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Editorial

Environmental Odour: Emission, Dispersion, and the Assessment of Annoyance

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Environmental odour is a major concern of residents in the vicinity of odour sources. This Special Issue of *Atmosphere* was open for the entire chain where odour can be an issue: (1) from the odour source characterised by emission factors and treated by emission models, (2) over the use of dispersion models to describe the transport and dilution of odour and odorous substances/mixtures in the atmosphere, (3) to the assessment of the relevant stimuli concentration, (4) the calculation of odour exposure to estimate the expected odour annoyance by odour impact criteria, and finally (5) odour abatement strategies. All types of odorous substances related to industry (e.g., rendering plants, refineries), municipal plants (e.g., wastewater treatment plants, solid waste landfills), and animal husbandry were included. Contributions on odour perception in urban areas and agglomerations as well as possible mitigation plans were encouraged. The goal was the exchange of ideas and achieving a better understanding of the specific aspects that are relevant to environmental odour.

The Special Issue "Environmental Odour: Emission, Dispersion, and the Assessment of Annoyance" comprises seven original papers and two reviews.

Four research papers [1–4] and one review [5] deal with the emission of odour, caused by a sewer system in Korea [1], by sewage sludge composting [2], the assessment of the uncertainty of the triangular odour bag method [3], and the relationship between odour concentration and hedonic tone [4]. The odour concentration is given as an odour perception relevant mass (European odour unit ou_E) per cubic meter (ouE/m^3), determined by a dilution process (e.g., [6]). The review of Bax et al. [5], which was conceived within the H2020 D-NOSES project, summarizes odour measurement techniques, highlighting their applicability, advantages, and limits. Besides measurement methods quantifying the emission of chemical substances, especially of industrial sources, field measurements and citizen science methods were also included. The European project H2020 D-NOSES (Distributed Network for Odour Sensing Empowerment and Sustainability), funded by the European Union's Horizon 2020 Research and Innovation Programme, is an important signal that odour is recognised as a well-known environmental and air quality issue. In this sense, there is hope that the European Environmental Agency will include this environmental agent in the near future in their annual air quality reports.

Park [1] discussed the conversion of chemical concentration values into odour concentration using the odour activity value. This method can help substitute olfactometric measurements by cheaper methods as gas chromatography. For the sewer system, three out of 14 chemical compounds, namely H_2S, CH_3SH, and $(CH_3)_3N$, were identified to contribute most to the odour emission. This methodology allows evaluating odour emissions by the use of Korean chemical concentration limit values. González et al. [2] analysed the greenhouse gas and the odour emission of composted sewage sludge. The odour emission is determined by using the conversion of the chemical concentration to odour concentration by the odour activity value. Dimethyl disulphide, eucalyptol, and α-pinene were identified as the most important odorous compounds. This study encloses an inventory of the gaseous and odorous emissions caused by the sewage sludge composting process. This can help in the development and further implementation of mitigation and control strategies.

Higuchi et al. [3] presented a round-robin test, which compared 130 Japanese and four Chinese laboratories using the triangular odour bag method to measure the odour concentration of dimethyl disulphide with a chemical concentration of 10.7 ppm. This method was developed in Japan [7] as an alternative to dynamic olfactometric devices. Accuracy and precision were used to judge the 134 laboratories showing that 110 (108 Japanese and two Chinese) and 104 (102 Japanese and two Chinese) (82.7% and 78.2%) conformed to the criterion of accuracy and precision, respectively, and two thirds (65.4%) conformed to both (86 Japanese and one Chinese laboratories). Li et al. [4] investigated the relationship between odour concentration and hedonic tone for the three odorous chemicals dimethyl disulfide, limonene, and butyl acetate as typical odorants with different characteristics. This investigation confirmed that the odour quality, described by the hedonic tone, depends strongly on the odour concentration. For limonene, its smell is pleasant when the odour concentration lies between 25 and 1995 ou_E/m^3 and above this range the hedonic tone tips over into the range of unpleasantness, whereas dimethyl disulphide and butyl acetate are perceived as unpleasant independent from the odour concentration.

The assessment of annoyance in the surroundings of an odour source is a complex issue that includes the dilution of odorous substances in the atmosphere and the evaluation by odour impact criteria. These aspects are covered by three research papers [8–10] and a review [11] dealing with the concentration fluctuations of ambient odour concentrations. To adapt the output of a dispersion model (one hour mean values of the ambient concentration) to a more perception-related measure, the fluctuation has to be taken into account. This is often called a peak-to-mean approach [12]. Ferrero et al. [11] presented a review investigating the ability to reproduce higher-order moments of the probability density function of concentrations. This is not only relevant for environmental odour but also for the flammability of substances and health-related chemicals with a non-linear dose–response relationship. Even if this review is focused on Lagrangian dispersion models, it is worth it to notice that, in general, dispersion models are well-known to reproduce the mean values of the ambient concentration well. The approaches to quantify the corresponding concentration fluctuations are often new and unknown. For livestock buildings, Zhang and Zhou [8] investigated the peak-to-mean ratio through field measurements using panellists to determine the odour intensity. The limitations of these field measurements were the intermittency (non-zero perception values) and the logarithmic relationship between odour concentration and perceived odour intensity (Weber–Fechner law). If the zero intensity values were omitted using the conditioned peak-to-mean ratio, then the peak-to-mean ratios lie in the range between 1 and 4, which correspond to the Italian (2.3) [13] and the German (4) [14] peak-to-mean factors, which are used to assess the expected maximum short-term odour concentration with respect to the hourly mean value of the ambient concentration. The importance to assess the fluctuation intensity was shown recently for various dispersion models and their related peak-to-mean approaches [13]. The relationship between the exposure to environmental odour and complaints was analysed by Moshammer et al. [9]. Odour exposure was quantified by the ambient odour concentration at the 98th percentile and by the exceedance probability for the threshold of 1 ou_E/m^3, also known as the percentage of odour hours. Both exposure measures showed comparable results [15]. The exposure was related to the complaint statistics, showing that the percentage of complaining households and (highly) annoyed persons were comparable in magnitude and in statistical model performance. The hedonic tone of the ambient odour exposure, quantified by the polarity profile, could not be identified as a predictor. Wu at al. [10] presented a comparison between the golden standard to assess odour annoyance by the application of dispersion models with simplified empirical equations to make a rough estimate for separation distances to avoid odour annoyance. The presented study showed a comparison of odour-related separation distances around a dairy farm in Beijing determined by two empirical models (Austrian and German empirical model) and a regulatory dispersion model (AERMOD). The finding of this case showed that countries with no specific requirements for managing environmental odour can promote the use of such empirical equations as a first-guess or screening tool to estimate possible areas affected by odour annoyance. An overview of such empirical equations was published recently [16].

This Special Issue presents a broad perspective of the current status and main aspects and developments on environmental odour as highlighted by the contributing scientific community. Although the results discussed here summarize cutting-edge research on air quality, they also open additional scientific questions, confirming that the topic of environmental odour still presents strong challenges that will be the focus of a new Special Issue of *Atmosphere* in this field of research. Therefore we encourage all colleagues to contribute to the new Special Issue on Environmental Odour, which is now open for submission. This upcoming Special Issue will be edited by Chuandong Wu and Jacek Koziel in addition to the two editors of this Special Issue, Martin Piringer and Günther Schauberger.

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