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A review of potential methods for zooplankton control in wastewater treatment High Rate Algal Ponds and algal production raceways

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ABSTRACT

High Rate Algal Ponds (HRAPs) can provide economical and efficient near tertiary-level wastewater (WW) treatment, with the nutrients recovered as algal biomass. HRAP performance can be negatively affected by the establishment of zooplankton grazers that can consume much of the algal biomass within a few days. Zooplankton management is therefore essential for maintaining WW treatment performance and algal productivity. This paper reviews zooplankton ecology in WW systems and eutrophic environments, and potential methods for zooplankton control in HRAPs. Promising options for zooplankton control include physical methods such as filtration, hydrodynamic cavitation, shear, bead mills; chemical methods such as increase of HRAP night-time CO_2 concentration, promotion of the lethal un-ionized ammonia toxicity, use of biocides, and the chitinase inhibitor chitosan; and biocontrol using competitor and predatory organisms. CO_2 and phototactic induced migration are proposed to concentrate zooplankton in specific areas to reduce the amount of pond water requiring treatment. Based on this review, we suggest that it may be most beneficial to maintain zooplankton grazer populations at low levels as part of a stable community, rather than to totally eradicate them. This will prevent the ecological imbalance of total control that could result in the establishment of other zooplankton species that are less easy to control.

Contents

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1. Introduction

Traditional wastewater (WW) treatment has three common fundamental stages; 1) primary treatment, to remove the solids, 2) secondary treatment, to clarify the effluent via aerobic degradation of soluble organic compounds, and 3) tertiary treatment, to remove dissolved nutrients (nitrogen, phosphorus) so as to reduce the potential for eutrophication of receiving waters [1]. High Rate Algal Ponds (HRAPs) are 0.3–0.5 m deep closed-loop, paddlewheel-mixed ponds (Fig. 1), and can be up to a few hectares in area. Such ponds are able to provide economical and efficient near tertiary-level WW treatment with the nutrients recovered as algal biomass [2,3]. HRAPs are considered to be effective reactors to reclaim water, nutrients and energy from organic wastewaters [4–7]. Algal productivity in HRAPs can be up to ~30 tonnes/ha/year and may increase to ~60 tonnes/ha/year when CO_2 is artificially added for extra carbon supply [8]. By comparison, algal productivity in traditional WW facultative ponds is only ~10 tonnes/ha/year [9]. The algal biomass grown in HRAP is usually composed of colonial microalgae, and is harvested from the effluent by natural settling of algal–bacterial flocs in Algal Harvest Ponds (conical tanks or ponds). The harvested algal biomass can be periodically removed for use as a fertilizer, protein-rich animal feed or for conversion into biofuel: biogas via anaerobic digestion; bioethanol via carbohydrate fermentation; bio-crude oil via high temperature liquefaction; or biodiesel via lipid trans-esterification [10,11]. Before being discharged into the environment, the algal settling pond effluent is further treated in a series of maturation ponds where zooplankton graze on any remaining microalgae.

HRAP performance depends on climatic (light, temperature), operational (pH, CO_2 concentration), water depth, dissolved oxygen (DO), nutrients, hydraulic retention time (HRT) and biological variables (parasites, fungi, zooplankton grazers) [12–14,8]. However, establishment of zooplankton grazers, which enter as contaminants from the surrounding environment, is one of the greatest challenges for HRAP performance and management [15]. Zooplankton can consume microalgae biomass with negative effects on the WW treatment performance [16]. Moreover, artificial control of HRAP water pH to close to neutral (~7–8) by CO_2 addition to promote wastewater nutrient removal and algal production also promotes zooplankton survival [17,18].

Herbivorous zooplankton grazers in HRAPs include ciliates, rotifers, cladocerans, copepods and ostracods. Of these, cladocerans (Subphylum Crustacea; Order Cladocera) and rotifers (Phylum Rotifera) constitute the greatest problem for both unicellular and colonial microalgae. These zooplankton have short generation times compared to copepods and ostracods resulting in rapid (within a week) depletion of algal biomass in both mass algal cultures [19–22] and WW treatment HRAPs [23–26]. Microalgae and bacteria are the main food source for zooplankton grazers. Grazing magnitude depends on the size of the grazer, abundance, grazing mechanisms (e.g., filtering or grasping), water temperature, food particle shape, size and availability [27–31]. Generally, algal biomass reduction depends on "what" and "how much" the zooplankton can ingest, and "how fast" it can reproduce.

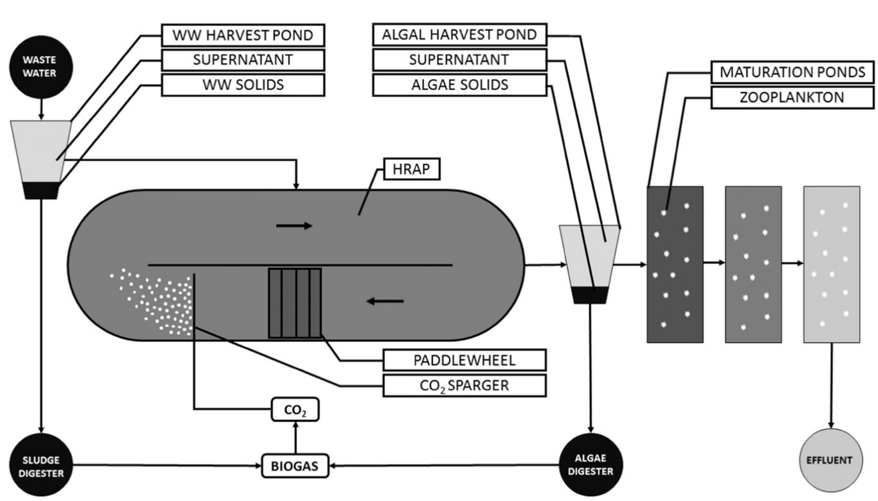

Fig. 1. Schematic diagram of a HRAP, Algal Harvest Pond, maturation ponds and anaerobic digesters for biogas production.