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Review of methods to measure bioaerosols from composting sites

Science summary: SC040021/SR3

A new report by the Environment Agency explores the best methods to measure bioaerosols released from composting sites that could pose a potential risk to human health.

Waste composting is an important part of the UK's recycling strategy. In recent years there has been a steady increase in waste composting, resulting in an increase in the number of composting sites as well as greater capacity in existing ones. Although this brings many benefits to the UK, there remain concerns over human exposure to bioaerosols from waste composting. Because micro-organisms are fundamental to the composting process, they will always be present in large quantities in the bulk material. Any handling process, such as turning the compost to give it air, is likely to create airborne dust that will contain micro-organisms.

Studies have shown that exposure to the pathogenic fungus *Aspergillus fumigatus* can trigger asthma, bronchitis and allergic responses. Those most at risk are likely to be workers on site. Workers and residents near to composting facilities will be less exposed because of the dilution and dispersion of bioaerosol emissions. However, there is still uncertainty over the concentration to which a compost bioaerosol must be reduced to be considered 'safe'.

Because of these concerns, the Environment Agency has adopted a policy position on composting and the potential human health effects of exposure to bioaerosols generated from composting. This places limitations on the location of composting facilities to prevent, where possible, the siting of composting activity within 250 metres of a workplace or boundary of a dwelling, unless justified by a site-specific risk assessment that shows the risks to be acceptable.

Thus, for many compost site operators some form of bioaerosol monitoring is required, for example before starting new operations or making big changes to existing ones, during normal operations to establish typical bioaerosol emissions, and after adopting control measures to reduce emissions.

In 2004, the Environment Agency commissioned WS Atkins to review methods for monitoring bioaerosols from compost sites, and to propose a standard sampling method for measuring bioaerosols associated with composting. The WS Atkins review forms Part 1 of this report. This report was subsequently sent for independent review to the Health and Safety Laboratory (HSL) and their review forms Part 2 of this report.

Part 1 reviews the following sampling/collection methods: impaction, impingement, filtration, cyclone scrubbing, electrostatic precipitation and sedimentation. It discusses their advantages and drawbacks with respect to monitoring bioaerosols on composting sites in terms of collection efficiency, sampling time, ease of use, cost and robustness in the field, and other qualities such as the ability to distinguish between different micro-organisms and preferably, to primarily detect those that might pose a risk to human health.

The report also looks at counting methods to measure the pathogens collected, based on culturable and non-culturable approaches such as direct staining and fluorescence microscopy, flow cytometry and biomarkers measured with polymerase chain reaction (PCR).

To conclude (Part 1), the standard method proposed by the report to measure bioaerosols in the vicinity of a green waste composting site is the Andersen single-stage sampler fitted with a hemispherical baffle, with the micro-organisms collected onto either nutrient agar or Tryptone Soya agar (TSA) and malt extract agar (MEA). The outputs from the sampling will be expressed as colony-forming units per cubic metre, with the results from the nutrient agar or TSA plates providing a figure for the total number of culturable mesophilic bacteria present, and enumeration of colonies of *Aspergillus fumigatus* present on the MEA plates providing a measure of the fungal content of the bioaerosol.

Part 2 of the report stresses the need for accurate sampling to better understand the health consequences of bioaerosols emitted from compost sites. Many types of samplers have been used over the years, including liquid impingers, solid impactors, filters and electrostatic precipitators. Although direct agar impaction methods, mainly the Andersen sampler, are still considered to be the benchmark for bioaerosol sampling, the practical limitations of these methods mean that future sampling strategies are likely to move away from these and towards filtration as the most likely alternative ahead of liquid impingers.

Impingers have the advantage of being compact, able to run for extended periods and to collect in liquid which allows for multiple analyses from the same sample. However, liquid collection is not compatible with size fractionation. Filtration methods, in addition to being simple, include the potential for size fractionation, ease of handling and transport of samples, multiple analyses from single samples and compatibility with collection methods already used for environmental pollution monitoring, such as particulate (PM_{10}) monitoring. These advantages must be balanced against potential limitations due to dehydration stresses affecting the micro-organisms collected.

In terms of analytical methods, there is scope to further explore culture methods to target the main species found in compost. Thermophilic actinomycetes and *Aspergillus fumigatus* are the most representative of composting material and also the agents most likely to present a respiratory hazard. Although mesophilic bacteria may be an easily cultured general indicator of microbial contamination, there is little evidence of it presenting a health hazard in waste handling.

The greatest scope for progress, however, is in the development of molecular-based methods. Methods for detecting target organisms by their unique DNA sequences are well established, but characterising mixed populations would be the goal for monitoring compost bioaerosols. In the longer term, the development of microarray-based detection systems offers the greatest potential in this area. Although the set-up costs may be high, an established system could be a simple and cost-effective monitoring method.
PCR-based methods are very sensitive in complex, mixed DNA samples, and do not require the presence of a culturable or living organism.

Practical problems in monitoring bioaerosol emissions from composting are equally important. The approach proposed by the Department for Environment, Food and Rural Affairs for further investigation is of a multi-level monitoring system, in which simple detection methods, perhaps even electronic particle counters, are used for basic monitoring and are supported by more in-depth (culture-based or other) analysis when required.

A final problem is how to interpret the results. The absence of health-based data on dose-response relationships between bioaerosols and respiratory allergy or infection makes it impossible to state that a certain level of exposure poses no risk. Therefore, the approach that can be taken is to benchmark exposure, as influenced by compost bioaerosols, against at one end of the spectrum 'typical' background bioaerosols in the absence of a significant emission source and at the other end against bioaerosols encountered in workplaces where there is a known and significant emission likely to cause respiratory ill health. Where the bioaerosol does not greatly exceed the background level, it must be assumed that there is no excess risk. This is complicated by the variable nature of 'typical background' bioaerosols used as a benchmark, which may be affected by orders of magnitude by climatic conditions and the presence of vegetation. Even when a compost bioaerosol emission exceeds background, it is not easy to establish at what point this starts to represent an excess risk, or the tolerability of any excess risk, when for example other bioaerosol emissions such as those downwind of agricultural activities are generally considered tolerable.

Part 2 of the report concludes that the Association for Organics Recycling (AFOR) protocol (2009), *Standardised protocol for the sampling and enumeration of airborne micro-organisms at composting facilities*, should be followed by those carrying out bioaerosol monitoring at compost sites (currently being updated by the Environment Agency and will be available for download from the AFOR website in 2009). In future, this should be used in conjunction with the *Guidance on the evaluation of bioaerosol risk assessments for composting facilities* (to be published on the Environment Agency website in 2009).

This summary relates to information from Science Project SC040021/SR3 reported in detail in the following output(s):

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