Institution: 10007822

Unit of Assessment: 12

Title of case study: Reduced bioaerosol emissions and dispersion from composting

1. Summary of the impact

Cranfield University has been a key contributor to development of policy and regulatory guidance for industrial composting in collaboration with the UK environmental regulators, Government departments and with in-kind and financial support from the waste management industry. The growth of the industry in the UK has needed applied research to support the evolving policy.

Cranfield has characterised and quantified the nature and magnitude of airborne bioaerosol emissions and dispersion from composting for the first time. This research has fed into policy development on the regulation of facilities, and the practices of bioaerosol monitoring and site-specific bioaerosol risk assessment.

2. Underpinning research

The implementation of the EU's Landfill Directive (EC/31/99) stimulated a rapid growth in industrial composting. In the UK, the amount of waste composted increased from 0.06 million tonnes in 1994 to 3.6 million tonnes in 2007.

Most UK composting facilities employ mechanically turned open-air compost piles (windrows), a technology with limited control over emissions to the air. Composting leads to aerosol emissions in the form of microbial cells and cell fragments which originate in the feedstock or in the composting process. Occupational exposures to aerosols of biological origin (bioaerosols) must be controlled to protect workers from respiratory disease. Little was known about the extent of exposure or the potential for health impacts for people living, studying or working near to composting facilities.

This is a critical concern for the public; for the industry, which needs to generate the business confidence required to secure investment in new infrastructure (and which often faces opposition from local people at the planning stage); for regulators which need robust evidence for proportionate decisions; and for the delivery of Government waste strategy.

Since 2002, Cranfield's research on bioaerosols has focussed upon developing the evidence base needed: to understand the magnitude of, and factors governing, the emission of bioaerosols from composting; to characterise bioaerosol concentrations in the vicinity of composting facilities; and, to improve the use of dispersion modelling for open windrow composting. The new knowledge has informed national policy on the regulation of composting facilities and supported risk assessments by site operators and regulatory professionals. Much of this applied research has been at operational waste management facilities. The scale, complexity and hazardous nature of this environment have imposed significant challenges for safe and scientifically rigorous sampling.

Initial research (2005-8 [G1]) focussed on quantification of bioaerosol emissions from composting to improve dispersion modelling. Flux-box techniques demonstrated that emissions from active windrow turning were up to 1000 times greater than those from static compost piles [P1,2]. Cranfield used these findings to estimate emission fluxes from composting operations and to generate source-depletion curves using dispersion models [P3]. This modelling identified

knowledge and information gaps, such as high quality bioaerosol concentration dataset for composting facilities, and set the agenda for subsequent research.

Replicated and repeated sampling (2008-11) under different meteorological conditions on-site and downwind of two open windrow composting facilities generated such a dataset for the first time [P6]. This dataset has been used as part of a recently completed (2013) study funded by the EPSRC and the Environment Agency (EA) to calibrate and validate a well-established dispersion model for open air composting [G4]. Whilst previous studies focused on culturable bioaerosols such as *Aspergillus fumigatus*, more recent (2007-09) research extended our knowledge of the emission and dispersal of cellular components and of the whole microbial community. This research generated the first dataset (2011) to compare the dispersion of endotoxin (which can stimulate the immune system and cause inflammatory conditions if inhaled) with viable microorganisms downwind of composting facilities [P6].

Defra funded collaborative follow-on research (2011-13) on endotoxin and β glucan at four additional composting facilities [G4]. Taken together, this work provides new information on the emission and dispersion of cells and cell components from composting facilities of different types. This information will inform future assessments of bioaerosol exposure and health impact.

Further progress on culture-independent bioaerosol characterisation [P5] demonstrated for the first time (2012) the influence that green-waste composting has on the on-site and downwind aerobiotic communities. Expansion of this work has consolidated our knowledge and understanding and paved the way to impact [G4][P4-6].

Key Researchers	Post details and dates	Research
Dr S.F. Tyrrel	Research Officer (1988-90); Lecturer (1990-2002); Senior Lecturer (2002-2008); Reader (2008-present).	Bioaerosol emissions and dispersion from composting
Dr G. Drew	Research Fellow (2005-2007); Lecturer (2007-present).	Bioaerosol emissions and dispersion from composting
Dr P. Longhurst	Research Officer (1993-96); Lecturer (1996-2003); Senior Lecturer (2003-present)	Bioaerosol emissions and dispersion from composting
Professor S. Pollard	Professor (2002-present)	Bioaerosol emissions and dispersion from composting
Dr F.Coulon	Research Fellow (2006-2007); Lecturer (2007-2013); Senior Lecturer (2013-present)	Bioaerosol emissions and dispersion from composting

3. References to the research (indicative maximum of six references)

Evidence of quality – peer-reviewed journal publications

P1 Taha, M, Pollard, S, Sarkar, U Longhurst, P, Estimating fugitive bioaerosol releases from static compost windrows: Feasibility of a portable wind tunnel approach. *Waste Management*, **25** (4 SPEC. ISS.), pp. 445-450, 2005. DOI: 10.1016/j.wasman.2005.02.013.

P2 *Taha, M, Drew, G, Longhurst, P, Smith, R, Pollard, S, Bioaerosol releases from compost facilities: Evaluating passive and active source terms at a green waste facility for improved risk assessments. *Atmospheric Environment*, **40**, pp. 1159-1169, 2006. DOI: 10.1016/j.atmosenv.2005.11.010

P3 Taha, M, Drew, G, Tamer, A, Hewings, G[d], Jordinson, G[d], Longhurst, P, Pollard, S, Improving bioaerosol exposure assessments of composting facilities - Comparative modelling of emissions from different compost ages and processing activities. *Atmospheric Environment*, **41**, (21), pp. 4504-4519, 2007. DOI: 10.1016/j.atmosenv.2006.12.056

P4 *Liu, J[c], Pankhurst, L, Deacon, L, Abate, W[a], Hayes, E[a], Drew, G, Longhurst, P, Pollard, S, Longhurst, J[a], Tyrrel, S, Jackson, S[b], Evaluation of inflammatory effects of airborne endotoxin emitted from composting sources. *Environmental Toxicology and Chemistry*, **30**, (3), pp. 602-606, 2011. DOI: 10.1002/etc.434

P5 Pankhurst, L, Whitby, C, Pawlett, M, Larcombe, L, Mckew, B, Deacon, L, Morgan, S, Villa, R, Drew, G, Tyrrel, S, Pollard, S, Coulon, F, Temporal and spatial changes in the microbial bioaerosol communities in green-waste composting, *FEMS Microbiology Ecology*, **79** (1), pp. 229-239, 2012. DOI: 10.1111/j.1574-6941.2011.01210.x

P6 *Pankhurst, L, Deacon, L, Liu, J[c], Drew, G, Hayes, E[a], Jackson, S[b], Longhurst, P, Longhurst, J[a], Pollard, S, Tyrrel, S, Spatial variations in airborne microorganism and endotoxin concentrations at green waste composting facilities *International Journal of Hygiene and Environmental Health*, **214** (5), pp. 376-383, 2011. DOI: 10.1016/j.ijheh.2011.06.001

* 3 identified references that best indicate the quality of the research

Key
a, University of the West of England, UK; b, University of Plymouth, UK; c, University of Exeter, UK; d, Environment Agency of England and Wales

Further evidence of quality – underpinning research grants

G1 2002-05. Bioaerosol releases from composting facilities. Malaysian Dept. of Health (£45K). Principal investigator: Prof. S. Pollard.
G2 2005-2008. Amenity impacts of waste management. Environment Agency Fellowship. Project SC040021/SR1 (£189K). Principal investigator: Prof. S. Pollard.
G3 2007-09. Endotoxin emissions from commercial composting activities. NERC. Project NE/E008534/1 (£75K to Cranfield). Principal investigator: Dr S. Tyrrel.
G4 2011-13. Bioaerosols and odour emissions from composting facilities. Defra. Project WR 1121 (£168K to Cranfield). Principal investigator: Dr S. Tyrrel.

4. Details of the impact (indicative maximum 750 words)

Cranfield's bioaerosols researchers have worked in collaboration with Environment Agency scientists and advisory groups to:

- set the research agenda;
- oversee research implementation;
- discuss how findings should inform policy and practice [C1].

The principal driver for the bioaerosols research that Cranfield has conducted over the past 10 years has been the need to inform UK regulatory policy and practice. The Environment Agency (EA) based its first position statement on bioaerosols from composting in 2001 upon the limited bioaerosols database available at the time. In its position statement, published at a time of unprecedented growth in the UK composting industry, the EA had to strike an appropriate balance between: the precautionary principle (in the absence of a strong evidence base); the commercial needs of a burgeoning industry; and the national requirement to divert organic waste from landfill.

Cranfield's research has informed the latest version of the EA's position statement [C2] in several ways. Our research has shown that whilst bioaerosol concentrations decline rapidly after emission, there are infrequent occasions when acceptable levels are exceeded. Evidence from our work

suggests that such occasional excursions are typical of open composting and hard to control, even at very well managed sites. Cranfield's research informed the EA's decision (2010) to take a more precautionary approach to permitting sites where sensitive receptors are close to composting operations [C2]. The EA's position statement requires the completion of risk assessments for site specific bioaerosols under specified higher risk circumstances [C2]. The EA-funded Fellowship [G3] developed the 2009 guidance document [C3] for the evaluation of these risk assessments, drawing upon collaborative investigations of the quality of assessments submitted by facility operators. In 2010-11, Cranfield staff delivered a series of training courses for EA regulatory staff (>100 attendees) on risk assessment of site specific bioaerosols [C4].

The development of source sampling close to emissions, using the IOM sampler[1], led to the inclusion of filtration sampling in the most recent revision of the Standard Protocol for the Monitoring of Bioaerosols at Open Composting Facilities [C5] and to Cranfield joining the advisory group for the development of the protocol [C6]. Tyrrel is an advisor to the EA on the development of its new M9 protocol [C6]. Tyrrel was nominated by the Environment Agency [C1] to be the UK Principal Expert on CEN[2] TC264 Working Group 28 on bioaerosols in ambient air. On the basis of Cranfield's research, this group has developed the first CEN Technical Specification for the measurement of bioaerosols in ambient air [C7] and has completed a new standard on sampling strategies for biowaste facilities [C8]. Standardisation benefits industry and regulators by removing uncertainty with respect to methods choice and by creating comparable datasets.

Whilst the evidence base has been significantly strengthened in the past ten years, there is some way to go before regulatory policy on bioaerosols in ambient air could be considered stable. The fact that the current position statement [C2] is referred to as "interim" guidance emphasises the fact that the regulatory position is expected to change as new information becomes available. Defra project WR 1121 [G4] (a consortium project including Cranfield, Imperial College, Open University and NPL) is already influencing the shape and direction of upcoming editions of the EA Position Statement [C2], the Standard Protocol [C5], and EA/Defra research priorities as they feed into the emerging Environmental Microbiology and Human Health call (part of the NERC Environment, Pollution and Human Health Theme).

5. Sources to corroborate the impact (indicative maximum of 10 references)

C1 Contact: Principal Air Pollution Scientist, Evidence Directorate, Environment Agency UK
C2 Environment Agency. 2010. Composting and potential health effects from bioaerosols: our interim guidance for permit applicants. Position Statement 031, Version 1.0.
C3 Environment Agency. 2009. Guidance on the evaluation of bioaerosol risk assessments for composting facilities. Prepared by Drew, G.H., Deacon, L.J., Pankhurst, L., Pollard, S.J.T., and Tyrrel, S.F. Environment Agency internal guidance document.
C4 Contact: Waste Recovery Team, Environment Agency UK
C5 AfOR (2009). A Standardised Protocol for the Monitoring of Bioaerosols at Open Composting Facilities. Association for Organics Recycling, UK.
C6 Contact: Research Scientist, Evidence Directorate: Research, Monitoring & Innovation.
C7 CEN/TS 16115-1:2011 Ambient air quality. Measurement of bioaerosols. Determination of moulds using filter sampling systems and culture-based analyses.
C8 Contact: Convenor, CEN TC264 WG28, Bavarian Food and Environment Agency, Germany.

[1] *Institute of Occupational Medicine (IOM) inhalable dust sampler*
[2] *European Committee for Standardization*