Conversion of the chemical concentration into odour concentration: evaluation of the key parameters

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Continuous odour measurements are seldom realised, mainly because of their high costs. They are therefore often substituted by chemical concentration measurements of odorous substances. Then a conversion of the chemical concentrations C (mg m^{-3}) into odour concentrations OC (ou_E m^{-3}) is necessary. Several methods are in use for the conversion: the chemical concentration C, the sum of odour activity value SOAV, the sum of odour intensity SOI, the equivalent odour concentration EOC, and the sum of odour activity factor SOAF. These conversion methods are evaluated by comparison with the olfactometric measurements of odorous mixtures. The results indicate that the SOI and EOC methods deliver reliable values for odorous mixtures composed of seven substances, and the accuracy is much better than for the first two methods, since SOI and EOC methods use not only the odour threshold concentration but also the slope of the Weber-Fechner law to include the sensitivity of the odour perception of the individual substances. On the other hand, the SOAF method shows a good precision on the prediction of odour concentrations of real odorous air samples in a waste disposal plant. The reason lies in the fact that the SOAF method includes the interaction effects in the complex odorous air samples.

1. Introduction

For environmental odour, it is difficult to realise continuous odour measurements of ambient concentrations and gaseous emissions of odour sources. This is mainly because the olfactometric measurements can only be done discontinuously and usually inside an odourless laboratory, and the costs of the olfactometric measurements are high. Thus, in many cases, odour measurements are substituted by concentration measurements of the odorous compounds.
Using concentration measurements of the odorous compounds instead of olfactometric measurements, a conversion of the chemical concentrations C (mg m^{-3}) into odour concentrations C_{OD} (ou_E m^{-3}) and odour intensities OI is necessary. For this conversion, several concepts are in use. The simplest approach is the direct use of the concentration of a single substance (e.g. H_2S) or a group of substances (e.g. VOC concentrations) as a surrogate of the odour concertation using a regression analysis. The second concept is called “Odour activity value” (OAV) and the “Sum of odour activity values” (SOAV). It is based on the normalisation of the concentration C by the odour threshold concentration C_{OT} (mg m^{-3}). If more than one substance is involved, then the sum of the individual OAVs is used (SOAV).

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For a more sophisticated conversion of the concentrations of odorous substances into odour concentrations, we use not only the odour threshold concentration but also the slope of the relationship between odour concentration and odour intensity. Using these parameters, two conversion methods are possible: the "Sum of the odour intensity" (SOI) and the concept of the "Equivalent odour concentration" (EOC) by Wu et al. (2016).

On the other hand, considering the potential odour interaction effects among the odour compounds in complex odorous mixtures, the "Sum of odour activity factor" (SOAF)-method was developed to assess the binary odour interaction effects. An odour activity value coefficient is proposed to evaluate the type and the level of binary interaction effects based on the measurement of OAV variation in a research on odorous gases in a waste disposal plant.

For the above five methods of converting the chemical concentrations of single substances into the odour concentrations and odour intensities of odorous mixtures, several key parameters are involved. Generally, the key parameters include the chemical concentration, the odour threshold and the sensitivity of the odour perception of the individual substances, as well as the odour interaction effects in the odorous mixtures. The topic of this paper is to compare these conversion methods as well as to explore the key parameters.

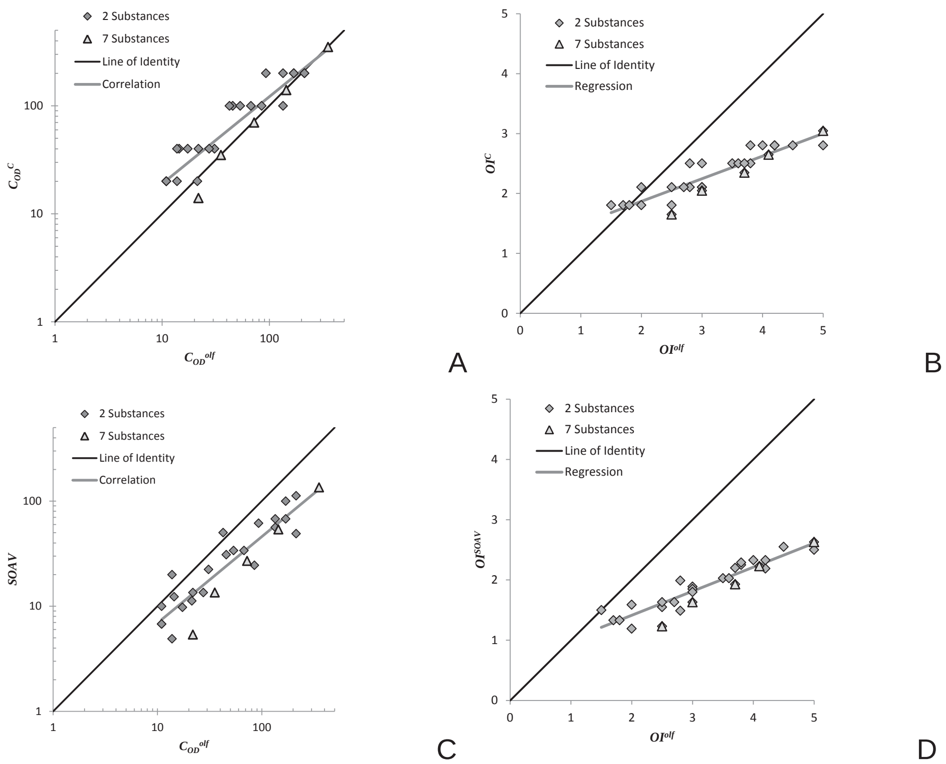

Figure 1: Comparison of the converted odour concentrations $C_{OD}{}^{C}$ (A) and SOAV (C) with $C_{OD}{}^{olf}$ (ou_E m^{-3}) and the converted odour intensities OI^{C} (B) and OI^{SOAV} (D) with the OI^{olf} for the 23 binary mixtures and the 5 mixtures of all seven substances.

2. Material and methods

The conversion of the chemical concentration of single substances to the odour concentrations and odour intensities of an odorous mixture using the five methods is the central topic of this paper. The ability of the first four conversion methods (C, SOAV, SOI, and EOC) to produce reliable odour concentrations is investigated here by comparing them with olfactometric odour concentration measurements; also the odour intensities will be compared. The experiments were conducted on 24 binary odorous mixtures and 5 odorous mixtures of seven substances which comprise seven typical odorous compounds: Butyl acetate, Benzene, Ethyl acetate, Toluene, m-Xylene, o-Xylene and a-Pinene. The four conversion methods were described in detail by Wu et al. (2016).

The ability of the last conversion method (SOAF) to produce reliable odour concentrations is investigated by comparing its conversion values with the olfactometric odour concentration measurements and the conversion results of the SOAV method. The experiments were conducted on 16 odorous air samples which were collected at four sampling sites in a waste disposal plant during a year. These measurements and conversion details of the SOAF method were described in detail by Wu et al. (2015).

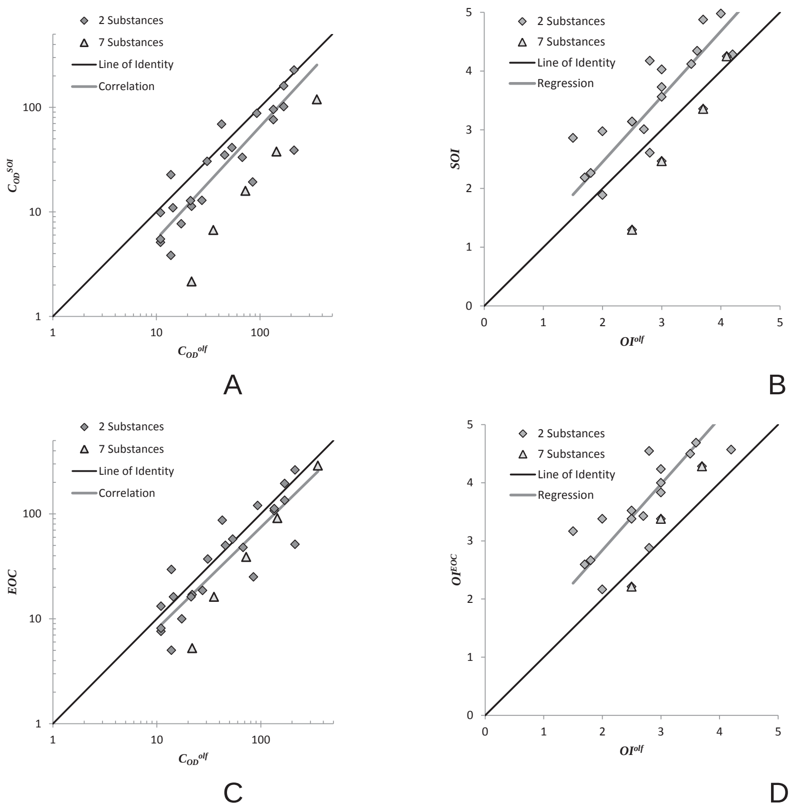

Figure 2: Comparison of the converted odour concentrations C_{OD}^{SOI} (A) and EOC (B) with C_{OD}^{olf} (ou_E m^{-3}) and the converted odour intensities SOI (C) and OI^{EOC} (D) with the OI^{olf} for the 23 binary mixtures and the 5 mixtures of all seven substances.

3. Results and discussion

The converted odour concentrations and odour intensities from the first two methods (C method and SOAV method) show the weakest quality (Fig. 1). These conversion

methods will not provide odour intensities which are close to those measured by the olfactometer. Instead, the odour intensities are severely under-estimated.
The odour concentration, calculated by the *SOI* (Fig. 2A), shows a good correspondence with the line of identity with a slope of 0.9471. The converted odour concentration underestimates the measured odour concentration by about 37%. This under-estimation is even more pronounced for the mixtures of the seven substances. The regression line for the odour intensity shows a good agreement with the line of identity (Fig. 2B). The slope of the linear regression is 1.12 which results in an overestimation of about 0.5 grades for a high odour intensity of grade 5.
The equivalent odour concentration *EOC* shows a slope of 0.9688 which is close to the line of identity with a weak underestimation of about 13% (Figure C). The regression line of the resulting odour intensities OI^{EOC} lies parallel to the line of identity with a slope of 1.14 and an overestimation of about 0.6 grades of the 5 grade intensity scale (Fig. 2D).

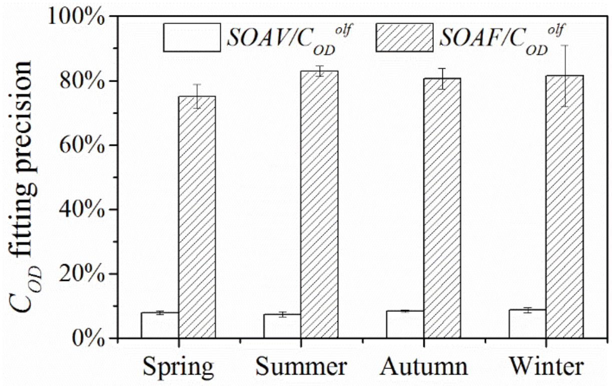

Figure 3: Comparison of the converted odour concentrations SOAF and SOAV with C_{OD}^{olf}*) for the gaseous samples collected in a waste disposal plant.*

The last two conversion methods, *SOI* and *EOC,* yield the best results. The regression lines for the odour intensity show a good agreement with the line of identity. It could be shown that conversion methods which use not only the odour threshold concentration but also the slope of the Weber Fechner law to include the sensitivity of the odour perception of the individual substances deliver more reliable values.
On the other hand, Fig. 3 reflects the comparison of mean SOAV, SOAF and C_{OD} of odour samples collected at four sites in each season. On average, SOAF matches 80.0% ± 5.7% of C_{OD}. This is 10 times higher than SOAV, which means that the SOAF method could be a promising method to convert chemical concentrations of compounds in complex gaseous mixtures into odour concentrations. The reason is that odour interaction effects among the compounds are taken into consideration.

4. Conclusion

The first four concepts (C, SOAV, SOI and EOC) are based on the working hypothesis that the mixture of odorous substances behaves additively, which is only a rough estimate. This means that no odour interaction effects between the substances is taken into consideration. Then the calculated odour concentration C_{OD}^{theo}, calculated by the SOAV, the SOI or the EOC methods, and the odour concentration measured by an olfactometer C_{OD}^{olf} lie on the line of identity, namely $C_{OD}^{olf} = C_{OD}^{theo}$. The SOI and EOC conversion methods deliver reliable values, since these methods use not only the odour threshold concentration but also the slope of the Weber Fechner law to include the sensitivity of the odour perception of the individual substances. For complex odorous mixtures such as gaseous emissions in a waste disposal plant, the interaction effects between various compounds can be complicated. The odour activity value coefficient was determined to evaluate the type and the level of binary interaction effects based on the measurement of the OAV variation.

Acknowledgments

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References

Wu, C. D.; Liu, J. M.; Zhao, P.; Piringer, M.; Schauberger, G. Conversion of the chemical concentration of odorous mixtures into odour concentration and odour intensity: A comparison of methods. Atmospheric Environment. 2016, 127, 283-292.

Wu, C. D.; Liu, J. M.; Yan, L. C.; Chen, H. Y.; Shao, H. Q.; Meng, T. Assessment of odor activity value coefficient and odor contribution based on binary interaction effects in waste disposal plant. Atmospheric Environment. 2015, 103, 231-237.