Bioresource Technology 102 (2011) 1028–1034

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Case Study

Treatment of waste gas from the breather vent of a vertical fixed roof *p*-xylene storage tank by a trickle-bed air biofilter

Shenteng Chang [a], Chungsying Lu [a,*], Shihchieh Hsu [a], How-Tsan Lai [b], Wen-Lin Shang [b], Yeong-Song Chuang [b], Chi-Huang Cho [c], Sheng-Han Chen [c]

[a] *Department of Environmental Engineering, National Chung Hsing University, 402 Taichung City, Taiwan*
[b] *Bureau of Environmental Protection Taichung County, 420 Fongyuan City, Taichung County, Taiwan*
[c] *Main-Link Engineering Consultants Inc., 403 Taichung City, Taiwan*

ARTICLE INFO

Article history:
Received 14 June 2010
Received in revised form 24 September 2010
Accepted 28 September 2010
Available online 28 October 2010

Keywords:
Activated carbon adsorber
Fixed-roof storage tank
p-Xylene
Standing storage loss
Trickle-bed air biofilter

ABSTRACT

This study applied a pilot-scale trickle-bed air biofilter (TBAB) system for treating waste gas emitted from the breather vent of a vertical fixed roof storage tank containing *p*-xylene (*p*-X) liquid. The volatile organic compound (VOC) concentration of the waste gas was related to ambient temperature as well as solar radiation, peaking at above 6300 ppmv of *p*-X and 25000 ppmv of total hydrocarbons during the hours of 8 AM to 3 PM. When the activated carbon adsorber was employed as a VOC buffer, the peak waste gas VOC concentration was significantly reduced resulting in a stably and efficiently performing TBAB system. The pressure drop appeared to be low, reflecting that the TBAB system could be employed in the prolonged operation with a low running penalty. These advantages suggest that the TBAB system is a cost-effective treatment technology for VOC emission from a fixed roof storage tank.

1. Introduction

Fixed roof storage tanks containing volatile organic liquids can be frequently found in bulk petrochemical storage facilities around Taiwan. Due to the lack of proper air pollution control devices, a large amount of volatile organic compounds (VOCs) are emitted from fixed roof organic liquid tanks because of evaporative loss of the liquid during its storage (known as standing storage loss or breathing loss) and as a result of changes in the liquid level (known as working loss). Standing storage loss is the expulsion of vapor from a tank caused by vapor expansion and contraction due to changes in temperature and barometric pressure. Working loss is the discharge of vapor during filling and emptying operations (USEPA, 2006). Emission of these substances into the atmosphere may lead to an adverse effect on the air quality and thus endanger public health and welfare (Purdom, 1980). Therefore, the development of an innovative and cost-effective treatment technology for VOC emission from fixed roof organic liquid tanks is needed in order to meet the growing demand for cleaner air.

The biofiltration process has been proven to be a promising and cost-effective control technology for odors, VOCs and air toxics (Wani et al., 1997). The trickle-bed air biofilter (TBAB) is a type of biofiltration process that employs synthetic, inorganic or organic media and receives liquid through a spray nozzle on the top of the reactor. Because of improved control of pressure drop across the biofilter bed, the pH and nutrient feed levels remain more constant allowing for a more consistent operation that does not suffer the effects of aging as natural packed media (Sorial et al., 1995; Álvarez-Hornos et al., 2008). The TBAB has been successfully employed to treat various kinds of individual VOCs (Lu et al., 2000a, 2001; Raghuvanshi and Babu, 2009; Ramirez-Lopez et al., 2010; Singh et al., 2010) as well as mixed VOCs (Lu et al., 2000b; Chang et al., 2001; Chang and Lu, 2003; Chan and Peng, 2008; Chan and Su, 2008; Chan and Lai, 2010) in the laboratory or in the field. The TBAB is therefore expected to have good potential for treating VOC emission from fixed roof organic liquid tanks.

To the knowledge of the authors, cost-effective air pollution control technologies to address VOC emissions from fixed roof organic liquid tanks have not been established in the literature. This article thus applied a TBAB system in the control of *p*-xylene (*p*-X, C_8H_{10}) emission from the breather vent of a fixed roof *p*-X tank in a bulk organic liquid storage and transfer operations of a harbor side petrochemical storage facility. Various empty-bed retention times (EBRTs) and different amounts of activated carbon (AC, used as an inlet VOC concentration buffer) were investigated. This formed part of an investigation to establish applicable operating conditions for VOCs control in a full-scale TBAB system.

* Corresponding author. Tel.: +886 4 22852483; fax: +886 4 22862587.
E-mail address: clu@nchu.edu.tw (C. Lu).

0960-8524/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2010.09.106

2. Methods

2.1. Experimental setup

The waste gas due to standing storage loss was emitted from the breather vent of a vertical fixed-cone roof storage tank containing liquid *p*-X and was directly collected via stainless steel piping to a pilot-scale TBAB system. The light gray storage tank is 15.3 m in diameter 13.72 m in height and usually holds 0.5 m of *p*-X liquid. The pressure of the breather vent is set at to open at 100 mm-H_2O while the working volume of the storage tank is 2500 m^3.

The experimental setup of the TBAB system is shown in Fig. 1. The collected waste gas was passed first through an adsorber packed with commercially available AC to buffer the fluctuation in inlet VOC concentration. This was subsequently passed through a humidifier to increase the moisture content of the waste gas. The waste gas was then delivered into a horizontal TBAB, which was made of stainless steel and having a length of 150 cm, a width of 40 cm and a height of 40 cm. The TBAB was filled with commercially available natural composts along with Double Start-packing material with a packing height of 20 cm. The percentage compositions of the natural compost is: organic substances, 60%; moisture, 35%; total nitrogen, 1.6%; total phosphorus, 1.0%; potassium oxide, 0.8%; and trace element, 1.6%. The Double Start-packing material has a specific surface area of 274 m^2/m^3 and a density of 76 kg/m^3. The flow rate of the TBAB system was controlled by a variable-speed air pump installed at the biofilter outlet (AEUL-XA3, TECO Eletric and Machinery Co. Ltd., Taipei, Taiwan). When the flow rate of the collected waste gas was lower than that of the TBAB system, a check valve introduced ambient air before entering the AC adsorber, providing clean air for desorption of VOCs from the AC surface. An additional function was to provide oxygen for aerobic biodegradation of VOCs by the microorganisms. The TBAB was equipped with three sampling ports located at the inlet and outlet of the AC adsorber and at the outlet of the TBAB. The diameter of each sampling port was 1 cm. Moisture inside the TBAB was supplied through fourteen spray nozzles in the headspace of the TBAB, while temperature inside the TBAB was not controlled throughout the study, simulating the expected conditions of a full-scale biofilter.

2.2. Startup

The startup of the TBAB was carried out in the laboratory before movement to the field. The TBAB was fed with an air stream containing 200 ppmv of *p*-X vapor at a rate of 40 L/min (lpm) for three weeks to reach a stable *p*-X removal efficiency of 80%. After the start-up, the TBAB was moved to a harbor side petrochemical storage facility in central Taiwan.

2.3. Analytical methods

Concentrations of total hydrocarbon (THC) and *p*-X were determined using a gas chromatograph (GC) (8610C, SRI Instrument, CA, USA) equipped with a flame ionization detector (FID). A 15 m non-polar fused silica capillary column with 0.53 mm inner diameter (Supelco Inc., PA, USA) was used for THC analysis while a 30 m Supelcowax fused silica capillary column with 0.32 mm inside diameter and 1 μm film thickness was used for *p*-X analysis. Air samples were collected in one-liter Teflon bag (SKC Inc., Eighty Four, PA, USA). One milliliter of the air sample was taken from this bag using a gas-tight syringe and injected into the GC/FID which was operated at injection temperature of 120 °C, detector temperature of 200 °C and oven temperature of 100 °C. Pressure inside the collection pipe and pressure drop (ΔP) across the beds of the AC adsorber and the biofilter were analyzed by a portable pressure meter (Series 475, Mk III, Dwyer Instrument, MI, USA). Temperatures and relative humidities of the atmosphere and the TBAB system were determined by a digital meter (SE-310, Center Tek., Taipei, Taiwan).

2.4. Experimental runs

The experimental runs, which were designed to establish the applicable operating conditions of TBAB system for treating VOC emission from a fixed roof *p*-X storage tank, are summarized in Table 1. Three empty-bed retention times (EBRTs) of 96, 48 and 32 s equivalent to inlet gas flow rates of 60, 120 and 180 lpm, respectively, were investigated. Three amounts of AC of 50, 100 and 225 kg were employed in the adsorber to determine the adequate AC masses for buffering the fluctuation of inlet VOC concentration (Chang et al., 2001).

Table 1
Test conditions of TBAB system.

Run	1	2	3	4	5
Q (lpm)	60	120	180	180	120
EBRT (s)	96	48	32	32	48
Buffer AC (kg)	50	50	100	225	225

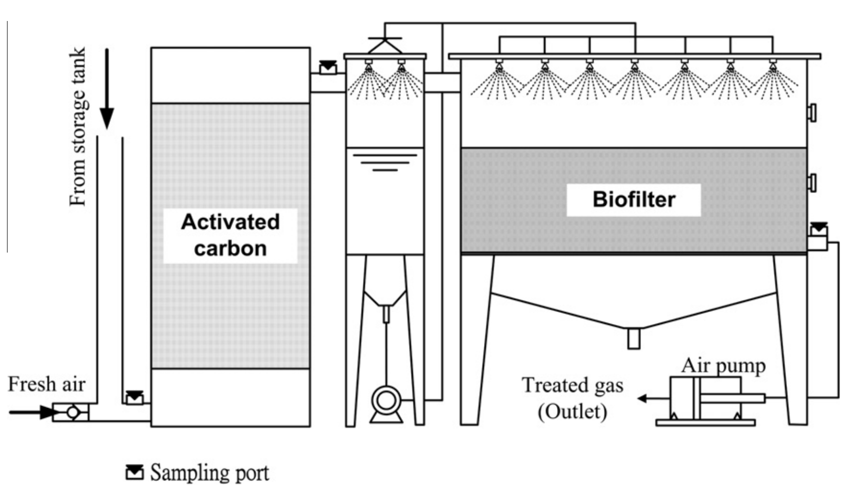

Fig. 1. Schematic diagrams of pilot-scale TBAB system.