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Some properties of a granular activated carbon-sequencing batch reactor (GAC-SBR) system for treatment of textile wastewater containing direct dyes

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Abstract

Resting (living) bio-sludge from a domestic wastewater treatment plant was used as an adsorbent of both direct dyes and organic matter in a sequencing batch reactor (SBR) system. The dye adsorption capacity of the bio-sludge was not increased by acclimatization with direct dyes. The adsorption of Direct Red 23 and Direct Blue 201 onto the bio-sludge was almost the same. The resting bio-sludge showed higher adsorption capacity than the autoclaved bio-sludge. The resting bio-sludge that was acclimatized with synthetic textile wastewater (STWW) without direct dyes showed the highest Direct Blue 201, COD, and BOD_5 removal capacities of 16.1 ± 0.4, 453 ± 7, and 293 ± 9 mg/g of bio-sludge, respectively. After reuse, the dye adsorption ability of deteriorated bio-sludge was recovered by washing with 0.1% sodium dodecyl sulfate (SDS) solution. The direct dyes in the STWW were also easily removed by a GAC-SBR system. The dye removal efficiencies were higher than 80%, even when the system was operated under a high organic loading of 0.36 kg BOD_5/m^3-d. The GAC-SBR system, however, showed a low direct dye removal efficiency of only 57 ± 2.1% with raw textile wastewater (TWW) even though the system was operated with an organic loading of only 0.083 kg BOD_5/m^3-d. The dyes, COD, BOD_5, and total kjeldalh nitrogen removal efficiencies increased up to 76.0 ± 2.8%, 86.2 ± 0.5%, 84.2 ± 0.7%, and 68.2 ± 2.1%, respectively, when 0.89 g/L glucose (organic loading of 0.17 kg BOD_5/m^3-d) was supplemented into the TWW.

Keywords: Direct dye; Bio-sludge; Granular activated carbon (GAC); Sequencing batch reactor (SBR); Adsorption

1. Introduction

The textile industry is one of the most important export industries of Thailand (Department of Industrial Works, 2002) and it discharges large amounts of wastewater during processing, especially, in the coloring and washing steps. The wastewater contains a high concentration of both organic matter and colorants (dyes) (Slokar and Majcen, 1997; Ramakrishna and Viraraghvan, 1997; Horning, 1978). Several types of dyes, such as disperse, vat, direct, acid, basic, and reactive dyes, are used in the textile industry.

Direct dye is commonly used in the printing process of the textile industry. Most of the printing process-textile factories belong to the small factory group (home-made textile products) (Hu, 1996; Slokar and Majcen, 1997; Wong and Yuen, 1996; Graca et al., 2001; Gupta et al., 1992). Chemical treatment processes, such as oxidation, precipitation, coagulation, and adsorption, are commonly used to remove color from the wastewater, especially in

Abbreviations: BOD_5, biochemical oxygen demand; COD, chemical oxygen demand; F/M, food (BOD loading)/microbe (total bio-sludge); GAC, granular activated carbon; GAC-SBR, granular activated carbon-sequencing batch reactor; HRT, hydraulic retention time; MB, moving bio-film; MLSS, mixed liquor suspended solids; SBR, sequencing batch reactor; SDS, sodium dodecyl sulfate; SRT, solid retention time; SS, suspended solids; SVI, sludge volume index; TWW, textile wastewater; STWW, synthetic textile wastewater; TKN, total kjeldahl nitrogen; TP, total phosphorus

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large factories (Slokar and Majcen, 1997; Ramakrishna and Viraraghvan, 1997), but chemical use and operating costs are quite high and a large amount of solid waste is produced (chemical-sludge waste) (Horning, 1978).

Nowadays, biological treatment processes, such as the activated sludge system, oxidation ponds, and aerated lagoons, are used in textile factories, especially in the small-scale factories (Nigam et al., 1995). The organic matter of textile wastewater (TWW) can be removed by biological treatment systems, but the color-causing substances still remain in the treated wastewater (Slokar and Majcen, 1997; Banat et al., 1996). However, a lot of research is still concentrated on the use of microorganisms to remove the color from TWW (Banat et al., 1996; Hu, 1996; Slokar and Majcen, 1997; Aksu, 2001; Assadi and Jahangiri, 2001; Balan and Monteiro, 2001).

Most of this research work is focused on the biological adsorption and degradation of azo, disperse, vat, and pigments sulfur dyes, but not so much on the biological removal of direct dyes because the direct dyes are easily dissolved in water and are hardly adsorbed on adsorbents, such as activated carbon (Slokar and Majcen, 1997; Cheremisinoff and Morresi, 1978). Nigam et al. (1995) reported that colorants, such as azo, diazo and reactive dyes were adsorbed onto the surfaces of both living and dead microorganisms. Hu (1996) also reported that both Gram-negative and Gram-positive bacteria of bio-sludge showed an ability to remove colorants. Also, our previous work indicated that the vat dye could be adsorbed onto the surface of both living and dead bio-sludge (Siriannuntapiboon and Saengow, 2004). The sequencing batch reactor (SBR) system can be applied for treatment of TWW containing vat dyes with high efficiency. In this study, bio-sludge from a biological wastewater treatment plant was used to remove direct dye from TWW. Both resting and autoclaved bio-sludges were tested for direct dye adsorption ability and the most suitable solvents for eluting colorants from the dye adsorbed-bio-sludge were investigated. The direct dye removal efficiency of living bio-sludge was tested in a GAC-SBR system under various hydraulic retention times (HRT) and organic loadings.

2. Materials and methods

2.1. Dyes

Two types of direct dye were selected for use in this study, viz., Direct Red 23 and Direct Blue 201. The properties of these direct dyes are described in Table 1.

2.2. Granular activated carbon (GAC)

The GAC type CGC-11 (C. Gigan Co. Ltd., Thailand) with a mesh size of $8 \times 10\,\text{mm}^2$, total surface area of 1050–1150 m^2/g, and apparent density of 0.46–0.48 g/ml was used in the experiment.

2.3. Wastewater samples

Two kinds of wastewater samples were used in this study: (1) TWW and (2) synthetic textile wastewater (STWW). TWW was collected from the influent sump tank of the central wastewater treatment plant of a textile factory in Samutprakarn province, Thailand. The chemical properties of TWW are described in Table 2. The TWW supplemented with 0.89 g/L glucose (final biochemical oxygen demand (BOD_5) concentration of about 1250 ± 10 mg/L) was used as TWW + glucose (Table 2). STWW was prepared based on the same conditions as those of TWW. The BOD_5 concentration of TWW was about 1100 mg/L and the dye concentrations (Direct Red 23 and Direct Blue 201) were 40 mg/L. The chemical compositions and properties of the STWW were as follows: glucose 1875 mg/L, urea 115 mg/L, $FeCl_3$ 3.5 mg/L, $NaHCO_3$ 675 mg/L, KH_2PO_4 55 mg/L, $MgSO_4 \cdot 7H_2O$ 42.5 mg/L, and direct dye 40 mg/L; chemical oxygen demand (COD) 2000 ± 10 mg/L, BOD_5 1100 ± 7 mg/L, total Kjeldahl nitrogen (TKN) 55 ± 1 mg/L, and pH 7.4 ± 0.1.

2.4. Preparation of bio-sludge for adsorption ability test

The bio-sludge inoculum was taken from the bio-sludge storage tank of the central domestic treatment plant of Bangkok, Thailand (Sripaya sewage treatment plant).

Table 2
Chemical properties of textile wastewater (TWW) and textile wastewater containing 0.89 g/L glucose (TWW + glucose)

Chemical properties	TWW		TWW + glucose
	Range	Average ± SD	Average ± SD
COD (mg/L)	1524–3645	1615 ± 7	2438 ± 11
BOD (mg/L)	281–975	625 ±	1250 ± 10
Suspended solid (SS) (mg/L)	216–402	309 ± 5	313 ± 4
pH	7.32–8.12	7.60 ± 0.3	7.60 ± 0.3
Color intensity (A_{535}), units	0.50–0.70	0.60 ± 0.1	0.60 ± 0.1

±: Standard deviation of three replicates.

Table 1
Types and properties of direct dyes

Scientific name	Trade name	Type	CI no.	Color	Wavelength at maximum adsorption (nm)
Direct Red23	Hirus Direct Sarle 4BS	Direct dye	29160	Red	500
Direct Blue201	Hirus Blue BRL	Direct dye	—	Blue	562
—	Textile wastewater	Mixed direct dyes	—	Red-violet	535