ENHANCING ALGAL DOMINANCE AND HARVESTABILITY FROM A WASTEWATER TREATMENT HIGH RATE ALGAL POND

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ABSTRACT

This paper investigates the influence of recycling harvested algal biomass on algal species dominance and harvestability in a pilot-scale HRAP over four months during a New Zealand summer. Two identical HRAPs were operated in parallel with and without harvested biomass recycling. Effluent from each HRAP flowed continually into two algal settling cones in series (3-h HRT each) to remove algal biomass. A portion of harvested algal biomass from the first algal settling cone was recirculated back to the HRAP on a daily basis. Daily algal biomass harvestability in the algal settling cones and Imhoff cone algal biomass settlability (after 10, 30, and 60 minutes and 24 hours) were measured five times a week. While similar colonial algal species were found in both HRAPs in summer, harvested algal biomass recycling promoted the dominance of *Pediastrum sp.* (>95% dominance). Increased dominance of the colonial algae greatly improved the efficiency of gravity algal harvest; >85% average biomass removal compared with ~70% average biomass removal in the control without algal biomass recycling. Furthermore, Imhoff cone algal settleability experiments in laboratory showed that recycling of harvested algal biomass could enable further reduction of the hydraulic retention time (and volume) of algal settling cone.

KEYWORDS

High rate algal ponds (HRAP); Algal dominance; Algal biomass recycling, Algal species control, Algal biovolume, settleability, harvestability

1 INTRODUCTION

High rate algal ponds (HRAPs) provide cost-effective and efficient wastewater treatment with minimal energy consumption and have considerable potential to upgrade oxidation ponds (Craggs et al., 2003; García et al., 2006; Park and Craggs, 2010). Furthermore, the algal biomass produced and harvested in these wastewater treatment systems could be converted through various pathways to biofuels (Craggs et al., 2010; Sukias and Craggs, 2010; Vasudevan and Fu, 2010). Both wastewater treatment and algal biofuel production require rapid and cost-effective harvest of algal biomass from HRAP effluent, therefore, methods to improve algal harvestability would be of great benefit (Benemann, 2003; van Harmelen and Oonk, 2006; Brennan and Owende, 2010). However, algal cells are difficult to remove due to their small size (<20 μm), similar density to water (1.08–1.13 g/ml) (Lavoie and de la Noue, 1986) and strong negative surface charge (particularly during exponential growth) (Moraine et al., 1979).

Recycling a portion of selectively harvested algal biomass back to the HRAP could promote algal species control (Benemann et al., 1977; Weissman and Benemann, 1979). Harvesting readily-settleable algal biomass and recycling a portion of the biomass back to the HRAP would increase the cell population of the rapidly settling algal species (i.e. non-motile colonial algal species with a large colony size). Recycling of rapidly settling algal species increases their relative population density compared with non-recycled algal species (e.g.

undesirable unicellular algae such as Chlorella sp.), eventually competitively excluding the non-recycled algal species and becoming the dominant algal species in the HRAP. However, the mechanisms of algal dominance and species control are poorly understood and repeatable practical methods for species control have not yet been demonstrated in outside wastewater treatment HRAP.

This paper investigates the influence of harvested algal biomass recycling on algal species dominance and algal biomass removal in a pilot-scale HRAP over four months during a New Zealand summer. A portion of algal biomass selectively harvested from a gravity algal settling cone was recirculated to one of two pilot-scale wastewater treatment HRAPs to enhance gravity algal biomass removal through the maintenance of easily-settleable colonial algal species. Dominant algal species were microscopically identified and a microscopic image analysis technique was developed to determine algal dominance based on algal biovolume.

2 MATERIALS AND METHODS

2.1 OPERATION OF PILOT-SCALE HRAP SYSTEMS

Experiments were conducted using two identical pilot-scale single-loop raceway HRAPs treating domestic wastewater at the Ruakura Research Centre, Hamilton, New Zealand (37°47'S, 175°19'E). Each HRAP had a surface area of 31.8 m^2, a depth of 0.3 m and a total volume of 8 m^3. The schematic diagram of the pilot-scale HRAP and further details of the HRAP specifications were previously described in Park and Craggs (2010).

2.2 ALGAL BIOMASS RECYCLING

Algal biomass settled in the bottom of the Algal Settling Cones (ASCs) was removed daily using a peristaltic pump. The first ASC following one of the two HRAPs ($HRAP_r$) was used as a selective algal harvester collecting readily-settleable algal biomass. A portion (1 L) of the freshly harvested (within 24 hours of settling) algal biomass from the first ASC was recirculated back to the $HRAP_r$ on a daily basis. The $HRAP_c$ was operated as a control without algal biomass recycling. All other operational parameters of the two HRAP were the same.

2.3 MEASUREMENT OF ALGAL HARVESTABILITY

Samples of HRAP water, and effluent from the first and second ASC were taken five times a week for total suspended solids (TSS) measurement (APHA, 2000). Percent algal biomass removal (algal harvestability) was determined from the difference between TSS concentration of HRAP water and TSS concentration of the ASCs.

2.4 MICROSCOPIC IMAGE ANALYSIS

Dominant algal species were identified (Brook, 2002) while population counts were made by microscopic analysis in a Utermöhl chamber (25mm diameter). A thoroughly mixed pond water sample (1 ml) was transferred into the Utermöhl chamber, evenly distributed to cover the surface of the chamber and then settled for 30-60 minutes. The chamber was then placed on an inverted light microscope equipped with a Leica microscopic camera (DFS 420c) and Leica microscopic image analysis package (Leica Application Suite, LAS version 3.1.0). The programme was calibrated to determine actual algal cell/colony sizes measured in micrometres. Parameters measured included length and width of the algal cell/colony. Typically 10 microscopic images were taken for the measurement of algal cell/colony dimensions and counting. Hillebrand et al (1999) and Vadrucci et al (2007) suggested general equations that were applied to calculate the biovolume of algal species using microscopically measured linear dimensions. Biovolume of the wastewater algal species were calculated monthly. This information was then used to determine relative algal dominance in the pond water over a four month experimental period.

3 RESULTS AND DISCUSSION

3.1 DOMINANT ALGAL SPECIES AND ALGAL BIOVOLUME

A portion of the selectively harvested algal biomass (daily biomass recycling ratio of ~8%) from the first ASC_r was recirculated to the $HRAP_r$ to improve algal biomass removal by gravity sedimentation. Five colonial algal species and various unicellular algal species were found to be present in both HRAPs during the summer months. Harvested algal biomass recycling maintained the dominance of *Pediastrum sp.* (>95% dominance) throughout the experimental period compared with the variable algal species composition in the $HRAP_c$..

3.2 ALGAL BIOMASS REMOVAL

Increased dominance of the colonial algae (Pediastrum sp.) in the $HRAP_r$ with harvested algal biomass recycling greatly improved the efficiency of algal harvest by gravity sedimentation; >90% average algal biomass removal after the second ASC compared with ~80% average algal biomass removal in the control without algal biomass recycling. Furthermore, harvested biomass recycling promoted aggregation of the colonial algae with wastewater bacteria to form large (>200 μm) floccs, which further enhanced gravity algal biomass removal. These results indicate that harvested algal biomass recycling could enhance algal biomass removal though the maintenance of easily-settleable colonial algal species.

4 CONCLUSIONS

The effect of recycling harvested algal biomass on algal species dominance and harvestability of algal biomass by gravity settling was investigated in a pilot-scale wastewater HRAP over four months during a New Zealand summer. Recycling of harvested algal biomass back to $HRAP_r$ promoted the dominance of a readily-settleable algal species, and greatly improved algal biomass harvest using a simple gravity algal settling cone. This suggests that harvested algal biomass recycling could maintain the dominance of easily-settleable colonial algae and may be a practical method to enhance algal biomass removal by gravity settling.

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