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Carbon dioxide capture and nutrients removal utilizing treated sewage by concentrated microalgae cultivation in a membrane photobioreactor

Ryo Honda [a,*], Jarungwit Boonnorat [b], Chart Chiemchaisri [b], Wilai Chiemchaisri [b], Kazuo Yamamoto [a]

[a] Environmental Science Center, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[b] Department of Environmental Engineering/Center of Advanced Studies in Industrial Technology, Kasetsart University, 50 Phaholyothin Road, Jatujak, Bangkok 10900, Thailand

HIGHLIGHTS

- Submerged membrane filtration enabled high algae productivity in treated sewage.
- Highest TN removal was 91%. Phosphorous became a limiting factor of algal growth.
- The CO_2 capture rate was highest when HRT was 1 day and SRT was 18 days.
- *Botryococcus braunii* became predominant to *Chlorella* and *Spirulina* spp.
- The reactor performance could be improved further by increase of nutrients loading.

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ABSTRACT

A highly efficient microalgae cultivation process was developed for carbon dioxide capture using nutrients from treated sewage. A submerged-membrane filtration system was installed in a photobioreactor to achieve high nutrient loading and to maintain a high concentration and production of microalgae. *Chlorella vulgaris*, *Botryococcus braunii* and *Spirulina platensis* were continuously cultivated with simulated treated sewage and 1%-CO_2 gas. The optimum hydraulic retention time (HRT) and solids retention time (SRT) were explored to achieve the maximum CO_2 capture rate, nutrient removal rate and microalgae biomass productivity. The carbon dioxide capture rate and volumetric microalgae productivity were high when the reactor was operated under 1-day (HRT) and 18-days (SRT) conditions. The independent control of HRT and SRT is effective for efficient microalgae cultivation and carbon dioxide capture using treated sewage.

1. Introduction

Microalgae are conventionally utilized for removing nutrients in water. Currently carbon dioxide capture by microalgae cultivation has been investigated as one of the mitigation processes of global warming. In combination with methane fermentation, lipid extraction or other bioenergy conversion processes, it is expected to produce carbon-neutral energy from carbon dioxide in the air.

Recent advancements have been made to the design and operation of photobioreactors to achieve high-efficient CO_2 capture and microalgae productivity (Posten, 2009; Xu et al., 2009; Acién Fernández et al., 2001; Richmond and Zhang, 2001; Hall et al., 2003; Ugwu et al., 2008; Pulz, 2001; Bosma et al., 2007; Chini Zittelli et al., 2006; Molina et al., 2001). A high algae concentration and a high growth rate are required for efficient microalgae cultivation and simultaneous CO_2 capture. In continuous cultivation, a high concentration of microalgae is maintained by a long solids retention time (SRT), and a high growth rate is maintained by high loading of nutrients and carbon dioxide. Without solid–liquid separation, supply of high-nutrient cultivation media is necessary to realize high loading of nutrients.

Many of the recent studies on microalgae cultivation for CO_2 capture have utilized cultivation media containing a high concentration of nitrogen and phosphorous (Acién Fernández et al., 2001; Richmond and Zhang, 2001; Meiser et al., 2004; Chini Zittelli et al., 2006; Nedbal et al., 2008) and purge gas containing high partial pressure of CO_2 (Meiser et al., 2004; Chini Zittelli et al., 2006; Nedbal et al., 2008). However, an additional energy input is necessary for producing a high nutrient medium and a high concentration of CO_2. Reduction of such energy input should be considered to improve the net CO_2 capture. Treated sewage is a good nutrient source as it has a higher nutrient content compared with natural water, and is relatively cheap and easily available in urban areas.

* Corresponding author. Present address: Research Center for Sustainable Energy and Technology, Institute of Science and Engineering, Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan. Tel./fax: +81 76 264 6393.
E-mail address: rhonda@se.kanazawa-u.ac.jp (R. Honda).

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