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Use of dispersion modelling for Environmental Impact Assessment of biological air pollution from composting: Progress, problems and prospects

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ABSTRACT

With the increase in composting as a sustainable waste management option, biological air pollution (bioaerosols) from composting facilities have become a cause of increasing concern due to their potential health impacts. Estimating community exposure to bioaerosols is problematic due to limitations in current monitoring methods. Atmospheric dispersion modelling can be used to estimate exposure concentrations, however several issues arise from the lack of appropriate bioaerosol data to use as inputs into models, and the complexity of the emission sources at composting facilities. This paper analyses current progress in using dispersion models for bioaerosols, examines the remaining problems and provides recommendations for future prospects in this area. A key finding is the urgent need for guidance for model users to ensure consistent bioaerosol modelling practices.

Contents

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1. Introduction

Integrated waste management systems that recover resources are increasingly in use in the UK and across Europe encouraged by the EU landfill directive (2008/96/EC). Composting is a good example of such a process which produces nutrient rich fertiliser and prevents methane production. However, composting also results in elevated concentrations of biological air pollution (bioaerosols), particularly during agitation activities (Taha et al., 2006). Bioaerosols are airborne particles of biological origin. They include fungi, bacteria, pollen, organic particulate matter, and by-products of cells. These microorganisms may be viable and culturable, i.e. a living cell that is capable of growing on artificial culture media; or non-viable and not capable of growing on artificial culture media (Douwes et al., 2003; Dowd and Maier, 2000; Pearson et al., 2015; Viegas et al., 2014). Bioaerosol exposure is associated with various adverse health outcomes due to exposure to microorganisms and/or their components, and there is qualitative evidence suggesting that populations who live or work close to composting facilities are at risk of adverse health outcomes, particularly self-reported respiratory related symptoms (Herr et al., 2003; Pearson et al., 2015). The risk of exposure to bioaerosols has resulted in public health concerns. In response, the Environment Agency in England currently adopts a precautionary stance requiring composting facilities with sensitive receptors, e.g. houses or places of work within 250 m of the site boundary, to complete a site specific bioaerosol risk assessment to show that bioaerosols will be maintained at 'acceptable levels' above the ubiquitous bioaerosol background (Environment Agency, 2010). Each category has acceptable levels currently specified as 300, 1000 and 500 colony forming units per cubic metre (CFU m^{-3}) for gram-negative bacteria, total mesophilic bacteria and *Aspergillus fumigatus* respectively, as measured by the AfOR (2009) standard protocol. In Germany, the Federal Ministry for Environment, Nature, Conservation and Nuclear Safety (BUNR) suggest a minimum setback distance of 300 m and 500 m for enclosed and open-windrow facilities respectively that process 3000 Mg or more (BUNR, 2002). However, there are currently no quantitative dose-response estimates for bioaerosol exposure defined as the scientific understanding of the link between exposure and human health is limited (Pearson et al., 2015; Walser et al., 2015). There is a need for improved assessment of exposure to bioaerosol emissions from composting, to establish a clearer association between exposure, dose received and health outcomes, as highlighted by Sykes et al. (2007) and more recently by Douglas et al. (2016a).

Dispersion models are routinely used to provide reliable estimates of aerosol and other pollutant concentations over wide timescales and areas. There is also the potential for these to be used to estimate bioaerosol dispersion. A dispersion model set up to predict concentrations of bioaerosol would have a number of uses including:

- Estimating short and long term concentrations at sensitive receptors.
- Calculating set-back distances to assess locations for new facilities so as to reduce the risk of exposure of neighbouring sensitive receptors.
- As a risk management tool to inform site managers of predicted periods of high off-site concentrations and attribute these to specific activities. This enables the specification of mitigation measures to avoid exceedances of bioaerosol concentrations.
- Allowing regulators to assess emissions and evaluate the effectiveness of mitigation strategies prior to permitting operations.
- Determining the most appropriate siting of equipment for ambient monitoring strategies as well as determine locations where the highest off site bioaerosols concentrations are likely to be detected.
- Providing additional data to improve exposure assessment within epidemiological studies, e.g. developing work such as that by Douglas et al. (2016a). Used in conjunction with health data, this would improve knowledge of dose response relationships thus informing future regulation and guidance.

Progress towards producing accurate estimates of downwind bioaerosol concentrations using dispersion models has been limited to date, primarily due to a lack of data on bioaerosol composition, emission rates and dispersal characteristics. These are difficult to quantify due to the varied and complex nature of the bioaerosol release, particularly at open windrow facilities. This in turn results in a lack of source term data for dispersion models used to assess sites. A summary of the complex nature of bioaerosol emissions from composting facilities is presented in Appendix A. The concentration, type (species) and timing of bioaerosol emissions from composting facilities vary by site due to differences in management practises and the processing techniques adopted.

Difficulties in quantification are further complicated by differing approaches to sampling used in past studies, amongst which there are no comparable relationships (Williams et al., 2013). The common bioaerosol sampling methods, and the advantages and disadvantages of each, are summarised in Appendix B. In England, there is a standardised sampling protocol (AfOR, 2009), which has recently been superseded by the 'M9' document (Environment Agency, 2017). Whilst this provides consistent data over time for the regulatory purposes it was designed to support, it currently provides a limited dataset, as the number of samples taken are limited (three samples; upwind, downwind and at the nearest sensitive receptor). This, like many sampling campaigns, was not designed to support dispersion modelling. Therefore at present insufficient data are available to validate the application of dispersion models to describe dispersion from composting sites. A further complication in interpreting bioaerosol data is that bioaerosols are ubiquitous in ambient air and background concentrations will vary depending on area and season (Maddelin, 1994; Swan et al., 2002). Therefore, determining whether concentrations are from composting or other sources of bioaerosols is difficult.

The aims of this paper are to:

(1) Review progress made to date in using dispersion models to estimate bioaerosol concentrations, summarising what input values have been used in the dispersion models, and assessing the quality of predictions.
(2) Highlight the key problems and challenges to dispersion modellers when attempting to predict bioaerosol concentrations from composting facilities.
(3) Identify future prospects and summarise the key areas where further research is necessary to close evidence gaps and improve model performance.

2. Review of progress and recognition of problems

2.1. Use of models

Dispersion models simulate the dispersion of a pollutant emitted to the atmosphere through the use of algorithms that describe the controlling atmospheric, physical and chemical processes (Holmes and Morawaka, 2006). There are various forms of dispersion models including box models, Gaussian, Lagrangian, and Eularian models and Computational Fluid Dynamic (CFD) models.

There have been a number of attempts to use dispersion models to predict bioaerosol dispersion, as summarised in Table 1. This