atmosphere

Editorial

Environmental Odour

Günther Schauberger [1,*], Martin Piringer [2,*], Chuandong Wu [3] and Jacek A. Koziel [4]

1 WG Environmental Health, Department of Biomedical Sciences, University of Veterinary Medicine Vienna, Veterinärplatz 1, 1210 Vienna, Austria
2 Department of Environmental Meteorology, Central Institute for Meteorology and Geodynamics, HoheWarte 38, 1190 Vienna, Austria
3 School of Chemistry and Biological Engineering, University of Science and Technology Beijing, Beijing 100083, China; wuchuandong@ustb.edu.cn
4 Department of Agricultural & Biosystems Engineering, Iowa State University, 4350 Elings Hall, Ames, IA 50011, USA; koziel@iastate.edu
* Correspondence: Gunther.Schauberger@vetmeduni.ac.at (G.S.); Martin.Piringer@zamg.ac.at (M.P.)

Environmental odour is perceived as a major nuisance by the rural and urban population. The sources of odorous substances are manifold. In urban areas, these include restaurants and services, small manufacturing and other sources that might cause complaints. Wastewater treatment plants, landfill sites and other infrastructures are the expected major odour sources in the suburbs. These problems are often caused by accelerated urban growth. On rural sites, livestock farming and manure spreading on fields, composting plants and biogas reactors are blamed for severe odour annoyance. In fact, environmental odours are a common cause of public complaints by residents to local authorities and regional or national environmental agencies. This Special Issue deals with the entire spectrum, from the estimation or measurement of odour emissions and the dispersion of odorous substances in the atmosphere to the determination of setback or separation distances and an estimation of odour annoyance levels in a neighbourhood. Each research paper had a specific focus; most consider one element of this chain, while some try to cover the entire chain. In particular, this Special Issue encouraged contributions dealing with field trials and dispersion modelling to assess the degree of annoyance and the quantitative success of abatement measures.

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This Special Issue, "Environmental Odour", comprises one review and nine original papers. A review by Bokowa et al. [1] summarises odour legislation in selected European countries (France, Germany, Austria, Hungary, the UK, Spain, the Netherlands, Italy and Belgium), North America (the USA and Canada) and South America (Chile and Colombia), as well as Oceania (Australia and New Zealand) and Asia (Japan and China). Many countries have incorporated odour controls into their legislation. However, odour-related assessment criteria tend to be highly variable between countries, individual states, provinces and even counties and towns. The discussion of odour in legislation ranges from no specific mention of odour in the environmental legislation that regulates pollutants known to have an odour impact to extensive details about odour source testing, odour dispersion modelling, ambient odour monitoring, setback distances, process operations and odour control technologies and procedures. The paper ends with a list of questions that may be used to discuss the formulation of odour regulation. As Brancher et al. [2] outlined, the odour impact criteria (OICs) of different jurisdictions do not a priori ensure analogous separation distances for an equivalent level of protection. This must be addressed first, when more homogeneous odour-related assessment criteria among different countries are intended.

Several papers deal mainly with the identification of odour emissions from wastewater treatment plants (WWTPs). The reliable determination of their odourant compounds is still challenging. Gao et al. [3] identified odorous volatile organic compounds (VOCs) from domestic wastewater at different processing units using gas chromatography-ion mobility spectrometry (GC-IMS) and gas chromatography quadrupole-time-of-flight mass spectrometry (GC-QTOF-MS). The results of the latter approach confirmed the odour contribution of organic sulfur compounds in wastewater before primary sedimentation and ruled out the significance of most of the hydrocarbons in wastewater odour. Varied volatile compounds were detected using GC-IMS, mainly oxygen-containing VOCs including alcohols, fatty acids, aldehydes and ketones with low odour threshold values. The GC-IMS technique may provide an efficient profiling method for the changes of inlet water and the performance of the treatment process at WWTPs.

Bian et al. [4] used the Odour Profile Method (OPM) with an odour patrol program; the OPM was based on a seven-level sugar scale for the gustatory sense to calibrate the perception of the intensity of odourants at a school within one mile of the Los Angeles County landfill. A landfill odour wheel was used to identify the odour type. This study shows that an Odour Patrol using the OPM can accurately define odour nuisance changes over time. The OPM not only confirmed the mitigation of a landfill odour problem, but also determined the odour character, the odour intensity, the odour frequency and the odour duration during this study period.

Cipriano et al. [5] discussed uncertainties in the quantification of odour measurements caused by, among others, the selection of a panel (required by dynamic olfactometry), the sampling and the stability of the samples. Proficiency tests (PTs) can help evaluate such contributions. They are, however, often implemented by only using dry gas cylinders containing stable compounds. Consequently, uncertainties related to the sampling activity cannot be assessed. In particular, high odour levels and the presence of water vapour in emission sources can create significant biases due to the sampling techniques used and the chemical reactions that can occur before analysis. Cipriano et al. [5] created an upgraded protocol for implementing PTs for odour determinations in conditions very similar to reality (i.e., high temperatures, high water contents and the presence of chemical interferents).

Hansen et al. [6] compared the Sum of Odour Activity Values (SOAV) method with the odour detection threshold measured using olfactometry and investigated the assumption of additivity. The odour activity value was used for the conversion of chemical concentration values into odour concentrations. Synthetic pig house air with odourants at realistic concentration levels was used in the study (hydrogen sulfide, methanethiol, trimethylamine, butanoic acid and 4-methyl phenol). An olfactometer with only Polytetrafluoroethylene (PTFE) is in contact with the sample air was used to estimate odour threshold values (OTVs) and the odour detection threshold for samples with two to five odourants. The results showed a good correlation (R^2 = 0.88) between the SOAV estimated based on the OTVs for panellists in the present study and values found in the literature. For the majority of the samples, the ratio between the odour detection threshold and the SOAV was not significantly different from one, which indicated that the OAV for individual odourants in a mixture can be considered additive. In conclusion, the assumption of the additivity between odourants measured in pig house air seems reasonable, but the strength of the method is determined by the OTV data used. The SOAV concept was, in the first Special Issue of Environmental Odour used by Park [7] and discussed in detail by Wu et al. [8].

The assessment of annoyance in the surroundings of an odour source is a complex issue that, apart from the estimation of odour emissions, includes the dilution of odorous substances in the atmosphere and an evaluation using OICs. Zarra et al. [9], for an Italian WWTP, and Zhang et al. [10], for a WWTP in Northern China, characterise odour nuisance using trained assessors and questionnaires, applied atmospheric dispersion modelling to calculate ambient odour concentrations and used OICs to determine separation distances. Although both use the Lagrangian dispersion model CALPUFF, the resulting isopleths of separation distances are very different, which is also attributable to the different OICs used. In contrast, Zarra et al. [9] calculated separation distances for hourly average odour concentration threshold values of 1.0 and 1.5 ou_E m^{-3} and the 85th and the 98th percentile, resulting in separation distances of up to a few 1000 m around the source. Zhang et al. [10] applied threshold values from 1 to 5 ou_E m^{-3} and percentiles from 70 to 98. The best predictor of odour exposure was obtained with a threshold value of 4 ou_E m^{-3} at the 99th percentile, resulting in separation distances of only a few hundred metres. However, both groups of authors reported a good agreement of the model-calculated separation distances with the odour nuisance levels obtained from the questionnaires and the trained assessors. An essential contribution of these papers is a dose–response function between the odour exposure and the annoying potential of WWTP odour.

Ravina et al. [11] analysed separation distances around a WWTP in Northern Italy. Odour dispersion modelling was carried out again with the CALPUFF model. For low odour concentration thresholds (C_T = 1 ou_E m^{-3}), the results showed that two different years (2018 and 2019) provided similar patterns of the separation distances. The difference between the two years tended to increase by increasing the concentration threshold value (C_T = 3 ou_E m^{-3} and C_T = 5 ou_E m^{-3}). The second phase of the assessment was the selection of the open field correction method for wind velocity used in the calculation of odour emission rates (OERs). The following three different relationships were considered: the power law, the logarithmic law and the Deaves–Harris (D–H) law. The results showed that OERs and separation distances varied, depending on the selected method. Taking the power law as the reference, the average variability of the separation distances was between −7% (D–H law) and +10% (logarithmic law). Higher variability (up to 25%) was found for single transport distances. The study provides knowledge toward a better alignment of the concept of the odour impact criteria.

Piringer et al. [12] investigated the impact of odour sources as livestock buildings on neighbouring residential areas due to climate change. Separation distances were calculated for two Central European sites with considerable livestock activity influenced by different orographic and climatic conditions. Two climate scenarios were considered, namely, the time period 1981–2010 (present climate) and the period 2036–2065 (predicted future climate). Based on the provided climatic parameters, stability classes were derived as an input for local-scale air pollution modelling. The separation distances were determined using the Lagrangian particle diffusion model LASAT. The main findings comprise the changes of stability classes between the present and the future climate and the resulting changes in the modelled odour impact. The model results based on different schemes for stability classification were compared. With respect to the selected climate scenarios and the variety of the stability schemes, a bandwidth of the affected separation distances resulted. The investigation revealed the extent, to which livestock husbandry will have to adapt to climate change, e.g., with impacts on today's licensing (permitting) processes.

Countries with no specific requirements for managing environmental odour can promote the use of empirical equations as a first-guess or screening tool to estimate possible areas affected by odour annoyance. Brancher et al. [13] compared separation distances obtained from selected empirical equations with those from dispersion models AERMOD and LASAT for sites in Brazil, China and Austria. As the separation distance shape often resembles the wind distribution of a site, wind data should be included in such approaches. Otherwise, the resultant separation distance shape is simply given by an idealised circle around the emission source. The results of this investigation suggested that some empirical equations reach their limitation in the sense that they are not successful in capturing the inherent complexity of dispersion models. However, empirical equations, developed for Germany and Austria, have the potential to deliver reasonable results, especially if used within the conditions for which they were designed. The main advantage of empirical equations lies in the simplification of the meteorological input data and their use in a fast and straightforward approach.

This Special Issue presents a broad perspective of the current status and main aspects of environmental odour as highlighted by the contributing scientific community. Although the results discussed here summarise cutting-edge research on air quality, they also open additional scientific questions, confirming that the topic of environmental odour still presents substantial challenges. While the quantification of odour emissions is, to a great extent, successfully regulated [3–5], OICs, which are necessary to assess annoyance in residential areas around odour sources, are issued on national levels and vary from country to country [2,14]. Some countries such as China, Japan and South Korea use odour standards based on limit values for ambient odour concentration rather than OICs. Therefore, the international harmonisation of OICs is seen as an urgent undertaking for the scientific and the regulator community to ensure analogous separation distances for an equivalent level of protection in the future.

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References

1. Bokowa, A.; Diaz, C.; Koziel, J.A.; McGinley, M.; Barclay, J.; Schauberger, G.; Guillot, J.-M.; Sneath, R.; Capelli, L.; Zorich, V.; et al. Summary and overview of the odour regulations worldwide. *Atmosphere* **2021**, *12*, 206. [CrossRef]
2. Brancher, M.; Piringer, M.; Grauer, A.F.; Schauberger, G. Do odour impact criteria of different jurisdictions ensure analogous separation distances for an equivalent level of protection? *J. Environ. Manag.* **2019**, *240*, 394–403. [CrossRef] [PubMed]
3. Gao, W.; Yang, X.; Zhu, X.; Jiao, R.; Zhao, S.; Yu, J.; Wang, D. Limitations of GC-QTOF-MS technique in identification of odorous compounds from wastewater: The application of GC-IMS as supplement for odor profiling. *Atmosphere* **2021**, *12*, 265. [CrossRef]
4. Bian, Y.; Gong, H.; Suffet, I.H. The use of the odor profile method with an "odor patrol" panel to evaluate an odor impacted site near a landfill. *Atmosphere* **2021**, *12*, 472. [CrossRef]
5. Cipriano, D.; Cefalì, A.M.; Allegrini, M. Experimenting with odour proficiency tests implementation using synthetic bench loops. *Atmosphere* **2021**, *12*, 761. [CrossRef]
6. Hansen, M.J.; Adamsen, A.P.S.; Wu, C.; Feilberg, A. Additivity between key odorants in pig house air. *Atmosphere* **2021**, *12*, 1008. [CrossRef]
7. Park, S. Odor characteristics and concentration of malodorous chemical compounds emitted from a combined sewer system in Korea. *Atmosphere* **2020**, *11*, 667. [CrossRef]
8. Wu, C.; Liu, J.; Zhao, P.; Piringer, M.; Schauberger, G. Conversion of the chemical concentration of odorous mixtures into odour concentration and odour intensity: A comparison of methods. *Atmos. Environ.* **2016**, *127*, 283–292. [CrossRef]
9. Zarra, T.; Belgiorno, V.; Naddeo, V. Environmental odour nuisance assessment in urbanized area: Analysis and comparison of different and integrated approaches. *Atmosphere* **2021**, *12*, 690. [CrossRef]
10. Zhang, Y.; Yang, W.; Schauberger, G.; Wang, J.; Geng, J.; Wang, G.; Meng, J. Determination of dose–response relationship to derive odor impact criteria for a wastewater treatment plant. *Atmosphere* **2021**, *12*, 371. [CrossRef]
11. Ravina, M.; Bruzzese, S.; Panepinto, D.; Zanetti, M. Analysis of separation distances under varying odour emission rates and meteorology: A wwtp case study. *Atmosphere* **2020**, *11*, 962. [CrossRef]
12. Piringer, M.; Knauder, W.; Baumann-Stanzer, K.; Anders, I.; Andre, K.; Schauberger, G. Odour impact assessment in a changing climate. *Atmosphere* **2021**, *12*, 1149. [CrossRef]
13. Brancher, M.; Piringer, M.; Knauder, W.; Wu, C.; Griffiths, K.D.; Schauberger, G. Are empirical equations an appropriate tool to assess separation distances to avoid odour annoyance? *Atmosphere* **2020**, *11*, 678. [CrossRef]
14. Sommer-Quabach, E.; Piringer, M.; Petz, E.; Schauberger, G. Comparability of separation distances between odour sources and residential areas determined by various national odour impact criteria. *Atmos. Environ.* **2014**, *95*, 20–28. [CrossRef]