DOI: 10.15625/vap.2019.000205

CHARACTERIZATION OF VOLATILE ORGANIC COMPOUND DISTRIBUTIONS BY LIGHT-WEIGHT ROTARY-WING UNMANNED AERIAL VEHICLE

Vo Thi Dieu Hien[1*], Nguyen Van Truc[2], Chitsan Lin[3], Bui Xuan Thanh[4]

[1]Faculty of Environmental and Food Engineering, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam. Email: hien.ic.tracodi@gmail.com

[2]Department of Environmental Sciences, Saigon University, Ho Chi Minh City, Vietnam. Email: truc1021006@gmail.com

[3]Department of Marine Environmental Engineering, National Kaohsiung University of Science and Technology, Taiwan. Email: ctlin@nkust.edu.tw

[4]Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology, VNU-HCM, Ho Chi Minh City, Vietnam. Email: bxthanh@hcmut.edu.vn

ABSTRACT

While petrochemical industry plays an important role of economic development in Kaohsiung city, it releases significant emission of volatile organic compounds (VOCs) that are major precursors for surface ozone and secondary organic aerosol (SOA). This study characterizes ambient VOCs at different heights in Renwu industrial district, Kaohsiung, Taiwan. The ambient air samples were taken at the heights of 0 m, 100 m, 200 m, 300 m, 500 m and 700 m by the unmanned aerial vehicle (a flying machine, UAV). Results showed that total VOC concentrations varied from 32 to 327 ppbv with the highest concentration sampled at 300m. Ketones were identified as the dominant group which represented 29±15 % of TVOC. Temperature inversion was observed at about 200m height that obviously affected the vertical transport of ambient VOCs. Ozone formation potentials (OFP) and SOA formation potentials fluctuated between 120-726 ppbv and 0.05-4.59 ppbv at different heights, respectively. It is clear that vertical variations in VOC concentration, OFP and SOAFP existed. The highest OFP and SOAFP were at 300 m, and are much higher than the ground level. Which raises attention whether ground level VOC data are biased to model ozone formation, suggests that more efforts should be employed to study the vertical variation in terms of how it affects the ozone air quality modeling. The achieved results showed that the designed UAV is appropriate for vertical ambient sampling, and had successfully demonstrated the need and the ability to characterize vertical variations of ambient VOCs.

Keywords: Volatile organic compounds; ozone formation potential; secondary organic aerosol formation potential; vertical VOC variation; unmanned aerial vehicle.

1. INTRODUCTION

Volatile organic compounds (VOCs) are known as toxic compounds and contribute a formation of more than 70 % of hazardous air pollutants (Pekey & Yılmaz, 2011). More importantly, VOCs are precursors forming photochemical products which adversely affect human health (WHO, 2000). The industrial park is one important source emitting VOCs into ambient air environment. In Kaohsiung city, one of the major petrochemical industrial city, Southern Taiwan, previous studies mostly focused the temporal and spatial variation of VOCs (Chang et al., 2005; Chen et al., 2012). Vertical variation information of VOCs is limited. Therefore, this study was conducted to investigate the characteristics of VOCs at the heights of 0 m, 100 m, 200 m, 300 m, 500 m, and 700 m.

2. MATERIALS AND METHODS

The air samples were taken at Renwu district (22.707290N, 120.356046E) on 12 February 2017, from 14:00-16:00 by using the UAV with the 400ml canisters. Then the samples were transferred to the laboratory and analyzed within one week by GC/MS (Agilent 6890/5973) coupled the preconcentration (Entech 7100 A) with recovery between 70 % and 130 %, relative standard deviation < 30 % and method detection limits of 0.05-0.95 ppbv. About 122 compounds were determined according to method TO-15 (McClenny & Holdren, 1999).

3. RESULTS & DISCUSSION

3.1. Vertical variation of TVOCs

The TVOCs concentration increased gradually from the ground (35.6 ppbv) to 200 m (68.4 ppbv). The highest concentration reached 327 ppbv at 300 m. Then TVOCs concentration tended to reduce at the height of 500 m (141 ppbv) and 700m (78.6 ppbv). These results also show the variation of temperature and moisture with the height. According to the normal phenomenon, the lower temperature and the higher moisture are at the more height. However, the increase in the temperature and the decrease in moisture occurred from the ground to 200 m in this study. The temperature inversion occurred in the range of 0-200m of height. This phenomenon affected the vertical diffusion of VOCs. The pollutants from the chimneys of upwind manufactories (heights of chimneys of 100-300 m) might be distributed and lie on this inversion layer. However, more fingerprint information or trajectory analysis need to investigate to confirm the pollution source in the future.

3.2. OFP and SOAFP

The air stratification showed a variation in TVOC distribution at different heights. Air stratification was determined using the ratio of TVOC concentrations at elevated heights and at ground-level. According to Tsai et al. (2012), if the ratio is higher than 1, there is a high potential of air stratification. The stratification data showed that TVOC concentration could be divided into two groups in Renwu: 1.4±0.5 (n=2) for below 200 m and 5.1±3.6 (n=3) for above 200 m. On the other hand, strong stratification occurred above the inversion layer during the study period. In Chaozhou, light stratification (1.1±0.1, n=2) occurred from 100-400 m. However, no stratification (0.9±0.0, n=2) for TVOC concentrations occurred from 700-1,000 m. Sangiorgi et al. (2011) also found a strong stratification of TVOC concentrations from 100 to 200 m above the ground at an industrial area of Milan (Italy) in 2006. In Kaohsiung, during 2006-2009, the air stratification of TVOC occurred frequently at both inland and offshore sites at 100-500 m in height, possibly due to the accumulation of air pollutants Tsai et al. (2012).

4. CONCLUSION

In this study investigating the vertical profile of VOCs, UAV was found to be very suitable for air sample collection up to 1,000 m in height. We found observed inversion layer (at 200 m) strongly affected the vertical distribution of TVOC, OFP, and SOAFP. Based on our backward trajectory modeling and air mass age analysis, the VOCs we found at both sites could be emitted from local or transported from distant sources. The air stratification suggested that vertical variations of air pollutants should be integrated into future air quality models.

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