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 (CO_2) scrubbing from biogas and CO_2 sequestration. The experiments presented in this thesis sought to determine if the treatment performance of HRAP is affected by the addition of CO_2 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 CO_2 added cultures, were compared to control cultures without CO_2 addition. The wastewater quality parameters monitored include temperature, pH, and concentrations of total suspended solids (TSS), ammoniacal-nitrogen (NH_4-N), dissolved reactive phosphorus (DRP), filtered biochemical oxygen demand ($fBOD_5$) 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 CO_2 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 CO_2 addition increased algal growth by ~20% in comparison to the control cultures. Despite enhancing algal growth (TSS), CO_2 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 NH_4-N and DRP in cultures with and without CO_2 addition indicated that CO_2 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 CO_2 addition, and subsequent pH restriction, appeared to reduce overall nutrient removal. Only

slight changes or an increase in nutrient removal as a result of CO_2 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 CO_2 added cultures indicate a greater potential for the reclamation of potentially valuable wastewater nutrients in the form of algal biomass.

Monitoring of $fBOD_5$ levels during several outside experiments showed that CO_2 addition had no effect on the $fBOD_5$ 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 CO_2 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 CO_2 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 CO_2 could be made available through the onsite combustion of biogas.

In summary, the obtained results suggest that CO_2 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 $fBOD_5$ removal. The reduction in nutrient treatment performance during summer, and especially the losses in *E. coli* removal resulting form CO_2 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 CO_2 rich waste streams. The beneficial effects of CO_2 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 CO_2 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

List of Figures

Introduction

Material and Methods

Summer Outside Mesocosm Experiment

High $fBOD_5$ Experiment with Glucose

High $fBOD_5$ Experiment with Egg Material

Results

First Laboratory Batch Experiment

Second Laboratory Batch Experiment

Third Laboratory Batch Experiment

Winter Outside Mesocosm Experiment

Ruakura Pilot-scale High Rate Algal Ponds

List of Tables