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Removal of Vat Dyes from Textile Wastewater Using Biosludge

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Biosludge from a wastewater treatment plant was able to adsorb colourants, particularly vat dyes, from textile wastewater. Autoclaved and resting biosludge showed different adsorption abilities with different types of vat dyes. The adsorption ability of the biosludge increased with an increase in sludge age (solid retention time; SRT). Autoclaved biosludge showed the highest adsorption ability under acidic conditions (pH 3) while the resting biosludge showed the highest adsorption ability under neutral or weak alkaline conditions. The maximum colourant (Vat Black 25) adsorption capacities of autoclaved and resting biosludge with a sludge age of 24 days were 85.54 ± 0.5 and 37.59 ± 0.6 mg/g biosludge, respectively. Using a sequencing batch reactor (SBR) system, the biosludge was able to remove both organic matter and colourants from both textile and synthetic textile wastewaters. The removal efficiencies of the system increased with an increase in SRT of the system. The removal efficiency of the system with textile wastewater was lower than with synthetic textile wastewater. The BOD_5 and colourant removal efficiency of the SBR system with textile and synthetic textile industrial wastewaters under a BOD_5 loading of 0.13 kg BOD/m^3-d were 70.1 ± 4.4% and 84.9 ± 2.0%, and 98.1 ± 1.5% and 87.5 ± 5.1%, respectively.

Key words: **sequencing batch reactor (SBR), textile industry, vat dye, biosludge, biological wastewater treatment system, sludge age, solid retention time (SRT)**

Introduction

Legislation on industrial wastewater has tightened controls on toxic substances, and consequently, a large number of researchers are addressing a variety of issues in this area (Slokar and Majcen 1997). The textile industry is an industry of interest (Slokar and Majcen 1997; Clarke and Steinle 1995; Horning 1978; Banat et al. 1996). Textile wastewaters contain a high concentration of both organic matter and colourants (dyes) (Slokar and Majcen 1997; Clarke and Steinle 1995; Horning 1978). Due to its properties, vat dye is mainly used in the textile industry (Hu 1996; Slokar and Majcen 1997; Wong and Yuen 1996; Graca et al. 2001; Gupta et al. 1992). At present, chemical treatment methods such as oxidation, ion exchange, precipitation, coagulation and adsorption are commonly used to remove colourants from textile wastewater (Slokar and Majcen 1997; Ramakrishna et al. 1997), but the chemical and operating costs are high and solid wastes are produced (chemical-sludge waste). Conventional biological treatment processes such as activated sludge system oxidation ponds and aerated lagoons are also used in the textile industry. Organic matter (BOD_5) is easily removed by biological treatment processes, but the colourants remain in the wastewater (Slokar and Majcen 1997; Kim et al. 2002; Banat et al. 1996). This means that the effluent quality of conventional biological wastewater treatment, especially colour substances and COD, is higher than the standard permissible level of the Department of Industrial Works of Thailand (Department of Industrial Works 1992). Over the last 20 years, research has concentrated on using microorganisms for the removal of colour from textile industrial wastewater (Banat et al. 1996; Fu and Viraraghavan 2001; Hu 1996; Slokar and Majcen 1997; Aksu 2001; Assadi and Jahangiri 2001; Balan and Monterio 2001; Kapdan et al. 2000). Biological colour removal ability was found in both aerobic and anaerobic microorganisms (Slokar and Majcen 1997). The colourant removal mechanisms are due to adsorption or degradation, or both adsorption and degradation (Slokar and Majcen 1997; Fu and Viraraghavan 2001; Hu 1996; Zaoyan et al. 1992; Walker and Weatherley 2000). Both living and dead microorganisms (Nigam et al. 1995) could adsorb colourants, such as azo, diazo and reactive dyes. Also both gram-negative and gram-positive biosludge bacteria showed an ability to remove colourants (Hu 1996). However, all the researchers above used pure microorganisms to remove colour from the textile industrial wastewater. In this study, the biosludge (mixed microorganisms) from various sewage treatment plants was tested for colour removal efficiency, especially for the vat dyes used primarily by the textile industry. The optimum conditions for living and dead biosludge to remove wastewater colourants were determined. The colour removal efficiency of living biosludge was tested in a sequencing batch reactor (SBR) system under various hydraulic retention time (HRT) conditions.

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Materials and Methods

Biosludge

Three types of biosludge were used in this study: biosludge type A, biosludge type B and biosludge type C. Biosludge type A and biosludge type B were collected from central wastewater treatment plants A and B, respectively. Biosludge type C was collected from a textile factory in Samuthpakarn, Thailand. The properties of each type of biosludge are described in Table 1. The biosludge was treated by washing with a 0.1 M acetate buffer (pH 6) and used as the resting biosludge. The biosludge was autoclaved at 121°C for 15 min and was used as autoclaved biosludge.

Dyes

Six types of vat dyes, mostly used in the textile industry, were selected for use in this study: Vat Black 25, Vat Green 1, Vat Black 8, Vat Yellow 1, Vat Green 13 and Vat Brown 1, as shown in Table 2.

Textile Wastewater

Two kinds of wastewater were used in this study: textile industrial wastewater (TIWW) and synthetic textile industrial wastewater (STIWW). TIWW was collected from a textile factory located in Samuthpakarn province, Thailand. The chemical properties of TIWW are described in Table 3. The STIWW was prepared to reflect the TIWW quality. The STIWW contained BOD_5 and vat dye concentrations of 2000 and 40 mg/L, respectively. The chemical composition of the STIWW is shown in Table 4.

Colourant Adsorption Test

The adsorption capacities of both the resting sludge and autoclaved biosludge were determined by the Jar Test System (Rubin 1978) using the STIWW containing various types of vat dyes. The colourant adsorption yields of both living and dead biosludge were analyzed by using Freundlich's adsorption isotherm equation (Rubin 1978).

Acclimatization of Biosludge for SBR System

Biosludge from central wastewater treatment plant A was used as an inoculum for the SBR system. The biosludge was acclimatized in the STIWW without dyes for one week before being used in the experiments.

Sequencing Batch Reactor System (SBR)

Six reactors (each with a 10-L capacity) were made from acrylic plastic (5 mm thick) as shown in Fig. 1. The reactor was 18 cm in diameter and 40 cm in height. The

TABLE 1. Types and sources of biosludge[a]

Type of biosludge	*Source*	*Treatment method*	*Treatment system*	*Sludge age SRT (days)*
Biosludge type A	Central wastewater treatment plant A	Biological	Extended activated sludge system	28
Biosludge type B	Central wastewater treatment plant B	Biological	Conventional activated sludge system	18
Biosludge type C	Textile wastewater treatment plant in Samuthpakarn province	Biological	Conventional activated sludge system	17

[a]Biosludge was collected from the recycle storage tank of a wastewater treatment plant. Central wastewater treatment plants were located in Bangkok City, Thailand.

TABLE 2. Types and properties of vat dyes

Scientific name	*Trade name*	*Type of dye*	*CI No.*	*Colour*	*Wavelength at maximum absorption (nm)*
Vat Black 25	Cibanone olive s.	Vat dye	69525	Dark blue	675
Vat Green 1	Indanthrene green b.	Vat dye	59825	Green	406
Vat Black 8	Mikethrene grey m.	Vat dye	71000	Violet	578
Vat Yellow 1	Mikthrene yellow	Vat dye	70600	Yellow	587
Vat Green 13	Indanthrene olive mw.	Vat dye	—	Green	676
Vat Brown 1	Solathrene brown g.	Vat dye	70800	Brown	452
—	Textile industrial wastewater[a]	Mixed-vat dyes	—	Dark blue	605

[a]The colour of wastewater from a textile factory in Samuthpakarn province.

TABLE 3. Chemical properties of textile wastewater (TIWW) from a textile factory in Samuthpakarn province

Chemical properties	*Concentration*	
	Range	*Average*
COD (mg/L)	1524–3645	2290
BOD (mg/L)	281–975	400
Suspended solid (SS) (mg/L)	216–402	309
pH	7.32–8.12	7.60
Colour intensity (A_{608}) (units)	0.50–0.70	0.60

working volume was 7.5 L. Low-speed gear motors, model P 630A-387, 100V, 50/60 Hz, 1.7/1.3 A (Japan Servo Co. Ltd., Japan) were used for driving the paddle shape impeller. The speed of the impeller was adjusted to 60 rpm. One air pump system, model EK-8000, 6.0 W (President Co. Ltd., Thailand), was used for supplying air for two sets of reactors.

Operation of the SBR System

In each reactor, 1.4 L of 10 g/L acclimatized sludge was inoculated, and the STIWW or TIWW was added (final volume of 7.5 L) within 1 h. During feeding of the wastewater, the system had to be fully and continuously aerated for 19 h. Aeration was then shut down for 3 h. After the sludge was fully settled, the supernatant had to be removed (the removed volume of the supernatant was based on the operation program as mentioned in Tables 5 and 6) within 0.5 h, and the system had to be kept under anoxic conditions for 0.5 h. After that, fresh wastewater was filled into the reactor to the final volume of 7.5 L and the above operation repeated. The operation parameters of the SBR system with STIWW and TIWW are described in Tables 5 and 6.

Chemical Analysis

The BOD_5, COD, mixed-liquor suspended solids (MLSS), suspended solids (SS), pH and dissolved oxygen (DO) of the influents and effluents were determined by using Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WPCF 1985). The colour intensity of the wastewater was determined in optical density as the absorbance at the wavelength at which absorption was maximum (Table 2) after dilution with 0.1 M phosphate buffer (pH 7).

Results

Colourant Removal Ability of Biosludge

The results are shown in Tables 7 and 8. Both autoclaved and resting biosludge could remove colourants in the STIWW containing vat dye. The removal yield reached the maximum level within 2 h in both reaction systems and the autoclaved biosludge always showed a higher removal ability than the resting biosludge. The autoclaved and resting biosludge showed the highest removal ability at a pH of 3 and 7, respectively (Table 7). The Vat Black 25 and Vat Green 1 could be easily removed by both autoclaved and resting biosludge. The maximum Vat Black 25 removal abilities of autoclaved biosludge and resting biosludge were 85.54 ± 0.5 and 37.59 ± 0.6 mg/g of biosludge, respectively. The biosludge from different wastewater treatment plants showed different colourant removal abilities as shown in Table 8. Both autoclaved and resting biosludge type A (sludge age of 24 days) showed the highest removal ability for all types of vat dyes. Biosludge type B (sludge age of 18 days) and biosludge type C (sludge age of 17 days) did not show any difference in colour removal ability for all types of vat dyes as shown in Table 8.

Biological Treatment of STIWW by SBR System

The experiments were carried out in an SBR system with STIWW (BOD:COD ratio was 1:1.3) containing 40 mg/L of Vat Black dye 25 (the colour intensity was 0.23 units at 675 nm) under various HRT values as mentioned in Table 5. The results are shown in Table 9

TABLE 4. Chemical composition and properties of synthetic textile industrial wastewater (STIWW)

Chemical composition		*Chemical properties*	
Composition	*Concentration*	*Properties*	*Concentration*
Glucose (mg/L)	1875	COD (mg/L)	2000
Urea (mg/L)	115	BOD_5 (mg/L)	1350
$FeCl_2$ (mg/L)	3.5	TKN (mg/L)	100
$NaHCO_3$ (mg/L)	675	SS (mg/L)	—
KH_2PO_4 (mg/L)	55	Colour intensity (Abs 608 nm) (units)	0.23
$MgSO_4.7H_2O$	42.5	pH	7.2
Vat dye (units)[a]	40		

[a]Six kinds of vat dyes, as shown in Table 2, were used as the colourant in the STIWW.

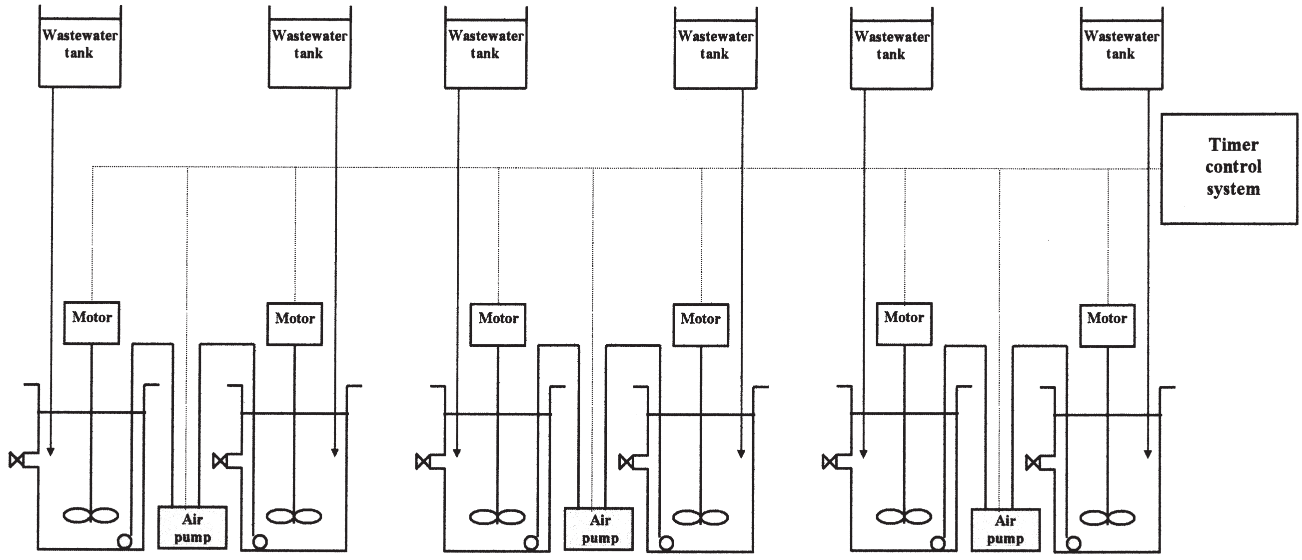

Fig. 1. Flow diagram of sequencing batch reactor system.

and Fig. 2. The SBR system became steady within 5 days of cultivation and the system showed almost stable removal efficiencies during the 1-month operation as shown in Fig. 2. The removal efficiencies of the system were higher than 95%, even when the system was operated under a BOD_5 loading of up to 0.45 kg BOD_5/m^3-d, as shown in Table 8. COD, BOD_5, TKN, SS and colour intensity in the effluent were 80 ± 1.4 mg/L, 58 ± 2.9 mg/L, 2.2 ± 0.02 mg/L, 40 ± 0.05 mg/L and 0.016 ± 0.002 units, respectively. The removal efficiencies increased with the decrease of BOD_5 loading as shown in Table 9. For example, the colour removal efficiency increased from 75.0 ± 5.4% to 90.6 ± 3.7% when the BOD_5 loading was decreased from 0.45 to 0.11 kg BOD_5/m^3-d. The effluent SS were not lower than 30 mg/L in all of the studied cases (Table 9).

TABLE 5. Operation parameters of sequencing batch reactor (SBR) system with synthetic textile wastewater (STIWW)

	Hydraulic retention time (HRT) (days)				
Parameter	*3*	*5*	*7*	*10*	*12*
Flow rate (mL/d)	2500	1500	1070	750	625
Hydraulic loading (m^3/m^3-d)	0.33	0.20	0.15	0.10	0.08
F/M ratio	0.22	0.13	0.10	0.07	0.06
BOD_5 loading (g BOD_5/d)	3.38	2.03	1.43	0.98	0.83
Volumetric BOD_5 loading (kg BOD_5/m^3-d)	0.45	0.27	0.19	0.13	0.11
Colourant loading (g colourant/d)	0.098	0.060	0.038	0.030	0.023
Volumetric colourant-loading (kg colourant/m^3-d)	0.013	0.008	0.005	0.004	0.003

TABLE 6. Operation parameters of sequencing batch reactor (SBR) system with textile wastewater (TIWW)

	Hydraulic retention time (HRT) (days)				
Parameter	*3*	*5*	*7*	*10*	*12*
Flow rate (mL/d)	2500	1500	1070	750	625
Hydraulic loading (m^3/m^3-d)	0.33	0.20	0.15	0.10	0.08
F/M ratio	0.07	0.04	0.03	0.02	0.02
BOD_5 loading (g BOD_5/d)	1.00	0.60	0.43	0.30	0.25
Volumetric BOD_5 loading (kg BOD_5/m^3-d)	0.13	0.08	0.06	0.04	0.03
Colourant loading (g colourant/d)	0.255	0.158	0.098	0.083	0.060
Volumetric colourant loading (kg colourant/m^3-d)	0.034	0.021	0.013	0.011	0.008

TABLE 7. Effect of the pH on the colour adsorption capacity of the biosludge type A

Type of dye	*Type of biosludge*	*Adsorption capacity under various pH conditions (mg/g of biosludge)*										
		3.0	*4.0*	*5.0*	*6.0*	*6.5*	*7.0*	*7.5*	*8.0*	*9.0*	*10.0*	*11.0*
Vat Black 25	Resting biosludge				35.0 ± 0.4	36.1 ± 0.6	37.6 ± 0.5	37.2 ± 0.7	35.4 ± 0.4			
	Autoclaved biosludge	85.5 ± 0.8	70.9 ± 0.9	40.7 ± 0.5	37.3 ± 0.4		35.9 ± 0.3		35.4 ± 0.6	33.5 ± 0.4	32.7 ± 0.3	26.5 ± 0.8
Vat Green 1	Resting biosludge				36.7 ± 0.3	37.7 ± 0.5	38.7 ± 0.6	38.2 ± 0.4	37.4 ± 0.7			
	Autoclaved biosludge	87.3 ± 0.6	79.5 ± 0.5	69.8 ± 0.7	62.6 ± 0.4		62.1 ± 0.3		61.0 ± 0.5	60.4 ± 0.7	51.0 ± 0.6	48.0 ± 0.3
Vat Black 8	Resting biosludge				35.3 ± 0.5	36.4 ± 0.4	37.8 ± 0.3	37.4 ± 0.7	35.9 ± 0.5			
	Autoclaved biosludge	78.3 ± 0.3	63.3 ± 0.6	46.2 ± 0.4	40.0 ± 0.4		36.1 ± 0.6		35.8 ± 0.5	33.1 ± 0.4	29.2 ± 0.3	19.3 ± 0.3
Vat Yellow 1	Resting biosludge				33.5 ± 0.5	35.9 ± 0.6	38.2 ± 0.8	38.2 ± 0.3	34.7 ± 0.4			
	Autoclaved biosludge	73.9 ± 0.6	61.4 ± 0.5	42.0 ± 0.4	31.1 ± 0.3		27.0 ± 0.2		25.5 ± 0.5	20.2 ± 0.2	18.3 ± 0.8	16.1 ± 0.6
Vat Green 13	Resting biosludge				34.7 ± 0.1	35.5 ± 0.4	36.8 ± 0.6	36.5 ± 0.4	35.2 ± 0.3			
	Autoclaved biosludge	81.0 ± 0.7	66.3 ± 0.7	51.5 ± 0.6	43.5 ± 0.4		41.3 ± 0.5		40.1 ± 0.7	39.8 ± 0.8	35.8 ± 0.9	32.7 ± 0.4
Vat Brown 1	Resting biosludge				37.0 ± 0.6	38.0 ± 0.8	38.7 ± 0.5	38.5 ± 0.7	37.1 ± 0.4			
	Autoclaved biosludge	85.4 ± 0.4	77.1 ± 0.7	51.1 ± 0.5	42.9 ± 0.7	33.2 ± 0.3	32.7 ± 0.7	31.3 ± 0.3	18.3 ± 0.8	15.0 ± 0.5	85.4 ± 0.4	77.1 ± 0.4

Biological Treatment of TIWW by SBR System

The COD:BOD_5 ratio of TIWW was 4:1 and the colour intensity was 0.60 units at 605 nm. The SBR system became steady within 10 days of culturing and the organic removal efficiencies (COD and BOD_5) were not stable during operation (30 days operation), as shown in Fig. 3. The removal efficiencies decreased with the increase of BOD_5 loading as shown in Table 9. The BOD_5 and colour removal efficiencies decreased by about 10% with the increase of BOD_5 loading from 0.03 to 0.13 kg BOD_5/m^3-d. The values of COD, BOD_5, TKN, SS and colour intensity in the effluent under a BOD_5 loading of 0.13 kg BOD_5/m^3-d were 278 ± 8.3 mg/L, 120 ± 4.3 mg/L, 8.9 ± 0.03 mg/L, 30 ± 0.04 mg/L and 0.034 ± 0.002 units, respectively.

Comparison of the Efficiency of SBR System with STIWW and TIWW

The results of the comparison of the efficiency of the SBR system with STIWW and TIWW are shown in Table 9. The SBR system with STIWW showed a higher removal efficiency than that with TIWW. The BOD_5 and colour removal efficiency of the SBR system under a BOD_5 loading of 0.13 kg BOD/m^3-d with STIWW were about 28% and 3% higher than with TIWW (Table 9). The effluent quality, especially COD and BOD_5, of the system with STIWW was more stable than with TIWW during operation (Table 9, Fig. 2 and 3). The SS value in the effluent of the system with STIWW and with TIWW under the same BOD_5 loading did not show any difference, as shown in Table 9. Also, the colour removal efficiencies of the system with STIWW and TIWW did not differ.

Discussion and Conclusion

The biosludge of the wastewater treatment plants clearly removed colourants in TIWW. The colourant removal ability of the autoclaved biosludge was about two times higher than that of the resting biosludge and the removal yield with the autoclaved biosludge increased in proportion to the increased biosludge mass in the reaction (Ohmomo et al. 1988). These results show that the main colour removal activity of this biosludge is due to the adsorption of colourants (vat dyes) by the biosludge. The adsorption mechanism of this biosludge might be similar to that of the melanoidin adsorption mechanism in *Rhizoctonia* sp. and *Aspergillus oryzae* (Sirianuntapiboon et al. 1991; Ohmomo et al. 1988). The maximum adsorption ability of autoclaved biosludge was obtained under acidic conditions (pH 3), because the low pH induced a positive charge of adsorption sites on the surface of the cells (biosludge) to react with the negative charge of the vat dye (Rubin 1978). However, the resting biosludge

TABLE 8. Maximum colour adsorption capacity of resting and autoclaved biosludge from various wastewater treatment plants[a]

Source of biosludge	Type of biosludge	*Adsorption capacity of biosludge in various types of vat dye (mg/g biosludge)*					
		Vat Black 25	*Vat Green 1*	*Vat Black 8*	*Vat Yellow 1*	*Vat Green 13*	*Vat Brown 1*
Biosludge type A	Resting biosludge	37.59 ± 0.6	38.7 ± 0.6	37.75 ± 0.3	38.23 ± 0.4	36.83 ± 0.7	38.74 ± 0.3
	Autoclaved biosludge	85.54 ± 0.5	87.29 ± 0.3	76.26 ± 0.4	73.90 ± 0.5	81.04 ± 0.4	85.36 ± 0.4
Biosludge type B	Resting biosludge	37.22 ± 0.3	37.95 ± 0.7	36.20 ± 0.7	37.05 ± 0.7	37.49 ± 0.5	38.27 ± 0.5
	Autoclaved biosludge	76.34 ± 0.4	85.89 ± 0.6	69.73 ± 0.2	70.46 ± 0.4	66.38 ± 0.8	74.13 ± 0.4
Biosludge type C	Resting biosludge	35.55 ± 0.6	38.36 ± 0.7	36.72 ± 0.5	35.29 ± 0.3	36.83 ± 0.6	36.88 ± 0.6
	Autoclaved biosludge	75.94 ± 0.9	85.57 ± 0.5	72.92 ± 0.6	75.46 ± 0.6	76.90 ± 0.4	79.77 ± 0.2

[a]The resting biosludge and autoclaved biosludge were tested under optimal pH of 7 and 3, respectively.

TABLE 9. Effluent qualities and removal efficiencies of SBR system with textile industrial wastewater (TIWW) and synthetic textile industrial wastewater (STIWW)[a]

Type of wastewater	BOD_5 loading (kg/m^3-d)	*Chemical properties* COD Effluent (mg/L)	COD % Removal	BOD Effluent (mg/L)	BOD % Removal	TKN Effluent (mg/L)	TKN % Removal	Colour intensity Effluent absorbency	Colour intensity % Removal	Suspended solid Effluent (mg/L)	Waste sludge (mg/d)	SRT (days)
TIWW	0.13	278 ± 8.3	89.0 ± 8.4	120 ± 4.3	70.1 ± 4.4	8.9 ± 0.03	85.4 ± 3.0	0.034 ± 0.002	84.9 ± 2.0	30 ± 0.04	1 250	12
	0.08	246 ± 6.2	90.3 ± 6.3	104 ± 6.4	74.0 ± 6.3	5.6 ± 0.05	90.8 ± 5.1	0.027 ± 0.003	88.0 ± 4.8	30 ± 0.03	1 000	15
	0.06	215 ± 5.3	91.5 ± 5.5	92 ± 5.9	77.0 ± 5.7	5.4 ± 0.04	91.1 ± 4.2	0.023 ± 0.001	89.8 ± 7.1	25 ± 0.03	940	16
	0.04	190 ± 9.7	92.5 ± 9.2	89 ± 4.1	77.8 ± 4.2	3.7 ± 0.03	93.9 ± 3.3	0.018 ± 0.001	92.0 ± 6.3	21 ± 0.02	840	18
	0.03	168 ± 4.6	93.3 ± 4.5	80 ± 3.7	80.1 ± 3.4	2.6 ± 0.06	95.7 ± 6.1	0.011 ± 0.002	95.1 ± 2.7	20 ± 0.02	750	20
STIWW	0.45	80 ± 1.4	96.8 ± 1.3	58 ± 2.9	95.7 ± 2.7	2.2 ± 0.02	92.7 ± 2.4	0.016 ± 0.002	75.0 ± 5.4	40 ± 0.05	3 750	4
	0.27	56 ± 1.6	97.8 ± 1.7	48 ± 2.5	96.5 ± 2.5	1.7 ± 0.07	94.5 ± 7.2	0.012 ± 0.001	81.2 ± 6.7	35 ± 0.04	2 500	6
	0.19	44 ± 1.7	98.3 ± 1.4	34 ± 2.1	97.5 ± 2.2	1.1 ± 0.01	96.4 ± 1.8	0.010 ± 0.003	84.4 ± 3.7	32 ± 0.03	1 875	8
	0.13	44 ± 1.3	98.3 ± 1.2	26 ± 1.4	98.1 ± 1.5	0.6 ± 0.01	98.2 ± 1.9	0.008 ± 0.001	87.5 ± 5.1	30 ± 0.03	1 250	12
	0.11	42 ± 1.1	98.3 ± 1.0	26 ± 1.1	98.1 ± 1.2	0.6 ± 0.01	98.2 ± 2.1	0.006 ± 0.002	90.6 ± 3.7	30 ± 0.03	1 000	15

[a] STIWW contained 40 mg/L of Vat Back 25 as colourant. Colour intensity (A675 nm) was 0.23 units. Colour intensity of TIWW ($A608_{nm}$) was 0.60 units.

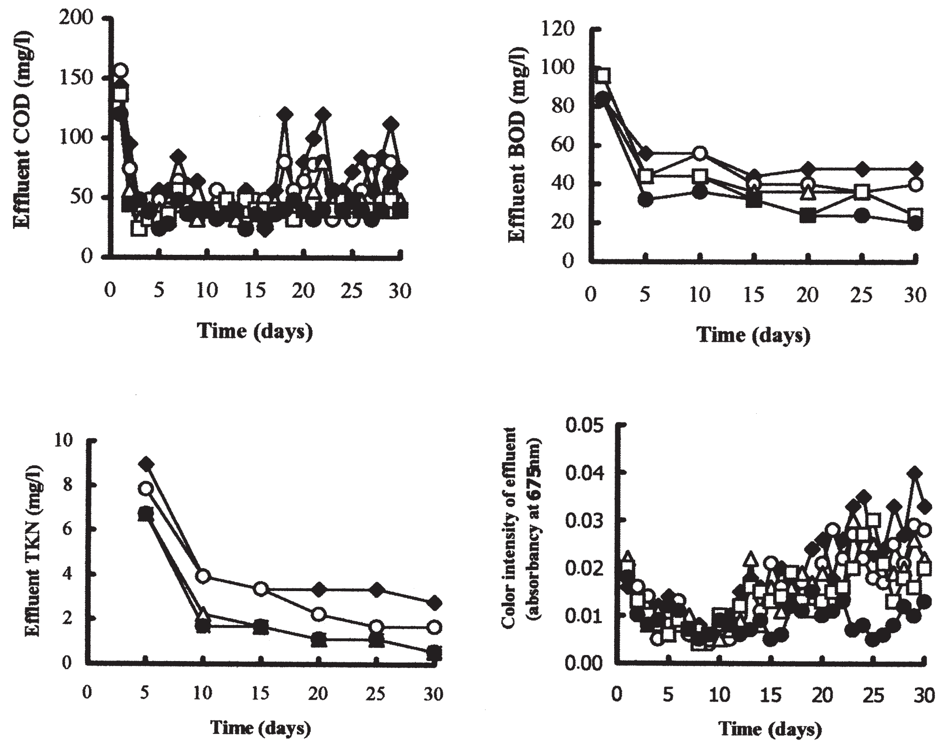

Fig. 2. Chemical profiles of effluents of SBR system operated with STIWW containing 40 mg/L of Vat Black 25 under HRT of 3, 5, 7, 10 and 12 h. Symbols: ◆ = BOD loading of 0.45 kg BOD_5/m^3-d; O = BOD loading of 0.27 kg BOD_5/m^3-d; △ = BOD loading of 0.19 kg BOD_5/m^3-d; □ = BOD loading of 0.13 kg BOD_5/m^3-d; and BOD loading of 0.11 kg BOD_5/m^3-d.

showed an optimum adsorption ability under pH 7. It can be suggested that stronger acidic and basic conditions had a negative effect on the growth of the cells (biosludge), and thus the adsorption ability decreased (Ohmomo et al. 1988). The adsorption ability of the biosludge increased with an increase in biosludge age (SRT), as shown in Table 9. The biosludge type A (SRT of 24 days) showed a higher adsorption ability than biosludge type B (SRT of 18 days) and type C (SRT of 17 days), as shown in Table 8. This can be explained in

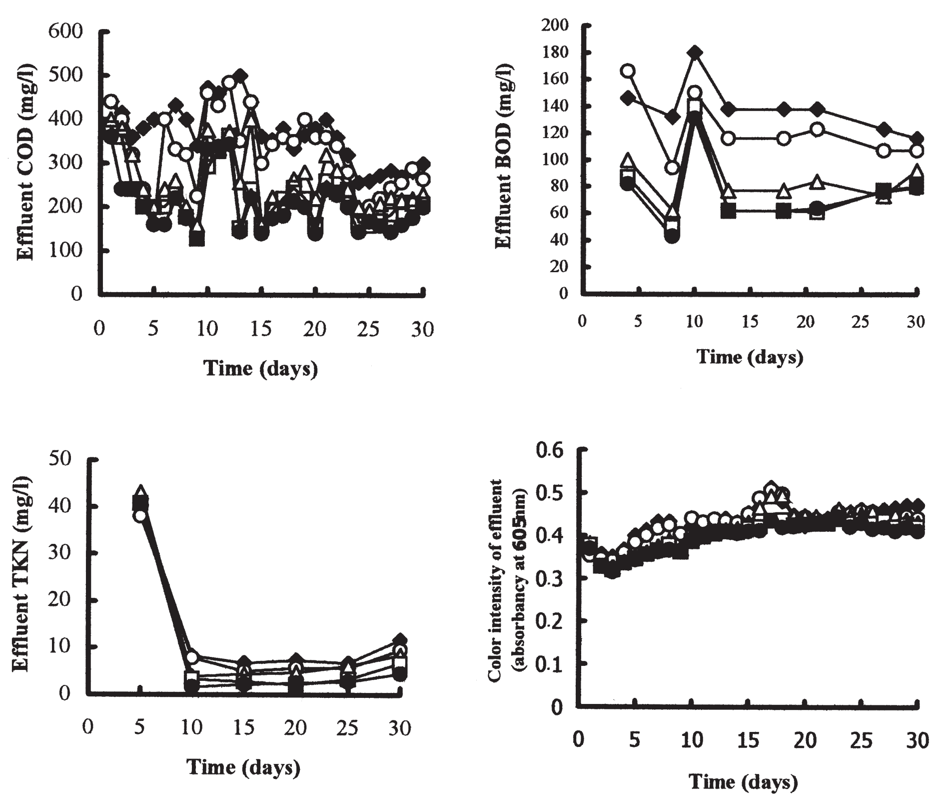

Fig. 3. Chemical profiles of effluents of SBR system operated with TIWW under HRT of 3, 5, 7, 10 and 12 h. Symbols: ◆ = BOD loading of 0.13 kg BOD_5/m^3-d; O = BOD loading of 0.08 kg BOD_5/m^3-d; △ = BOD loading of 0.06 kg BOD_5/m^3-d; □ = BOD loading of 0.04 kg BOD_5/m^3-d; ● = BOD loading of 0.03 kg BOD_5/m^3-d.

that biosludge with a longer SRT has more adsorption sites than biosludge with a shorter SRT, similar to the report by Nelson and Shivaraman (1988). In practice, the autoclaved biosludge from the wastewater treatment plant that was operated under an SRT of longer than 20 days, such as from the extended aeration activated sludge system, might be most suitable. However, the use of autoclaved biosludge as an adsorber still has many disadvantages, similar to activated carbon (Sirianuntapiboon and Chaiyasing 2000). The results show that the SBR system could remove both organic matter and colourants from TIWW and STIWW and that the removal efficiencies of the system were almost stable during operation (30 days culture), as shown in Fig. 2 and 3. However, the organic matter removal efficiency (COD and BOD_5) of the system with TIWW was lower than with STIWW because the STIWW contained glucose as easily biodegradable compounds (BOD_5:COD = 1:1.3) while TIWW contained several types of organic matter that were poorly biodegradable compounds (BOD_5:COD = 1:4). Even so, the SBR system did not show any difference in the colour removal yield of both TIWW and STIWW. This was because the colour removal yield depended on the biosludge age (SRT) and mass. The effluent SS of the system also increased due to the reduction of the sludge age which resulted from the increase of BOD_5 loading (Metcalf and Eddy Inc. 1991). It was concluded that the usual aerobic biological treatment systems such as activated sludge or SBR systems could be applied to remove textile dyes, especially vat dyes, from wastewater by increasing the SRT or sludge age. The advantage of such a system is that both organic matter and colourants can be removed at the same time by both bioadsorption and biodegradation mechanisms.

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