Biological aerated filter treated textile washing wastewater for reuse after ozonation pre-treatment


ABSTRACT

The combination of chemical and biological treatment processes is a promising technique to reduce refractory organics from wastewater. Ozonation can achieve high color removal, enhance biodegradability, and reduce the chemical oxygen demand (COD). The biological technique can further decrease COD of wastewater after ozonation as a pre-treatment. In this study the ozonizing-biological aerated filter processes were used to treat textile washing wastewater for reuse after conventional treatment. The result showed that when the influent qualities were COD about 80 mg/L, color 16 degree and turbidity about 8 NTU, using the combination processes with the dosages of ozone at 30–45 mg/L with the hydraulic retention time (HRT) of biological aerated filter (BAF) at 3–4 hours respectively, gave effluent qualities of COD less than 30 mg/L, color 2 degree and turbidity less than 1NTU. The cost of treatment was less than one yuan/t wastewater, and these processes could enable high quality washing water reuse in textile industry.

Key words | biological aerated filter, ozonation, washing wastewater, water reuse

INTRODUCTION

Large volumes of water are consumed in textile industry, about 120–280 L of water for every kilogram of cloth processed (Perkins 1999), so it is very important to seek the efficient use of water. The increasingly strict limitations of environmental regulations for wastewater disposal will increase the cost of wastewater treatment. The water resource scarcity and increasing water prices call for water reuse in the textile industry on a large scale.

Conventional treatment (mainly physicochemical or biological treatments) could remove most organic pollutants, but most refractory organics remain in the wastewater without appropriate treatment. In order to reuse water the refractory organics must be removed. The optimal treatment process with high quality effluent and low operating cost must be selected, and moreover appropriate operating conditions of the wastewater treatment processes are required.

The degradation of the organic pollutants in the washing wastewater of textile was studied by some treatment processes, which used ozone, Advanced Oxidation Processes (AOPs), and membrane filtration procedures. Two schemes were conducted: firstly, a single ozonation stage followed by an UF stage; and secondly, a membrane filtration stage, using different MF and UF membranes, followed by a chemical oxidation stage. Ozone, UV radiation, and the AOPs constituted by ozone plus UV radiation or ozone plus hydrogen peroxide were used (Glaze et al. 1987; Huang & Shu 1995).

More specifically, ozone is a powerful oxidizing agent that may react with organic compounds either directly or via radicals formed in a chain reaction as OH radicals. Ozone can be used in wastewater treatment to reduce COD, color, toxicity and pathogens and to improve wastewater biodegradability, see Hoigne (1998), Ciardelli et al. (2001), Bertanza et al. (2001).

However, there is a clear limitation of filtration processes through membranes because of membrane fouling; this effect is associated with a decline in the permeate flux with
processing time (Kweon & Lawler 2004). Specifically, the washing wastewater contains some polysiloxane, which accelerates damage to membranes and shortens the working life of membranes.

In this study, a combination process of ozonation and biological aerated filter was used to treat the textile washing wastewater. Ozone can be used in this washing wastewater to reduce COD, color, and to improve wastewater biodegradability. After ozone pre-treatment the organic matter was further removed by the biological aerated filter (BAF), which incorporates an inert medium to support biomass and filter out suspended solids (Pujol et al. 1994; Stephenson 1997). BAF is an alternative to the traditional activated sludge process. It is very effective in removing suspended solids (SS), COD, biochemical oxygen demand (BOD), especially for wastewater at low loads of SS and COD.

The main objective of this work was the study of a biologically treated washing wastewater with ozone as a pre-treatment. First, initial pH, ozone dosages and H₂O₂ dosages as catalyst had to be examined. Then, remaining organic matter was removed by BAF, and the effect of hydraulic retention time (HRT) of BAF was considered.

MATERIALS AND METHODS

Characteristics of wastewater

Wastewater was collected from washing water of one textile plant in Gaoming town, Guangdong province, China. It was treated by anaerobic–aerobic processes; the characteristics of the washing wastewater effluent by anaerobic–aerobic were shown in Table 1.

Apparatus and methods

The experimental apparatus was mainly composed of two parts: one was the ozone oxidation equipment, while the other part was biological aerated filter treatment apparatus. Figure 1 shows the schematic of the process. The details of the equipments are listed in Table 2.

The ozonation oxidation treatment: ozonation-gas was injected to wastewater by venturi, and mixed uniformly by circulating pump, so ozonation could oxidize the organics with higher efficiency.

Table 1 | The characteristics of the washing wastewater effluent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Discharged limit†</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD (mg/L)</td>
<td>65–120</td>
<td>&lt;30</td>
</tr>
<tr>
<td>BOD₅ (mg/L)</td>
<td>10–20</td>
<td>&lt;5</td>
</tr>
<tr>
<td>pH Value</td>
<td>6–9</td>
<td>6–8</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>6–8</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Color (degrees)</td>
<td>16–32</td>
<td>2–4</td>
</tr>
</tbody>
</table>

†Sampling period was from March 2007 to July 2007.

The BAF treatment: an up-flow BAF was used. The media were ceramic balls with size range of 3–5 mm.

All samples in the experiments were measured by standard methods of China.

RESULTS AND DISCUSSION

Ozonation oxidation experiment

Effect of initial pH

Initial wastewater pH was adjusted to the desired value with sulfuric acid or sodium hydrate. Under acid conditions ozone can mainly react directly with organic compounds. Under alkaline conditions ozone can mainly decompose to OH radicals (OH), which react with the target compound (Von Gunten 2003; Koch 2002). Figure 2 shows that effect of initial pH on COD removal efficiency. The COD removal rate was maximum at pH = 7, which achieved 26.1% with O₃ = 45 mg/L. It was not beneficial to oxidation under acid conditions in this washing wastewater, because the COD
removal rate was lowest compared to under neutral and alkaline condition.

The initial pH value of wastewater was about 7, which suited the ozonation oxidation condition well, therefore, the initial pH was not changed for ozonation oxidation.

**Effect of initial COD concentration**

Figure 3 showed the difference in the initial COD concentrations (from 68 to 114 mg/L) with dosages of ozonation from 0 to 90 mg/L. The rate of the COD removal was high at the beginning and then decreases with increasing the O3 dosages. The efficiency of COD removal increases with increasing initial COD concentrations. After the dosage was 45 mg/L the efficiency of COD removal scarcely increases with increasing the ozone dosage in the wastewater.

**Effect of H2O2 dosages**

Ozone has been demonstrated to be an effective oxidation technique for the oxidation of certain pollutants in water. However, other organic compounds such as aliphatic carbon chains, amides, and nitroso compounds cannot be effectively oxidized by ozone due to their low reactivity towards ozone. To enhance oxidation of ozone-resistant compounds, hydrogen peroxide (H2O2) can be added which enhances ‘OH production by accelerating ozone decomposition (Acero & Von Gunten 2001; Staehelin & Hoigne 1982).

As shown in Figure 4, H2O2 in the O3/H2O2 experiments was used with a ratio of n (O3)/n (H2O2) = 2. Adding H2O2 slightly enhanced the oxidation efficiency by accelerating ozone decomposition into ‘OH. The COD removal rate was 27.3% by addition of H2O2 compared to 26.1% by O3 alone at O3 = 45 mg/L.

**BAF experiment**

**Effect of ozonation dosage**

The wastewater was treated by the ozonizing - biological aerated filter processes in which the hydraulic retention
time of BAF was fixed at 3 h, the ratio of gas to liquid was 5 and the temperature of wastewater was 18–25°C. The ozone dosage was then varied. The experimental results are shown in Table 3 and 4. The COD removal rate of the non-ozone processes was only 15.7%, the color degrees and turbidity had slightly reduced. On the other hand, when the processes added ozone as pre-treatment, the removal rate of COD, color degrees and turbidity had increased significantly. When the dosage of ozone was 75 mg/L, COD removal rate of the wastewater was 83.2%, the color of effluent was reduced to about 2 degrees, and turbidity was 0.7 NTU.

**Effect of hydraulic retention time**

The effect of hydraulic retention time of BAF on COD removal efficiency was studied after ozonation oxidation pretreatment. We fixed the dosages of ozone at 30 and 45 mg/L and changed HRT of BAF from 2 to 4 hour. The treatment efficiencies of these processes with different HRT of BAF are shown in Figures 5 and 6.

Under ozone dosages of 30 and 45 mg/L respectively and hydraulic retention time of BAF at 2h, the average COD of effluent was about 36.8 mg/L and 26.4 mg/L; the COD average removal rate of the processes reached about 44% and 60%. In the case of a 3h HRT, the average COD was reduced to 28.6 mg/L, and 20.6 mg/L and the average removal rate was 56.7% and 68.7%. In the case of 4h, the average COD was decreased further to 23.4 mg/L and 18.6 mg/L, and the average COD removal rate went up to 64.5% and 71.8%. The processes showed excellent treatment efficiency for textile washing wastewater.

In order to meet the standard of water reuse (COD less than 30 mg/L), when the ozone dosages was 30 mg/L, HRT

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**Table 3** Effect of ozonation dosages on COD removal efficiency by ozonation and BAF process

<table>
<thead>
<tr>
<th>Ozonation dosages (mg/L)</th>
<th>COD (mg/L)</th>
<th>COD removal rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Influent</td>
<td>Pre-oxidation</td>
</tr>
<tr>
<td>0</td>
<td>74.5</td>
<td>74.5</td>
</tr>
<tr>
<td>15</td>
<td>76.8</td>
<td>64.6</td>
</tr>
<tr>
<td>30</td>
<td>80.3</td>
<td>65.9</td>
</tr>
<tr>
<td>45</td>
<td>78.6</td>
<td>63.1</td>
</tr>
<tr>
<td>60</td>
<td>88.2</td>
<td>64.5</td>
</tr>
<tr>
<td>75</td>
<td>75.2</td>
<td>60.2</td>
</tr>
</tbody>
</table>

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**Table 4** Effect of ozonation dosages on color and turbidity removal efficiency by ozonation and BAF process

<table>
<thead>
<tr>
<th>Ozonation dosages (mg/L)</th>
<th>Color (degree)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Influent Pre-oxidation Effluent</td>
<td>Influent Pre-oxidation Effluent</td>
</tr>
<tr>
<td>0</td>
<td>16 16</td>
<td>16</td>
</tr>
<tr>
<td>15</td>
<td>16 8</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>16 4</td>
<td>2</td>
</tr>
<tr>
<td>45</td>
<td>16 2</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>16 2</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>16 2</td>
<td>2</td>
</tr>
</tbody>
</table>

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**Figure 4** Effect of H₂O₂ dosages on COD removal rate (C COD: COD concentration, RCOD (%): removal of COD efficiency, pH: 7, T:18–25°C, n(O₃)/n(H₂O₂) = 2).
of BAF must be more than 3 h. When the ozone dosage was 45 mg/L, HRT of BAF could be 2 h.

Economy and technology analysis

A combination process of ozonation and biological aerated filter was used to treat textile washing wastewater. The conditions were as follow: pH = 7, the dosages of ozonation were 30–45 mg/L, HRT = 3–4 h, the ratio of gas to liquid was 5. After advanced treatment of the washing wastewater, COD was less than 30 mg/L, the color was 2 degrees, and turbidity was less than 1 NTU.

The treatment cost of this wastewater: 1 kg ozonation consumes about 20 kWh of electricity. The main cost of ozonation oxidation is electricity power, at about 0.42–0.63 yuan/t. The BAF process cost was about 0.3 yuan/t. The total cost was about 0.72–0.93 yuan/t.

CONCLUSIONS

The effects of pH and H₂O₂ addition on COD removal efficiency were not obvious. COD removal rate was slightly increasing with increasing COD concentration. The best COD removal rate was about 30% by ozonation alone.

The process added ozonation as pre-treatment, and the removal rate of COD had increased significantly by BAF treatment in the next step, which was more than 50% with the dosages of ozonation more than 30 mg/L, compared to 15.7% by BAF treatment alone.

The ozonation-biological aerated filter processes were a promising technique for washing wastewater advanced treatment. The most favorable conditions were: initial pH 7, the dosages of ozonation were 30–45 mg/L, the COD removal efficiency was about 30%; BAF processes: HRT = 2–3 h. The COD of the effluent by advanced treatment was less than 30 mg/L, the color was 2 degrees, and turbidity was less than 1 NTU. It could meet the standard for water reuse. The treatment cost of this washing wastewater was lower than one yuan/t.

REFERENCES