



Hydrodynamic evaluations in high rate algae pond (HRAP) design

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HIGHLIGHTS

- The CFD model improves the current design model.
- Ratio between pond's length and width of channel is higher than 10 to minimize the dead zone.
- CFD based design could achieve even distribution in channel.
- Modification of conventional pond could be drawn by CFD simulation.

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ABSTRACT

Since open ponds are considered to be a proper means to produce microalgae biomass at large scale, the design of these ponds remains a major issue in this field. Besides light intensity, the hydrodynamic characteristics are critical to obtain high microalgae productivity. Hydrodynamic mixing is required to ensure frequent exposure of algae cells to light, to avoid the settling of algae cells, to homogenize the nutrient distribution and to enhance the utilization of CO₂ in the pond. However, the current design of algae ponds lacks visual assessment of hydrodynamic characteristics in the pond, resulting in the appearance of dead zones where the flow is stagnant and in the presence of non-uniform velocity throughout the pond, both of which are still major problems because of their negative impact on algae growth. Therefore, this paper describes these characteristics to support current pond design by using Computational Fluid Dynamic (CFD). In order to simulate the hydrodynamic characteristics of the pond, the variation of velocity, ratio of channel length to width (L/W), and depth of culture were performed and power consumption, dead zone volume and shear stress were evaluated. The results showed that a ratio of L/W higher than 10 yields better performance with respect to velocity uniformity and shear stress. However, power consumption increased, as well. The hydrodynamic flow in the modified pond was simulated, providing better understanding for dead zone volume reduction. To implement this modeling evaluation in the design, an experimental validation is, however, still required.

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1. Introduction

Mass cultivation of algae has been studied for over two decades [28] and the most common commercial approach to produce algae biomass on a large scale is an open pond or high-rate algae pond (HRAP) system [32,27]. This system utilizes sunlight as the main energy source for the photosynthetic reaction to produce biomass and other valuable compounds. The HRAP system is simpler in design and construction than a photobioreactor but it is not neces-

sarily cheaper due to the high downstream processing cost. In addition, it is generally characterized by lower productivity and high risk of contamination [5]. As in algae photobioreactors, the available light in ponds appears to be the major controlling factor in productivity [26]. A uniform mixing is also required to obtain consistent yield of biomass by ensuring frequent exposure of algae cells to light, avoiding the settling of algae cells to the pond's bottom, homogenizing the nutrient distribution and enhancing the utilization of CO₂ in the pond [23,6]. The performance of mixing can be determined by variation of the hydrodynamic properties (circulation velocity, presence of dead zones and shear stress) which are influenced by the geometry of the pond [10,25]. Therefore, the investigation of hydrodynamic characteristics and geometry is highly important in the algae pond design.

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