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Culture of *Scenedesmus* sp. LX1 in the modified effluent of a wastewater treatment plant of an electric factory by photo-membrane bioreactor

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ABSTRACT

To investigate the coupled technology for advanced wastewater treatment and microalgal biomass production, a photo-membrane bioreactor was constructed. The microalga *Scenedesmus* sp. LX1 was cultured in the bioreactor using liquor prepared from the effluent of an electronic device factory. The algal cell growth, nitrate nitrogen removal, orthophosphate phosphorus removal were investigated. When cultured with batch operation, the average specific growth rate was about 0.09 d^{-1}, and low nitrogen (N), phosphorus (P) concentrations in the liquor were achieved. However, under continuous operation with an inflow of 60 $L\,h^{-1}$, the average specific growth rate was only 0.02 d^{-1}, and removal rates of 100% for orthophosphate P and 46% for nitrate N were achieved. With the inflow of 120 $L\,h^{-1}$, the accumulated metal ions in the bioreactor adversely affected the algal cells. The algal cells were much easier to settle, and the removal efficiency for N and P decreased.

1. Introduction

The cultivation of microalgae as a source of a variety of products, including animal feeds, health products, and pharmaceuticals, has been investigated for many years (Joseph et al., 1988). At present, microalgal biomass that can be used for bio-fuel manufacturing is considered as a promising resource for the production of renewable energy (Chisti, 2007; Mata et al., 2010; Zemke et al., 2010). Achieving a high yield of biomass with a relatively low cost is essential for this purpose. Cultivation with wastewater is an important measure to reduce microalgal production cost, and is of particular interest to many research groups. Currently, worldwide freshwater resources are becoming increasingly scarce. Studies on technologies for the reclamation of wastewater are, therefore, highly significant. The conventional A^2O technology has been widely applied in wastewater treatment. This process removes most of the organic contaminants, nitrogen, and phosphorus in the wastewater. However, the secondary effluent from the sedimentation tank still contains high levels of inorganic N and P, which may cause eutrophication and water pollution, hence the need for advanced treatment. Microalgal culture first proposed by Oswald (1988) is a prospective method for advanced wastewater treatment. Recently, a technology that coupled advanced wastewater treatment and algal biomass production was described by Hong-ying (Li et al., 2010a,b). In this system, nutrients (N, P, and so on), and fresh water in the wastewater can be fully utilized for microalgal culture. This helps to effectively reduce the cost of culture. At the same time, the wastewater undergoes advanced purification, which helps in addressing freshwater resource scarcity.

In the past several decades, more research was done on microalgal culture for N, P removal of domestic sewage than that of industrial wastewater. The main reason for this may be the difference in their compositions. Industrial wastewater, such as tannery wastewater, chemical industry wastewater, and so on, has more metal ions in addition to various organic, N, and P compounds. This may influence algal cell growth (Li et al., 2007). While the domestic sewage has less metal ions generally. The growth of algal cells and the removal of nutrients (N, P, and so on) in the secondary effluent of industrial wastewater may be different from those in the secondary effluent of domestic sewage. Investigations on the characteristics of advanced treatment of industrial wastewater using algal culture are needed for full utilization of wastewater resources.

To achieve the coupled technology, a photo-bioreactor is needed. With continuous operation, maintaining a stable biomass concentration in a photo-bioreactor with short algal cell retention time is difficult. Algal cell immobilization technology to overcome this problem has been studied for many years

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(Lau et al., 1997; Tam and Wong, 2000). Algal cells are entrapped into a matrix such as calcium alginate and carrageenan, and small beads are formed. Algal beads suspend in the liquor, which can be trapped easily. So, this technology can prevent the wash out of biomass in bioreactors. However, this technology is complex for algal cells recovery. Further more, algal beads easily rupture with algal cells growth in the beads. The photo-membrane bioreactor containing a photo-bioreactor unit and a membrane filtration unit is an alternative for advanced wastewater treatment and microalgal production. Microfiltration can effectively trap microalgal cells (Hung and Liu, 2006; Liang et al., 2008), prevent the wash out of microalgal cells, and enhance the microalgal cell retention time in the bioreactor. Thus, the algal cell concentration can be controlled in a photo-bioreactor with a membrane unit. Furthermore, the algal cells can be effectively separated from the outflow. Research on photo-membrane bioreactors for microalgal cultivation in wastewater is scarce, and photo-membrane bioreactor performance including wastewater treatment efficiency and algal cell growth needs to be investigated in detail.

In this study, a pilot photo-membrane bioreactor was constructed in an electronic device factory. To study the algal cell growth and N, P removal characteristics in the industrial wastewater, which have certain nutrients and metal ions, the culture liquor was made up by the modified effluent from the wastewater treatment facility of the factory. The microalga *Scenedesmus* sp. LX1 was cultured in the bioreactor using the modified effluent. The growth state of the algal cells, the removal efficiency for N and P, and the influence of metal ions on the algal cell growth were investigated.

2. Methods

2.1. Photo-membrane bioreactor

A pilot photo-membrane bioreactor system with a total volume of 1300 L was constructed. The schematic diagram is shown in Fig. 1. This bioreactor system consisted of three parts: a photo-bioreactor unit, a membrane filtration unit, and a fluid transport and mixing unit.

The main body of the photo-bioreactor unit consisted of four plexiglass columns and a gas distributor installed at the bottom of each column. Each gas distributor had holes (50 μm diameter). The effective volume of each column was 120 L. Instead of using a fluorescent lamp, an LED lamp with a red/blue light ratio of 5:1 was fixed around the column, which enhanced the microalgal cell growth (Li et al., 2010a,b,c). The total power of the light was about 2.0 kW, and the maximum light intensity on the column face was about 6000 lux.

The membrane filtration unit was composed of two parts: a filtration flume and a membrane bundle. The volume of the flume (dimensions of 2800 × 600 × 500 mm) was about 800 L. A hollow-fiber membrane with an aperture of 0.2 μm was fixed in the flume (10 m^2 total filter area). Air was passed through the bottom for mixing the liquor and reducing the algal cell adsorption by the membrane. The outflow was driven through a diaphragm pump connected to the hollow-fiber filtration membrane.

Using the pneumatic diaphragm pump, the algal culture liquor was circulated from the filtration tank to the agitation tank and the photo-bioreactor columns. The pH of the culture liquor was monitored by a probe during the operation.

2.2. Algal species and culture liquor

A species of green alga *Scenedesmus* sp. LX1 was isolated from tap water laid aside for some time in the laboratory (Li et al., 2010a). Important characteristics of this microalga are its high grease content (>30%) (Li et al., 2010a), and its high potential in the bio-energy field.

The culture liquor was prepared using the effluent from the wastewater treatment workshop of an electronic device factory. The pH of the effluent was about 7.0. Table 1 shows that the N and P concentration in the effluent were very low. However, the Fe^{3+} concentration was relatively high. Clearly, the nutrients in the effluent were scarce. To meet the requirements for the algal

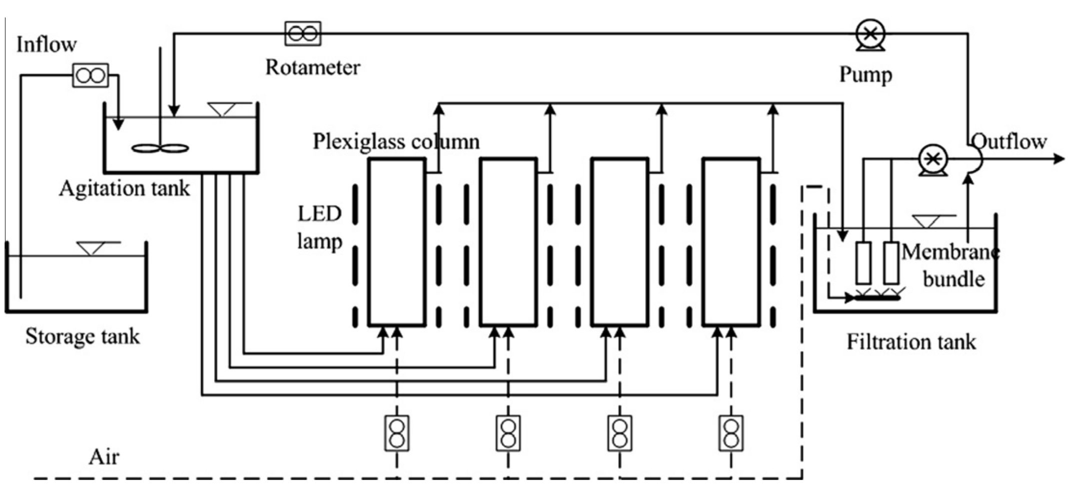

Fig. 1. The photo-membrane bioreactor system used in the experiments.

Table 1
Dissolved components of the effluent of the wastewater treatment workshop in the factory.

Component	NH_3–N	NO_2–N	NO_3–N	TP[a]	Fe^{3+}	Cu^{2+}	Zn^{2+}
Concentration (mg L^{-1})	0.27 ± 0.1	0.02 ± 0.01	0.51 ± 0.2	0.04 ± 0.02	1.24 ± 0.2	0.25 ± 0.05	0.18 ± 0.05

[a] Abbreviation of total phosphorus.