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Responses of *Synechocystis* sp. PCC 6803 to total dissolved solids in long-term continuous operation of a photobioreactor

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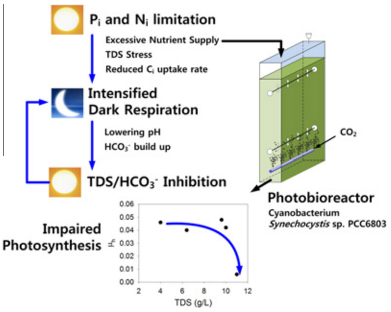
HIGHLIGHTS

- ▶ The growth of *Synechocystis* sp. PCC 6803 was inhibited by high-TDS stress.
- ▶ The high TDS was due to addition of inorganic C and N as nutrients.
- ▶ High TDS led to higher C_i, lower pH, and HCO_3^- dominance.
- ▶ TDS stress from HCO_3^- and NO_3^- differed from stress from Na^+ and Cl^-.

GRAPHICAL ABSTRACT



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ABSTRACT

This study evaluated how *Synechocystis* sp. PCC 6803 responds to high total dissolved solids (TDS) associated with eliminating nutrient limitation during long-term operation of a photobioreactor. The unique feature is that the TDS were not dominated by Na^+ and Cl^-, as in seawater, but by HCO_3^- and NO_3^- from nutrient delivery. The TDS-stress threshold was about 10 g/L. Whereas inorganic N and P limitations slowed the rate of inorganic C (C_i) uptake in the light, TDS stress was manifested most strongly as a substantial increase of endogenous respiration rate at night. Relief from TDS stress was incomplete when lowered pH led to a HCO_3^- increase (560 mg C/L as a threshold). Impaired photosynthesis led to a cascade of reduced C_i-uptake, pH decrease, HCO_3^- accumulation, and HCO_3^--associated stress. Thus, long-term photobioreactor operation requires balancing the delivery rates of CO_2, N, P, and other TDS components to avoid general and C_i-associated TDS stresses.

1. Introduction

Harnessing radiant energy from the sun presents a great opportunity for ultimately mitigating climate change and other problems arising from society's dependence on fossil fuels (Rittmann, 2008; Stephens et al., 2010). Using photosynthetic microorganisms to capture solar energy to make renewable fuel feedstock is among the promising approaches (Chisti and Yan, 2011; Rittmann et al., 2008). Microalgae-to-energy is not a new concept, but it is not yet a well-developed technology, due in part to inefficiencies associated with biomass production, harvest, and conversion to fuel (Clarens et al., 2010; Sander and Murthy, 2010; Stephenson et al., 2010).

Microbial photosynthesis captures radiant solar energy and uses it to reduce the carbon (C) in CO_2 to create organic matter that makes up the building blocks of new biomass. Biomass synthesis also requires uptake of inorganic nutrients, particularly nitrogen (N_i) and phosphorus (P_i) (Hagemann, 2011; Rittmann and McCarty, 2001). Thus, photosynthesis requires a proper matching of the deliveries of light energy, inorganic C (C_i) in CO_2, and N_i and P_i from the aqueous phase. Delivery of these materials can affect other aspects of the water quality in the culture medium. In particular, addition of C_i, N_i, and P_i increases the salt content of the solution.

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