Waste Management 32 (2012) 317–326

Contents lists available at ScienceDirect

Waste Management

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

Characterization and control of odorous gases at a landfill site: A case study in Hangzhou, China

Ding Ying [a,b], Cai Chuanyu [a], Hu Bin [a], Xu Yueen [c], Zheng Xuejuan [c], Chen Yingxu [a], Wu Weixiang [a,*]

[a] Department of Environmental Engineering, Zhejiang University, Hangzhou 310029, China
[b] Department of Environmental Science, Hangzhou Normal University, Hangzhou 310036, China
[c] Tianziling Landfill Site, Hangzhou 310022, China

ARTICLE INFO

Article history:
Received 8 March 2011
Accepted 15 July 2011
Available online 9 August 2011

Keywords:
Odors
Municipal solid waste
Landfill
Environmental factors
Hangzhou, China

ABSTRACT

Municipal solid waste (MSW) landfills are one of the major sources of offensive odors potentially creating annoyance in adjacent communities. At the end of May 2007, an odor pollution incident occurred at the Tianziling landfill site, Hangzhou, China, where the residents lodged complaints about the intense odor from the landfill, which drew a significant attention from the government. In this study, ambient air monitoring was conducted at the Tianziling landfill site. The main odor composition of the gas samples collected on June 1st 2007 and the reduction of various odorous gases from the samples collected on June 1st 2009 due to the applied odor control techniques were determined using gas chromatography-mass spectrometry (GC-MS). In addition, variations of primary odorous gaseous (NH_3 and H_2S) concentrations at different locations in the landfill site from July 2007 to June 2009 were also investigated by using classical spectrophotometric methods. Results showed that a total of 68 volatile compounds were identified among which H_2S (56.58–579.84 μg/m^3) and NH_3 (520–4460 μg/m^3) were the notable odor components contributing to 4.47–10.92% and 83.91–93.94% of total concentrations, respectively. Similar spatial and temporal shifts of H_2S and NH_3 concentrations were observed and were significantly affected by environmental factors including temperature, air pressure and wind direction. Odor pollution was worse when high temperature, high humidity, low air pressure, and southeast, northeast or east wind appeared. Moreover, the environmental sampling points of the dumping area and the leachate treatment plant were found to be the main odor sources at the Tianziling landfill site. The odor control technologies used in this project had a good mitigating effect on the primary odorous compounds. This study provides long-term valuable information concerning the characteristics and control of odors at landfill sites in a long run.

1. Introduction

Municipal solid waste (MSW) landfills are a potential source of offensive odors that can create annoyance in urban areas. Although these odorous gases generated by anaerobic decomposition of wastes account for less than 1% of the total emissions, they exert a disproportionately adverse effect on the environment because of their unique physical and chemical properties (Allen et al., 1997; Dincer et al., 2006; Zou et al., 2003; Fernandez-Martinez et al., 2001). As a result, odor problems have become a growing concern during the last few decades for both MSW operators and communities located close to MSW landfills (Sarkar et al., 2003; Dincer et al., 2006).

On the Keller's postulation, all landfill gases contain the following six classes of compounds: saturated and unsaturated hydrocarbons, acidic hydrocarbons and organic alcohols, aromatic hydrocarbons, halogenated compounds, sulfur compounds such as carbon disulfide and mercaptans, and inorganic compounds (Allen et al., 1997). Over the last few decades, attentions to characterization of volatile organic compounds (VOCs) in landfill gas have been paid by many scientists since VOCs have detrimental effects on human and animal health (psychological stress, irritation of mucous membranes, long-term toxic reactions and causing cancer) and these air pollutants have been known as precursors of photochemical smog formation and the cause of uncomfortable odor problems (Atkinson, 2000; Belpomme et al., 2007; Gallego et al., 2008; Hutter et al., 2006; Irigaray et al., 2007; Liang and Liao, 2007; Peng et al., 2006; Wolkoff and Nielsen, 2001). Allen et al. (1997) examined the trace VOCs in landfill gas at seven UK waste disposal facilities by using gas chromatography-mass spectrometry (GC-MS) and identified over 140 compounds, of which more than 90 were common to all seven sites. James and Stack (1997) investigated the ambient VOCs at landfill sites with and without a leachate pool. Thirty-three VOCs were identified with 11 of the most hazardous compounds quantified. Schuetz et al. (2003) determined non-methane organic compounds (NMOCs) at two different areas at a French landfill site and 37 NMOCs were quantified. Subsequently, 47 NMOCs in the landfill gas samples

* Corresponding author. Tel./fax: +86 571 81604036.
E-mail addresses: erchu@zju.edu.cn, weixiang@zju.edu.cn (W. Weixiang).

0956-053X/$ - see front matter
doi:10.1016/j.wasman.2011.07.016

including primarily alkanes, alkenes, halogenated hydrocarbons and aromatic hydrocarbons were quantified (Scheutz et al., 2008). Bogner et al. (2010) measured the concentrations and mitigation of nonmethane hydrocarbon (NMHC) emissions from a biocover placed above an existing intermediate soil cover at a Florida landfill. Dincer et al. (2006) identified and quantified 53 odorous gases at five sampling sites emitted from a municipal landfill in the city of Izmir, Turkey. Chiriac et al. (2009) studied the dispersion of 16 VOCs released from a MSW landfill over a period of one year. Zou et al., 2003 found that the VOC emission from the Datianshan landfill site in Guangzhou was quite serious with the number of VOCs released from that site varying between 38 and 60 from winter to summer seasons (Zou et al., 2003).

Odor perception itself is a complex event understandably because it is affected by many factors such as physiology, weather patterns, subjective perception, inurement and interaction among different odors (Firestein, 2001; Noble et al., 2001; Davoli et al., 2003). Environmental factors influencing odor emission were studied by some researchers including seasonal changes and weather conditions (Zou et al., 2003; Capelli et al., 2008; Gallego et al., 2008). However, few studies have been conducted on the environmental behavior of inorganic odorous gases. And there's little published information on primary odor levels associated with seasonal variations in landfill sites affected by many influencing factors mentioned above.

Landfilling is a popular disposal method for MSW in China (Zou et al., 2003). Statistical data showed that the total generation of MSW was approximately 1.52×10^8 ton in 2007 with an annual growth rate of 8–10%. Hangzhou is the central city of Zhejiang Province with a population of 6.6 million, which has a world famous tourist attraction, known as the West Lake, visited by tens of thousands of tourists from all over the world every year. The annoying odors released to the atmosphere from the Tianziling landfill site, the largest one in Hangzhou, has the potential to decrease the quality of life in Hangzhou and cause possibly negative consequences on human health and welfare (Park et al., 2009; Saral et al., 2009). Unfortunately, there are limited studies on landfills, especially the odor data concerning landfill sites, in Hangzhou, as well as in China as a whole.

The main objectives of this research were to (1) identify the composition of the primary odorous gases in the Tianziling landfill site, which may pose health concerns to nearby neighborhoods; (2) investigate the seasonal and horizontal variations of the primary odors with respect to environmental influencing factors; and (3) examine the effect of odor control engineering technologies on the attenuation of primary odors concentrations. The results of the present study may provide long-term valuable information concerning the characteristics of primary odorous gases in landfill sites.

2. Materials and methods

2.1. Site description and odor problem

The Tianziling landfill site located to the north of Hangzhou City (120.2E, 30.3N) is the first standardized valley-style sanitary landfill in China, which has been in operation from 1991 to 2007 before the second landfill site was commissioned ever since with a designed filling capacity of 2.2×10^7 m^3. The site does not accept medical, industrial and hazardous waste. The capacity of landfill is $2000 \sim 4000$ t/d of domestic wastes, which accounts for more than 60% of the municipal solid waste in Hangzhou. A wastewater treatment plant with a capacity of 1500 t/d is simultaneously operated for leachate treatment. However, near the landfill site was a residential area, Shitang, which was apparently susceptible to the landfill gas because an odor complaint was recorded at the end of May 2007 that drew significant attention from the government.

2.2. Odor control engineering

The conventional landfilling and cover practices at this site were carried out according to the ''Municipal Solid Waste Landfill Technical Specifications'' (CJJ17-2004, China). After the odor pollution incident occurred, a comprehensive odor control engineering project has been carried out since July 2007 to especially rein in the two main sources described early. In the dumping area, the cover soil thickness was increased and the High density polyethylene (HDPE) membrane was used to prevent direct exposure of fresh wastes to the ambient air. Meanwhile, the landfill gas was collected for electricity generation. In the leachate treatment plant, the treatment facilities such as the regulating reservoir and aeration tank were all covered with the odorous gas collected and removed by biofiltration.

2.3. Sampling and analytical methods

The gas sampling was conducted at 6 points (Fig. 1) immediately after the odor pollution incident occurred (on June 1st, 2007). The average air temperature was about 21 C and the relative humidity was 70–72%. Point 1 and 2 were selected to represent the odors from the dumping area of the second municipal waste landfill site and the landfill leachate treatment plant, respectively. The other 4 points were the spots in or adjacent to the two odor sources, among which point 3 was the administration office area, point 4 was the factory boundary, point 5 was the residential area near the landfill possibly affected by the odors, and point 6 was the 165 platform belonging to the first dumping site which had gone out of service. All six sampling points selected to represent different odor levels in the ambient air were arranged into a straight line. Sampling was carried out following recommendations described in the European Standard EN 13725. Gas samples in triplicate were collected into 1L Nalophan® bags using a special sampler based on the ''lung'' principle. Samples were transported to the laboratory and analyzed within 24 h after collection by SPME and GC-MS. After the primary odors were identified, long-term monitoring of NH_3 and H_2S at four sampling points (point 1–4) was performed from July 2007 to June 2009. Sampling was conducted one day a week at two hour intervals and the NH_3 and H_2S concentrations were evaluated by the spectrophotometric method. The weather data (including average temperature, relative humidity and air pressure) during the third quarter of 2007 to the second quarter of 2009 (2007-3rd to 2009-2nd) were also collected in the sampling days (Table 1). After 2-year operation of odor control engineering, the field sampling was conducted again at 6 points on June 1st, 2009 and were analyzed by SPME (Davoli et al., 2003) and GC-MS (Dincer et al., 2006), in order to evaluate the effectiveness of the odor control technologies.

The gas samples obtained on June 1st, 2007 and June 1st, 2009 were analyzed using a gas chromatography (GC) (Agilent 6890N, Agilent, USA) equipped with a mass selective detector (Agilent 5973 inert MSD, Agilent, USA) and a thermal desorber (Tekmar, Aerotrap 6000, USA) as described by Dincer et al., 2006, with some running conditions adjusted. Odor samples were desorbed for 5 min at 250 C using helium flowing at the rate of 35 mL/min. The internal trap temperature during sample desorption was 30 C. The trap was desorbed for 5 min at 250 C. The carrier gas was helium provided at 0.8 mL/min. The split ratio was 1:50. The inlet temperature was 250 C. The temperature program for odors was: initial oven temperature 30 C, hold for 2 min, then 30–125 C at 10 C/min, hold for 30 min. The samples obtained from long-term monitoring of NH_3 and H_2S at four sampling points were analyzed by the spectrophotometric method. The gaseous components were transferred into aqueous solution by bubbling the gases in a solution of sulfuric acid and zinc acetate, respectively. NH_3