FUNGAL BIOREACTOR WITH ULTRAMEMBRANE SEPARATION FOR DEGRADATION OF COLORED- AND ENDOCRINE DISRUPTING- SUBSTANCES

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ABSTRACT

A bioreactor system employing a white rot fungus *Trametes hirsuta* IFO4917 and ultramembrane filtration (UF) unit was proposed and experimentally investigated for the removing colored-substances and endocrine dispuptors (EDs). Among 20 white-rot fungi, *T. hirsuta* IFO4917 which can effectively decolorize humic acid and degrade a wide range of EDs; bisphenol A (BPA), nonylphenol (NP), 17β-estradiol, estrone and estriol, was utilized to the bioreactor. A bench scale (10 L), sequencing batch reactor using this fungus was developed and applied to decolorization of a melanoidin containing synthetic wastewater. The fungus was immobilized onto polyurethane foam cubes to stably maintain the biomass, and UF was applied to achieve a complete solid/liquid separation. In this fungal-UF system, more than 70 % of thdecolorization was constantly achieved at 2-day HRT. A pilot-scale plant (200 L) was also constructed and applied to the treatment of the secondary effluent from a night soil treatment process. 65-70 % of decolorization was achieved at a 1.5-day-cycle sequencing batch operation. Typical EDs, NP, octylphenol and benzophenone, found in the influent were also removed efficiently with removal of 94 %, 89 % and 81 %, respectively.

KEYWORDS

White-rot fungi, Immobilization, Ultrafiltration, Decolorization, Endocrine disruptors degradation.

INTRODUCTION

Problems of recalcitrant organic compounds including natural/synthetic colored-components and endocrine disruptors (EDs) have received substantial attention recently. Due to their resistance to biological degradation, conventional biological treatment cannot effectively remove them contained in industrial wastewaters, night soil and/or landfill leachates. Such wastewaters are, therefore, treated by physico-chemical processes like ozonation, photocatalytic degradation and/or adsorption generally. However, since these have a common problem of high cost, novel biological processes applicabletto the treatment of recalcitrant compounds are required to be developed.

White-rot fungi are the most promising biological agents which may be utilized for developing such novel biological wastewater treatment processes. They possess extracellular lignin-degrading enzymes which have high oxidoreductive potential with very relaxed- or none-substrate specificity, and this allows them to degrade a wide variety of recalcitrant substances including natural/synthetic colored-components (Arisoy, 1998; Bumpus et al.,1985). In spite of their great potential, however, wastewater treatment processes employing white-rot fungi have not been fully investigated and have never practiced to date. Especially there has been no or very little information on the fungal treatment of synthetic and natural EDs which are frequently found in the wastewater treatment plants like bisphenol A (BPA), nonylphenol (NP), 4-*t*-octylphenol (OP), di-(2-ethylhexyl)phthalate

(DEHP), 17β-estradiol (E2), estrone (E1) and estriol (E3). In this study, color removal and EDs degradation by a bioreactor employing a white rot fungus *Trametes hirsuta* IFO4917 equipped with ultramembrane filtration (UF) unit was proposed (fungal-UF system), and its performance was experimentally investigated.

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COLOR REMOVAL BY LAB-SCALE FUNGAL/UF SYSTEM

The lab-scale fungal bioreactor shown in Fig. 1 was applied to the preliminary experiment for decolorization of synthetic wastewater. 1,000 pieces of 12 x 12 x 15 mm polyurethane foam cubes immobilizing *T. hirsuta* IFO4917 cells were prepared in a 12-L glass bottle as the fungal bioreactor. A tangential flow UF system provided by Takuma Co. using the polysulfone ultramembrane with molecular weight cut-off (MWCO) of 30,000 Da was utilized for completing solid-liquid separation.

The lab-scale fungal-UF system was operated in a sequencing batch mode. The bioreactor was fed with 10 L of the model colored wastewater supplemented with 1,000 mg/L ethanol as the substrate. The model wastewater contained peptone and meat extract as the main organic components and synthetic melanoidins (Miyata et al., 1998) as the typical color components (4,200 color units (CU)). The bioreactor was aerated at 5 L/min from the bottom for 3 days and decolorization was performed at 30 °C under non-sterilized condition (the 1st cycle). The fungally-decolorized wastewater was sent to the stock tank and subjected to the UF unit at a pressure of 1.5 kgf/cm^2 until 5 L of the permeate was obtained. The concentrate in the stock tank was heated at the defined temperature for 10 min for killing microbes which contaminated the bioreactor. Then 5 L of the fresh model wastewater as influent was fed to the bioreactor with returning 5 L of the heat-treated concentrate (the 2nd cycle). From the 2nd cycle, the fungal bioreactor was aerated for 1 day, and these operations were repeated daily (HRT=2 days).

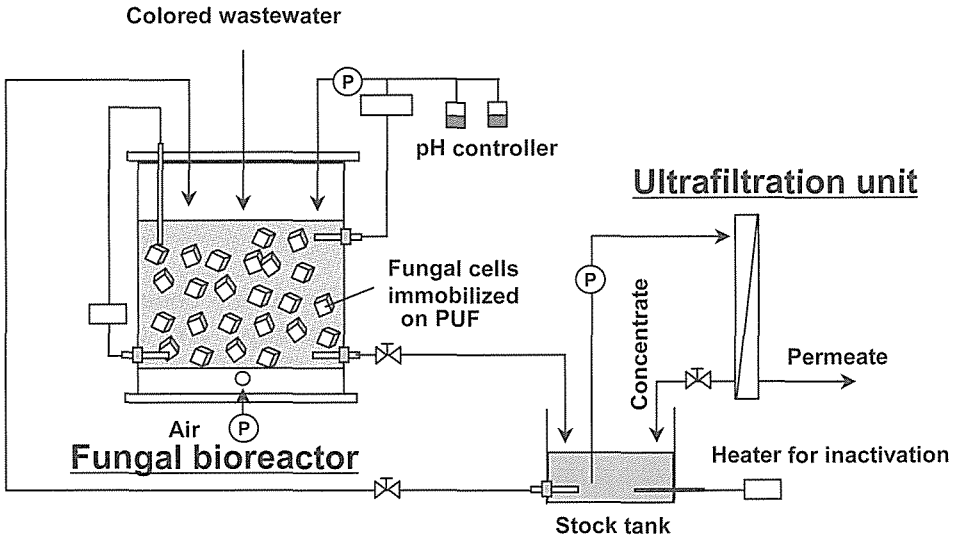

Fig.1. Schematic diagram of sequencing batch fungal-UF system for decolorization of colored wastewater.

When the lab-scale fungal-UF system was operated under the non-sterilized condition (without heating the concentrate), the air/water-born microbes contaminated the fungal bioreactor (more than 10^6 cfu/ml), resulted in the decrease of fungal decolorization efficiency (Fig. 2). In order to reduce the effects of microbial contamination, the UF concentrate was heated at 50 °C for 10 min before returned to the fungal bioreactor. This heat-inactivation could lower the air/water-born microbes as

cfu by approximately 80 %, while both MIP and MnP activities in the retentate showed no significant loss. The fungal-UF system showed a relatively high and stable decolorization performance with the heating (Fig. 3). At the nearly steady state, the fungal bioreactor showed an average decolorization rate of ca. 1,300 CU/day and the UF unit an average CU rejection efficiency of ca. 60 %. The whole fungal-UF system constantly achieved about 70 % of the decolorization, therefore, the contribution of the fungal bioreactor alone to the total decolorization was approximately 45 %. UF was effective not only for physically removing higher-molecular-weight colored components which could not be decolorized by the fungus, but also for concentrating the extracellular decolorizing enzymes, manganese peroxidase (MnP), manganese independent peroxidase (MIP) and laccase, which were produced by the fungus (data not shown).

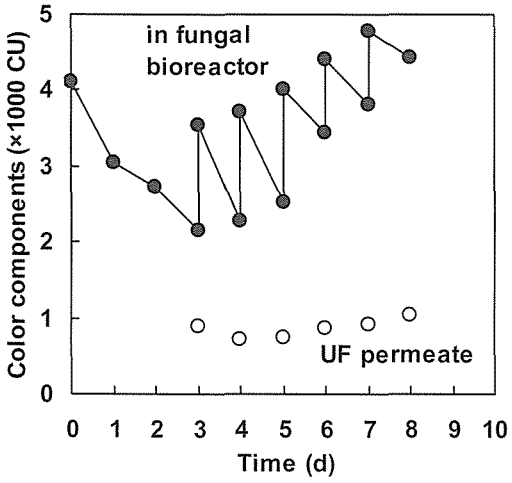

Fig.2. Decolorization performance of lab-scale fungal-UF system without heat treatment

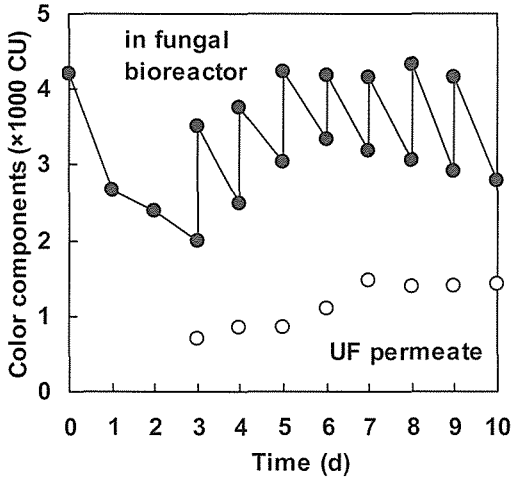

Fig.3. Decolorization performance of lab-scale fungal-UF system with heat treatment

COLOR AND EDs REMOVAL BY PILOT-SCALE FUNGAL-UF SYSTEM

The fungal-UF system was scaled up to a pilot-scale plant (working volume, 200 L), and applied to the treatment of the secondary effluent from a biological treatment process of night soil in order to evaluate the possibility of the practical use (Fig. 4). The secondary effluent, that is the influent to the pilot-scale fungal-UF system, contained a considerable concentration of colored components (approx. 1,000 CU). NP, OP, DEHP and benzophenone which are recognized or doubted as EDs were also detected in the influent. Operations were done in a trial-and-error mode to optimize the decolorization and EDs removal efficiencies under non-sterilized conditions.

Using the pilot-scale fungal/UF system, 65-70 % of decolorization efficiency was achieved, when the fungal/UF system was operated at a 1.5-day-cycle sequencing batch mode with addition of ethanol at 1.3 g/L of the system influent (an optimized condition). The fungal decolorization accounted for approximately 60 % of the decolorization by the whole system. A long-term treatment led to the accumulation of acetic acid which tended to inhibit the fungal decolorization. Transformation of ethanol into acetic acid seemed to be caused by the metabolism by bacteria or yeast contaminated the system. NP, OP and benzophenone were also degraded efficiently with removal of 94 %, 89 % and 81 %, respectively, however, the removal of DEHP was not so effective (45 %). Summary of the performance of the pilot-scale fungal/UF system under this condition is given in Table 1.

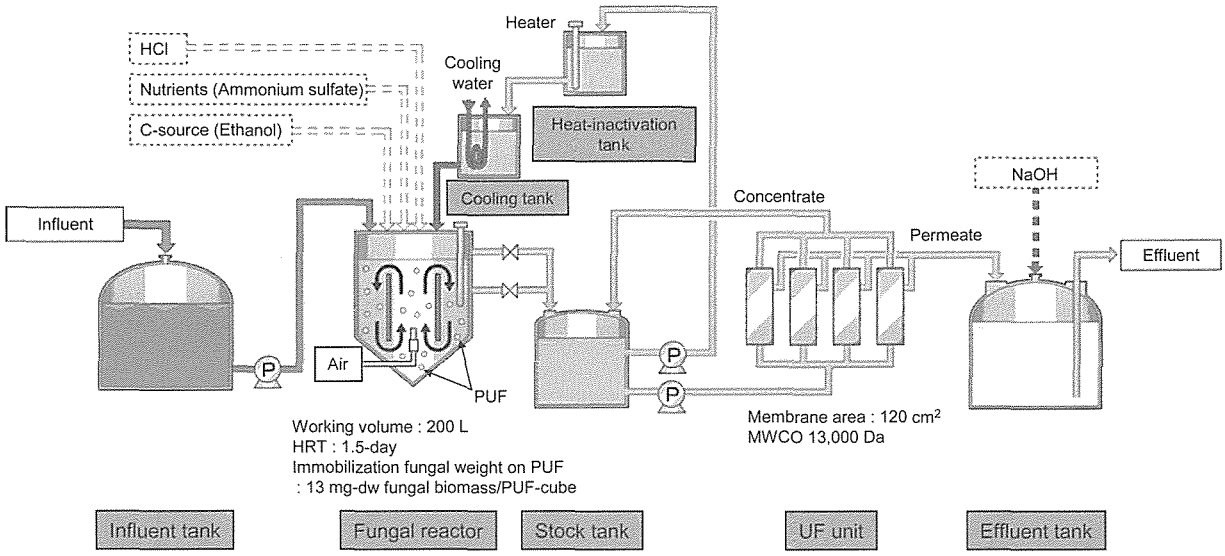

Fig.4. The schematic diagram of the pilot-scale fungal-UF system

Table 1. Removal of colored components and EDs by fungal-UF system

Color and EDs		Influent	Effluent	Removal (%)
Color (CU)		1260	400	68
EDs (μg/l)	NP	1.6	<0.1	>94
	OP	2.9	0.32	89
	DEHP	1.1	0.6	45
	Benzophenone	0.13	<0.025	>81

CONCLUSIONS

The experimental results strongly suggested that the fungal-UF system has a great potential for application to the treatment of a variety of wastes/wastewaters containing colored components and EDs. In addition to the application to the secondary effluent from the night soil treatment processes demonstrated here, treatment of leachate containing EDs, binding to lignin and humic substances, from waste disposal sites by this system would be of interest in future studies. Design and operational parameters of the fungal-UF system such as the volume fraction of PUF in the fungal bioreactor, timing and concentration of the ethanol addition, HRT of the fungal bioreactor, and MWCO of the UF unit, should be further optimized for its practical use.

REFERENCES

Arisoy M. (1998) Biodegradation of chlorinated organic compounds by white rot fungi, *Bull. Environ. Contam. Toxicol.*, 60, 872-876.

Bumpus J. A., Tien M., Wright D., Aust S. D. (1985) Oxidation of persistent environmental pollutants by white rot fungus, *Science,* 228, 1434-1436.

Miyata N., Iwahori K., Fujita M. (1998) Manganese-independent and -dependent decolorization of melanoidin by extracellular hydrogen peroxide and peroxidases from *Coriolus hirsutus* pellets, *J. Ferment. Bioeng.*, 85, 550-553.