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Feasibility of a two-stage biological aerated filter for depth processing of electroplating-wastewater

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ABSTRACT

A "two-stage biological aerated filter" (T-SBAF) consisting of two columns in series was developed to treat electroplating-wastewater. Due to the low BOD/CODcr values of electroplating-wastewater, "twice start-up" was employed to reduce the time for adaptation of microorganisms, a process that takes up of 20 days. Under steady-state conditions, the removal of CODcr and NH_4^+-N increased first and then decreased while the hydraulic loadings increased from 0.75 to 1.5 $m^3\,m^{-2}\,h^{-1}$. The air/water ratio had the same influence on the removal of CODcr and NH_4^+-N when increasing from 3:1 to 6:1. When the hydraulic loadings and air/water ratio were 1.20 $m^3\,m^{-2}\,h^{-1}$ and 4:1, the optimal removal of CODcr, NH_4^+-N and total-nitrogen (T-N) were 90.13%, 92.51% and 55.46%, respectively. The effluent steadily reached the wastewater reuse standard. Compared to the traditional BAF, the period before backwashing of the T-SBAF could be extended to 10 days, and the recovery time was considerably shortened.

1. Introduction

Electroplating, one of the oldest industries concentrating on surface finishing and metal deposition, generates large amounts of toxic wastewater. The primary contaminants in the wastewater are heavy metal ions and high polymer organic substances that are difficult to degrade biologically (Cavaco et al., 2007). Various effective treatment processes are available for the removal of metal ions, such as chemical precipitation, lime coagulation, ion exchange, reverse osmosis, and solvent extraction (Marina et al., 2007; Panayotova et al., 2007). Lime coagulation and reverse osmosis can also effectively remove high polymer organic substances, but the costs of equipment and operation are prohibitively expensive. The literature (Taira and Hiroshi, 2004) suggests that the use of biological treatments may be at least as effective and cheaper to degrade high polymer organic substances. However, utilizing traditional biological methods the removal of these substances to low levels remains difficult due to the low BOD/CODcr (B/C) values of electroplating-wastewater. Furthermore, the investment required and footprint is gigantic (Suntud et al., 2008).

The biologically aerated filter (BAF) is a new, flexible and effective bioreactor that requires less space than traditional biological methods and can process a range of wastewaters. It can be utilized widely in the tertiary processing stages of wastewater treatment, removing simultaneously BOD, suspended solids (SS) and T-N to generate water suitable for reuse (Rogalla and Bourbigot, 1990). However, the BAF also has certain disadvantages. Firstly, the inlet concentration of SS should be less than 60 mgL^{-1}; above that level, excessive time-consuming backwashing is required. Secondly, traditional BAF cannot effectively cleanse industrial wastewater with low B/C values.

To solve these problems, T-SBAF was developed for tertiary level treatment, enabling urban reuse of wastewater from the electroplating process. In order to reduce the SS, two series-wound columns associated with a new reactor were designed. An anaerobic biofilter was packed with floating material to intercept and capture the SS to ensure the normal operation of an aerobic biofilter. Hydrolyzation and acidization in the anaerobic biofilter makes the high polymer organic substances decompose into smaller molecules more amenable to bio-degradation in the following aerobic biological treatment which occurs in the second column (Allan et al., 1999; Kocadagistan et al., 2005; Osorio and Hontoria, 2002).To our knowledge, there are no reports on a T-SBAF for purifying industrial wastewaters with low B/C values.

This paper assesses the feasibility of T-SBAF for purifying wastewater from the electroplating process. Factors affecting the removal of toxic compounds in electroplating-wastewater, including hydraulic loadings, air/water ratios and backwashing, were also investigated.

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2. Methods

2.1. Reactor description

The laboratory-scale T-SBAF reactor, made of acrylics, had a dimension of $L \times B \times H = 200 \times 100 \times 600$ mm. It consisted of two columns in series (volume ratio 2:3). The first column was an anaerobic biofilter and operated downflow, and the second was an upflow aerobic biofilter. The two columns were connected by means of a valve located on the bottom of the mid-clapboard. It enabled independent backwashing of each column. A schematic diagram of the reactor is shown in Fig. 1.

The anaerobic biofilter was packed with elliptically-shaped, floating foam made from waste wrappage polystyrene. The size of each particle of the packing foam ranged from 6 to 8 mm, and the density was 0.85 g cm^{-3}. The aerobic biofilter was filled with elliptical, sunken light granular ceramics; with a density of 1.76 g cm^{-3} and particle size of 4–6 mm. Both columns were packed 300 mm high. Water samples were taken from five different locations numbered $1^{\#}$ to $5^{\#}$ in Fig. 1.

The system operates, firstly by downflow, and then upflow, in the linked vessels. At the outlet of the system, 50% of the effluent goes back to the influent to enhance denitrification in the anaerobic biofilter. Although organic substances and SS loading of the influent resulted in filter clogging in the upper part of anaerobic biofilter, backwashing of the anaerobic biofilter is easier than the aerobic biofilter because of the floating packaging foam compared to sunken materials. After being filtered in the anaerobic biofilter, the influent which continues to contain a small amount of SS enters the aerobic biofilter where the likelihood of clogging is greatly reduced making the cleaning cycle much less frequent.

2.2. Wastewater characteristics

The wastewater used for the feasibility study was obtained from an electroplating plant in the Luhe District of Nanjing. Electroplating-wastewater contains heavy metal ions such as Ni^{2+}, Zn^{2+}, Pb^{2+}, and Cr^{2+} and so on, all of which are difficult to remove by bio-chemical methods. Physico-chemical pretreatments were therefore used. Lime was used to neutralize the acidity of the wastewater, to a pH of 7–9. Afterwards, *N*,*N*-dithio-carboxyl diethylenetriamine ethyl polymer (a heavy metal chelating agent) was added in order to precipitate the majority of metal ions. Pretreated electroplating-wastewater samples were collected weekly in clean 50 L plastic containers. The characteristics of the wastewater are summarized in Table 1. Based on the average B/C of 0.196, the quality of the pre-treated wastewater was obviously too low for regular biological treatments.

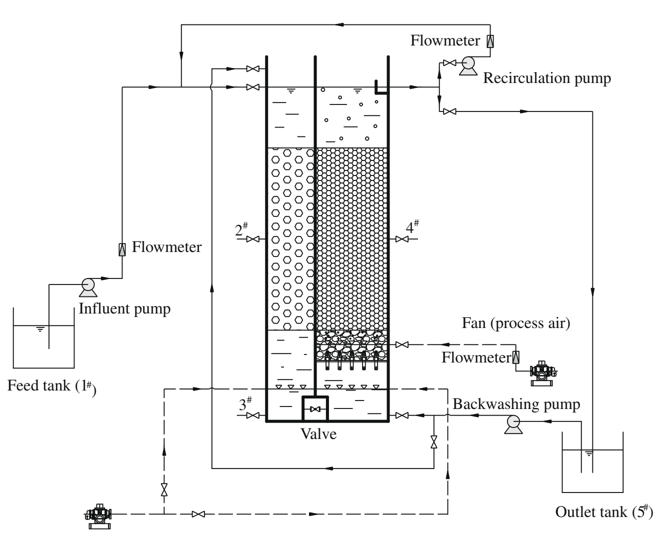

Fig. 1. Schematic diagram of the T-SBAF experimental reactor.

Table 1
The characteristics of original wastewater.

Amount (mgL^{-1})	Characteristic parameter of the wastewater					
	BOD	CODcr	$NH_4^+ - N$	T-N	SS	pH
Maximum	41.37	206.61	20.92	24.32	112.73	8.0
Minimum	29.45	163.73	15.47	17.69	89.38	7.5
Average	36.51	186.27	17.12	19.95	109.41	7.8

2.3. Analytical methods

Samples were analyzed for SS, COD, T-N, $NH_4^+ - N$, and $NO_3^- - N$ in accordance with the USA Standard Methods for the Examination of Water and Wastewater (APHA, 1998). BOD was measured using a 3–Star BOD meter; temperature and pH were measured using a Crison GLP 22 pH-meter, and dissolved oxygen (DO) was determined with a JPBJ-608 dissolved oxygen measurer. SS was measured by the weight method. COD was analyzed using the potassium dichromate method. The Nessler reagent colorimetric method was used to measure the concentration of $NH_4^+ - N$, and the spectrophotometric analysis kits were applied to analyze T-N.

2.4. Bacterial source

The degrading bacteria came from activated sludge from the Wastewater Treatment Plant in Nanjing. The plant employed Kalusaier Oxidation Ditch technology, with the processing ability of 100,000 tonnes per day, the major sources of which were domestic wastewater and mixed industry wastewaters, including electroplating-wastewater. The influent was 200–300 mgL^{-1} in COD and 5–10 mgL^{-1} in $NH_4^+ - N$. Those values were reduced, respectively, to 40–50 mgL^{-1} in COD and 2–5 mgL^{-1} in $NH_4^+ - N$ after treatment; within the urban sewage emission standards at the national level 1 of China.

2.5. Measurement of the biofilm

The Ceramsite filter (20 g, wet height) was sampled and placed in a 100 mL triangular bottle with a stopper. The biomass was measured by the Lipid-P method (Yu et al., 2002). The final results were expressed as nmol Pg^{-1} Ceramsite filter, with 1 nmol P equal to about 10^8 cells with the size of colibacillus. The Ceramsite filter used to analyse the biomass was sampled at 0.3 m from the bottom of the aerobic biofilter of the T-SBAF.

3. Results and discussion

3.1. Systematic start-up

Owing to the low B/C value of the electroplating-wastewater, the "twice start-up" system was employed to shorten the time of biofilm formation.

The anaerobic biofilter of the T-SBAF is easily inoculated using natural inoculum. The "twice start-up" process mainly targeted optimization of processes in the aerobic biofilter.

The initial startup involved activated sludge being placed in the reactor to occupy about 10% of the space. The feed water was a