Chemical and sensory evaluation of malodorous volatile organic compounds from an urban wastewater treatment plant

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1 Introduction

Odour annoyance is the prevalent complaint related to indoor air quality (Peng, 2009). Although malodours are not necessarily associated with adverse health effects, they do affect the quality of life of exposed people. The chemical composition of malodours often include, but are not limited to, ammonia and hydrogen sulphide, as well as malodorous volatile organic compounds (VOCs). Indoor odours not only have indoor sources, such as building products, but can also be of outdoor origin. The penetration of malodours from outdoors can constitute a significant indoor odour source, with new residential suburbs often encroaching on areas with outdoor odour sources, such as urban wastewater treatment plants (WTP) (Estrada, 2011).

Both sensory and chemical data are widely used to evaluate odour intensity and acceptability (i.e. odour concentration, OC). Understanding the relationship between these two types of data is important for conducting environmental impact assessments, as well as for the management of malodours, however at present, the nature of this relationship is not well understood. This study aimed to fill this gap in knowledge, using data collected from a WTP.

2 Materials/Methods

Air samples were collected from the largest WTP in Guangzhou, China using Tenax tubes with self-made cold-traps, as well as 3L gas bags, in a three-day field sampling campaign at six major workshops. Tubes and gas bags collected samples simultaneously, three times per day and 54 samples were collected in total. All samples were stored in a fridge at -20°C and were analysed within 48 hours. A thermal-desorption/GC-MS method was applied to identify malodorous VOCs in the samples collected. The OCs of these samples were evaluated by six trained panellists using the triangle odour bag method (SYAES, 1993).

To investigate the quantitative relationship between malodorous VOC species, their concentration levels and the corresponding odour, three steps were used in the data analysis. First, the concentrations of individual malodorous VOCs were converted into a value between 0 and 1 using the maximum difference normalisation method. Second, principal components analysis (PCA) was utilised to classify individual malodorous VOCs into five independent groups. Third, a multiple linear regression model was established to describe the relationship between OCs and concentration levels for the dominant malodorous VOC groups. Finally, this model was validated using 10 random air samples collected from the same wastewater treatment plant (WTP).

3 Results and Discussion

More than 70 VOCs (including alkanes, alkenes and aromatics etc.), were detected in the air samples, among which 30 malodorous VOCs were identified as having a concentration ranging from 0.37 to 1872.24 $\mu g.m^{-3}$. Aromatics were the dominant VOC species emitted by the wastewater treatment plant and it is likely that they entered into the wastewater as a by-product of the manufacture of agricultural chemicals and chemical intermediates, paints and synthetic rubber (Li, 2010).

The results of the PCA are shown in Table 1. The malodorous VOCs detected in this study were grouped into five categories (i.e. aromatics, halo-hydrocarbons, aldehydes, hydrocarbons and S, N-containing organic compounds). Those species with a loading more than 0.4 were selected for multiple linear regression analysis.

Table 1. PCA results of malodorous VOCs in the wastewater treatment plant.

PC	VAF	MP	OS	Type
PC_1	23.6%	Elthylbenzene	0.285	Ar
		m,p-Xylene	0.275	
		o-Xylene	0.294	
PC_2	44.5%	Chloroform	0.299	HH
		Carbon Tetrachloride	0.299	
		Trichloroethylene	0.288	
		Tetrachloride	0.255	
PC_3	59.9%	Acetaldehyde	0.424	Al
		Propanal	0.334	
		Butanal	0.394	
PC_4	72.4%	2- Butylene	0.411	Hy
		2-Methylpentane	0.478	
		2,4- Dimethylheptane	0.379	
PC_5	80.7%	Dimethyl Sulfide	0.515	SN
		Acetonitrile	-0.652	

PC: principal components; VAF: variance accounted for; MP: major pollutants; OS: object scores; Ar: Aromatics; HH: halo-hydrocarbons; Al: aldehydes; Hy: hydrocarbons; SN: S, N-containing organic compounds.

A logarithmic relationship between OC and VOC concentration has been suggested by previous studies (Gostelow, 2001), which is consistent with the results of this study. For example, the regression model built in this study indicates that two groups, aromatics and halo-hydrocarbons, significantly contributed to OC levels. Therefore, it is likely that a simplified model, using these two malodorous VOC groups as independent variables, would be able to predict the odour levels related to WPT emissions.

Based on this finding, a simplified model was built and applied to predict the OC of the additional random air samples collected in the same WTP. As presented in Figure 1, the predicted results fit the measured values very well for non-diluted samples. However, the values given by this model were higher than those measured when the samples were diluted to some level. The reason for this remains unknown.

4 Conclusions

This study investigated the relationship between the chemical and sensory evaluation of malodorous OVCs. It pointed out that odour levels are mainly affected by a few principal malodorous VOC species, such as aromatics and halo-hydrocarbons. The results provide fundamental knowledge about the odour characteristics in relation to modern WPTs, and will help to identify malodorous sources in indoor environments.

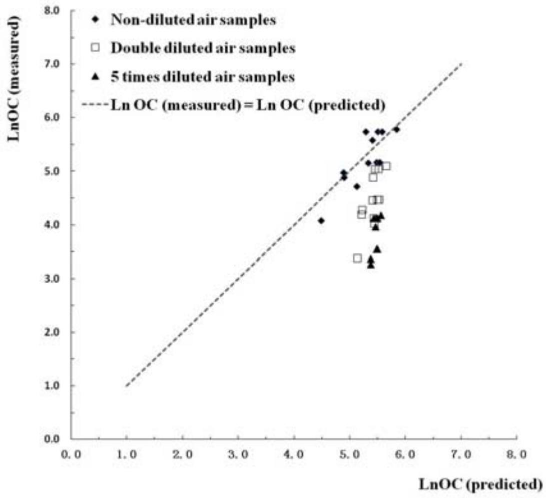

Figure 1: Predicted and measured odour concentrations of additional random air samples collected in the same wastewater treatment plant.

5 References

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