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Method development for determining the malodor source and pollution in industrial park

I-Fang Mao [a,b], Mei-Ru Chen [c,d], Lee Wang [e], Mei-Lien Chen [f], Sin-Chen Lai [d], Chung-Jung Tsai [c,d,*]

[a] Department of Occupational Safety and Health, Chung Shan Medical University, No. 110, Sec. 1, Jianguo N.Rd., Taichung, Taiwan
[b] Department of Medical Research, Chung Shan Medical University Hospital, No. 110, Sec. 1, Jianguo N.Rd., Taichung, Taiwan
[c] Department of Occupational Safety and Health, Chung Hwa University of Medical Technology, No. 89, Wenhwa 1st St., Rende Dist., Tainan City, Taiwan
[d] Institute of Biosafety, Chung Hwa University of Medical Technology, No. 89, Wenhwa 1st St., Rende Dist., Tainan City, Taiwan
[e] Department of Public Health, Chung Shan Medical University, No. 110, Sec. 1, Jianguo N.Rd., Taichung, Taiwan
[f] Institute of Environmental and Occupational Health Sciences, National Yang-Ming University, No. 155, Sec.2, Li-Nong St., Beitou, Taipei, Taiwan

HIGHLIGHTS

- This study developed a method to explore malodor pollution in industrial park.
- The method presented the odor distribution and identified potential malodor source.
- An open ditch for collecting wastewater was determined as the main malodor source.
- TVOC concentration and wind speed played key influences on the malodor pollution.

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ABSTRACT

Malodor pollution emitted from industrial park has become an important environmental issue. However, the difficulty in investigating malodor pollution is in determining the malodor source. The objective of this study was to develop a model for determining the malodor source and pollution in industrial park, via multiple time and site measurements of odor intensity and air pollutants, together with wind direction in different seasons, and the critical environmental factors could be also identified by correlating the odor intensities with meteorological conditions and the concentrations of air pollutants. A high-malodor-polluted industrial park involving metal and petrochemistry processing industries was selected as the study subject, and sampling was performed close to residential districts. Nine sites were selected as sampling points by a chessboard design, with each site measured for 5 days in fall and spring, respectively. Odor intensity (ratings 0–5) and environmental factors, including meteorological condition, PM_{10}, $PM_{2.5}$, total volatile organic compounds (TVOCs), ammonia and reduced sulfides, were evaluated six times daily. The results indicated that the incidences of odor ratings 1–5 were 71.9% and 81.0% in two seasons in the sampling area, and an open ditch for collecting industrial wastewater for feeding to the wastewater treatment plant was identified as the main odor source. Multiple regression analysis showed that the odor rating significantly correlated with TVOC concentration and wind speed ($P<0.05$); odor intensity increased by 0.001 units on the rating scale for each 1 ppb increase in TVOCs, and decreased by 0.154 units for each 1 m/s increase in wind speed. This study developed a method to explore malodor pollution in industrial park, providing a novel thinking to understand and resolve malodor problems.

1. Introduction

Malodor pollution associated with industrial or agricultural activity has become an important environmental issue, because people are paying increasing attention to environmental quality and human tolerance to offensive smells is gradually decreasing. Additionally, many industrial parks, landfills, incinerators or composting plants are located in lower income and house value communities. The health effects of malodor on nearby residents thus are a concern and this has become an environmental justice issue (Heaney et al., 2011). In Taiwan, there were 54,971 complaints regarding air pollution in 2009, 56.8% of which were from malodor pollution (31,205 cases). Complaints regarding malodor increased ten-fold from 2003 to 2009, and the primary source was industrial activities (about 30.0%–39.0% of all). One of the most critical problems for investigating the malodor pollution from industrial parks is the difficulty in identifying the malodor source. Because numerous factories simultaneously work in the same industrial park,

* Corresponding author at: Department of Occupational Safety and Health, Chung Hwa University of Medical Technology, No. 89, Wenhwa 1st St., Rende Dist., Tainan City, Taiwan. Tel.: +886 6267 4567x817; fax: +886 6289 4028.
E-mail address: cjtsai@mail.hwai.edu.tw (C.-J. Tsai).

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the difficulty of malodor source identification often results in the controversies on determination and penalties from governmental bodies.

Recent malodor studies are focused primarily on the malodor problem and health effects associated with agricultural activities (such as industrial hog operations, livestock manure and food waste composting) (Blanes-Vidal et al., 2012; Defoer et al., 2002; Donham et al., 2007; Horton et al., 2009; Mao et al., 2006; Nicolas et al., 2006; Sironi, et al., 2007; Wing et al., 2008); however, the reliable and practical methods to realize the circumstances of malodor pollution and to determine the source in industrial park are seldom. Although olfactometry is the most common method of measuring odor concentrations worldwide (ASTM, 1997; CEN, 2003; Japan Ministry of the Environment, 2003; Taiwan EPA, 2008) and the olfactometric results can represent the odor comprehensive reception by humans, this method is labor intensive, time consuming, costly, subject to error among individuals, and incurs delays between sampling and measurement (Bliss et al., 1996; Hobbs et al., 1995; Schulz and van Harreveld, 1996). Olfactometry cannot be used for real-time and continuous measurements, and it presents the difficulties in searching for the malodor source. Instruments analysis, such as gas chromatography–mass spectrometry (GC–MS), can be used to determine the odorous components. However, the relevance between critical odorant measurements and olfactometric results had no universally acknowledged correlation until now (Defoer et al., 2002; Hobbs et al., 1995; Noble et al., 2001). Analytical methods cannot yet replace human olfaction for determination of odor levels; thus, the result of odorous component analysis cannot be fully correlated to the malodor complains from the nearby residents. This study tried to develop a method to determine the malodor source and pollution in industrial park, via multiple time and site measurements of odor intensity and air pollutants, together with wind direction in different seasons. Meanwhile, the critical environmental influences on this form of malodor problem could be identified by correlating the odor intensities with meteorological conditions and the concentrations of air pollutants.

2. Methods

2.1. Description of sampling area and strategies

An industrial park with high malodor pollution in southern Taiwan was selected as the study area because it accounted for the overwhelming majority of local complaints of malodor in 2008, with 79% (97/123) of all complaints, and furthermore three cases occurred in which nearby students felt ill and required hospitalization. The industrial park had a total area of 375.5 ha, and contained 546 factories, including those in the petrochemical, chemical, plastic, metal, printing, textile and other industries. One elementary school and one junior high school were situated on the south of this industrial park nearby.

The selected sampling area was close to schools and residential districts in the high-malodor-polluted industrial park (Fig. 1). Nine sites in this area were selected as sampling points using a chessboard design (A1–A9), two of which were located by a school (A8) and residential district (A9), respectively. The sampling area contained nine petrochemistry processing companies and one wastewater treatment plant. Odor intensity and environmental measurements were executed an average of six times daily during the day-shift work period at each sampling site. Because of seasonal changes in wind direction, this

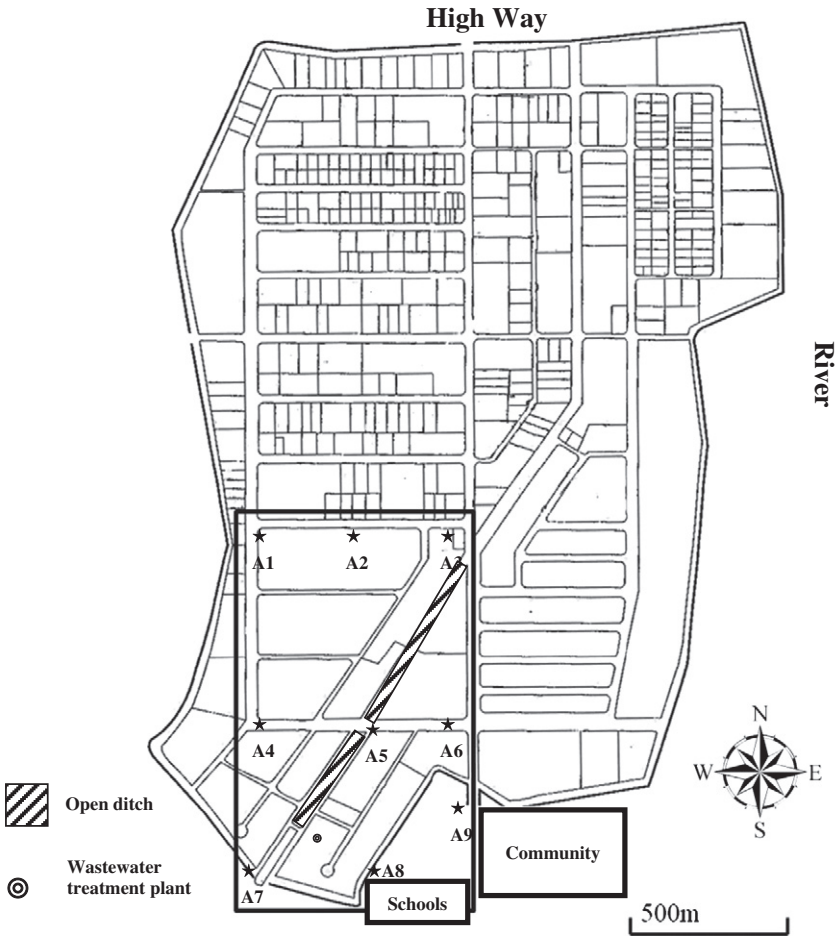

Fig. 1. The diagram of the sampling sites and region in the studied industrial park.