond treating municipal wastewater	8
Figure 1.5: Schematic drawing of photosynthetic oxygenation.....	9
Figure 1.6: The relationship between the inorganic carbon species and pH	11
Figure 1.7: The proportions of ammonia and ammonium as a function of pH	12
Figure 1.8: Schematic drawing of an Advanced Integrated Wastewater Pond System.....	16
Figure 1.9: Algae farming in high rate algal ponds	21
Figure 1.10: Schematic drawing of a counter current pit	22
Figure 1.11: Schematic drawing of carbon transformations in a HRAP	24

Material and Methods

Figure 2.1: Schematic diagram of the CO ₂ addition assembly	37
Figure 2.2: Laboratory batch experiment set up	39
Figure 2.3: Location of the Ruakura research facility	41
Figure 2.4: Outside mesocosm experimental setup	44
Figure 2.5: Schematic diagram of the Ruakura pilot-scale advanced pond system	47
Figure 2.6: High rate algal pond pH controller and CO ₂ gas bottle.....	48
Figure 2.7: Carbon dioxide sparging board	49
Figure 2.8: Carbon dioxide addition to the eastern HRAP	49
Figure 2.9: Close-up of a Hydrolab datasonde	50
Figure 2.10:Datasondes in the Ruakura pilot-scale high rate algal ponds.....	51

Summer Outside Mesocosm Experiment

Figure 3.19: Daily maximum and minimum air and culture temperature	71
Figure 3.20: Daily insolation and rainfall.....	72
Figure 3.21: Algal biomass (indicated by TSS).....	73
Figure 3.22: Maximum day-time pH	74
Figure 3.23: Ammoniacal-nitrogen (NH ₄ -N)	75
Figure 3.24: Dissolved Reactive Phosphorus (DRP)	75
Figure 3.25: fBOD ₅	76
Figure 3.26: Feecal indicator (<i>E. coli</i>).....	77

High fBOD₅ Experiment with Glucose

Figure 3.27: Daily insolation	78
Figure 3.28: Algal biomass (indicated by TSS).....	79
Figure 3.29: Maximum day-time pH	80
Figure 3.30: Ammoniacal-nitrogen (NH ₄ -N).....	81
Figure 3.31: fBOD ₅	82
Figure 3.32: Feecal indicator (<i>E. coli</i>).....	83

High fBOD₅ Experiment with Egg Material

Figure 3.33: Daily maximum and minimum air and culture temperature	84
Figure 3.34: Daily insolation and rainfall.....	85
Figure 3.35: Colonies of <i>Micractinium sp.</i> and <i>Scenedesmus sp.</i>	86
Figure 3.36: Algal biomass (indicated by TSS).....	86
Figure 3.37: Maximum day-time pH	87
Figure 3.38: Ammoniacal-nitrogen (NH ₄ -N).....	88
Figure 3.39: Dissolved Reactive Phosphorus (DRP).....	89

Results

First Laboratory Batch Experiment

Figure 3.1: Large colonies of <i>Dictyosphaerium sp. algae</i>	54
Figure 3.2: Small colonies and single cells of <i>Dictyosphaerium sp. algae</i>	54
Figure 3.3: Algal biomass (indicated by TSS).....	55
Figure 3.4: Maximum day-time pH	56
Figure 3.5: Ammoniacal-nitrogen (NH ₄ -N).....	56
Figure 3.6: Dissolved Reactive Phosphorus (DRP).....	57

Second Laboratory Batch Experiment

Figure 3.7: Algal biomass (indicated by TSS).....	59
Figure 3.8: Maximum day-time pH	60
Figure 3.9: Ammoniacal-nitrogen (NH ₄ -N).....	61
Figure 3.10: Dissolved Reactive Phosphorus (DRP).....	61

Third Laboratory Batch Experiment

Figure 3.11: Algal biomass (indicated by TSS).....	64
Figure 3.12: Maximum day-time pH	65
Figure 3.13: Ammoniacal-nitrogen (NH ₄ -N).....	65
Figure 3.14: Dissolved Reactive Phosphorus (DRP).....	66

Winter Outside Mesocosm Experiment

Figure 3.15: Daily maximum and minimum air temperature	67
Figure 3.16: Daily insolation and rainfall	68
Figure 3.17: Algal biomass (indicated by TSS).....	69
Figure 3.18: Maximum day-time pH	70

Figure 3.40: fBOD ₅	89
Figure 3.41: Faecal indicator (<i>E. coli</i>).....	90

Ruakura Pilot-scale High Rate Algal Ponds

Figure 3.42: pH, DO and temperature in relation to insolation (winter)	92
Figure 3.43: pH, DO and temperature in relation to insolation (summer)	93
Figure 3.44: Culture temperature (August to December 2005).....	94
Figure 3.45: Algal biomass (indicated by TSS).....	96
Figure 3.46: Maximum day-time pH	97
Figure 3.47: Ammoniacal-nitrogen (NH ₄ -N).....	97
Figure 3.48: Dissolved Reactive Phosphorus (DRP).....	98

List of Tables

Table 1.1: Solubility products of calcium and magnesium salts.....	13
Table 1.2: Assumptions for modelling the maximum CO ₂ assimilation potential of a municipal wastewater treatment HRAP	25
Table 4.1: Algal growth promotion (indicated by TSS) in CO ₂ added cultures.....	100
Table 4.2: Differences in ammoniacal-nitrogen removal, algal biomass and maximum day-time pH during the first 6 days of the second laboratory batch experiment ..	107
Table 4.3: Average ammoniacal-nitrogen removal, algal biomass concentrations and maximum day-time pH values from the Ruakura HRAP	107
Table 4.4: Differences in DRP removal, algal biomass and maximum day-time pH between day 2 and day 7 of the second laboratory batch experiment.....	110
Table 4.5: Average DRP removal, algal biomass concentrations and maximum day-time pH values from the Ruakura HRAP	111
Table 4.6: <i>E. coli</i> removal from 3 summer outside mesocosm experiments.....	115