Environmental Pollution 240 (2018) 95–104

Contents lists available at ScienceDirect

Environmental Pollution

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

Ambient VOCs in residential areas near a large-scale petrochemical complex: Spatiotemporal variation, source apportionment and health risk☆

Chin-Yu Hsu [a], Hung-Che Chiang [a, d], Ruei-Hao Shie [b], Chun-Hung Ku [a], Tzu-Yu Lin [a], Mu-Jean Chen [a], Nai-Tzu Chen [a], Yu-Cheng Chen [a, c, *]

[a] National Institute of Environmental Health Sciences, National Health Research Institutes, 35 Keyan Road, Zhunan Town, Miaoli, 35053, Taiwan
[b] Green Energy and Environment Research Laboratories, Industrial Technology Research Institute, Hsinchu, Taiwan
[c] Department of Occupational Safety and Health, China Medical University, 91 Hsueh-Shih Road, Taichung, 40402, Taiwan
[d] School of Medicine, College of Medicine, China Medical University, 91 Hsueh-Shih Road, Taichung, 40402, Taiwan

ARTICLE INFO

Article history:
Received 11 June 2017
Received in revised form
13 February 2018
Accepted 17 April 2018

Keywords:
VOCs
Cancer risk
Source apportionment
Spatiotemporal variation
Petrochemical complex

ABSTRACT

This study investigated ambient volatile organic compounds (VOCs) and assessed excess health risks for child, adult and elderly populations in a residential area near a large-scale petrochemical complex in central Taiwan. A total of 155 daily VOC samples were collected in canisters from nine sites in spring, summer and winter during 2013–2014. We used a positive matrix factorization (PMF) model incorporating a conditional probability function (CPF) to quantify the potential sources of VOCs with the influences of local source directions. We then evaluated the non-cancer and cancer risks of specific VOCs with probabilistic distributions by performing a Monte-Carlo simulation for the child, adult, and elderly populations. Most of the VOCs were higher in summer than in winter or spring for the sampling sites. The presence of vinyl acetate, chloroethene, and 1,2-dichloroethane were significantly high within a 5-km radius of the petrochemical complex. Four potential sources of ambient VOCs, industrial emission (49.2%–63.6%), traffic-related emission (13.9%–19.1%), fuel evaporation (12.3%–16.9%), and aged emission (10.2%–14.8%), were identified. The cancer risk of ambient VOC exposure was mainly attributed to the industrial source in the study area, while the non-cancer risk was of less concern. Benzene associated with fuel evaporation resulted in the highest cancer risk (4.1×10^{-5}–5.5×10^{-5}) as compared to that of the other toxic VOCs.

1. Introduction

Air pollutants from large-scale chemical/petroleum facilities have been widely recognized as a main risk factor for public health in many countries (Liu et al., 2008a; Nadal et al., 2009, 2011; Parra et al., 2009; Yu et al., 2006). Among air pollutants, volatile organic compounds (VOCs) are among the significant contaminants but are difficult to quantify accurately. VOCs can be fugitive as they may be derived from various substances and sources (such as a chemical facility, traffic, a gas station, the combustion process, and even households) and vary by season, location, climate effect, etc. Once VOCs reach a certain level, they not only affect the chemistry of the atmosphere (i.e. tropospheric ozone and secondary organic aerosols) (Khalade et al., 2010) but also impact the health of the general population (Aungudornpukdee et al., 2010; Lee et al., 2002; Ware et al., 1993; Yu et al., 2006). Several studies have reported that local residents living near emission/fugitive sources of chemical/petroleum facilities are exposed to relatively high levels of VOCs (Civan et al., 2015; Mo et al., 2015; Yu et al., 2006). As a result, a positive correlation between cancer risks (leukemia and brain tumor) and VOC exposures/surrogates for residents proximal to petrochemical facilities has also been demonstrated (Liu et al., 2008a; Yu et al., 2006).

The No. 6 Naphtha Cracking Complex (Mailiao Complex), which comprises 64 various plants (e.g., oil refineries, naphtha cracking plants, petrochemical processing plants, and a coal-fired

☆ This paper has been recommended for acceptance by David Carpenter.

* Corresponding author. National Institute of Environmental Health Sciences, National Health Research Institutes, 35 Keyan Road, Zhunan Town, Miaoli, 35053, Taiwan.
E-mail address: yucheng@nhri.org.tw (Y.-C. Chen).

https://doi.org/10.1016/j.envpol.2018.04.076
0269-7491/

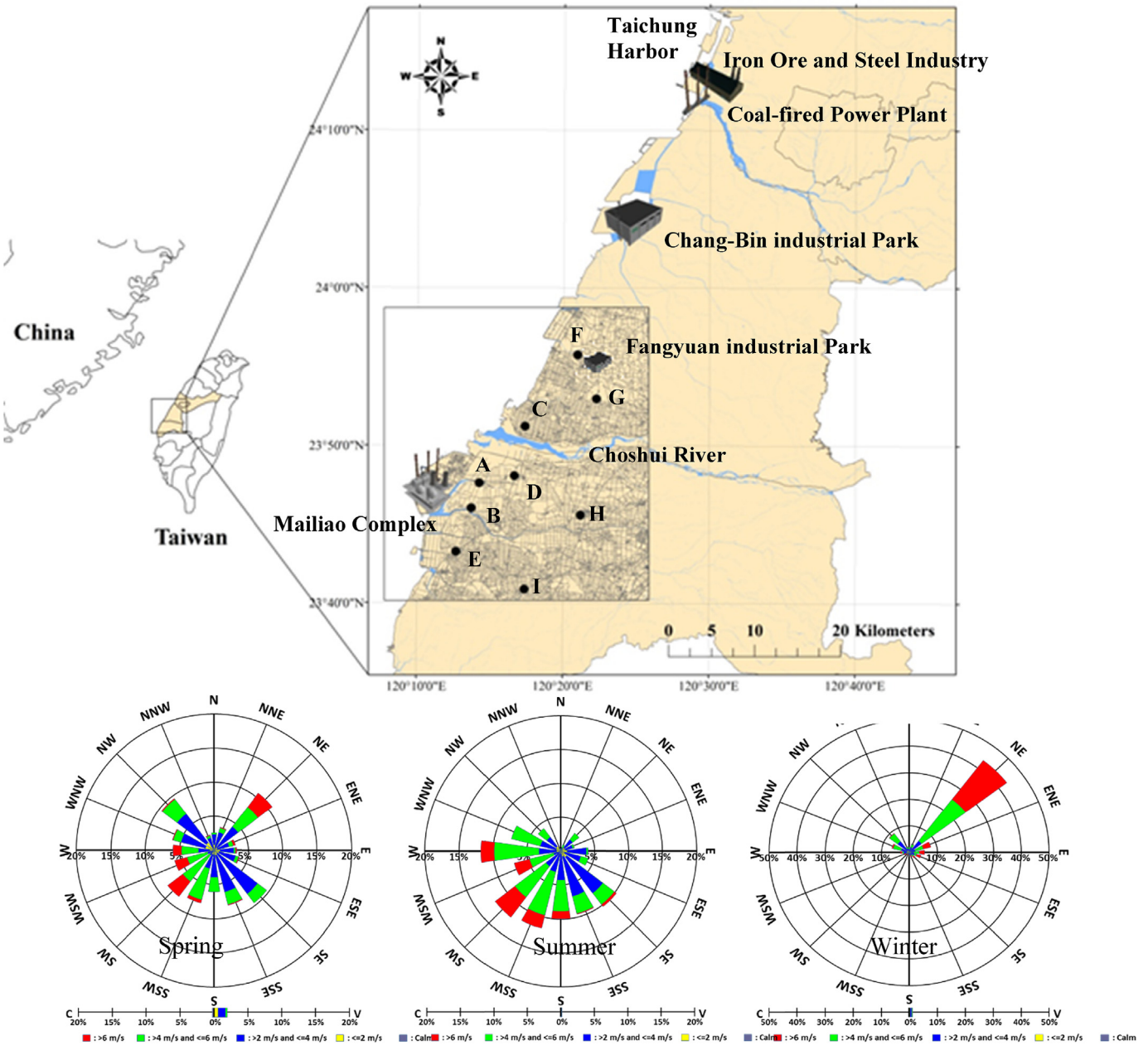

Fig. 1. Overview of the sampling sites (A–I) and wind rose diagrams for the study periods of the spring summer and winter in Changhua and Yunlin Counties.

power plant), is the contributor to local and regional VOCs in the ambient air. Although the Taiwan EPA has imposed emission standards for ambient air quality and resultant health implications, residents living near the Mailiao Complex still have a long-standing concern regarding ambient VOC exposure. In addition, while most studies have conducted short time measurements in the area exactly downwind during high concentration events or chemical accidents (Shie and Chan, 2013; Yen and Horng, 2009), no one has identified the potential sources of ambient VOCs in conjunction with health risks. There is thus a strong need to systematically investigate the concentrations and characteristics of ambient VOCs with spatiotemporal variations in residential areas near the Mailiao Complex.

The profiles of VOC species with performing receptor models can aid in identifying emission sources and quantifying their respective contributions to air pollution (Ling and Guo, 2014; Liu et al., 2008c). Risk assessment is then used to evaluate the impact of hazards on human health and to identify a solution required for a specific environmental problem because it is one of the most effective measures to evaluate health impact (Asante-Duah, 1993; LaGrega et al., 1994). Additionally, the sources identified with risk assessment can be used to compare one source to another in order to prioritize solutions based on health concerns (Chen et al., 2016; Hsu et al., 2016). Though the estimated risks may not necessarily translate into the expected rates of disease due to the uncertainty of assumptions during the process of risk assessment, the application of a probabilistic approach including variation in the algorithmic parameters could reduce the uncertainty.

The National Health Research Institutes have conducted a mission-oriented project for assessing the health risk associated with air pollution exposure in Changhua and Yunlin counties in central Taiwan. Here, we completed a full-year measurement of