Environment Agency

using science to create a better place

International workshop on bioaerosols from green-waste composting

Science Report: SC050009/110

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It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the summary of a workshop held by the Environment Agency's Human Health Science team looking at the science underpinning bioaerosol risk assessment.

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Science at the Environment Agency

Science underpins the work of the Environment Agency, by providing an up to date understanding of the world about us, and helping us to develop monitoring tools and techniques to manage our environment as efficiently as possible.

The work of the Science Group is a key ingredient in the partnership between research, policy and operations that enables the Agency to protect and restore our environment.

The Environment Agency's Science Group focuses on five main areas of activity:

- **Setting the agenda**
  - To identify the strategic science needs of the Agency to inform its advisory and regulatory roles.
- **Sponsoring science**
  - To fund people and projects in response to the needs identified by the agenda setting.
- **Managing science**
  - To ensure that each project we fund is fit for purpose and that it is executed according to international scientific standards.
- **Carrying out science**
  - To undertake the research itself, by those best placed to do it – either by in-house Agency scientists, or by contracting it out to universities, research institutes or consultancies.
- **Providing advice**
  - To ensure that the knowledge, tools and techniques generated by the science programme are taken up by relevant decision-makers, policy makers and operational staff.

Steve Killeen

Head of Science

Executive Summary

On 28 February 2006 the Environment Agency held an invited workshop on the assessments of risks to health from bioaerosols associated with the composting of green waste. The workshop was part of our work programme to support our position regarding bioaerosols, potential health effects and risk assessments.

The objectives of the workshop included updating delegates on how the Environment Agency approaches the issues that surround bioaerosols from green-waste composting and to draw attention to some of the research currently sponsored by the Environment Agency in this area. The delegates included UK regulators, academics, composting industry staff and risk assessment contractors.

The audience heard workshop presentations that described:

- the challenges the UK faces to meet its Landfill Directive obligations
- how the Environment Agency is changing the way it manages license applications
- the composting industry's viewpoint on the challenges it faces
- research in Germany and Holland on bioaerosol health effects
- current science and knowledge gaps
- bioaerosol modelling
- research currently underway that is sponsored by the Environment Agency.

After the presentations, smaller groups discussed the content of the presentations and, more specifically, aspects of the pressing need to standardise sampling and culturing protocols. It was agreed that variations in the protocols and methodologies hindered the interpretation and comparison of risk assessments. All present thought that further research was needed in several areas to improve the quality of the scientific data used in bioaerosol risk assessments.

The workshop was welcomed by all the participants as an opportunity to discuss current research and developments on bioaerosols from green-waste composting. The workshop provided an excellent opportunity to promote work funded by the Environment Agency and highlighted the importance and utility of collaborative working and funding in this area.

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1 Introduction

On 28 February 2006 the Environment Agency held an invited workshop on the assessments of risks to health from bioaerosols associated with the composting of green waste. The workshop was part of our work programme to support our position regarding bioaerosols, potential health effects and risk assessments. The workshop aimed to bring together the UK regulators, leading UK and overseas researchers, industry representatives and consultants to discuss the present position and the data used in risk assessment exercises. The objective of the day was to inform delegates on how we now approach this issue, and to present the findings from research that we either sponsor or manage. The format allowed discussion between the regulators, industry, consultant contractors and academics to identify perceived gaps in the knowledge required to underpin future risk assessments.

This document summarises the presentations and discussion sessions from the workshop and presents the main conclusions. The purpose of the document is to provide an information source for both the workshop delegates and for wider audiences who may have an interest in the risk assessment of bioaerosols from green-waste composting.

The workshop was organised by the Environment Agency's Human Health Science team. It was attended by 38 delegates (see Appendix 1) who were:

- UK regulators
- leading UK researchers
- international experts
- industry representatives
- risk assessment contractors.

1.1 Background

The Landfill Directive commits the UK to reducing the amount of biodegradable waste it sends to landfill to 35 per cent of that produced in 1995 by 2020. One mechanism being used to achieve this is green-waste composting. The Environment Act of 1995 requires us to prevent "pollution of the environment due to the release (into any environmental medium) … of substances which are capable of causing harm to man or any other living organisms supported by the environment". The Environment Agency has already committed significant resources to understanding the risks to health from composting. This means that we have built-up a research and development (R&D) programme to study and understand the risks posed by the micro-organisms and microbial product, associated with composting that can, under certain circumstances, give rise to threats to human health.

The Environment Agency's current position is a presumption against permitting the composting of green waste within 250 m of a workplace, or dwelling boundary, unless the site operator has undertaken a site-specific risk assessment which shows that the bioaerosol levels are, and can be maintained, at appropriate levels at the dwelling or workplace. It is not a 250 m exclusion zone, but it is a trigger distance for the requirement for a risk assessment to be undertaken. The Environment Agency

has also given a commitment to continue to work with others to identify appropriate control measures to allow operations within 250 m.

1.2 Workshop objectives

The objectives of this workshop were to:

- inform delegates of research sponsored or managed by the Environment Agency
- gain an overview of research undertaken in Germany and the Netherlands
- update attendees on how the Environment Agency approaches this issue
- identify perceived gaps in the knowledge required to support future risk assessments.

The workshop consisted of a scene-setting introduction followed by eight presentations, with question and answer sessions at the end of each presentation. Towards the close of the day, the participants divided into three smaller groups (breakout groups) and looked at topical questions raised during the day. Finally, a short plenary session reviewed the breakout groups' conclusions.

The following sections of this report summarise the presentations, breakout group discussions and plenary session. The appendices contain a delegate list, workshop agenda and the presentations.

2 Presentation summaries

Alison Gowers, Human Health Science Team manager, opened the workshop. After welcoming the delegates, Ms Gowers noted the Environment Agency's commitment to ensure that its policies were based on sound science. The workshop was intended to emphasise this and demonstrate that the science sponsored by the Environment Agency is filling known knowledge gaps to support current policy.

2.1 The state of play in the UK (Dr Nina Sweet, Environment Agency)

Dr Sweet opened her presentation by describing the challenge the UK faces to meet the Landfill Directive. The predicted growth rate in the year-on-year disposal of municipal biodegradable waste means that by 2020 over 200 composting or mixed biological treatment (MBT) plants will be required, with an average throughput capacity of 45,000 tonnes each.

After describing the Environment Agency's position, and how it was derived, Dr Sweet noted that the Environment Agency cannot afford to be complacent in this area and that we recognise that further work is needed. The presentation summary concluded with the following points:

- composting is an important element of many waste management strategies
- like any other waste management activity, potential risks to the environment must be managed and prevented
- the perceived risk to human health from bioaerosols can be very emotive
- it is vital that Environment Agency policy in this area is based on the best available science.

2.2 Environment Agency's regulatory perspective (Phil Saunders, Environment Agency)

Mr Saunders described the current approach of the Environment Agency in regulating compost sites. He explained how the permitting regime is changing so that it is not only easier to apply for permits, but that applications will be dealt with more swiftly and efficiently. This will lead to an improved consistency of both standards and operations across England and Wales.

Mr Saunders spoke briefly about what the Environment Agency expects to be submitted when an operator undertakes a risk assessment for bioaerosols. The risk assessment that accompanies a licence application should:

- identify the hazards and their consequences
- identify the risks
- explain the significance of the risks
- estimate the risks (probability)
- look at the source, pathway and receptor
- tell us how risks will be managed and controlled.

2.3 The composting industry's perspective (Dr John Mullett, Development Director, Cambridge Recycling Services)

Dr Mullett noted that he had consulted with both industry and industry consultants before giving his perspective at the workshop. The industry believes that it can prosper and develop, and that this will require the design and operation of facilities to safety standards acceptable to the public. To that end the industry welcomes regulation where it is clear what the goals are and if the regulations are applied consistently across the board to all types of waste treatment.

Dr Mullett asked that the Environment Agency and other regulators derive a clear framework for regulation now *and* a framework within which the regulation will evolve as evidence accumulates. However, industry also has a role to play, and should:

- help to formulate workable regulatory requirements, but not seek to determine 'safe' exposure limits
- seek to minimise exposure and hence risks
- seek to work in partnership, bearing in mind the limitations of the science
- offer all available data (for example, monitoring data) to the scientific community to aid risk assessment.

2.4 Role of dispersion modelling in bioaerosol risk assessment (Martin McVay, Environment Agency)

Mr McVay described how dispersion modelling is sometimes used to assess the risks from bioaerosols. Before such modelling can be useful, several requirements must be met. Defining for example the source term emission rates, sample averaging times, background concentration of the species of interest, and so on, reduces the degree of uncertainty attached to any model output. Current regulatory models are only validated for stack emissions, and not for emissions from ground level. Mr McVay finished by pointing out that:

- uncertainty in predictions is dictated by the weakest link in any chain
- state-of-the-art computer model predictions may be no better than those generated by generic look-up tables.

2.5 Hazards associated with bioaerosols, inflammatory responses (Dr Caroline Herr, Justus-Liebig University, Giessen, Germany)

Dr Herr presented data collected over several years that showed the debilitating effects of compost bioaerosol exposure on members of the public. A compost site had been operated uphill within 500 m of a residential area. In 1997, Dr Herr's team measured airborne viable micro-organisms and conducted a questionnaire to evaluate the health effects. After 5 years (3 years after the site was closed) the team took samples from the exposed population and measured blood-borne biomarkers and again conducted a questionnaire to look at the health effects. Their results clearly showed ill health in the exposed population (compared with a control unexposed population), even 5 years after the cessation of exposure.

2.6 A European perspective on composting (Dr Inge Wouters, Institute of Risk Assessment Science, University of Utrecht, Netherlands)

Dr Wouters gave a Dutch perspective on composting. The mid-1990s saw a major expansion in the Dutch organic waste recycling industry. Biological treatment (mainly composting) recycled 1.5 million tonnes of waste in 2004 through around 100 sites. Although legislation exists to standardise the quality of the final compost, no regulations exist for bioaerosols. Dr Wouters went on to describe some of the work undertaken during her PhD, which included dose–response relationships and bioaerosol production along the whole of the waste-handling chain. Holland has set an occupational exposure limit (OEL) at 200 endotoxin units per cubic metre (200 EU/m^3). While this is an occupational standard, to use this figure to protect public health in the UK would present a considerable challenge to UK industry.

In terms of generating, and describing, dose-response relationships, Dr Wouters noted that nasal lavage and serology testing showed considerable inter-individual variability in exposure–response relationships in compost workers, also that acute and delayed upper airway inflammation occurred in compost workers compared to controls. This is not mediated by the immune system and is most likely related to bioaerosol exposure and symptoms.

2.7 Knowledge gaps (Greg Jordinson, Environment Agency)

Mr Jordinson began his presentation by outlining the recent chronology of bioaerosol risk assessment in the UK. The Composting Association made a useful contribution to bioaerosol measurement by producing a protocol for bioaerosol measurement in 1999. Since then the Environment Agency, amongst others, has produced a variety of reports that suggest further work is needed to detect, measure and assess adequately the hazards to human health. Some of the knowledge gaps identified since 1999 include source term definition to improve dispersion modelling, a need to detect and measure both the viable and non-viable fractions of bioaerosols, dose–response data and improvement in abatement techniques.

Mr Jordinson highlighted two ongoing Environment Agency projects:

- a joint project with the Health and Safety Laboratories (HSL) to look at source term definitions and source tracking
- a post-doctoral fellow at Cranfield University to examine amenity risk assessments and generate data to improve such risk assessments.

The Environment Agency is also to sponsor other work, yet to start. This includes finalising a report on detection and measurement technologies to provide a defined, standardised methodology to detect and measure bioaerosols. The Environment Agency will also manage, on behalf of the Department of Energy, Food and Rural Affairs (Defra), three projects to look at abatement, rapid monitoring and dose–response of bioaerosols. These projects should help to fill the more significant knowledge gaps highlighted since 1999.

2.8 Environment Agency–Health and Safety Laboratories joint project: source term definition and bioaerosol characterisation (Dr Brian Crook, Health and Safety Laboratories)

Dr Crook described the joint HSL–Environment Agency project to characterise bioaerosols and define source terms using a dust-drum method. Bioaerosols from compost handling are known to stay airborne for a period of time and travel off-site, but the circumstances under which dilution and dispersion occur are not clearly defined. Part of the work done by HSL measured levels at different distances downwind to validate models and establish risk zones. A variety of compost samples of differing ages were taken from sites that used different composting technologies. Using both culture and molecular techniques the quantities of bioaerosol from each sample were determined. The source term data need to be incorporated into dispersion modelling, but, although the characterisation work shows promise, it requires more work to determine the best techniques.

2.9 Environment Agency–Cranfield University post-doctoral programme and progress (Dr Gillian Drew, Cranfield University)

This post-doctoral fellowship's main aim is "To transfer into the Agency innovative risk and amenity impact science for waste management in order to inform and underpin policy development and enhance process and operational decision-making". Six objectives will help to deliver this by examining:

- emissions monitoring
- bioaerosol enumeration
- bioaerosol sources
- dispersion modelling
- exposure diaries
- dissemination.

To improve knowledge about site emissions, an emission-monitoring project is evaluating bioaerosols from three sites. This includes viable organism culturing, examining variability in viability over distance and time and looking at the effects of temperature changes and relative humidity on bioaerosol levels and viability. Dr Drew's team has also produced a new methodology to enumerate thermophilic actinomycetes.

Research has also shown that bioaerosol emissions are episodic – and that this is related to on-site activities. To predict acute, episodic exposures, there is a need to take into account both the peak emissions and the periods when receptor exposure coincide with the peak emissions. Another project underway is using odour data to develop a methodology to predict acute, episodic exposures.

Results and conclusions will be disseminated during the coming year, with Environment Agency staff workshops for bioaerosol risk assessments and published articles (three papers have already been published in peer-reviewed journals and another two are to be submitted shortly).

3 Questions addressed in breakout group discussions

After the presentations, attendees were divided into three breakout groups. Each group contained a range of experiences to include Environment Agency staff, composting industry staff, academics and consultants. The groups were assigned the same questions (see below), but discussion was not limited to these questions.

- Question 1: Would a standardised method to assess bioaerosols be welcomed, and should endotoxins be part of this assessment?
- Question 2: What bioaerosol components should be part of such a standardised method?

4 Breakout groups' reports

4.1 Breakout group A

4.1.1 Members

Alan Rosevear (facilitator), Pete Braithwaite (rapporteur), Inge Wouters, Peter Sykes, Richard Smith, Jenny Kirton, John Burden, Brian Crook, Gordon Nichols, Philippa Yates, David Morgan, Alison Gowers

4.1.2 General points from the discussions in group A

Group A focused on the following discussion points:

- Do we have the monitoring methods we need?
- Are we measuring the right organisms?
- Whose role is it to produce improved monitoring guidance?
- Molecular DNA techniques are possibly at an early stage – these will no doubt improve in the future.
- Counting techniques are used in Scandinavia and prove more reliable.
- Industry is looking for a lead on what species to monitor for – they use consultants for advice, but there is limited expertise in the UK. Industry wants the Environment Agency to provide clearer guidance.
- Issues as to the representativeness of samples over time – difficulty of exposing plates and problems of overloading because of gusts of wind, vehicle movements, and so on.
- Appropriate averaging periods – how long do conditions persist?
- Is the perception of risk of exposure to bioaerosols out of proportion?
- Are we using the right techniques? Are they viable (difficulties overloading plates) or non-viable (optical methods), and is there a place for counting techniques as they are more reliable?

4.2 Breakout group B

4.2.1 Members

Nina Sweet (facilitator), Greg Jordinson (rapporteur), Caroline Herr, Martin McVay, Asli Tamer, Ted Bleszynski, Phil Metcalfe, Peter Mills, John Mullett, Peter Olsen, Howard Ellard, Mike Riby

4.2.2 General points from the discussions in group B

The group welcomed the concept of a standardised protocol to detect and measure bioaerosols from green-waste composting. The group also supported the idea that, if possible, the protocol should be reviewed by the Standing Committee of Analysts. The protocol should also take into account cost-effective sampling. One of the benefits of the standardisation of methods would be to allow a comparison of the risk assessments across sites. Other methods, which include DNA fingerprinting of bioaerosols, would allow source tracking of bioaerosols from different sources (for

example, agriculture versus composting versus MBT). The group supported further research using molecular biology techniques to determine their applicability, cost-effectiveness and usefulness. Further work that group B thought useful included:

- investigating whether particular organisms are associated with particular processes and feedstocks
- work to break the public perception that detecting odour equated to exposure to bioaerosols.

4.3 Breakout group C

4.3.1 Members

Rob Kinnersley (facilitator), Phil Saunders (rapporteur), Toni Gladding, Ken Jones, Gillian Drew, David Border, Jon Pickering, Lynn McGoff, Jan Gronow, John Lee, Neil Donegan, Terry Prigmore, Jenny Lissaman

4.3.2 General points from the discussions in group C

Group C agreed that a standardised sampling and analytical methodology was appropriate, and suggested that standardised methodologies to assess bioaerosols would be useful not just routinely but also for research purposes. The research methodology could be used when assessing contentious sites with potential multiple sources. The group was concerned that the method be fit-for-purpose and cost-effective. A number of issues were felt to be important and should be considered when designing such methods, these included:

- Would the routine method only look at viable organisms or would it simply use indicator organisms?
- What sample averaging times were intended (these are normally 15 minutes, but the acute effect of endotoxin occurs in seconds)?
- Bioaerosol emissions are intermittent over time and space, so ideally the sampling should take this into account.
- Conditional sampling?
- Comparators and/or absolutes?
- Surrogates such as dust?

Group C also considered what factors should be looked at when permitting sites. They were concerned about the relevance of using surrogates (for example, dust) and whether there is a correlation between dust and bioaerosols. Endotoxins were felt to be an occupational, and not environmental issue. However, fungal glucans can be used as a fungal load surrogate. Group C queried whether or not, as toxins, glucans might be an environmental issue in their own right. Data that was missing here included information on glucan dispersal (that is, its spatial range). The group was interested in the joint work being done by HSL and the Environment Agency in terms of environmental genomics, and whether or not monitoring could be done using molecular probes for indicator organisms.

Group C called for further work to produce a suitable wet impinger, recognising that the Anderson sampler is useful for grab sampling, as is the Burkhard spore trap.

When modelling data, the group suggested that non-stack models were needed as current models are based on emissions from tall stacks rather than low-level emissions from composting sites. Such models should include realistic size profiles

under a range of conditions (a query raised at this point suggested the possibility of technology transfer using data from powder handling). Other terms that would improve the model include resuspension factors of deposited bioaerosol.

Work also needs to be done on the potential impact of any synergistic effects of different bioaerosols on health.

The current data sets gathered for bioaerosol modelling were thought to be too incomplete and incompatible – were these worth reviewing? If research groups could produce inter-comparable data sets this would improve things considerably.

5 Round-up session highlights

The breakout groups reports were briefly presented to all the delegates, followed by a brief discussion.

In general, all three groups agreed that a standardised methodology would be extremely useful. Data gathered in this fashion would reduce (not eliminate) the significant degree of uncertainty when attempting cross-comparison of studies or risk assessments.

Broadly speaking, the industry welcomed clear, concise regulation consistently applied to all sectors of the waste management industry. Provision of further data on emissions and health would help promote appropriate regulation. Discussion, and review, of the 250 m requirement for a risk assessment would be welcomed, but a reduction of the 250 m requirement would only be appropriate after further data have been gathered.

Several attendees noted that, while happy with the direction and progress of the Environment Agency's ongoing and proposed work programme, they had been unaware of its extent. These delegates felt that the work programme would help to fill some of the more significant data gaps, and thus improve the risk assessment of bioaerosols from green-waste composting.

6 Workshop summary

6.1 Conclusions

The workshop was welcomed by all participants as an opportunity to discuss the current research and developments on bioaerosols from green-waste composting. It provided an excellent opportunity to promote work funded by the Environment Agency and highlighted the importance of collaborative work and funding in this area.

There was widespread agreement that a standardised sampling and analysis protocol was necessary and that this will help all parties to assess risks from green-waste bioaerosols. The Environment Agency is working with HSL to publish a guidance document in autumn 2006. In the past, comparison of gathered data or risk assessments has been hindered by the different methods used by various contractors.

Bacterial endotoxins were thought to be an occupational, as opposed to an environmental, problem and therefore they did not need to be included in the standardised sampling and analysis methodology. However a method for fungal glucans may well be needed.

The composting industry welcomed the approach taken by the Environment Agency in its ongoing work programme, but called for a 'level playing field' when licence conditions were set or permits granted. More data, gathered and delivered in a comparable fashion, should help regulators deliver transparent, clear regulations in a consistent manner.

The Environment Agency will continue to work in this area to provide peer-reviewed quality scientific data to support the development of our regulatory approach.

6.2 Further work needed

The Environment Agency works to ensure that the regulations it applies are appropriate to the reality (versus the perception) of the risk of the activities it regulates. If we are to advance our credibility with the public and the composting industry as we work to minimise risks to health, by applying appropriate regulations, we must improve our scientific knowledge in the following key areas:

- Historically, air-dispersion models have been based on stack emissions. This is not appropriate for composting sites for which the main emissions are within 5 m of ground level. Therefore, the development of non-stack models is essential.
- Fungal glucans are an emotive issue. More data are needed to understand their effects on health and to determine their suitability as a total fungal load surrogate during sampling.
- Molecular biological techniques, such as the polymerase chain reaction and denaturing gradient gel electrophoresis, may prove to be more cost-effective in assessing bioaerosols than the current culture techniques. Again, further work to identify whether or not bioaerosol emissions carry identifiable 'fingerprints' to identify sources is necessary, as are more data to verify the applicability and cost-effectiveness of molecular biology techniques. This should build on work already being undertaken on our behalf by HSL.
- Measurement of bioaerosols using counting techniques, such as those already used in Scandinavia, offer advantages over the culturing methodologies currently

used in the UK. Such counting techniques can utilise longer-term sampling (than those used for culturing viable bioaerosols), and are immune to selection effects. Their applicability within a regulatory context needs to be reviewed.

7 Appendix 1

7.1 Delegate list

Name	Organisation
Ted Bleszynski	New Earth Solutions
David Border	David Border Associates
Peter Braithwaite	Environment Agency
John Burden	John Burden Consulting
Brian Crook	Health and Safety Laboratories
Lucy Clark	Environment Agency
Neil Donegan	Cory
Gillian Drew	Cranfield University
Howard Ellard	Viridor
Toni Gladding	Open University
Alison Gowers	Environment Agency
Jan Gronow	Cranfield University
Caroline Herr	Justus-Liebig University, Giessen, Germany
Ken Jones	University of Wales Institute Cardiff
Greg Jordinson	Environment Agency
Rob Kinnersley	Environment Agency
Jenny Kirton	Atkins Consulting
John Lee	Health Protection Agency
Jenny Lissaman	Environment Agency
Lynn McGoff	CRC Services
Martin McVay	Environment Agency
Phil Metcalfe	ADAS
David Morgan	BIFFA
John Mullett	CRC Services
Gordon Nichols	Health Protection Agency
Peter Olsen	Scottish Environmental Protection Agency
Gillian Pawson	GP Planning
Jon Pickering	Organic Resource Agency Ltd
Terry Prigmore	Environment Agency
Mike Riby	Environment Agency
Alan Rosevear	Environment Agency
Phil Saunders	Environment Agency
Richard Smith	Cranfield University
Nina Sweet	Environment Agency
Peter Sykes	University of Wales Institute Cardiff
Asli Tamer	Cranfield University
Inge Wouters	Institute of Risk Assessment Science, Netherlands
Philippa Yates	SITA

8 Appendix 2

8.1 Workshop agenda

Environment Agency Workshop on assessments of risks to health from bioaerosols associated with green-waste composting.

28 February 2006, Manor House, Howbery Park, Wallingford, Oxfordshire

08.45-09.15 Registration (tea and coffee available)

09.15-09.20 Opening remarks and welcome (Alison Gowers, Environment Agency)

09.20-09.50 Introduction – The state of play in the UK (Nina Sweet, Environment Agency)

09.50-10.20 Environment Agency regulatory perspective (Phil Saunders, Environment Agency)

10.20-10.50 The composting industry perspective (Dr John Mullett, Development Director, Cambridge Recycling Services)

10.50-11.15 Tea and coffee, discussion

11.15-11.45 The role of dispersion modelling in bioaerosol risk assessment (Martin McVay, Environment Agency)

11.45-12.15 Hazards associated with bioaerosols, inflammatory responses (Dr Caroline Herr, Justus-Liebig University, Giessen, Germany)

12.15-12.45 A European perspective on composting (Dr Inge Wouters, Institute of Risk Assessment Science, University of Utrecht, Netherlands)

12.45-13.10 Knowledge gaps (Greg Jordinson, Environment Agency)

13.10-14.00 Lunch

14.00-14.30 Environment Agency–Health and Safety Laboratories joint project: source term definition and bioaerosol characterisation (Dr Brian Crook, Health and Safety Laboratories)

14.30-15.00 Environment Agency–Cranfield University post-doctoral programme and progress (Dr Gillian Drew, Cranfield University)

15.00-15.20 Tea and coffee, discussion and move into breakout groups

15.20-16.00 The afternoon talks will be followed by breakout sessions to examine particular topics raised during the day or of concern to the attendees. Examples of topics might include whether or not we have enough data to produce guidance to assess risks to off-site individuals

16.00-16.30 Report from break out sessions and discussion

16.30 Closing comments (Alison Gowers, Environment Agency)

9 Appendix 3

9.1 Workshop presentations

1 Introduction – The state of play in the UK (Dr Nina Sweet, Environment Agency)

2 Environment Agency regulatory perspective (Phil Saunders, Environment Agency)

3 The composting industry perspective (Dr John Mullett, Development Director, Cambridge Recycling Services)

4 The role of dispersion modelling in bioaerosol risk assessment (Martin McVay, Environment Agency)

5 Hazards associated with bioaerosols, inflammatory responses (Dr Caroline Herr, Justus-Liebig University, Giessen, Germany)

6 A European perspective on composting (Dr Inge Wouters, Institute of Risk Assessment Science, University of Utrecht, Netherlands)

7 Knowledge gaps (Greg Jordinson, Environment Agency)

8 Environment Agency–Health and Safety Laboratories joint project: source term definition and bioaerosol characterisation (Dr Brian Crook, Health and Safety Laboratories)

9 Environment Agency–Cranfield University post-doctoral programme and progress (Dr Gillian Drew, Cranfield University)

Bioaerosols Workshop
28th February 2006

Nina Sweet - Policy Adviser, Biological treatment

The state of play in the UK?

- What are we dealing with?
- How are we processing?
- What are the issues?
- What have we done so far?

- Where do we go from here?

Legislation

- The Landfill Directive
  - by 2020 35% of that produced in 1995 to landfill
- The Environment Act 1995
  - "pollution of the environment due to the release (into any environmental medium)… of substances which are capable of causing harm to man or any other living organisms supported by the environment".
  - "harm to the health of living organisms… and, in the case of man, includes offence caused to any of his senses" (S 1(4) EPA 1990)

The Landfill Directive and the UK landfill regulations

- Tough targets for the diversion of biodegradable municipal solid wastes
- Reduce biodegradable municipal waste to landfill to 75% of that produced in 1995 by 2010, 50% by 2013 and 35% by 2020
- Recycle compost 25% of household waste by 2005/6 and 30% by 2010/2011

What's in the bin?

Environment Agency

BIODEGRADABLE

17% Kitchen

20% Garden

18 % Paper

3 % Fines

3 % Textiles

16 % Other

8 % Metal

7 % Glass

7 % Plastics

May be anywhere between 30 - 50 % (w/w) biodegradable municipal waste

Source: Strategy Unit 2002. Not drawn to scale

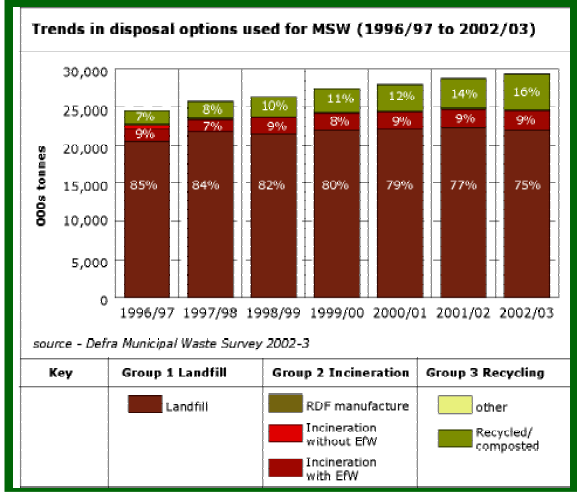
Environment Agency

What is that we are composting?

- Biodegradable municipal waste
- Year on year growth has been running at between 1% and 3% per annum since 1995
  - An average growth of 1% per annum produces a diversion requirement estimated at:
    - 6 mtpa between 2006 and 2010, rising to 14 mtpa between 2016 and 2020
    - Number of new compost/ MBT facilities required by 2020 = 200+ (at average throughput capacity of 45,000 tpa)
- LATS & Dataflow will improve data quality and certainty

Environment Agency

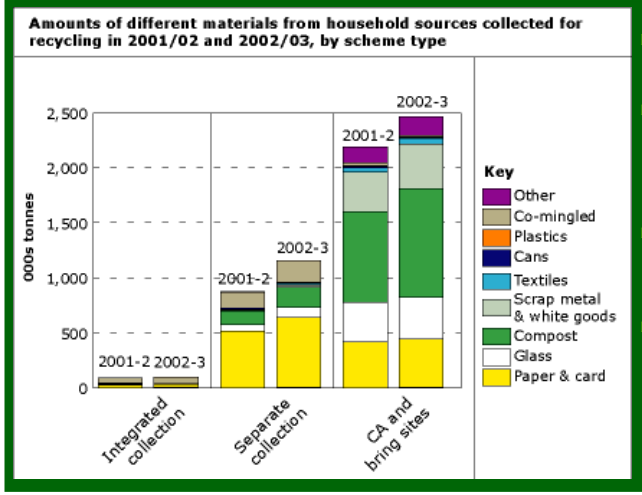
BMW trends



- TRENDS
- proportion of MSW going to landfill disposal now falling
- incineration stable at 9%
- rapid growth in recycling/ composting, up from 2% to 16% over 7 years

Environment Agency

Source separated material



- Impact of collection method
- main source of paper & card was separate door to door collection
- Main source of green waste was CA sites
- Very little was recovered from integrated collection in 2002-3

MBT

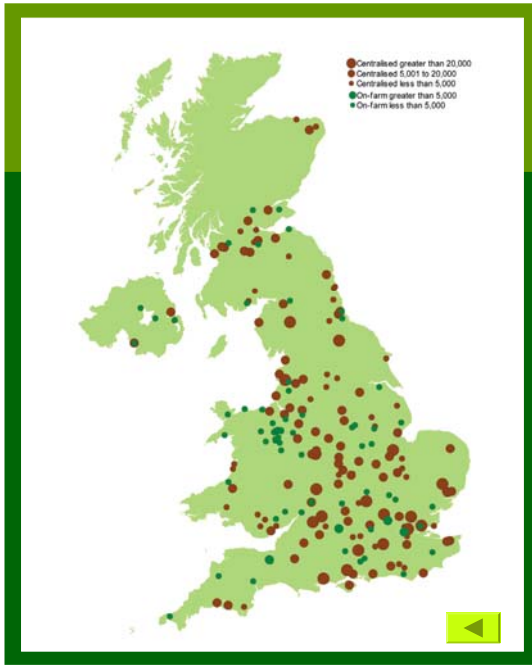
Composting

Home composting

Centralised sites

On Farm

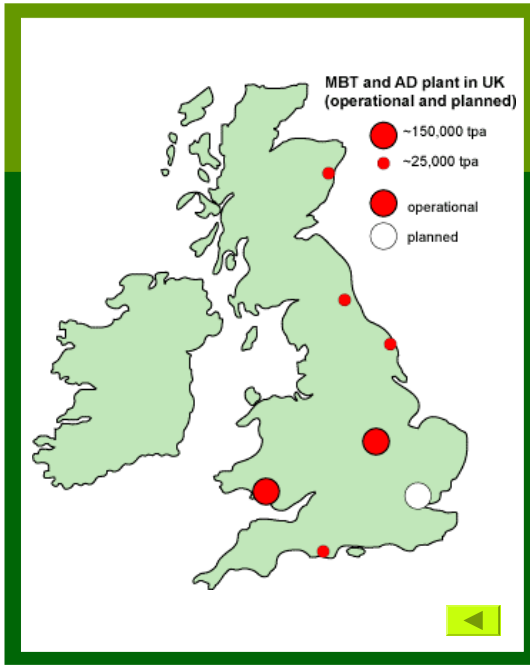
Large sites



Environment Agency

Existing sites

- Composting plant
- There are 173 on-farm
- 149 centralised, and
- 3 other composting facilities
- A variety of technologies are in use
- 'Centralised' composting plant take collected separated green and kitchen waste



Environment Agency

Existing sites

- MBT and AD plant
- There are 6 operational MBT plants at present
- 2 large plants with an annual throughput capacity of around 150,000 tonnes
- 4 smaller plants of around 20,000 tpa
- there is also one very small AD demonstrator plant for kitchen waste
- 2 other significant plants are in the planning stage

Environment Agency

Bioaerosols what are we doing?

- Recognise potential problem
- Issued a position statement in 2001
- Based on best available R&D
- Risk assessment

Our position

- a presumption against permitting within 250 metres of a workplace or dwelling boundary without a site-specific risk assessment, based on clear, independent scientific evidence which shows that the bioaerosol levels are and can be maintained at appropriate levels at the dwelling or workplace.
- Agency will continue to work with others to identify appropriate control measures to allow operations within 250 m

Agency position on bioaerosols

- HSE published R&D report
- Supports the Agency's precautionary position
- It is not a 250m exclusion zone - but is a trigger distance for the requirement for a risk assessment to be undertaken

However….

- Need for some further work following HSE report
- Can not be complacent
- Agency will continue to work in this area.
  - Cranfield risk assessment
  - HSL continued work
  - New lit review work

Conclusions

- Composting is an important element of many waste management strategies
- Like any other waste management activity, potential risks to the environment must be managed and prevented
- The perceived risk to human health from bioaerosols can be very very emotive
- Vital that Agency policy in this area is based on the best available science.

Environment Agency Regulatory Perspective

How the Agency regulates composting sites

Phil Saunders
Technical Manager Waste Treatment Process

Purpose of this presentation

- Inform you of what we are required to do as a regulator
- Inform you of what we require from you as a risk assessor, consultant, or site operator
- Inform you of how we will change way we regulate over next 12 months to make it easier for you.

What are we required to do?

Ensure that waste is recovered or disposed of without endangering human health or harming the environment.

- without risks to water, air, plants or animals
- without causing nuisance through noise or odours
- without adversely affecting the countryside

How do we regulate? Statutory guidance

Environment Agency

Regulation should be proportionate to the risks involved and the benefits to be obtained

- It should be goal based having an objective and a means of fulfilling the objective
- It **should not** serve as an end in itself
- It **should not** be over-prescriptive
- It **should not** impose and unjustifiable burden on those regulated
- Waste management facilities are of benefit to the environment and sustainable development

What permit is needed?

Environment Agency




What do you have to do?

Environment Agency

- Compete an application form, sign it, pay fee,
- Provide details of:
  - planning permission,
  - technically competence,
  - financial provision
  - relevant convictions,
  - prove that occupier of land
- Provide risk assessment

Risk assessment information

Environment Agency




Risk assessment what do you have to provide?

Environment Agency

- Identify hazards and their consequences
- Identify risks
  - Significance of the risks
  - Estimate risks (probability)
- Look at Source - Pathway - Receptor
- Tell us how you will manage and control risks

Risk assessment pitfalls

Environment Agency

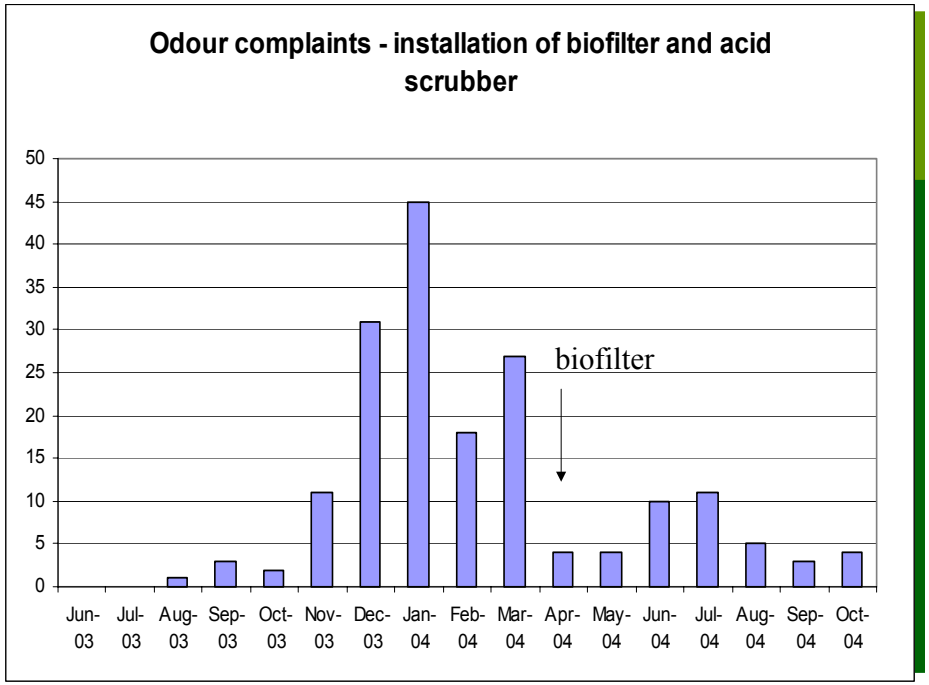
Generic risk assessment when site specific one needed and vice versa

Failure to identify all the hazards and operations

Failure to consider all possible outcomes

Not linking hazards with risk controls

Inappropriate use of data



Modern regulation- the future

- April 2006 low risk exemptions, non fee paying
  - application forms, centralised processing
  - plain English guide all exemptions
- April 2007
  - complex fee paying and low risk exemptions on line application, payment and registration
  - Lower risk waste licences, on line applications and payment
- Faster, improved consistency, long term cheaper

Environment Agency Regulatory Perspective

Thank you.

Any questions.

Phil Saunders
Technical Manager Waste Treatment Process
e. mail: phil.saunders@environment-agency.gov.uk

Bioaerosols A Composting Industry perspective

Dr John Mullett
Director Composting Association
(Director CRS)

My background

- First degree Botany , Ph D in industrial marine biology.
- Worked 20+ years in organic waste treatment
- Recent experience as organics manager for WMI – much work overseas and with variety of systems
- Founded CRS in 1999 to develop and supply IVC composting technology for the UK
- Have designed and built 6 plants, initially using clamps latterly tunnels - both source separated and mixed waste feedstocks.

The Composting Industry Perspective

- I prefer to define "The Composting Industry Perspective" as organic waste processing industry, as the issues are pertinent to many sources and treatments of organic matter. .
- Source separated organics IVC, mixed waste composting and Anaerobic digestion maturation all have bioaerosol issues in common with GW composting

Whose perspective?

- I have consulted some in the industry or consultants to the industry
- My thanks to the following for assistance
  - Emily Nichols, Ed Stentiford, Tony Gladding, Lawney Dampney, Charlie Trousdell, Phil Wallace, Brian Crook, Chris Field, Steve Bullock, Barry South

however

- This presentation is my own personal assessment of the situation

Please bear in mind

- ONLY the Waste Processing Industry actually recycles organic waste in our society
  - Consultants don't,
  - Regulators don't, not even
  - Banks do it
- We do however, need help to do it right and to make sure that we don't hurt anyone or anything doing it

Why are we doing it?

- It's a great business opportunity with significant green credentials
- These green credentials are:
  - The diversion of organic waste from landfill whilst
  - adding organic matter to soils
- Both have beneficial affects on our environment
  - Reduction of greenhouse gas emissions
  - Increases in soil fertility whilst binding carbon
  - Improvement in water utilisation in soils

Can the industry prosper?

- To prosper the industry needs to be able to design and operate facilities within publicly acceptable safely standards
- Regulatory bodies ARE the arbiter of publicly acceptable standards and therefore
  - Industry needs to know what the regulatory requirements are
  - how to comply with them
  - how to plan new facilities which will comply with requirements

Regulation we do NOT want….

- Regulations that are unclear
  - What are the acceptable exposure limits for neighbours and employees?
- Regulations that are unjustified
  - Occupational exposure zero so we can be sure to be safe
- Regulations that are not applied consistently
  - Enclosed, not enclosed etc

Regulation
we do NOT want….

- Regulations that change frequently reducing confidence in being able to predict processes that are acceptable
- Regulations that penalise one industry over another – waste vs farming, mushrooms etc
- Regulations that penalise one part of the industry over another…e.g. ABPR

Composting
High risk to animal health

- Composting plants will wash wheels of delivery vehicles to ensure no waste carried out of enclosed reception

Landfill
LOW risk to animal health ?

- No buildings, no wheel wash, and vehicles drives over waste for some distance then onto road. Same waste and therefore same risk – just different regulations

In an ideal world

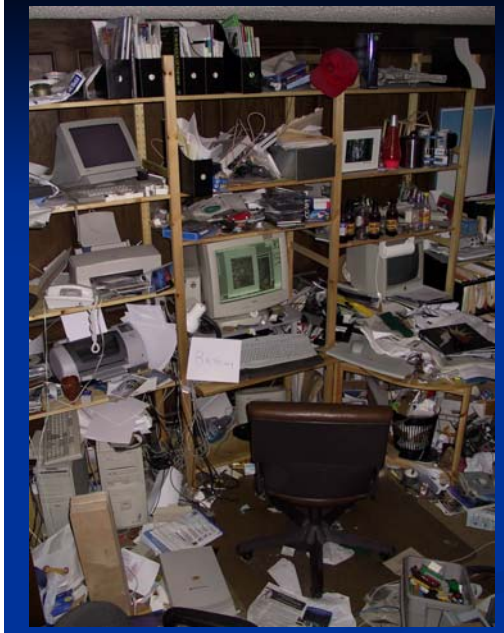
- A body of scientific information would determine quantitative emissions from all sources, continuous as well as intermittant
- Medical opinion would determine "safe" limits
- Engineering and mathematical modelling would determine how to achieve "safe" limits
- Monitoring technology would be available at low cost to ensure compliance with "safe" limits

We don't live in that world

- Scientific data is patchy, and absent in many key areas
- Humans vary in susceptibility to bioaerosol risk
- Medical consensus regarding acceptable occupational and neighbourhood risk is not determined

We don't live in that world

- Mathematical models are not refined for localised predictions
- Local climate and topography have big impact on risk modelling - information not usually available
- Different monitoring methods give different results



Situation now?

what a mess"

BUT WE DO WANT REGULATION NOW

- We want to operate safely
- We want to know the rules
- We want to be able to invest in project proposals which will receive EA and HSE approval
- We want fair and consistent regulation

Observations looking outwards

- The EA and HSE must execute regulation in the absence of a scientifically robust database and a clear medical viewpoint
- Consultants are being asked to measure and critique in a regulation vacuum – in some cases acting as technical guru – in others giving advice which is overruled by EA officials
- EHO's are hardly mentioned but do they have a role going forward

Last but not least.. "The Locals"

- Understandable concerns no-one wants a waste operation near them
  - No waste = no risk
- Bioaerosols are used as a weapon to generate fear of health risks from waste and hence resistance to proposals
  - Absence of clear OEL stimulates uncertainty concerning "safe"
  - Are the EA responsive to this lobbying?

Or is it more like this!

is Bioaerosol Regulation the new "POLITICAL" SCIENCE?

YES but please be transparent

- How are acceptable levels to be determined
  - Quantitative risk assessments or modelling do not determine safety – exposure limits do
  - One option – undertake risk assessments to determine acceptable risks
  - Another option – determine the best available technology not involving excessive cost and use that to determine acceptable levels

Other examples of political sciences

- What is the safe level in compost of PTE's
- USA take a risk based approach – result high levels acceptable
- Germany first – Bundesgutemeinshaft standard a marketing standard used to differentiate source separated from mixed. (BATNEC)
- Now widely adopted including UK PAS 100
- Holland –PTE's in = PTE's out by leaching etc

The way forward

- Scientists, Doctors and Mathematicians must move forward to develop an assessment of this human health hazard, and not just for waste management but for everyone
- The EA and the other regulators must derive a clear framework for regulation now AND a framework for evolution of the regulation as evidence accumulates.

The way forward

- Industry should: Assist in formulating workable regulatory requirements but not seek to determine "safe" exposure limits
- Seek to minimise exposure and hence risks
- Seek to work in partnership bearing in mind the limitations of the science
- Offer all available data (e.g. monitoring data) to the scientific community to aid risk assessment

Please lift the fog
find a clear way forward
and lets have a ..

The role of dispersion modelling in bioaerosol impact assessment

Martin McVay
Environment Agency

The role of dispersion modelling

- Prerequisites to modelling
- What level of modelling?

Prerequisites to modelling

- Species of interest
- Averaging time
- Environmental Assessment Level
- Background concentrations

Prerequisites to modelling

- Emission rate
- Constant or time-varying?
- Constant → relatively easy
- Time-varying → not impossible

Prerequisites to modelling

- Time-varying in what way?
- Dependent only on operations?
- Dependent also on meteorology?

Prerequisites to modelling

- Is plume depletion significant?
- Particle size distribution
- Deposition velocities

What level of modelling?

- Look-up table method (IPPC H1)
- Computer modelling
  - Software
  - Hourly meteorological data
  - Site-specific source characterisation
  - Buildings, terrain elevations, etc.

Look-up table method (IPPC H1)

Process contribution ($\mu g/m^3$)
= dispersion factor ($\mu g/m^3$ / g/s)
$\times$ release rate (g/s)

PC = DF $\times$ RR

When are emissions insignificant?

max. PC (long-term)
≤ 1% of long-term EAL
and
max. PC (short-term)
≤ 10% of short-term EAL

If not insignificant, further assessment may be required if-

max. PC (long-term) + long-term background
> 70% of long-term EAL
or
max. PC (short-term)
+ 0.2 × (2 × long-term background)
> 20% of short-term EAL

Dispersion factor (DF)

- Read from look-up tables
- Generic H1 factors:

Effective height of release (see Module 2) (m)	Dispersion Factor (µg/m³/g/s)	
	long term: maximum annual average	short term: maximum hourly average
0	148	3900
10	32	580
20	4.6	161
30	1.7	77
50	0.52	31
70	0.24	16
100	0.11	8.6
150	0.048	4.0
200	0.023	2.3

Dispersion factor (DF)

- 0 m effective height of release →
  3900 µg/m³ / g/s DF (short-term impact)
- Equivalent to 3900 × 10^{-6} cfu/m³ / cfu/s

Estimated process contribution

- Suppose worst-case bacteria emissions ~12,000 cfu/s
- $12{,}000 \times 3900 \times 10^{-6} = 47$ cfu/m^3
  < 10% of 1000 cfu/m^3
  (taking reference background level as short-term EAL)

Look-up table method (IPPC H1)

- But… generic H1 factors for 0 m release heights questionable over short distances
- Sector-specific look-up tables can be generated if deemed appropriate
- Dispersion factors may take source-receptor distance into account

Table 3 Maximum hourly and annual mean ground level concentrations beyond a given distance from a typical landfill area source (µg/m^3 per g/s emitted)

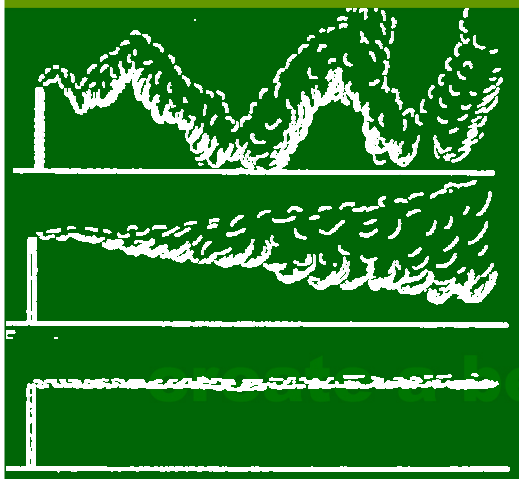
Shortest distance from sensitive receptor to nearest edge of ground level area source	Maximum hourly ground level concentration (µg/m^3 per g/s emitted)	Maximum annual mean ground level concentration (µg/m^3 per g/s emitted)
50 m	8000	165
100 m	6000	80
150 m	5000	45
200 m	4000	35
250 m	3500	25
300 m	3000	20
350 m	2500	15
400 m	2000	15
450 m	2000	10
500 m	1500	10

Computer modelling

- Current regulatory models can
  - model deposition / plume depletion
  - model time-varying emissions
  - link emission rate to wind speed
  - take local wind patterns into account

- Validated mostly for stack emissions

Computer modelling



Unstable (sunny day)

Neutral (cloudy, windy)

Stable (clear night)

Computer modelling

- Windy conditions → higher emissions?
- Stable conditions → poorer dispersion?
- Current regulatory models skip calm hours
- New models may cope better

Computer modelling

- Annual average
  → extreme met. conditions not so critical
- Worst 1-hour average
  → model limitations to be considered

Computer modelling

- Uncertainty in predictions dictated by weakest link in chain
- State-of-the-art computer model predictions may be no better than those generated by generic look-up tables if emission rates are not known with sufficient confidence

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UNIVERSITY MEDICAL CENTER
GIESSEN and MARBURG

INSTITUTE OF HYGIENE AND
ENVIRONMENTAL
MEDICINE
Head: Prof. Dr. med. Th. Eikmann

Environment Agency Workshop on assessments of risks to health from bioaerosols associated with green waste composting.

28 February 2006, Manor House, Howbery Park, Wallingford, Oxfordshire

Hazards associated with bioaerosols

Health effects (inflammatory responses) associated with residential bioaerosol pollution

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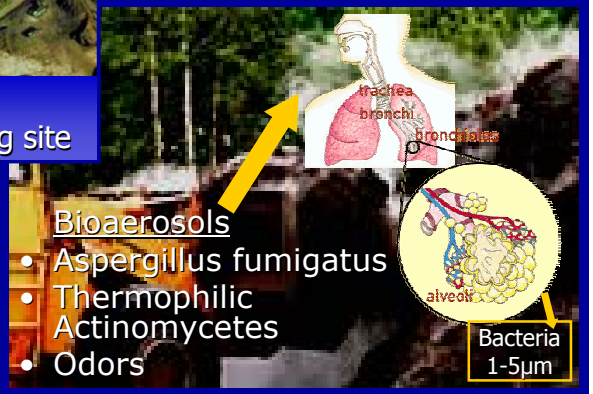
Bioaerosols in outdoor air

Example
composting site



Bioaerosols
- Aspergillus fumigatus
- Thermophilic Actinomycetes
- Odors

Millner, PD et al. Bioaerosols associated with composting facilities. Compost & Science Utilization 2, 6-57 1994

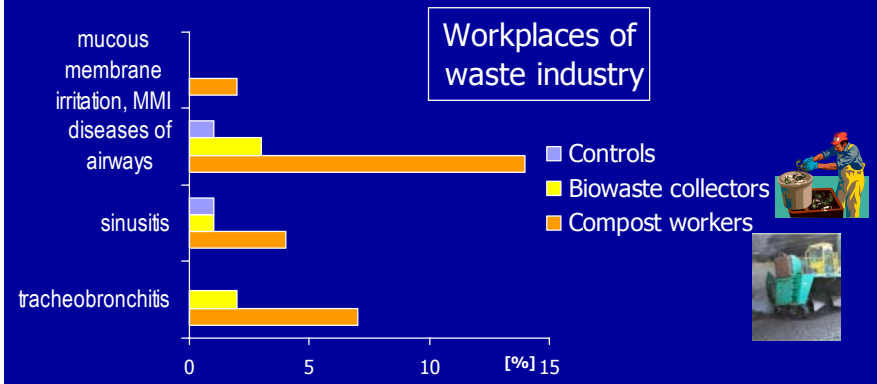
Health effects of bioaerosols in workers of waste plants: clinical

- no increase in diseases — Epstein et al. 1993, Lees 1993
- more frequent general complaints (mostly not significant) — Schappler-Scheele et al. 1999
- more frequent symptoms and diseases:
  - aerosol exposure
    - upper respiratory tract (MMI, bronchitis, sinusitis) — Bünger et al. 1998
    - lower respiratory tract (asthma, EAA, ODTS) — Malmros et al. 1992, Hartung et al. 1998
    - eye (conjunctivitis) — Grüner et al. 1998
  - dermal exposure
    - skin (mycoses, pyodermia, eczema, otitis ext.) — Grüner et al. 1998, Bünger et al. 1998, Clark 1994
    - gastrointestinal (nausea, vomiting, diarrhoea) — Bünger et al. 1998, Sigsgaard 1994, Ivens 1998

Health effects of bioaerosols in workers of waste plants: laboratory

- increased upper airway inflammation (total cells and IL8) and respiratory symptoms — Wouters et al. 2002
- compost workers: (sub-) chronic inflammatory reactions in the upper airways, presumably induced by non-allergenic pro-inflammatory agents like endotoxins and beta(1, 3)-glucans — Douwes et al. 2000
- higher levels of specific antibodies — Bünger et al. 1997, Belin & Malmberg 1986 , Clark et al. 1984
- oral (hepatitis A) and parenteral infections (hepatitis B) — Grüner et al. 1998
- livestock and agricultural workers
  - ischaemic heart disease slightly increased risk
  - … exposure in a swine confinement house induced an interleukin-6 and more than 50% increase of fibrinogen in plasma (risk factor for IHD) in healthy volunteers. Sjögren et al. 1999 & 2003

Bioaerosols and health



… significantly increased antibody concentrations against fungi and actinomycetes were measured in workers at composting plants

Bünger J et al. Health complaints and immunological markers of exposure to bioaerosols among biowaste collectors and compost workers Occup Environ Med. 57, 458-64 (2000)

Bioaerosols: aspects to consider

Background & Workplace concentrations of viable microorganisms (cfu*/m³)

	Molds	Actino-mycetes	Bacteria
Background			
HMUEJFG, 1999	1.5 x 10^4	n.n.	9.2 x 10^2
Bossow, 1999	<2x10^3	<3x10	<10^2
Bünger, 2000	<10^3	<10^2	<10^2
Workplace			
Composting sites	10^7	10^5	10^7
Biowaste collection	10^5	10^4	10^5

*cfu: colony forming units

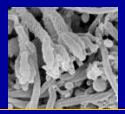
- Ubiquitous occurrence
  - season
  - natural environments
- Exposure assessment
  - reproducibility
  - meteorology
  - topography
  - parameters of microorganisms
    - viable, non-viable, parts
    - organic compounds
      - glucanes
      - endotoxins
      - volatile (MVOC)

odor annoyance

Herr C, Bittighofer PM, Bünger J, Eikmann T, Fischer AB, Grüner Ch, Idel H, zur Nieden A, Palmgren U, Seidel H-J, Velcovsky H-G. (1999). Wirkung von mikrobiellen Aerosolen auf den Menschen. Gefahrst – Reinh Luft 59, 229-239.

Cross sectional study in 97/99/02

- Measurements of viable microorganisms in residential outdoor air near composting sites in 1997

- Survey in residents near different sites and controls





- Questionnaires (1997/99/02)
  - health status: airways, allergy
    - modified acc. MURL (1994), ISAAC (1998)

  - individual odor annoyance (n=900)
  - somatization (perception of bodily complaints, SOMS2)
  - health related quality of life (SF-36)

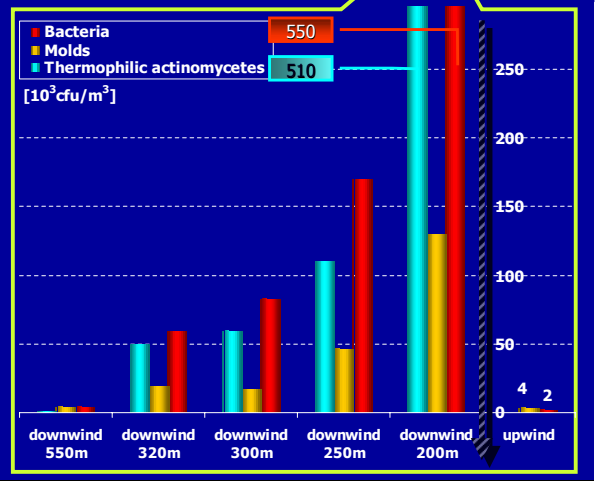
Rationale: nausea, loss of appetite, vomiting, general complaints
- associated with annoying environmental odors (Steinheider et al. 1998)

Residential air: measurements

- "Worst case" situation
  - work procedures on site
  - inversion weather
- Viable microorganismen
  - MD-8-collector, 1.5m above ground
  - 8m³/h, Filtration
- ➔ Results of this one site:

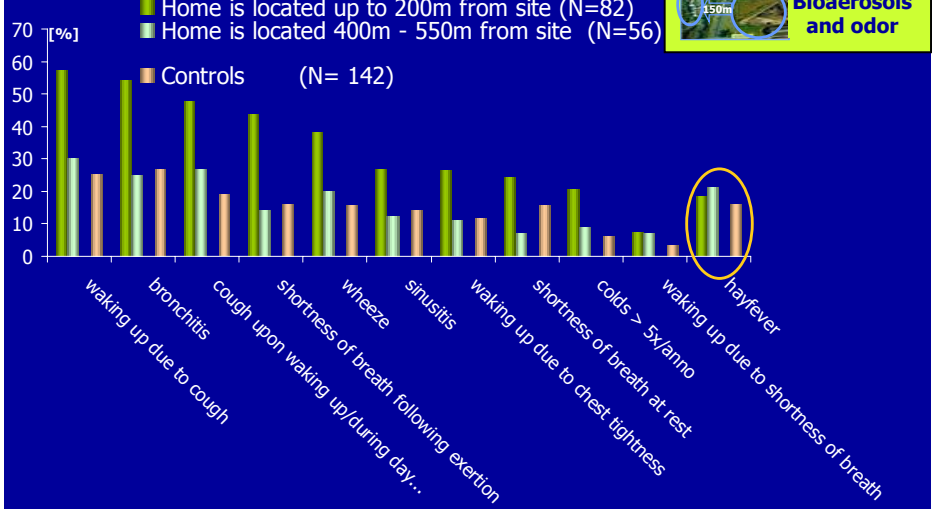
Workplace exposure in residential area
- >10^5 cfu/m³
  - bacteria/
  - thermopilic actinomycetes
- >10^4 cfu/m³ molds

cfu: colony forming units



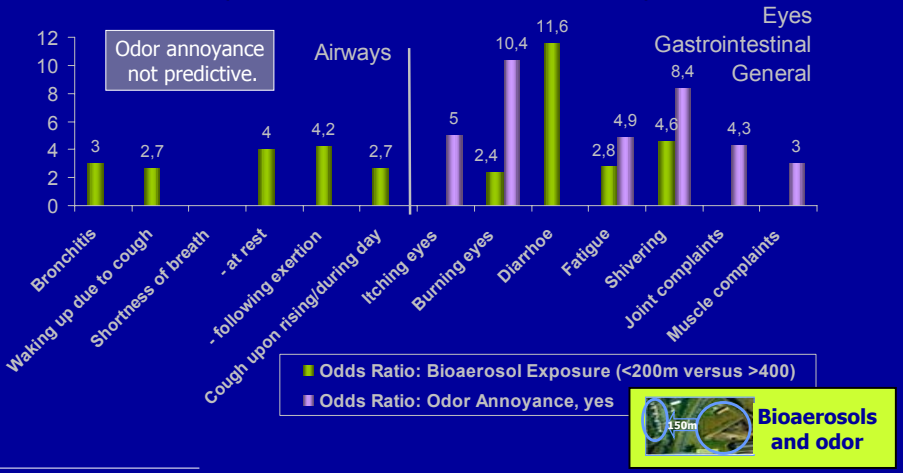
Self-reported airway complaints*

- Complaints, symptoms, diseases of the past year



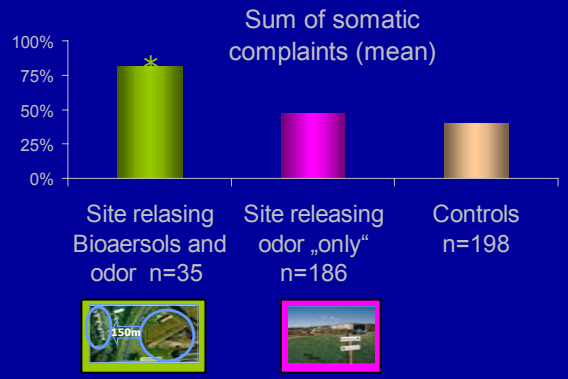
Self-reported airway complaints:

Logistic regression including (OR p≤ 0.05) bioaerosol exposure and individual odor annoyance



*Analyses with logistic regression p<0,05, adjusting für multiple variables, only relevant findings, p>0.05 reported
Herr C, zur Nieden A, Jankofsky M, Stilianakis NI, Bödeker R-H, Eikmann T. Effects of bioaerosol-polluted outdoor air on airways of residents: a cross sectional study. Occup Env Med 60, 336-342 2003

Somatoform complaints in the vicinity of two different composting sites

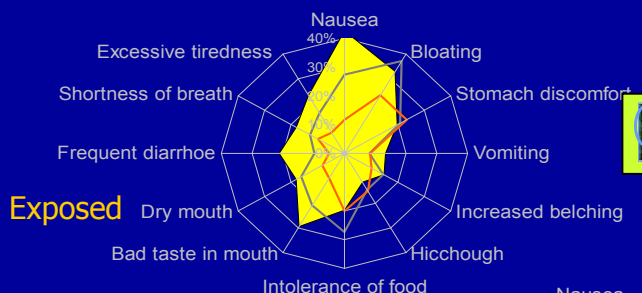


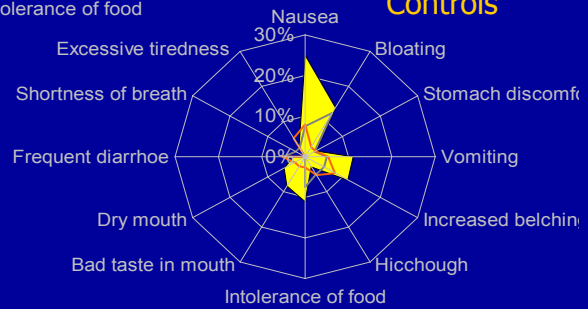
*p=0.02 vs. controls adjusting for: duration and location of residency, age, gender, health status (SF-36)

➔ odor annoyance „only“: no increased rate of reported complaints

Follow-up: Exposed vs. Controls

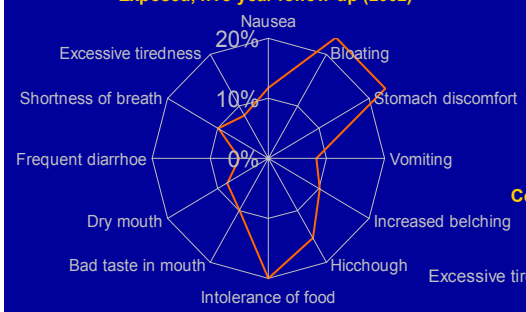
Follow-up: Exposed vs. Controls



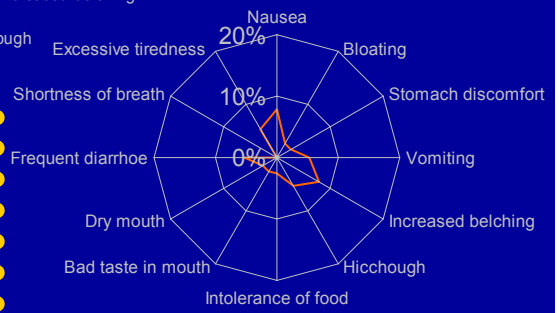


Follow-up: Exposed vs. Controls

Exposed, five-year follow-up (2002)

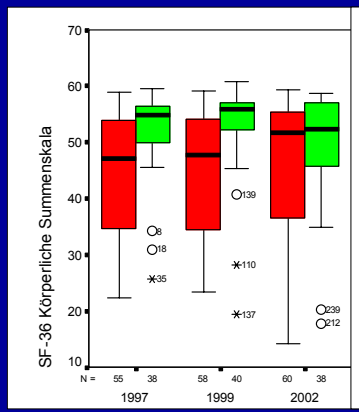


Controls, five-year follow-up (2002)

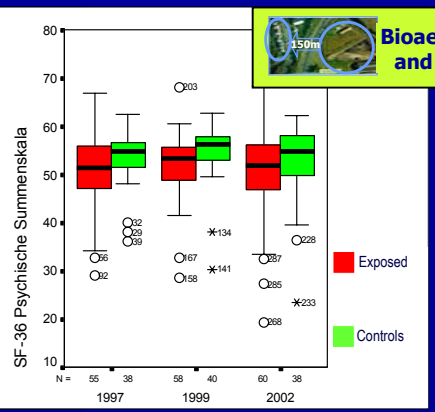


- Pattern of gastrointestinal and general bodily complaints remains different throughout follow-up, until five years after closure of composting site!

Health Related Quality of Life



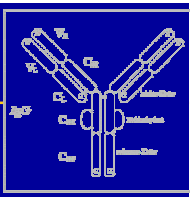
Bodily Health

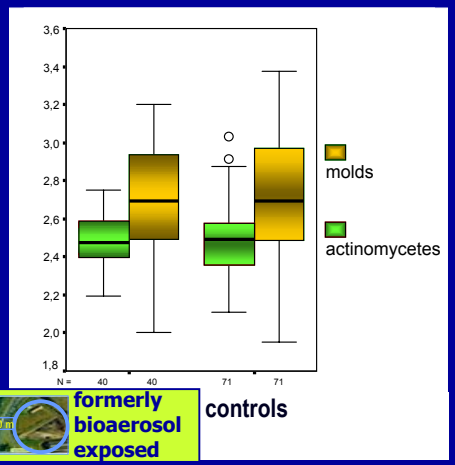


Mental Health

Bodily Quality of Life improves in exposed subjects during the follow-up!

Biomarker: IgG Antibodies





- Follow-up 5 years after closure of the site with bioaerosol exposure (2002, N=111)
- Analyses of variance
  - age, gender, history of hayfever or allergy
  - district (countryside/town)

➔No relevant difference in antibody titer ($p>0.05$): formerly exposed vs. controls

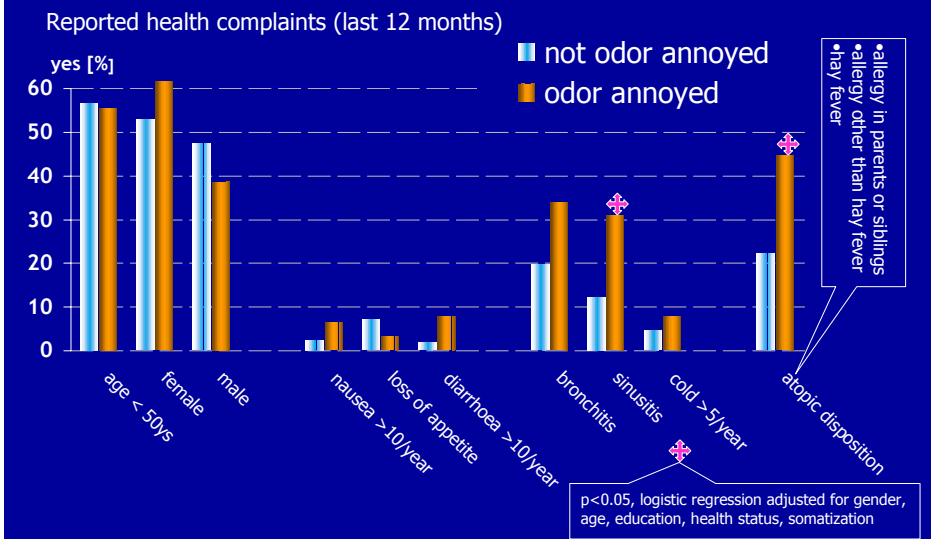
Uncertainties

? Latency: exposure/determination

? ubiquitous occurrence

? unknown predictors of titer (R^2=10 %)

Characterizing subjects annoyed by odors in "normal" neighborhoods? (no odor source)



Indoor storage of biowaste

Odds ratios for reported health complaints in subjects storing biowaste indoors for >2 days (p<0.05)

Striped columns: overall, n=316

Solid columns: subgroup of atopics with allergy or hay fever

Doctor's lifetime diagnoses of

1) allergy other than hay fever: 3,2 / 2,7

2) skin disease: 4,8 / 3,2

Skin rash ...

1) itching >2 months, ever: 6,4 / 3,6

2) itching, >2 months, past year: 4,8 / 2,8

3) in past year: 2,6 / 2

fatigue, past year: n.s. / 2,6

diarrhea, past year: n.s. / 5,2

- Separately stored waste
  - → Increased levels of
    - endotoxins
    - extracellular polysaccharides
    - glucanes in dust.

Increased levels of markers of microbial exposure in homes with indoor storage of organic household waste. Wouters et al. Appl Environ Microbiol 2000 Feb;66(2):627-31

Herr C, zur Nieden A, Stilianakis NI, Gieler U, Eikmann T. Health effects associated with indoor storage of organic waste. Int Arch Occ Env Med 77 90-96 2004

Bioaerosols

- Bioaerosols in residential air
  - may reach work place levels (worst-case)
  - mucous membrane irritation syndrome (MMI)
  - indication of long-term effects, (5 years after cessation of exposure)
    - somatic vs. cognitive conditioning?
- Environmental odors
  - do not necessarily lead to an increase in somatic complaints
  - → "objective" exposure measurements necessary
  - in "normal" neighborhoods seem to be a problem especially for subjects with a history of atopy or sinusitis.
- Indoor storage of organic waste
  - association with skin complaints= atopiforme dermatitis
  - atopics might be at higher risk
- Research needs
  - immissions from agricultural site
  - personal waste management (immunocompromised individuals)
  - health relevance of environmental odors
- Thresholds? Based on local background concentrations

..... questions

Supported by:
Hessian Ministry of Environment,
Federal Environmental Protection Agency
BMBFT and EU

A Dutch perspective on composting

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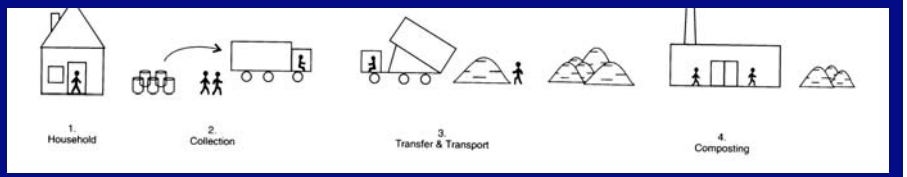
Outline

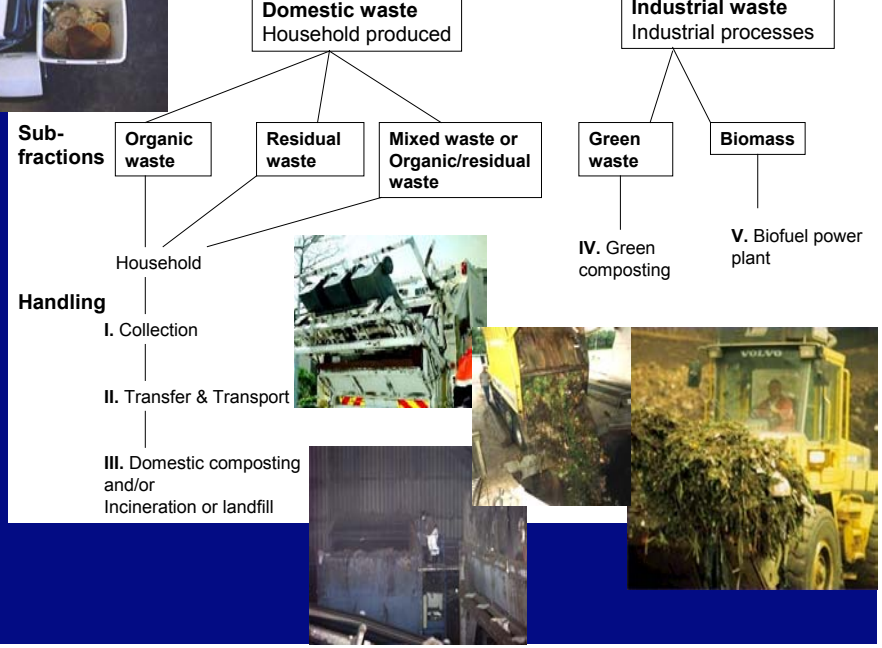
- Practice – technologies
- Rules
- Research
- Conclusions

The waste industry

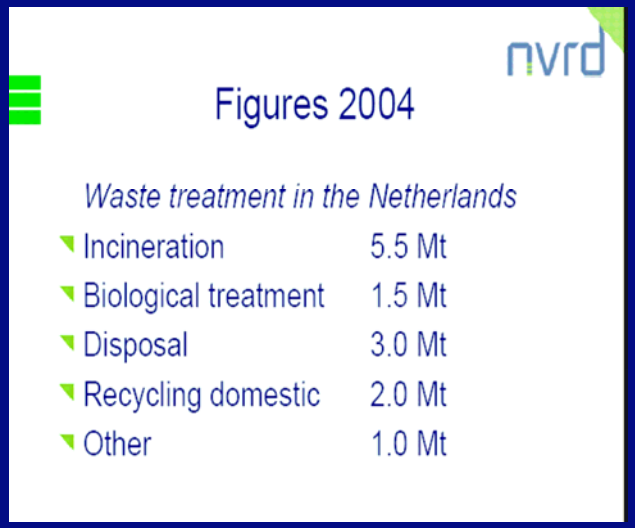
- Pre-industrial:
  re-use and recycling
- Post-industrial:
  increased volume
  waste management systems (collection and landfill, incineration)



- Mid 90's:
  rapid development of the (organic waste)recycling industry



Amounts



Technologies

- Vegetable, Green and Fruit (VGF composting)
  indoors
  24 aerobic composting sites
  (table-, in vessel- and tunnel-composting)
  1 anaerobic

- Green waste composting
  mostly outdoors
  100 composting sites
  (table- and windrow-composting)

Dutch approach

- The Dutch National Waste Management Plan (LAP) minimum standards for the treatment

- BOOM-decree - decree for quality and use of other organic fertilisers) for compost legal limits for concentration of heavy metals

- Certification of compost to ensure quality (KIWA) e.g. other contamination (glass)

Rules

- No regulations for bio-aerosols
- Dutch emission guidelines
  water: water-solid surface
  (metals (Cu,Zn), eutrophying substances e.g. phosphate)
  air: dust should be avoided
  fragrance: avoided e.g. by biobeds
  for green waste composting adjusted rules

According to best available techniques

Green waste composting special rules

Based on method:

- A: frequent turning by machine
- B: conventional turning by crane or shovel
- C: no turning (not advised)
- D: forced aeration and frequent turning ? <100 m

Production	Method A	Method B
0-5k	100-300m	300-400m
5-10k	300-600m	400-600m
10k-20k	600-800m	600-1000m
>20k	>800m	>1000m

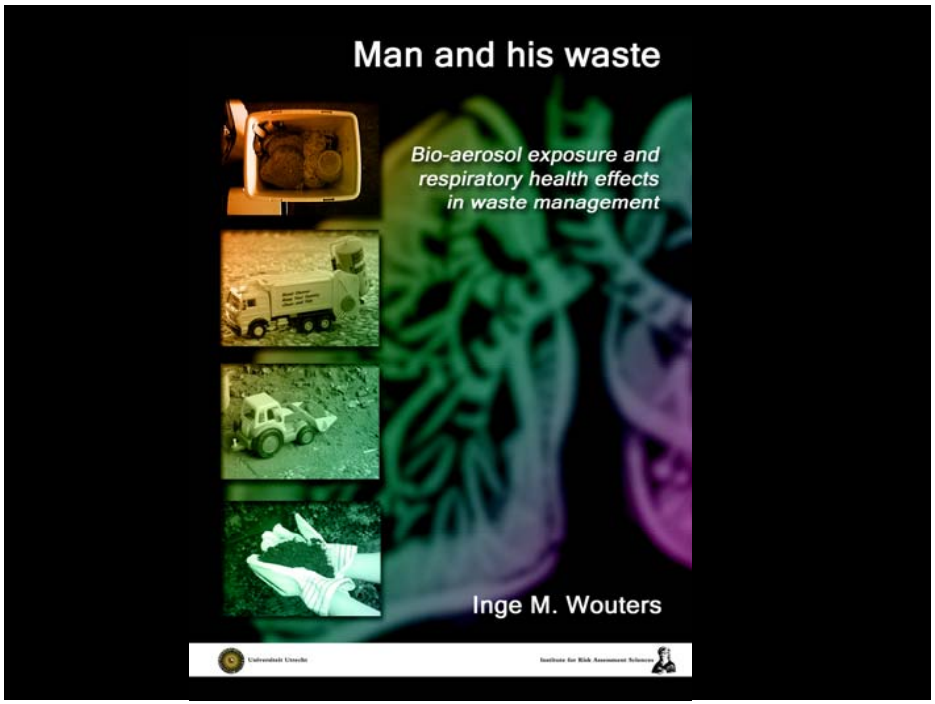
Residents & Environmental &Occupational Health Risk

Op 10 augustus 1995, nu dus drie-en-een-half jaar geleden, stond het volgende bericht op pagina 3 van NRC Handelsblad:

Grote zorg over gebruik biobak bij fractie van VVD - Den Haag, 10 aug. De VVD-fractie in de Tweede Kamer maakt zich grote zorgen over de gezondheidsrisico's van het gebruik van zogeheten biobakken, de afvalbakken voor groente-, fruit- en tuinafval. De kamerleden Te Veldhuis en Kamp hebben ministers De Boer (milieu) en Borst (volksgezondheid) gisteren een lijst met vragen gestuurd. De kamerleden wijzen daarbij onder meer op een onderzoek van het Centraal Bureau voor de Schimmelcultuur in Baarn waaruit blijkt dat in broeierige bakken 'zelfs de vorming van kankerverwekkende stoffen niet mag worden uitgesloten'. Einde bericht.

Mid 90's:

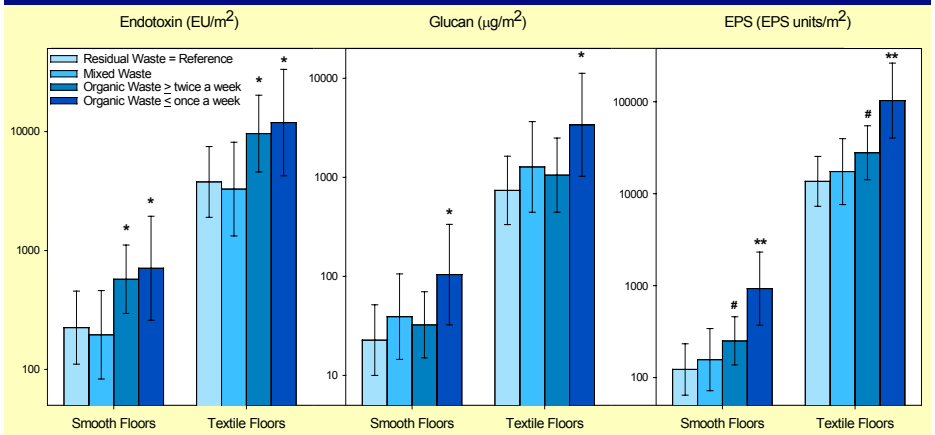
Poulsen et al. concluded that waste management resulted in new and poorly described health risks mainly due to exposure to bio-aerosols



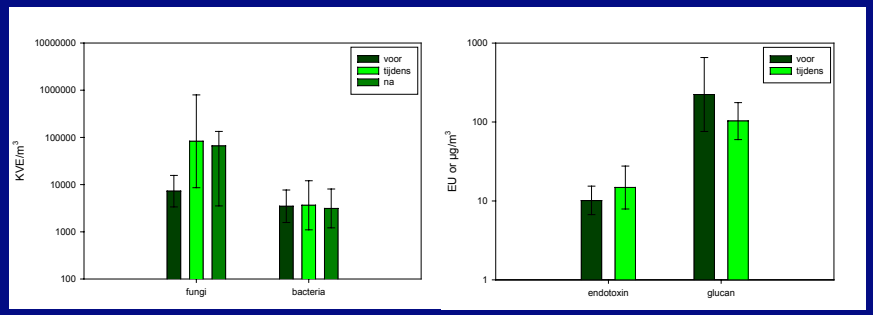
Objectives

- Bio-aerosol exposure in the total waste management chain
- Health effects in key-populations (symptoms questionnaire, airway inflammatory responses by nasal lavage, serology, BHR)
- Dose-response relationships

Bio-aerosols in living rooms



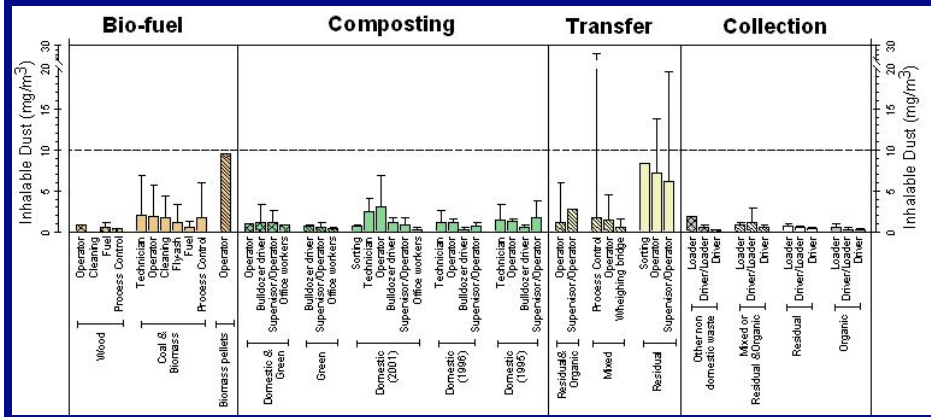
Bioaerosol release



Methods Occupational Exposure Studies

- Inhalable dust by personal monitoring
- Bio-aerosol exposure:
  Endotoxin – marker of (gram-) bacteria
  Glucan – marker of fungi
  EPS-Pen/Asp – marker of fungi

Inhalable Dust Levels (mg/m³)

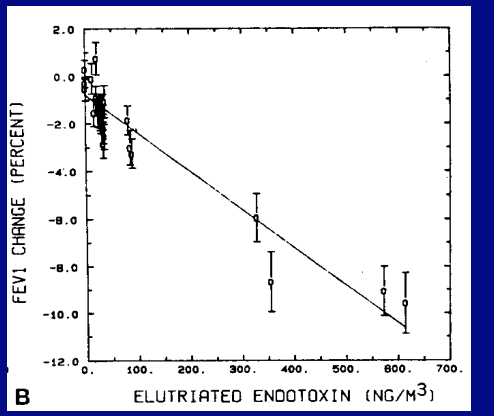


>10 mg:	6%	1%	n.a.	<1%
>4 mg:	14%	7%	n.a.	<1%

Wouters et al. Ann Occup Hyg 2006

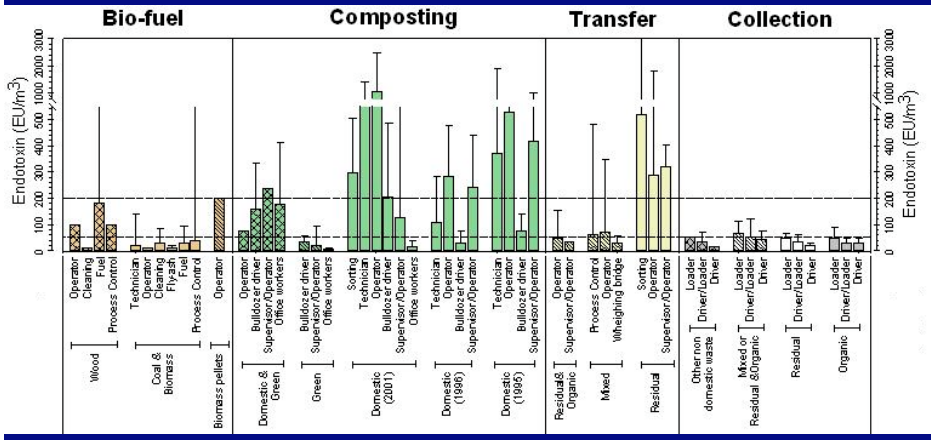
Occupational Exposure Limits for endotoxin

- Observational studies on acute respiratory effects suggest LOELs/NOELs below 100 EU/m^3 (Milton 1994, 1995; Zock 1998)
- Dutch recommended health based OEL is set at 50 EU/m^3 based on a challenge study with cotton dust (LOEL ≈ 90 EU/ m^3) (DECOS 1998)
- Dutch legal limit is set at 200 EU/m^3; effective from Januari 2003



(Castellan 1987)

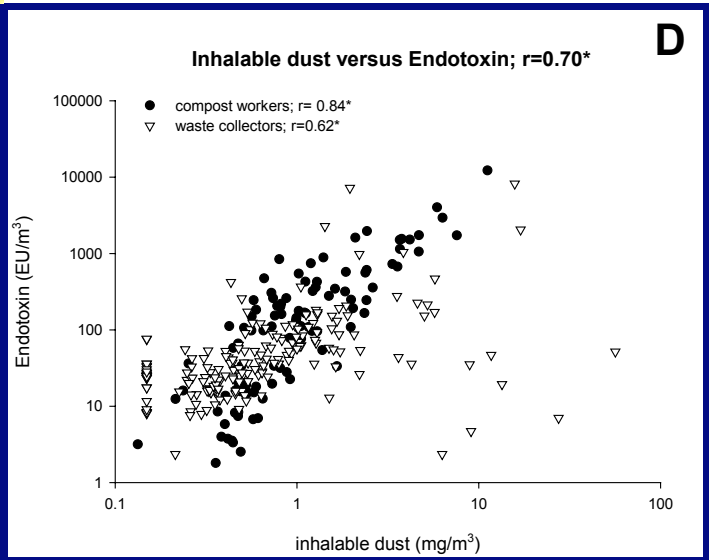
Inhalable Endotoxin Levels (EU/m^3)



>50 EU:	40%	100%	25%	85%	n.a.	45%
>200 EU:	14%	33%	5%	45%	n.a.	10%

Wouters et al. Ann Occup Hyg 2006

Correlation dust and endotoxin



Levels in various occupational environments

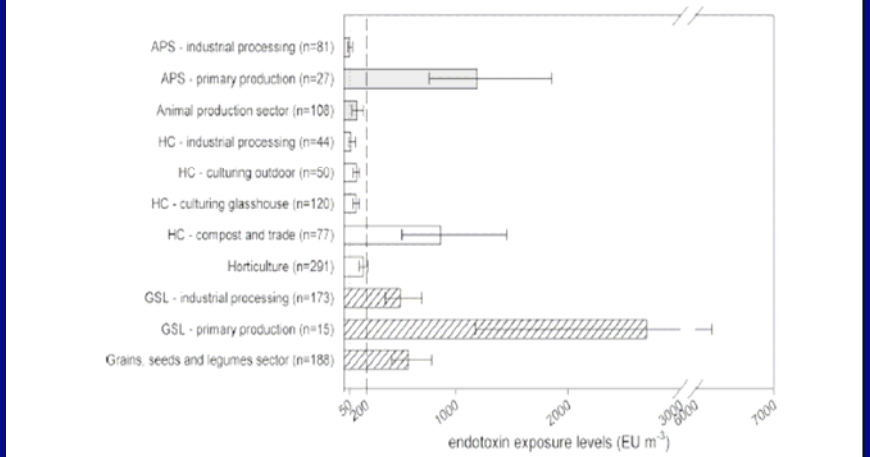


Fig. 2 Endotoxin exposure (GM and 95% CI) levels in three sectors and subsectors of the agricultural industry.

Spaan et al. J. Environ. Monitoring, 2006

Respiratory Symptoms in Compost Workers

	General Population		Composting population				
			Overall			Domestic	
	%	PR	%	PR (CI)		%	PR (CI)
Lower respiratory tract last 12 mo							
Wheezing	24	1	22	1.0 (0.7-1.4)		25	1.1 (0.7-1.8)
Wheezing with SOB[a]	16	1	9	0.7 (0.4-1.2)		12	0.9 (0.4-1.8)
Wheezing without a cold	13	1	10	0.8 (0.5-1.3)		12	0.9 (0.4-1.9)
Woken up due to chest tightness	12	1	6	0.7 (0.4-1.3)		10	1.2 (0.6-2.6)
SOB in rest	8	1	12	1.8 (1.1-3.0)*		17	2.6 (1.4-5.0)**
Exercise induced SOB	21	1	30	1.7 (1.2-2.3)**		33	1.8 (1.2-2.8)**
Woken due to SOB	6	1	5	1.0 (0.5-2.0)		6	1.2 (0.4-3.2)
Woken due to cough	32	1	14	0.6 (0.4-0.9)**		20	0.8 (0.5-1.4)
Cough symptoms[b]							
Daily cough	16	1	29	1.8 (1.3-2.5)***		36	2.2 (1.4-3.4)***
Daily cough up phlegm	10	1	20	1.9 (1.3-2.9)**		26	2.6 (1.5-4.3)***
Dyspnea							
Dyspnea going one flight of stairs	19	1	19	1.3 (0.9-2.0)		23	1.7 (1.0-2.9) *
Dyspnea versus contemporaries	3	1	6	2.5 (1.2-5.5)*		10	4.8 (2.0-11.8) ***

* p<0.05, ** p<0.01, *** p<0.01 compared to general population

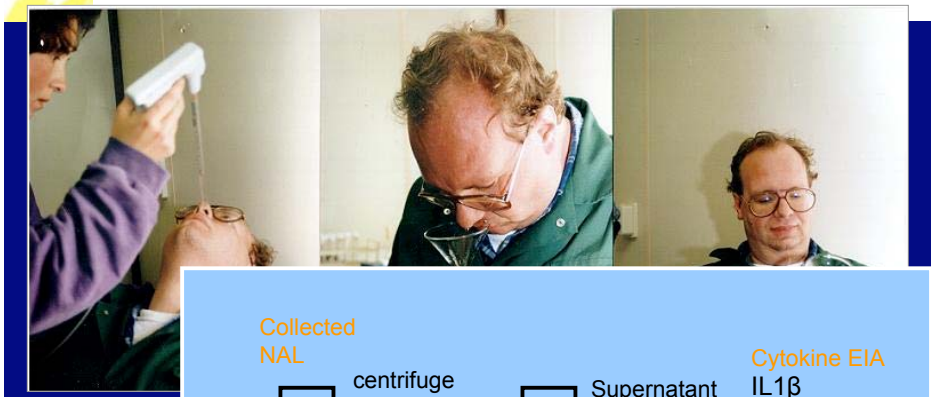
[a] SOB, Shortness of breath

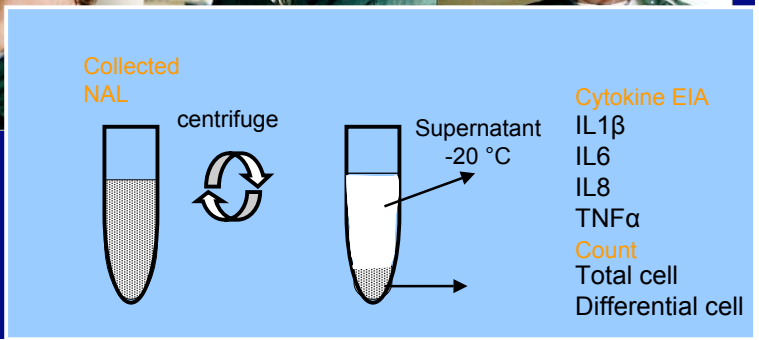
[b] Daily for at least part of the year

Symptoms and exposure

		'neurological & nose'	'respiratory & eyes and throat'	'flu-like & gastro-intestinal'	'irritation of skin'
Dust	0 60	1.0	1.0	1.0	1.0
	>0.60 - 1. 03	1.94 (0.80-4.72)	1.42 (0.51-3.90)	1.34 (0.52-3.45)	0.85 (0.25-2.94)
	> 1.03 - 1. 77	0.75 (0.19-2.91)	2.64 (0.94-7.41) #	1.76 (0.62-5.01)	2.11 (0.64-6.91)
	> 1.77	3.08 (1.19-7.95)*	3.27 (1.19-9.00)*	2.24 (0.81-6.18)	3.14 (1.03-9.59)*
Endo	23	1.0	1.0	1.0	1.0
	> 23 - 81	1.52 (0.57-4.09)	0.99 (0.30-3.24)	1.19 (0.42-3.38)	0.47 (0.09-2.45)
	> 81 - 284	1.42 (0.52-3.92)	2.28 (0.84-6.17)	1.78 (0.68-4.67)	1.99 (0.65-6.08)
	> 284	3.06 (1.22-7.66)*	3.56 (1.35-9.38)*	2.12 (0.79-5.68)	2.96 (0.99-8.84) #
	50	1.0	1.0	1.0	1.0
	> 50 - 200	1.84 (0.72-4.69)	2.22 (0.77-6.40)	1.75 (0.63-4.85)	2.80 (0.82-9.55)
	> 200	1.61 (0.80-3.27)	2.97 (1.42-6.25)*	1.72 (0.82-3.61)	3.20 (1.28-8.02)*
Glucan	0 92	1.0	1.0	1.0	1.0
	>0.92 - 2 14	0.50 (0.15-1.66)	2.15 (0.95-4.87) #	1.49 (0.62-3.56)	2.30 (0.83-6.32)
	> 2.14	2.04 (1.00-4.19)*	2.67 (1.21-5.88)*	1.90 (0.83-4.36)	3.42 (1.35-8.65)*

Nasal Lavage & Serology





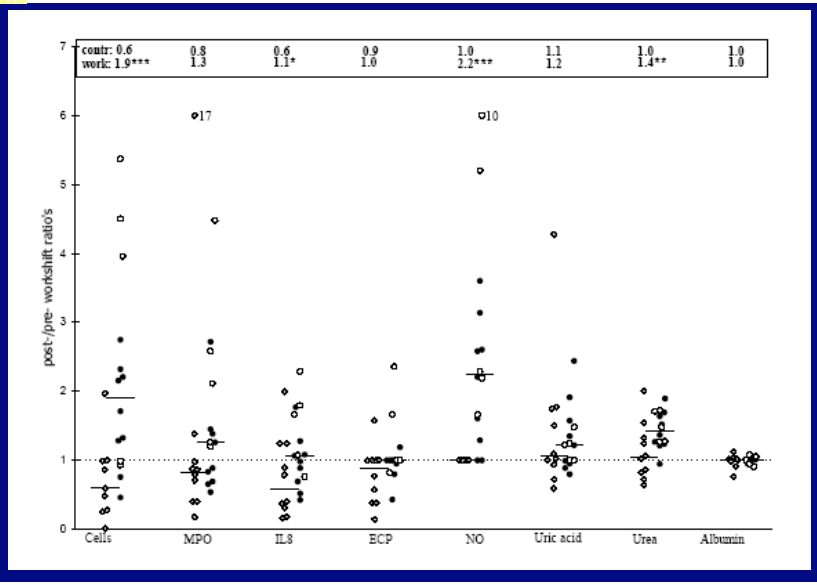
Differential Counts & Serology

- NAL major cell type:
  neutrophils and epithelial cells

- Serology:
  IgG titers against *A. fumigatus, Aspergillus-4, Pennicillium-4, Cladosporium-3, M. faeni and T. vulgaris* similar for waste collectors and controls

  Rarely positive IgE tests against molds in waste collectors (2%) and compost workers

Compost workers: NAL over shift-ratio increased



Association NAL and Respiratory Symptoms (waste collectors – post shift)

	Cells	IL8
Cough	1.80 #	2.52 **
Cough with phlegm	2.00 #	2.36 *
Wheezing chest	1.33	4.28 *
Dyspnea	0.80	2.44
Shortness of Breath	3.00	2.75
Chest tightness	2.00	1.83
Stuffed nose	1.22	1.71 *
Runny nose	1.50 #	1.59 *
Itchy nose/sneeze	1.47	1.15
Throat irritation	2.33 #	2.14 #

Conclusions Waste Studies

- Bio-aerosol exposure levels above OEL
- Waste collectors and compost workers showed increased respiratory and systemic symptoms
- Acute and delayed upper airway inflammation compared to controls, which is non-immune mediated and most likely related to bio-aerosol exposure and symptoms
- Considerable inter-individual variability in exposure-response relationships

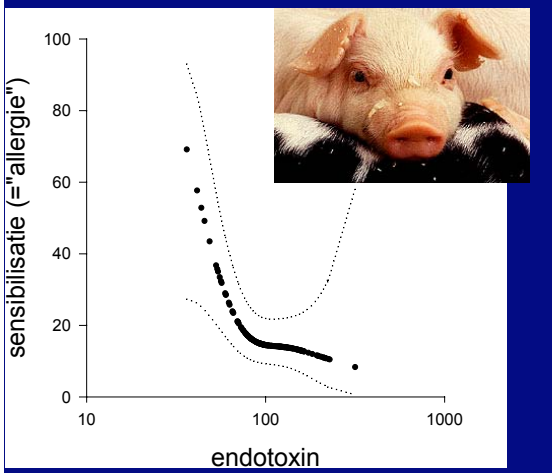
However,

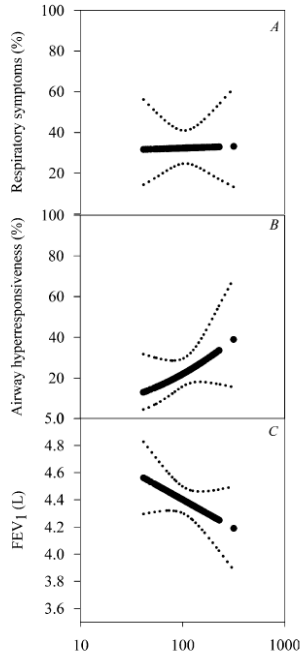
- Implications unknown?
- Accelerated lung-function decline?
- Dose-response relationships differ between persons

Hygiene Hypothesis

Exposure to endotoxins or other microbes might protect from the development of atopy or asthma in children or adolescents

Protective effects in adults? (Portengen et al., 2005)





Emissions

- Hardly studied internationally

MVOC

Compost-derived and microbial volatile organic compounds (MVOC) at up to 800 m (Terpenes) coincided with typical compost odour (Mueller et al. 2004)

Fungi

Increased levels of mesophilic fungi and T.vulgaris in vicinity of green waste composting

Dropped to 0 in 200m (Sanchez-Monedero et al., 2005)

Emissions

Table 5 Health effects* of highest (>10⁵ CFU† m⁻³ air) versus near background concentrations of outdoor bioaerosol, pollution, duration of present residency, and odour annoyance in a residential area with a neighbouring composting site

		Bioaerosol pollution in residential air‡ up to >10⁵ CFU m⁻³ air		Duration of present residency >5 years		Odour annoyance in the residential area	
Reported health complaints§	SS¶	OR**	95% CI††	OR	95% CI	OR	95% CI
Respiratory tract							
Frequency of colds >5×/year	209	1.94	0.65 to 6.78	**4.72**	**1.19 to 31.83**	3.09	0.50 to 60.14
Bronchitis	210	**3.02**	**1.35 to 7.06**	**2.91**	**1.29 to 7.03**	1.86	0.71 to 5.54
Waking up due to coughing	202	**2.70**	**1.23 to 6.10**	**2.51**	**1.19 to 5.53**	1.95	0.81 to 5.08
Wheezing	207	1.96	0.84 to 4.82	**2.95**	**1.22 to 7.99**	1.97	0.72 to 6.35
Shortness of breath at rest	203	**3.99**	**1.31 to 15.19**	1.50	0.56 to 4.49	1.97	0.59 to 9.02
Coughing on rising or during the day‡‡	210	**2.67**	**1.17 to 6.10**	1.51	0.69 to 3.29	1.51	0.61 to 3.75
Shortness of breath after exertion	205	**4.23**	**1.74 to 11.34**	2.03	0.90 to 4.91	2.15	0.79 to 6.90
Eyes and general health							
Itching eyes >10×/year	206	1.35	0.61 to 3.05	**2.85**	**1.31 to 6.50**	**4.97**	**1.89 to 15.67**
Smarting eyes >10×/year	205	**2.44**	**1.02 to 6.22**	**2.42**	**1.06 to 5.86**	**10.40**	**2.87 to 66.96**
Nausea or vomiting >5×/year	204	2.65	0.87 to 9.97	**4.10**	**1.28 to 18.44**	§§	§§
Excessive tiredness >5×/year	200	**2.80**	**1.22 to 6.72**	1.83	0.84 to 4.11	§§	§§
Shivering	210	**4.63**	**1.44 to 20.85**	**3.67**	**1.32 to 12.20**	§§	§§
Joint trouble >10×/year	207	1.27	0.54 to 3.07	1.52	0.65 to 3.71	**4.30**	**1.55 to 14.17**
Muscular complaints >10×/year	201	1.17	0.47 to 2.99	1.39	0.55 to 3.86	**2.99**	**1.02 to 11.03**

*Only the significantly increased complaints from table 3 are listed and printed in bold type.
†CFU, colony forming units.
‡Distance of home to the emitting site 150–200 m.
§Frequency or occurrence in the past 12 months. If not otherwise stated, rates are for a single occurrence.
¶SS, sample size.
**OR, odds ratio of those living the stated distance from site compared to those living >400 m from the site adjusted for odour annoyance in the residential area, period of residence in the present home >5 years, and age.
††CI, confidence interval.
‡‡Criteria of the World Health Organisation for chronic bronchitis.
§§Due to the small number of subjects of this complaint reliable odds ratio could not be determined.

Herr et al , OEM 2003

Conclusions and future directions

Moderate microbial exposure, associated (neutrophilic) inflammatory responses

Atopic response in relation to occupational exposures deserves more attention

Susceptibility issues? – Longterm effects

Which microbial exposures play role, other exposures (MVOCs)?

Prevention ……..and future developments?!

Assessing Health Risks - The Gaps

Greg Jordinson
Human Health Science Team

creating a better place

Outline

- Chronology
  - Microbiology gaps
  - Modelling gaps
- What are we doing about the gaps
- What are we going to do

Chronology - a little of what has gone before!

- Composting Association 1999
- EA 2001 (P315 and P428)
- HSL 2003 (RR130)
- EA 2004 (M17)
- T. Gladding (P214)
- ADAS 2005

Composting Association

- *Aspergillus fumigatus*, mesophilic bacteria
- Culturing
- Sampling procedure
- Monitoring strategy
- Data reporting

EA 2001 (P315 and P428)

- Abatement
- Dose response
- Epidemiology
- Improve dispersion modelling terms
- Source term

HSL 2003 (RR130)

- Viable + non viable need to be measured
- Measure Immunotoxicity
- DNA profile tracking
- Improve source term data for modelling

Don't discard 250 m just yet!

EA 2004 (M17)

Noted no standard assay in 2004

- Impaction for viable or
- Impingement for non-viable

But which micro-organisms?
Allergenicity?

ADAS 2005

- 90 % below 1000 cfu m^3 by 125m
- no size variation in particle deposition rate

Called for:

- better source term definition
- more data analysis for modelling

So, more to come?

Open University

Inter alia P1-214

Called for:

- Exposure standards for endotoxins

Noted:

- Viables underestimates exposure

What are we doing about it?

- Bioaerosols
  - Source term emission characterisation (HSL)
  - EA post doctoral fellowship Cranfield University

What are we going to do about it?

New project:

- Recommend
  - which, how for micro-organisms
  - how for endotoxin
  - sampling strategies for compost bioaerosols

What else is going to be done?

Defra sponsored, EA managed

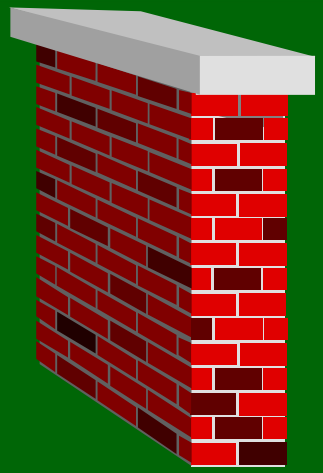
- Dose response review
- Framework for bioaerosol control during waste management
- Rapid, responsive monitoring network for bioaerosol emissions

What else might be done?

- Specify methods?
  - micro-organisms?
  - endotoxins?
  - viable + non-viable
  - exposure limits?
  - model terms?

What have I forgotten?

So we have been busy, but not finished yet



Thank you for listening

Greg Jordinson
Human Health Science Team
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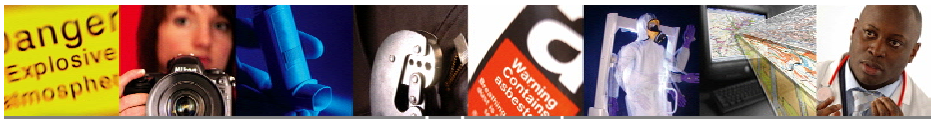
WASTE COMPOSTING – SOURCE TERM DEFINITION AND BIOAEROSOL CHARACTERISATION

BRIAN CROOK

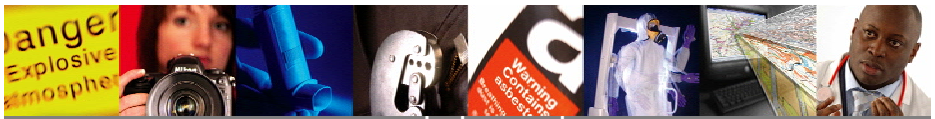
MICROBIOLOGY SECTION



OR:
WHERE DOES IT COMES FROM?
WHAT IS IT MADE OF?
HOW MUCH?
WHY DO WE CARE?

BRIAN CROOK

MICROBIOLOGY SECTION



OVERVIEW

- The EA/HSE funded project
- Bioaerosol sampling at compost sites
- Source terms – dustiness index
- Characterisation of bioaerosols

A PICTURESQUE VIEW OF A COMPOST SITE

UP AT THE SHARP END

LESS THAN IDEAL CONDITIONS

DOWNWIND SAMPLING

WHY ARE WE CONCERNED - WHAT ARE THE HEALTH ISSUES?

- Exposure to bioaerosols
- Constituents of compost bioaerosols include fungi such as *Aspergillus fumigatus* (allergen, opportunist pathogen); thermophilic actinomyctes (allergens)
- Workers' exposure
- Dispersion off site → neighbours (other workplaces, passers by, residents)

EVIDENCE FOR ILL HEALTH

Workers' Exposure:

- Todays speakers have shown waste workers to have acute and (sub-) chronic non immune or type III allergic inflammation in upper airways; others significantly raised antibody levels to specific fungi and actinomycetes (Bunger, 2000).
- Individual case studies – ODTS, extrinsic allergic alveolitis

Residential Exposure:

- Evidence is less clear, but concern exists

EVIDENCE FOR ILL HEALTH

Residential or peripheral exposure:

- If compost bioaerosols contain allergens and pathogens, how much is a hazardous exposure?
- How much above 'background' or 'normal' bioaerosol levels is hazardous?
- What is a 'normal' level of bioaerosol?
- How far away until a compost bioaerosol returns to 'background'?

EVIDENCE FOR ILL HEALTH

Dispersion of bioaerosols:

- Bioaerosols from compost handling will remain airborne and travel off site
- Dilution and dispersion effects in open air
- How far until they are fully dispersed?
- Various published studies on compost bioaerosol dispersion – variable results
- Consensus is that >200m levels return to background

WHAT ARE THE CONTROLS?

To workers' exposure:

- Air conditioned vehicle cabs
- Respiratory protection
- Work Practice – establishment of risk zones

Residential/peripheral

- Exclusion distances (Environment Agency 200m guide)
- Site design and operation

MONITORING

Exposure levels – HSL's current work:

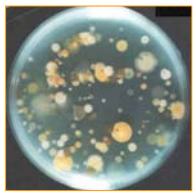
- Workers' personal exposure
- Deriving source terms for modelling dispersion
- Measuring levels at different distances downwind to validate models and establish risk zones

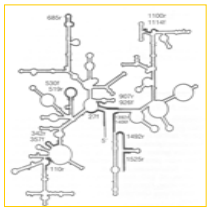
METHODS FOR MONITORING BIOAEROSOLS ON COMPOST SITES

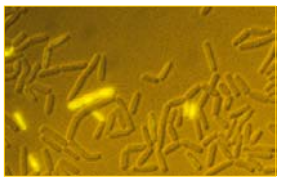
Air and bulk material sampling

METHODS FOR MONITORING BIOAEROSOLS ON COMPOST SITES

Culture and non-culture based microbiological analysis:







MONITORING BIOAEROSOLS ON COMPOST SITES: SITE B

Partisol and IOM samples -culture based microbiological analysis:

Operation	Sampling Location	CFU/m³ bacteria 25°C	CFU/m³ fungi 25°C	CFU/ m³ *A.fumigatus*	CFU/m³ actino
Turning	50m Upwind	88	221	0	0
Turning	50m Downwind	1,637	2,038	3,350	494
Turning	100m Downwind	322	1,739	3,400	354
No operation	50m Upwind	60	119	0	0
No operation	50m Downwind	139	104	100	35
No operation	100m Downwind	0	0	0	51
Driver Turning	IOM	5,897	2,243	2,050	13636
Driver screening	IOM	49,825	3,147	600	17406
Rest room	IOM	853	1,024	0	1060

METHODS FOR MONITORING BIOAEROSOLS ON COMPOST SITES

Dustiness drum - Estimation of potential for release of bioaerosols from compost material

DUSTINESS ESTIMATES FOR COMPOST

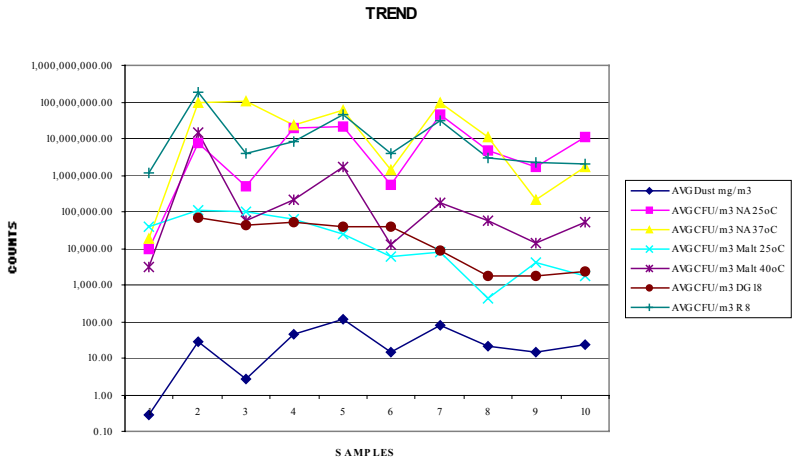
- Compost samples taken at different stages of process, analysed for dustiness in terms of dust, fungal spores, micro-organisms and endotoxin.
- Indices of dustiness for dust, micro-organisms and endotoxin per mass of waste estimated from equations derived by Breum et al., 1997.

DUSTINESS ESTIMATES FOR COMPOST

SITE A – IN VESSEL COMPOSTING

- Sample 1 from clamps after initial shredding
- (outer 'crust' because main bulk very wet)
- Sample 2 from clamp after 2 weeks
- Sample 3 first sample from maturation pad
- Samples 4 – 10 from maturation pad up to 10 months old

DUSTINESS ESTIMATES FOR COMPOST: SITE A

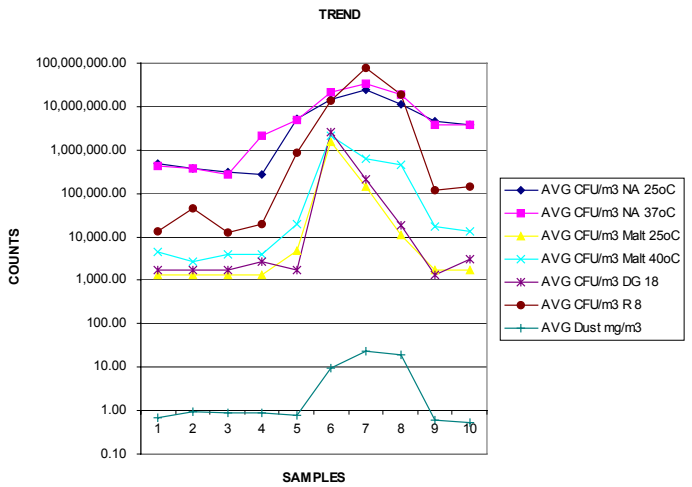


DUSTINESS ESTIMATES FOR COMPOST

SITE B – OPEN WINDROW COMPOSTING

- Sample 1 shredded waste
- Samples 2 – 10 from windrows covering 16 weeks composting

DUSTINESS ESTIMATES FOR COMPOST: SITE B

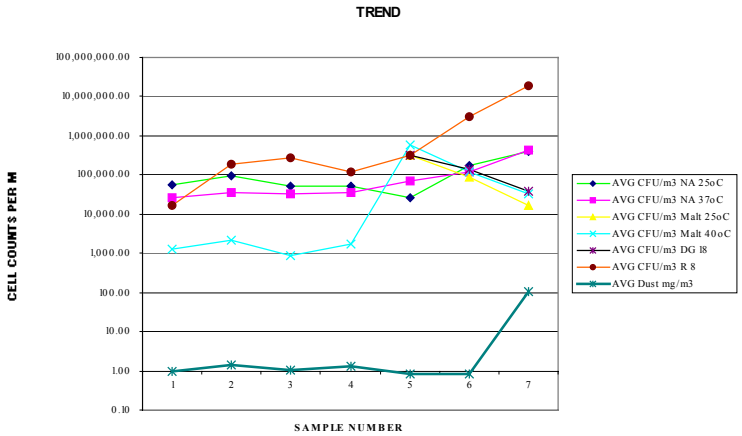


DUSTINESS ESTIMATES FOR COMPOST

SITE C – IN VESSEL COMPOSTING

- Sample 1 shredded waste
- Sample 2 from clamp
- Samples 3 – 7 from maturation pad up to 2 weeks old

DUSTINESS ESTIMATES FOR COMPOST: SITE C



CHARACTERISING BIOAEROSOLS ON COMPOST SITES - DGGE

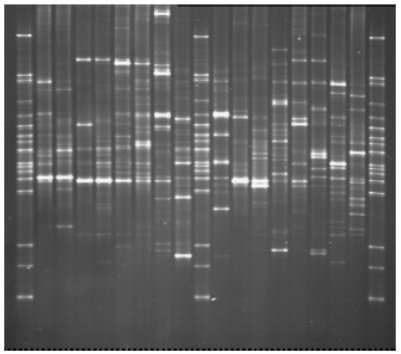
DENATURING GRADIENT GEL ELECTROPHORESIS (DGGE)

- A molecular approach to analysing the genetic diversity of complex microbial populations.
- Based on electrophoresis of PCR-amplified 16S rDNA fragments against a gradient of denaturants (urea and formamide).
- Enables separation of DNA fragments of the same length but different base-pair sequences.

CHARACTERISING BIOAEROSOLS ON COMPOST SITES - DGGE

An example of DGGE on DNA isolates from a lake sample

Source: http://www.nioo.knaw.nl/CL/MWE/protocol_DGGE.pdf



Initial tests with compost bioaerosols – limited success.

Plan B – gene probe characterisation of isolates & compare with DGGE results

SUMMARY AND FUTURE STEPS

- On site sampling – building up a picture - to continue under HSE funded project (exposure risk zones)
- Source term data – potentially useful data from dustiness tests – apply to dispersion models
- Characterisation of compost bioaerosol. Promising data from the use of molecular techniques – needs further work on best techniques

The Environment Agency/ Cranfield University Post-doctoral fellowship: Programme and Progress

G. Drew, R. Smith, S.J.T. Pollard, and J. Gronow

Integrated Waste Management Centre, Cranfield University

Background

- Risk management from waste management facilities is increasingly concerned with the potential amenity impacts
- Issues: odour, dust, noise and bioaerosols
- Assessment methods less well developed than more conventional pollutants

Aim:

- To transfer into the Agency innovative risk and amenity impact science for waste management in order to inform and underpin policy development and enhance process and operational decision-making

Objectives

- Support and inform development of amenity impact assessments, focussing on organic waste facilities
- Interpret impact assessment outputs in light of the supporting science
- Provide state-of-the-art reviews of available scientific evidence

Objectives

- Expand research on methods of quantitative risk assessment at organic waste treatment facilities, particularly composting, improving understanding of bioaerosol monitoring and modelling
- Provide technical support to the Agency's operational, policy, process and science staff
- Disseminate information and knowledge on modelling and monitoring to the Agency and other regulators, academia, consultants and industry

Tasks

- Emissions monitoring
- Bioaerosol enumeration
- Bioaerosol sources
- Dispersion modelling
- Exposure diaries
- Dissemination

1. Emissions monitoring

Monitoring at 3 composting sites

- Source term emissions:
  - Actinomycetes 13-22 x 10^3 cfu/m^2/s
  - *Aspergillus fumigatus* 8-11 x 10^3 cfu/m^2/s
- Activities monitored (turning):
  - Actinomycetes 18.9-36.0 x 10^6 cfu/m^3
  - *Aspergillus fumigatus* 9.8-36.8 x 10^6 cfu/m^3

1. Emissions monitoring

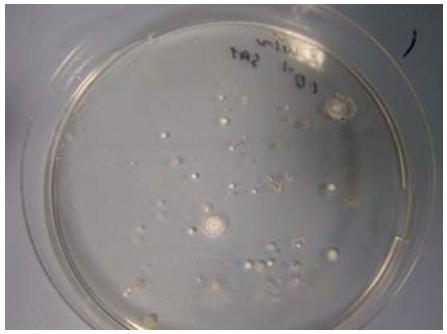
- New project to extend this database
- Sampling regime (in preparation):
  - Minimum two further composting facilities
  - Sampling at 50 m, 100 m, 150 m, 200 m, 250 m, and 300 m from source
  - Examine variations in viability with distance and time
  - Examine effects of temperature changes and relative humidity on bioaerosol levels and viability
  - Assessment of bioaerosol agglomeration
- Timescale: 18 months

2. Bioaerosol Enumeration

- Enumeration of actinomycetes frequently difficult due to overgrowth of bacteria
- New method developed using soil compost agar
- Actinomycetes growth was best achieved at an incubation temperature of 44 °C, after 7 days
- Half strength nutrient agar: 8% of samples could be enumerated
- Compost agar: 87% of samples could be enumerated

2. Bioaerosol Enumeration

(a) Half strength nutrient media for actinomycetes, enumerated from samples collected at windrow turning at a dilution of 10-1.



(b) Soil compost supernatant media for actinomycetes, enumerated from samples collected at windrow turning at a dilution of 10-1.

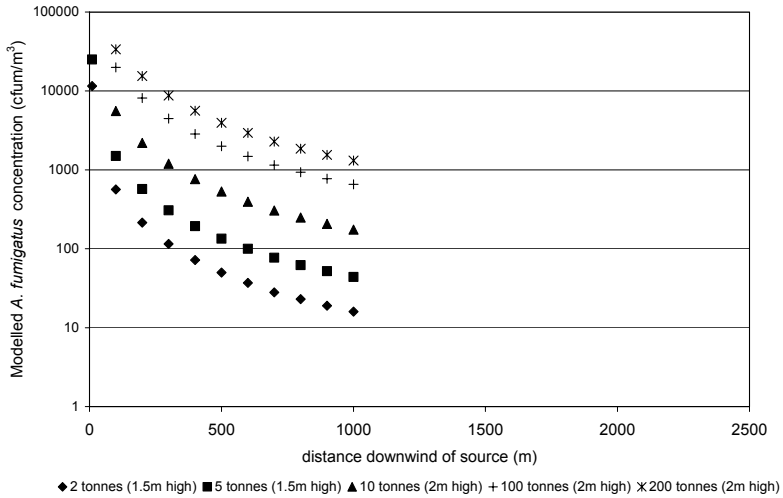
3. Bioaerosol sources

- Review and compare waste and non-waste sources of bioaerosols, and the episodic nature of their emissions
- Examine the health effects, to improve current understanding of the dose-response relationships
- Examine the aggregation tendencies of bioaerosols and the effects of particle size changes on dispersal.
- Review the potential health effects of non-viable bioaerosol components
- Completion date: June 2006

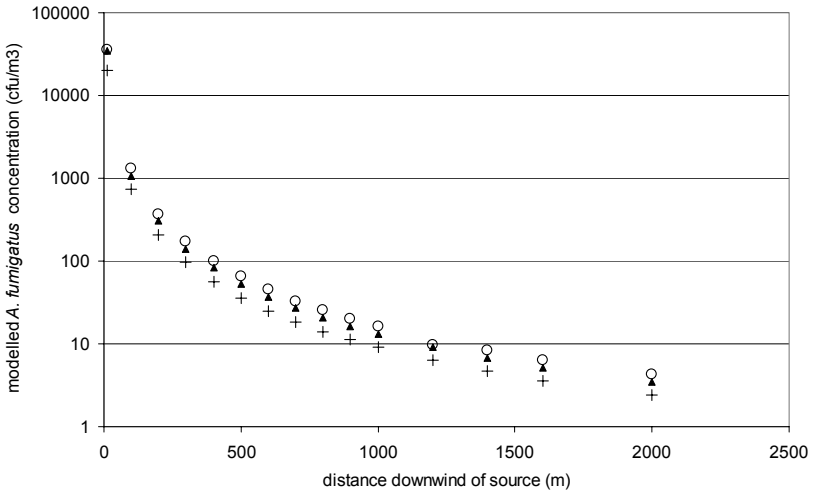
4. Dispersion modelling

- Initial modelling using SCREEN3 to produce source depletion curves
- Based on data from 1 composting facility
- Results suggest that concentrations will return to background within 100m of the site, depending on tonnage of site

4. Dispersion modelling



4. Dispersion modelling



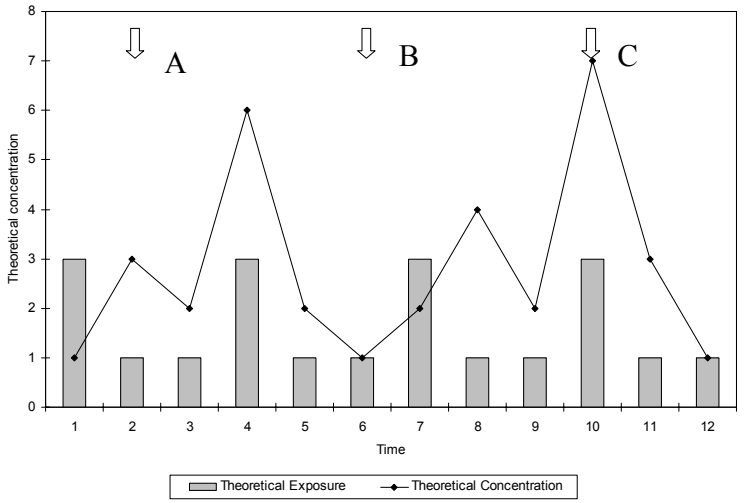
4. Dispersion modelling

- Now focus on more detailed modelling using ADMS 3.3
- Using odour as proxy have tested influence of averaging times
- Initially review methods used
- Further tests to examine options within ADMS
- Timescale: 4 months

5. Exposure diaries

- Research has shown that bioaerosol emissions are episodic – related to on-site activities
- To predict acute, episodic exposures, need to take into account:
  - peak emissions; and
  - the periods when receptor exposure will coincide with the peak emissions
- Use odour data to develop methodology

5. Exposure diaries



6. Dissemination

- M.P.M. Taha, A. Tamer, D. Aldred, G.H. Drew, P.J. Longhurst and S.J.T Pollard (2006) Improved enumeration of actinomycetes burden in bioaerosols from compost facilities using a low-nutrient, soil compost agar, *Atmos. Environ. submitted* (short communication)

- Macleod C.J., Duarte-Davidson R., Fisher B.E.A., Ng B., Willey D., Shi J.P., Martin I., Drew G. and Pollard S. (2006) Modelling human exposures to air pollution control (APC) residues released from landfills in England and Wales, *Environ. Intl., in press*

6. Dissemination

- M.P.M. Taha, G.H. Drew, P.J. Longhurst, R. Smith and S.J.T Pollard (2006) Bioaerosol releases from compost facilities: evaluating passive and active source terms at a green waste facility for improved risk assessment, *Atmos. Environ.,* 40: 1159-1169

- M.P.M.Taha, S.J.T Pollard, U. Sarkar and P. Longhurst (2005) Estimating fugitive bioaerosol releases from static compost windrows: feasibility of a portable wind tunnel approach, *Waste Manage.*, 25: 445-450

6. Dissemination

- Drew G.H., Smith R., Pollard S.J.T., Longhurst P.J. and Kinnersley R. (2005) Amenity impacts of episodic emissions from composting facilities. In: *Proc. 10th European Biosolids and Organic Residuals Conference*, UKWIR and Aqua Enviro Consultancy Services, Wakefield, 13-16th October 2005, ISBN 1-903958-15-6, Session 25, Paper 84, 6pp.

- Taha, M.P.M. and Pollard, S.J.T. (2004) Emission and Dispersal of Bioaerosols during the Agitation of Green Waste Compost Piles. *In Proc. Waste 2004 Conference*, 28-30th September, 2004, Stratford-upon-Avon, Warwickshire, UK, pp. 735-743

6. Dissemination

- G.H. Drew, R. Smith, V. Gerard, C. Burge, M. Abbott, R. Kinnersley, R. Sneath, and P.J. Longhurst (in prep) Appropriateness of selecting different averaging times for modelling chronic and acute exposure to environmental odours

- G.H. Drew, A. Tamer, M.P.M.Taha, R. Smith, P.J. Longhurst, Kinnersley R. and S.J.T Pollard (2006) Dispersion of bioaerosols from composting facilities. Submitted to Waste 2006 Conference

6. Dissemination

- Bioaerosol source term modelling sensitivity studies – journal paper
- A critical review of current issues in composting bioaerosol risk assessments
- Odour from composting – review

Associated Projects

- £60k EPSRC DTA
- £45k Malaysian Department of Health continued professional development studentship
- £170k Community odour modelling contract with WRG

Research Summary

- At source emission fluxes and modeled bioaerosol depletion profiles
- Substantive improvements in enumeration methods for at source bioaerosol sampling
- Planned activities on improved emissions modelling to account for bioaerosol characteristics

Acknowledgements

- Environment Agency
- Malaysian Department of Health
- MPM Taha
- A Tamer