Detection and characterisation of inflammatory agents associated with bioaerosol emitted from biowaste and intensive agriculture – Endotox-II

Overview
Exposure to bioaerosols is associated with a range of health effects including allergenicity, toxicity and infectivity. Waste management and intensive agricultural facilities are known to emit bioaerosol with potential for significant occupational and community health impacts. However, there are significant knowledge gaps related to temporal characteristics of emissions, exposure characteristics of the general public to bioaerosol, the interplay between process-based exposures and background exposure to natural bioaerosol, quantifying health risk and setting health-based standards. The key barrier hindering progress in these areas is the lack of advanced microbiological methods (sampling, analytical, interpretative) to quantify and qualify bioaerosol emissions and dispersion. Therefore Endotox-II set out to advance research into enhanced and novel molecular methods and associated process studies with the following objectives:

i. develop sampling methodologies to size fractionate endotoxin in bioaerosol and elucidate its structural features.
ii. develop a novel biosensor for rapid detection of endotoxin and other bioaerosol-related inflammatory agents and cells (live/dead).
iii. evaluate the potential of a SIBS real-time bioaerosol sensor to enhance understanding of the emission and dispersion of bioaerosols.
iv. characterise industry-specific bioaerosol emissions in ambient air and inflammatory potential using the suite of enhanced techniques developed through controlled laboratory experiments.
v. detect microbial hazards around biowaste and intensive agricultural facilities using novel methods.
vi. utilise new knowledge from real-time detection, and on the endotoxin physical characterisation, to generate improved exposure assessments surrounding biowaste and intensive agricultural facilities using dispersion modelling and Openair

Over 4 years, the researchers from Cranfield University, Open University, Plymouth University, University of West England alongside Public Health England came together to address these objectives.

Size fractionation and spatio-temporal characteristics of endotoxin
The team at the OU optimised filter materials, extraction protocols and sampling duration impacts on endotoxin recovery. These improved methods were used to investigate size-fractionated endotoxin from authentic waste / agricultural sources in controlled environment chamber and real-world biowaste and intensive agricultural sites utilising an 8 stage non-viable Andersen impactor. Site activity and sampling distances were important factors and most of the endotoxin was associated with coarse size particles at source as well as downwind for both the composting and chicken house. However, a considerable amount of endotoxin was present in the fine size fraction (0.43–2.1 µm) as well at the composting source. Lower downwind concentrations of endotoxin were found at the chicken house compared to composting. This knowledge on the quantity and fraction of endotoxin associated with particles of different sizes informs our ability to assess exposures and likely health impacts.

Elucidation of structural characteristics of endotoxin and rapid endotoxin detection
Endotoxins (LPS) extracted from the size-fractioned bioaerosols from controlled experiments and from the field were analysed using innovative lung cell models (MPI alveolar macrophages and Co-cultures of MPI and MLE-12 epithelial cells) to elucidate their unique inflammatory responses. Generally, the coarse size fractions were most stimulatory. Polymyxin B treatment confirmed that most of the response is due to endotoxin. Regarding dose and exposure dependent responses to LPS, cytokine production (eg IL-6) was much higher in co-cultures compared with individual cell cultures. Epithelial cell damage, confirmed by scanning electron microscopy, in response to LPS exposure was observed only in co-cultures and found to be induced by factors produced by the macrophages. Proteomic analysis of secreted proteins was performed to identify the factors responsible for cellular damage. Damage to epithelial cells has been reported in conditions such as lung injury. The results show the importance of using the co-culture model over macrophage or epithelial cultures alone for studying bioaerosol/endotoxin induced inflammatory responses/mechanisms.
Real-time bioaerosol detection

A novel bioaerosol sensor unit (Spectral Intensity Bioaerosol Sensor (SIBS)) capable of measuring particle size and shape along with highly resolved fluorescence intensity measurements of single particles in real-time was evaluated. The principal purpose was to assess the capabilities of the SIBS and to enhance understanding of the bioaerosols emission and dispersion from industrial processes. The findings confirmed that SIBS is capable of providing quantification and spatio-temporal characterisation of bioaerosols alongside the size distribution and characteristics of airborne biological materials based on intrinsic bio fluorophores signatures. The SIBS can quantify and characterise emission events from industrial processes. It can also provide information in support of health impact assessment and source term parametrisation for dispersion modelling.

Microbial hazards around biowaste and intensive agricultural facilities

The samples (raw source material and air) taken from the composting and chicken house facilities were screened using a range of culture-based and molecular methods to gain insight into their microbial composition. In test chamber experiments we demonstrated that organisms present in the source materials were aerosolised and could be recovered from the air. These included Legionella pneumophila, mycobacteria and a variety of Gram-negative organisms for compost. High numbers of Gram-positive organisms (Staphylococci and Enterococci) were present in the chicken litter and were recovered from the air. For the air sample at the compost site, the type of organisms recovered were broadly similar to those emitted during controlled aerosolisation of raw material. These findings confirm the potential for pathogens to be aerosolised by waste management and agricultural processes and support the precautionary approach currently adopted by regulatory agencies. The findings also confirm the utility of novel microbiological methods in support of environmental health research and protection in such environments.

Improved exposure assessments surrounding biowaste and intensive agricultural facilities

The team at UWE has adopted a phased modelling approach to improve the quality of the input data on source characteristics and pollutant parameters coupled with health-based exposure assessment thresholds to model and validate dispersion models. Based on the data outputs generated from real-time monitoring of bioaerosols and particulate matter along with size-fractionated endotoxin, time-varying emission factors for different on-site activities were incorporated and downwind data was utilised to assess and validate model outputs. The results have contributed to improving our understanding of the extent of bioaerosols dispersion under different emission scenarios and the likely risk of community exposure to bioaerosols emission from such facilities. This will allow site operators and regulators to improve the exposure assessment methodologies surrounding biowaste and intensive agricultural facilities.

References