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Non–methane hydrocarbon emission profiles from printing and electronic industrial processes and its implications on the ambient atmosphere in the Pearl River Delta, South China

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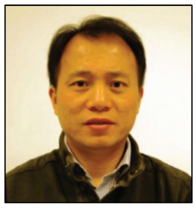
ABSTRACT

Thirty–seven non–methane hydrocarbons (NMHCs) were quantified for seven industrial work processes, covering the electronic industry and the printing industry, in the Pearl River Delta (PRD). NMHC source profiles (% by wt.) for the respective work processes and their associated industrial solvents were obtained. In order to examine the contribution of the individual work processes to the neighborhood atmospheres, ambient samples on the rooftop of the printing and electronic factories were collected. Total NMHC concentrations of 3 700±740 ppbv and 169±64 ppbv were detected, respectively. Air samples from roadside of a main roundabout, from rooftop of a residential building in the town center and from a background site were also collected to examine the impact of industrial and vehicular emissions on local NMHC levels. NMHC emissions from the printing factory were significantly higher than that from the electronic factory. The two work processes, plastic molding and soldering in the electronics factory, emitted mainly C_3–C_7 alkanes, while paint solvents used in the printing factory released C_7–C_8 aromatics. Toluene was the most abundant NMHCs measured for all work processes in the printing factory. It was due to the heavy usage of various solvent–based inks and paint solvents. In general, high toluene levels were found in the ambient and industrial–related atmosphere and this led to low benzene–to–toluene ratios (B/T, ppbv/ppbv) in this study. The B/T ratios for urban, suburban and roadside ambient atmospheres were smaller than 0.2. Much lower ratios (<0.04) were measured for industrial work processes associated with usage of ink and paint solvents. Our study suggests that toluene–rich emission from the printing industry contributes to the gradual increase in the atmospheric toluene background in the PRD.

Keywords: *NMHCs, industrial emission, toluene, solvent, printing*



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1. Introduction

The Pearl River Delta (PRD), located in South China, is among the top urbanized and industrialized regions and is also a world renowned manufacturing base in China. With the rapidly growing economy and industrial activities, it experiences deteriorating air quality, such as extremely high surface ozone levels (Jiang et al., 2010), frequent haze episodes as well as remarkable visibility reduction (Wu et al., 2005). Non–methane hydrocarbons (NMHCs) are important precursors of tropospheric ozone and secondary organic aerosol (SOA). Under favorable meteorological conditions and in the presence of nitrogen oxides, NMHCs can produce a series of intermediate organic species, ozone and SOA (Odum et al., 1997; Poisson et al., 2000). Hydrocarbons, such as benzene and toluene, are toxic. Under high exposure, they can pose adverse effects to the health of local residents (Caprino and Togna, 1998).

Several studies have shown that industrial emissions are an important contributors to the high levels of NMHCs in the PRD region (Chan et al., 2006; Tang et al., 2007; Barletta et al., 2008; Ling et al., 2011; Yuan et al., 2013). However, there is very limited data on the NMHC emission profiles from specific industrial processes in the PRD, although chemical composition of major VOC emission sources have been reported in other countries (Scheff and Wadden, 1993; Chen et al., 2001; Na et al., 2004). An investigation of VOC profiles in a printing factory of Beijing showed that *n*–nonane, *n*–decane, *n*–undecane, toluene, and *m*/*p*–xylene were the dominant species (Yuan et al., 2010). In source samples collected from stack emissions and fugitive emissions of printing industry in the PRD, benzene and toluene were found to be the major species associated with letterpress printing, while ethyl acetate and isopropyl alcohol were the most abundant compounds of offset and gravure printing processes (Zheng et al., 2013). However, VOC source profiles are regional–specific and vary largely. We hence carried out this field measurement to characterize the NMHC industrial emissions for two prominent PRD industries: electronics and printing.

According to an annual projected emission inventory study (CH2M HILL, 2002), the largest VOC contributor in the industrial sector in the PRD was the printing industry. It was estimated that about 15 400 tons in 1997 (CH2M HILL, 2002) and about 318 000 tons in 2006 in the PRD (Yu et al., 2011) and about 895 000 tons for the whole China in 2009 (Yang et al., 2012) were emitted from the printing industry. Wadden et al. (1995) reported that there were strong fugitive emissions from an offset printing shop in US. The average VOC emission rate was 470 g/hr with a range of 160–1 100 g/hr (Wadden et al., 1995). Thus, the printing industry is the first choice in our study. The electronic industry (4 tons/yr) was also selected for the study, because the work processes are also employed in a variety of other manufacturing industries. Processes such as plastic casing molding and paint spraying can be found in the toy, shoe and car manufacturing industries.

In this paper, the NMHC source signatures of individual industrial work processes of the electronics and printing industries were reported. The source signatures were used to examine the impact of emissions from these two industries on local atmospheric NMHC levels. Also, we compare benzene–to–toluene (B/T) ratios measured in this study with previous PRD studies to illustrate the recent changes in the NMHC composition in the PRD atmosphere. The industrial source signatures obtained will also help in the improvement of uncertainties in modeling results for this region.

2. Experiment

2.1. Sampling design

The field experiment was carried out in Qingxi town within a highly industrialized PRD city, Dongguan, in January of 2005. Dongguan is bounded by Guangzhou, Huizhou and Shenzhen (Figure 1). Its good geographical position and infrastructural logistics support led to tremendous industrial development. Dongguan is among China's largest exporting domains in recent years. Using a regional chemical transport model – Sulfur Transport Eulerian Model (STEM–2Kl), the values of VOCs in wide areas of Dongguan in 2001 were found to be 14–16 ppbv, and were just lower than those in areas of Hong Kong and Guangzhou (Streets et al., 2006). The diversity of industries in Dongguan provides an almost self–supported industrial development environment. For example, 70–90% of electronic accessories and parts are available locally. Qingxi, situated in the southeast comprehensive manufacturing base in Dongguan, was an ideal location for the study of VOC emissions from the electronics and printing industries, because they are the prevalent industries there. Medium–sized enterprises of two target industries, with 200–300 staff, were selected in this study.

In this study, three categories of VOC samples were collected, including ambient, source of industrial work processes, and utilized industrial solvents. Five types of ambient air examined include suburban background, urban roadside, urban rooftop, electronics factory (EF) rooftop, and printing factory (PF) rooftop. The electronics factory mainly manufactures computer accessories such as, keyboards, speakers and power supply units. Electronics work processes examined included plastic casing molding, logotype printing, circuit board assemblies soldering and paint spraying. The printing factory mainly produces printed products and decorating cartons. Printing work processes examined include printing, glossing and carton gluing. Source samples were collected inside the two factories in the proximity of the seven industrial work processes. Also, evaporative VOC compositions of nine industrial solvents were obtained. The site description, daily sampling schedule and sample size are briefly listed in Table 1. Two background ambient samples were also collected in the early morning (06:00–07:00) of the last two sampling days. The other ambient samples were taken during working hours (08:30–16:30) with ambient temperatures ranging between 18.1–26.5 °C. The sampling height was 1–1.5 m above the ground or rooftop.

2.2. Sample collection and chemical analysis

From 6th January to 8th January, 2005, 42 VOC samples (14 ambient, 19 industrial source and 9 solvent) were collected using evacuated 2–L electropolished stainless steel canisters, prepared by the Rowland–Blake Laboratory of University of California–Irvine (UCI). Fifteen–minute "integrated" samples were collected for ambient and source categories. A calibrated critical orifice flow controller and a vacuum gauge were used. Initial sampling flow rates (100±5 mL/min) were calibrated using a digital flow meter (DC–Lite, BIOS, US). Approximately 1.5 L air sample was collected for each canister. The solvent category was obtained by another method. A drop of solvent was introduced into a canister, and let to be evaporated inside the canister. This method would underestimate the abundance of heavy molecular weight hydrocarbons (HC), because they have a lower tendency to evaporate. For example, components with carbon number greater than six constitute lesser fractions of gasoline vapor compared with gasoline (Na et al., 2004). Solvent evaporative compositions rather than actual compositions are given in this study.

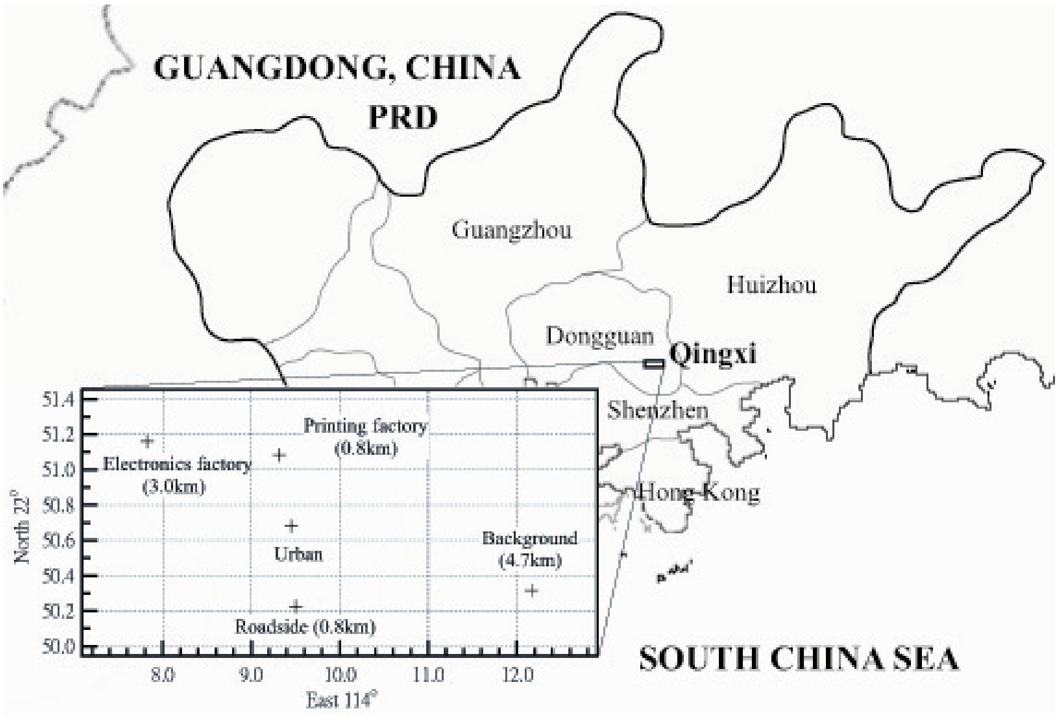

Figure 1. *Locations of five sampling sites in Qingxi, Dongguan.*