Assessment of odour activity value coefficient and odour contribution based on binary interaction effects in a waste disposal plant

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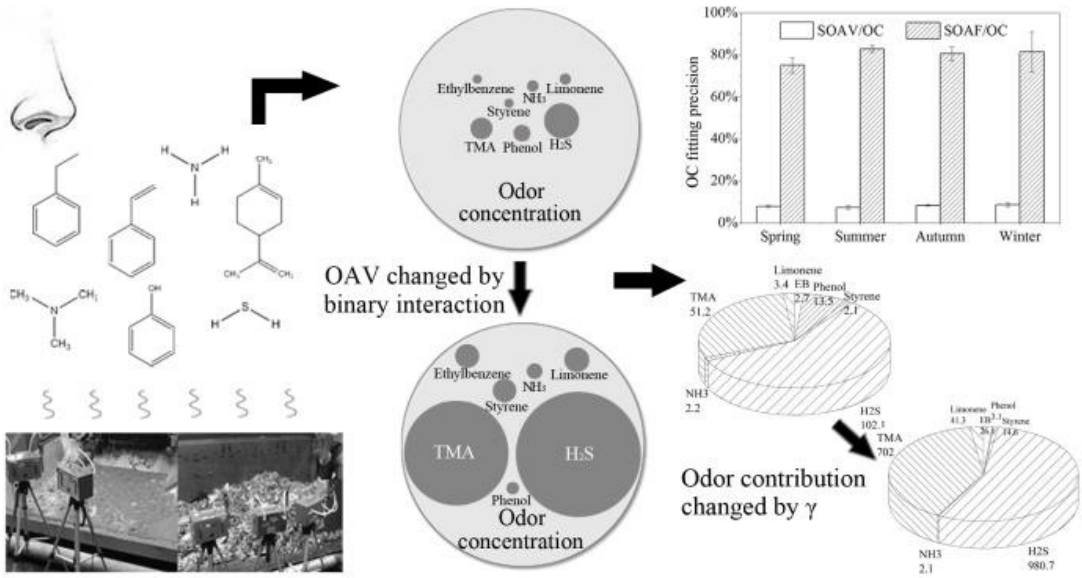
Graphical Abstract



The odour activity value (OAV) has been widely used for the assessment of odour pollution from various sources. However, little attention has been paid to the extreme OAV variation and potential inaccuracies of odour contribution assessment caused by odour interaction effects. In our recent studies (Wu et al., 2015), an odour activity value coefficient (γ) was first proposed to evaluate the type and the level of binary interaction effects based on the determination of OAV variation in the binary odorous mixture. By multiplying OAV and γ, the odour activity factor (OAF) was used to reflect the real OAV. The correlation between the sum of OAF and odour concentration reached 80.0 ± 5.7%, which was 10 times higher than the sum of OAV used before. Results showed that hydrogen sulfide contributed most (annual average 66.4 ± 15.8%) to odour pollution in the waste disposal plant. However, as the odour intensity of samples in summer is rising, the odour contribution of trimethylamine was improved to 48.3 ± 3.7% by the synergistic interaction effect, which was not found in previous studies.

1. Introduction

Recently, the emission of odorants has attracted enormous attention due to their harmful effects on human health and atmospheric environment (Qin et al., 2013) . Odour activity value (OAV) has been widely used for the assessment of odour pollution

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from various sources. However, applying OAV in the assessment of odour contribution is valid only under the hypothesis that interaction effects between components can be ignored (Feilberg et al., 2010, Hales et al., 2012). Indeed, odorants in mixtures have shown complex interaction effects, such as additive, antagonistic and synergistic interaction (Yan et al., 2014). These interaction effects lead to extreme OAV variation and potential inaccuracy in the assessment of individual odour contribution. Yet studies concerning the evaluation of odour interaction effects and the revise of OAV variation are limited. Therefore, a proper method is still needed to evaluate these interaction effects in odorous mixture.

2. Materials and methods

Air sample in the food waste disposal plant was collected by a 5 L Tedlar sampling bag (SKC Inc., USA). Analytical methods for the determination of various components in air samples were based on a pre-concentration step followed by the subsequent separation and detection by a gas chromatography/mass spectrometry and gas chromatography/ flame photometric detector.

Odour concentration (OC), odour intensity (OI) and odour threshold value (OTV) were measured with dynamic olfactometry (AC'SCENT, USA) by sniffing panelists. Then OAV was calculated as the ratio of the concentration to the OTV of each odorant.

γ was measured in an odorless laboratory. A determined odorant and the reference odorant were mixed, volatilized and diluted by pure air in a Tedlar bag. Concentrations were adjusted to make the determined odorant and the reference odorant to reach same OI value, namely, form isointense mixture. In this instance, the ratio of OAV_{Pure} to OAV_{Mixed} was defined as γ (OAV_{Pure} was OAV of the single determined odorant, and OAV_{Mixed} was OAV of the determined odorant in isointense mixture) (Wu et al., 2015).

3. Results and discussion

A total of 28 odorants were detected, and the average concentration of each category was in the following order: Aromatics (919.4 μg m^{-3}) > Terpene (757.0 μg m^{-3}) > Nitrogenous compounds (607.9 μg m^{-3}) > Oxygenated compounds (305.6 μg m^{-3}) > Halogenated compounds (92.0 μg m^{-3}) > Alkanes (72.7 μg m^{-3}) > RSCs (53.0 μg m^{-3}).

Mean OAV of odorants with detectable frequency higher than 50% were calculated in this study. On the basis of Chen (Chen et al., 2000) and Parker's (Parker et al., 2012) theory, odorants with detectable frequency over 50% and OAV above 1 were defined as key odorants in this study, including hydrogen sulfide, trimethylamine, phenol, limonene, ethylbenzene, styrene and ammonia. The sum of the seven key odorants' mean OAV was 177.2, which was far less than average OC (2183 ± 1692 ou m^{-3}). Therefore, a proper method is needed to evaluate odour interaction effects precisely.

Hydrogen sulfide was selected as reference odorant for its highest OAV and distinct odour characterization, and binary interaction effects between key odorant and the reference odorant were assessed to optimize the evaluation of odour interaction effects in this study. Based on the study of OAV-OI relationship of single odorants and odorants in isointense mixture with hydrogen sulfide, the functional formula relating γ with OI was concluded as $lg\ \gamma = k'\ OI_{Mixture} + b'$.

The ratio of OAV_{Pure} to OAV_{Mixed} reflects the change of odorous ability caused by binary interaction effects, so γ might quantitatively characterize the type and the level of binary interaction effects. Previous researchers had also reported similar odour interaction effects in binary mixtures. These results were meaningful for binary interaction effects studies but limited to a given mixing proportion in controlled laboratory experiment. By proposing the odour activity value coefficient in our study, we expect quantitatively evaluating the type and the level of binary interaction effects in odour samples from various odour sources. OAF stands for the real OAV which is taking binary interaction effects into consideration.

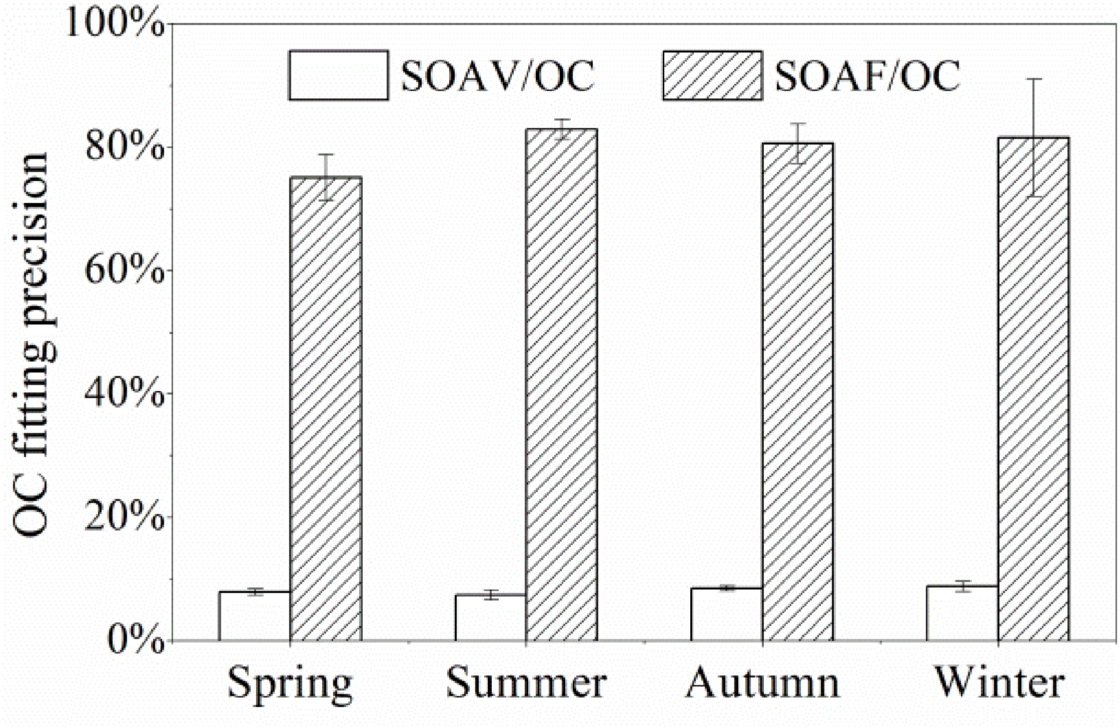

Figure 1: Comparison of SOAV, SOAF and OC of odour samples in each season. SOAV: the sum of odour activity value, SOAF: the sum of odour activity factor, OC: odour concentration determined by dynamic olfactometry. Error bars indicate disparity of odour emission at each sampling site (Wu et al., 2015).

Fig. 1 reflects the comparison of mean SOAV, SOAF and OC of odour samples collected at four sites in each season. On average, SOAF matched 80.0% ± 5.7% of OC. It was 10 times higher than SOAV which was widely used in previous assessments of odour contribution. The average odour contribution of key odorants in each season was reflected in Fig. 2. Generally, hydrogen sulfide was the largest contributor (annual average 66.4 ± 15.8%) to odour pollution in the waste disposal plant. However, as OI of odour samples in summer were rising, the odour contribution of trimethylamine was improved to 48.3 ± 3.7% by the increasing synergistic interaction effect, while odour contribution of phenol decreased to 0.1 ± 0.02% for the increasing antagonistic effect.

4. Conclusions

This study showed a novel odour activity value coefficient method for the assessment of binary interaction effects. The correlation between SOAF and OC was about 10 times higher than that of SOAV, and odour contribution of trimethylamine in summer was improved to 48.3 ± 3.7% by the synergistic interaction effect, which was not found in previous studies. This might be useful for precise prediction and effective treatment of odour pollution in various regions.

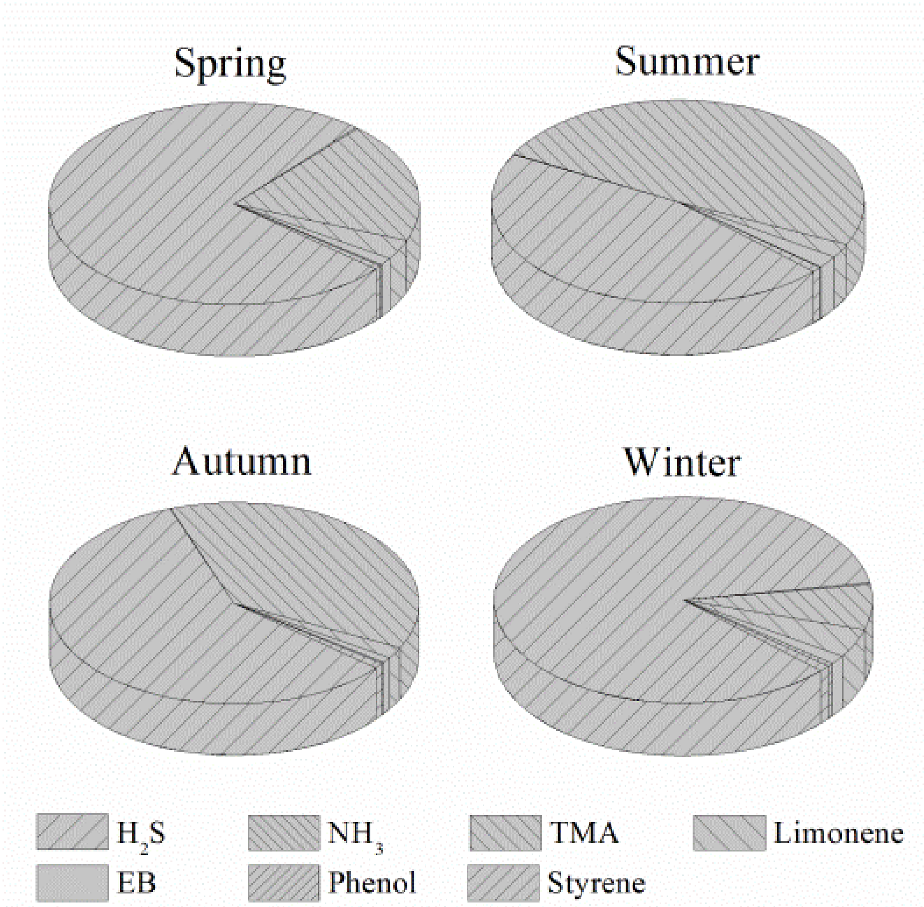

Figure 2: Average odour contribution of key odorants in each season. EB: ethylbenzene, H_2S: hydrogen sulfide, NH_3: ammonia, TMA: trimethylamine (Wu et al., 2015).

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