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ScienceDirect
Journal of Hazardous Materials 150 (2008) 109–114
Journal of Hazardous Materials
www.elsevier.com/locate/jhazmat

Degradation characteristics of secondary effluent of domestic wastewater by combined process of ozonation and biofiltration

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Received 2 September 2006; received in revised form 17 April 2007; accepted 17 April 2007
Available online 24 April 2007

Abstract

The performance of the combined process of ozonation and biofiltration was studied for treating the secondary effluent from sewage treatment plant. It was found that COD, NH_3–N, and TOC were removed from 40–52, 10–19, and 9–13 mg/L in the raw water to 18–23, 0.5–1.5, and 7–8.5 mg/L in the effluent water (removal efficiency were 58, 89, and 25%, respectively), respectively, with an ozone dose of 10 mg/L (0.7–1.1 mg O_3/(mg TOC) and 0.2–0.25 mg O_3/(mg COD)), and contacting time of 4 min. Under the operation conditions, ozonation enhanced the biodegradability of the organics in the secondary effluent, as illustrated by increasing biodegradable dissolved organic carbon (BDOC) value from 0.8–1.1 mg/L in the raw water to the 2.0–2.7 mg/L in the effluent water. Meanwhile, the percentage of the organics with molecular size less than 1 k Da in the secondary effluent increased from 52.9 to 72.6%. The experimental results supported the expectation that the combined process of O_3/Biofiltration might enhance the overall treatment efficiency of secondary effluent treatment.

Keywords: Ozonation; Biofilter; Advanced treatment; Secondary effluent of domestic wastewater

1. Introduction

Because of the increasing pressures of wastewater discharge on water supplies and the shortage of water resources, more and more attentions have been paid on the reuse of secondary effluent of municipal wastewater [1,2]. Especially, China is also facing serious water shortage problems [3,4], and advanced treatment of wastewater for reuse is thus in urgent need. The process of coagulation–flocculation–clarification–filtration is one of the well-known conventional processes for advanced treatment of municipal wastewater. However, it seems to have some obvious disadvantages such as large land occupation, complicated operation and sophisticated management despite of its acceptable treatment performance. Whereas, other attractive advanced treatment process such as microfiltration (MF) or ultrafiltration (UF) technology, which are in widespread use in the west countries, may be difficult to use at large in developing countries such as China at present, due to its possible higher costs. Therefore, it seems necessary to develop relatively low cost processes (including some combined processes) with relatively higher treatment efficiency.

Chemical oxidation can degrade organic compounds without any additional waste produced. The most common oxidants are ozone and H_2O_2 etc. Ozone is a very powerful oxidant (Redox potential 2.07 V for ozone *versus* 2.8 V for hydroxyl radical) for water and wastewater treatment. Once dissolved in water, ozone reacts with a large number of organic compounds in two possible ways: direct oxidation, as molecular ozone, or indirect reaction through the formation of secondary oxidants such as free radicals, particularly hydroxyl radical. Ozone treatment of several types of wastewaters, resulting in considerable organics elimination, had been reported by some researchers [5–7]. Furthermore, ozonation is expected to cause an increase of the biodegradable organic carbon for subsequent biological stages [8–10].

Biofilter originated in late 1980s and early 1990s in Europe [11], and is considered as an alternative to the traditional acti-

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doi:10.1016/j.jhazmat.2007.04.092

vated sludge process, which is commonly used in biological wastewater treatment. The primary advantages of the process are a reduced footprint resulting from the elimination of secondary clarifiers and their associated operational difficulties, and a low hydraulic retention time due to high biomass retention in the system. More important, less surplus sludge was produced during the operational period, which thus enormously reduced the surplus sludge treatment costs. Attentions about biofilters have been paid in wastewater treatment field [12–15] in the last two decades.

In general, biodegradable COD proportion in the secondary effluent of sewage, which can be indicated by biodegradable dissolved organic carbon (BDOC) is relatively low. In order to improve the treatment efficiency, it is necessary to increase BDOC of the influent to be treated biologically. As a powerful oxidant, ozone can transform some refractory organic matters to biodegradable organic ones, that is, BDOC, which can be removed more easily through biodegradation. The combined process of ozonation and biological treatment is one of the most promising processes among advanced treatment processes [16]. Based on the above description, chemical oxidation (ozonation in this study) as pretreatment unit of biochemical treatment (biofilter in this study) is necessary as well as promising for improving the treatment efficiency of secondary effluent.

The aim of the present study is to investigate the characteristics of degradation/conversion of organics, especially biorefractory organics, by combining preozonation with biofiltration for the treatment of secondary effluent from domestic wastewater treatment plant.

2. Material and methods

2.1. Water characteristics

The raw water in this study was the secondary effluent obtained from a conventional activated sludge system in Wenchang Municipal Wastewater Treatment Plant of Harbin in China, in which the anaerobic/aerobic (A/O) process was used. The raw water was firstly filtered by sand column with 300 mm in height to avoid the negative impact of suspended solid (SS) on the laboratory study, because the removal characteristics of the dissolved organics were focused in this study. The secondary effluent quality after filtration is shown in Table 1.

Table 1
Characteristics of the secondary effluent fed to ozonation/biofiltration system

Parameter	Range	Average
COD (mg/L)	40–55	52.5
BOD (mg/L)	11–15	13
TN (mg/L)	20–25	22.5
NH_3–N (mg/L)	10–20	13
TOC (mg/L)	9–13	11
UV_{254} (cm^{-1})	0.16–0.22	0.19

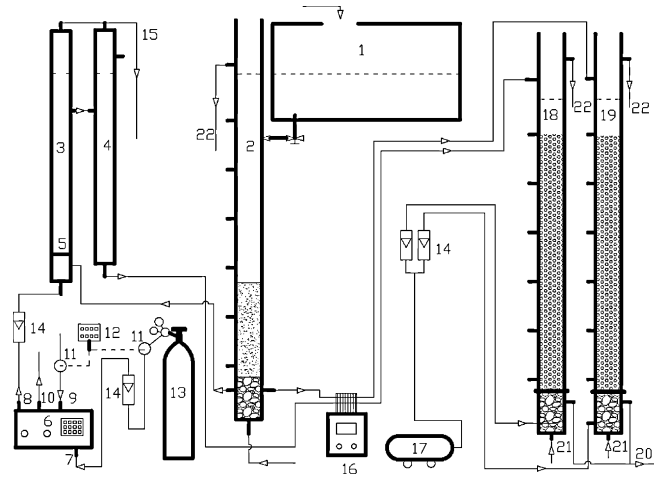

Fig. 1. The schematic diagram of the ozonation/biofiltration process (1) feed tank; (2) sand filter column; (3) ozonation reaction column; (4) retention column; (5) gas diffuser; (6) ozone generator; (7) oxygen feed inlet; (8) ozone outlet; (9) cooling water inlet; (10) cooling water outlet; (11) electromagnetic valve; (12) automatic controller; (13) oxygen bottle; (14) gas flowmeter; (15) outlet of residual ozone gas; (16) peristaltic pump; (17) air compressor; (18) No. 1 biofilter column; (19) No. 2 biofilter column; (20) biofilter outlet; (21) backwashing water inlet; (22) backwashing water outlet.

2.2. The experimental procedure

The schematic of the ozonation/biofiltration system is shown in Fig. 1. It consists of two treatment trains: biofiltration process and ozonation followed by biofiltration process (ozonation/biofiltration). The raw water was filtered by 300-mm high sand (Diameter 1–3 mm) column before it was sent to the ozonation column or pumped directly to the No. 2 biofilter column.

The biofilter columns are 2400 mm in height and 50 mm in inner diameter. The columns contained a clay-based media approximately 2–4 mm in diameter with an average specific surface area of 2–6 m^2/g. A percolated plate was placed in each column to support the 1600 mm media layers. Air was provided into the columns through a diffuser located near the bottom of the columns. The hydraulic flow rates were controlled in the range of 0.433–1.732 $m^3/(m^2/h^{-1})$ with the peristaltic pump. Each column was backwashed at irregular intervals (21–49 days) with combined air (6 L/min) and water (8 L/min) simultaneously.

Ozone was produced from pure oxygen using a DHX-SS-G1 ozone generator (Harbin Jiujiu Electrochemistry Engineering and Technology Company, China). The pure ozone dose was controlled at approximately 10 mg O_3/min for ozonation. During reaction, the ozone dose and residual amount of ozone were monitored to calculate the utilization efficiency and amount of ozone used. The ozonation reactor (glass-made) and retention column have working volume of 1.2 and 1.0 L, respectively. The ozone generator was controlled to work for 1 min every 40 min periodically (during working time, the two electromagnetic valves were of start-up to open the oxygen feed and the cooling water, respectively. At other time, both of the valves are shut down controlled automatically by the controller according to the flow rate of the influent and retention time. The amount of ozone used was 0.77 to 1.1 mg O_3/(mg TOC) and 0.2–0.25 O_3/(mg