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Evaluating the quality of bioaerosol risk assessments for composting facilities in England and Wales

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ABSTRACT

A critical evaluation of 44 environmental risk assessments for composting facilities, submitted in support of environmental permits or exemption from licensing is presented. Assessments were scored semi-quantitatively, in triplicate, by reference to 11 generic and 11 bioaerosol-specific risk assessment attributes developed from existing regulatory guidance. Radar plots of the two attribute groups illustrate where opportunities for improvements exist, and are being used to inform regulatory guidance to the operators of composting facilities and their professional advisors. Aspects of the regulatory risk assessments requiring attention include (i) descriptions of the limitations and uncertainties within risk analyses; (ii) presentation of methodological details of sampling and analysis; and (iii) the provision of background information.

KEYWORDS: bioaerosols, compost, quality, risk, assessment, regulation

1. INTRODUCTION

Environmental regulators (such as the Environment Agency in England and Wales) now require operators of waste processing plants to submit risk assessments in support of environmental permits and licences, or exemption from these forms of regulatory control (Pollard *et al.*, 2006). Risk assessments provide operators with the basis for operational controls on site and allow them to target controls where exposures to significant risk are of greatest concern. Furthermore, they reassure the regulator and local communities that facilities are being operated safely and responsibly without undue risks to operational staff, to public health or to the environment. The Department for Environment, Food and Rural Affairs (Defra) in England and Wales has issued overarching guidelines for environmental risk assessment and management (DETR, 2000). The guidelines stress key components of environmental risk assessment and management, and provide practical guidelines to risk assessors. In addition they discuss quality-critical features of risk assessments that are submitted to Defra and its executive agencies.

Composting is one such resource recovery process subject to risk assessment in England and Wales. In the UK, compost production increased from *ca.* 1 million tonnes (mt) in 2000/01 to 2.67 mt by 2004/05 (Composting Association, 2006). This trend is set to continue in order to meet the targets set in Defra's 2007 Waste Strategy for England (Defra, 2007) and as a result, the number of composting facilities and the amount of waste processed will increase. This has led to concerns regarding potential health effects during waste processing and particularly those associated with exposure to bioaerosols generated in the process (National Audit Office, 2002). The

Environment Agency (EA) is responsible for regulating composting facilities within England and Wales. Their current policy position on what are being termed bioaerosol risk assessments, is that

> "*There will be a presumption against permitting of any new composting process [or any modification to an existing process] where the boundary of the facility is within 250 m of a workplace or the boundary of a dwelling, unless the application is accompanied by 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"* (EA, 2001; 2008)

The suggested threshold limits for bioaerosols are 300, 1000 and 1000 CFU m^{-3} for gram-negative bacteria, total bacteria and total fungi respectively (Wheeler *et al.*, 2001). Appropriate levels of bioaerosols is therefore considered in relation to these suggested threshold levels and in relation to background concentrations (either upwind or concentrations measure before the site was operational if available).

The policy has encouraged the submission of bioaerosol risk assessments by composting facility operators and their environmental consultants. Here we review the quality of these assessments as part of an ongoing programme of bioaerosol research (Taha *et al.*, 2006; 2007; Wheeler *et al.*, 2001) that will increase our understanding of bioaerosol generation, dispersion and their impact on receptors. The responsibility for interpreting site-specific risk assessments falls to EA regulatory staff. At a recent EA sponsored bioaerosol workshop, a lack of inter-comparability between risk

assessments was highlighted as a potential influence on the consistency of regulatory decisions (EA, 2006; Sykes *et al*., 2007).

In this paper, we provide a constructive critique of bioaerosol risk assessments in the UK. To our knowledge, this is the first synthesis of its kind. It provides valuable insight into the qualities of existing assessments and indicates where opportunities for improvement exist. Such analysis will be used to inform forthcoming regulatory guidance. A series of workshops are underway to convey these results to Agency staff and external interested parties.

2. MATERIALS AND METHODS

2.1. Rationale

We sought to distinguish those features addressed adequately by the risk assessments from those addressed less adequately. We were interested in features that were systematically performed competently, or conversely those uniformly treated in less depth. Our intent was to inform regulatory guidance accordingly, allowing for certain aspects to be given greater attention. Forty-four (n = 44) composting and bioaerosol risk assessments submitted to the EA were assessed. These included a mixture of both full environmental risk assessments as well as more focussed bioaerosol monitoring reports, with accompanying statements on risk. This essentially created two separate groups of reports that were assessed as such. As two bioaerosol monitoring reports did not include full statements on risk, these were assessed only on their bioaerosol attributes. The samples sizes for the general attributes (n=42) and bioaerosol attributes (n=44) were therefore different. The assessments were

completed by 25 different environmental consultants for 37 different facility operators across the UK. The risk assessments were completed between December 2000 and October 2007. For four of the sites, a second risk assessment or follow-up monitoring exercise was included. The sites included a mixture of in-vessel and open windrow technologies, treating a variety of organic wastes.

2.2. Development of risk assessment attributes.

Key attributes, selected on the basis of their prominence in existing guidance (DETR, 2000), our understanding of their importance to informing risk-based decisions (Pollard *et al.*, 2006) and in consultation with policy staff, are listed in Table 1. Attributes were selected as being general characteristics of risk assessments, as well as those specific to composting and bioaerosols. The more general risk assessments did not all include a section focussed on bioaerosols, so these risk assessments were only evaluated on the general risk assessment characteristics and not the composting or bioaerosol specific attributes. Within these groupings (Table 1), attributes were characterised as either major or minor. For example, “problem definition” is fundamental to describing the circumstances and rationale for any risk assessment, and is a major attribute. “Identification of other emissions” allows us to examine the wider risks associated with a composting facility, but is not fundamental to describing the risks associated with bioaerosols released from a composting facility so is a minor attribute.

2.3. Scoring the features of risk assessments.

A linear scoring method was developed for appraising the assessments. The attributes were scored qualitatively. Typically, a scale of 1 to 4 was used to describe the degree of attention ascribed to that feature of the risk assessment, from “not examined” through to “fully examined”. Some attributes could only be scored using a binary “yes/no” evaluation on a scale of 1 to 2 (Table 1). The scores for each attribute were totalled to give a general and a bioaerosol score for each assessment, which was then used to rank the risk assessments. This provided not only a quality score for each risk assessment, but allowed an assessment of individual attributes across the sample (n = 44). Triangulation in the assessment was achieved by having the risk assessments analysed by two different assessors, with a third assessor providing a quality control function. This third assessor analysed a selection (18%) of the risk assessments and the results were compared with the analyses of the first two assessors. The results from the third assessor were found to be within +/-10% of the results from the first two assessors, confirming a general consistency in the analysis of all three assessors.

3. RESULTS AND DISCUSSION

3.1. Overall results.

The range of possible scores for the general and bioaerosol attributes was 11 to 34 and 11 to 32, respectively. The result of the scoring system for the general attributes ranged from 12 to 29, with a mean of 20. For the bioaerosol/composting attributes, the range was 12 to 27, with a mean of 18. The results presented below reveal that the quality of risk assessments submitted to the EA is highly variable. Despite an

increase in research focusing on bioaerosols, there has not been an improvement in quality between 2000 and 2007 (Figure 1). This may well be because interpretation of the various guidance documents (e.g. DETR, 2000) aimed at providing a common framework for risk assessments is frequently left to individual consultants working on behalf of operators, resulting in a wide variety of methods being applied. This could also reflect a lack of clarity in the guidance currently available.

3.2. General attribute results

The general attributes were evaluated individually, providing an indication of where the practitioners are focusing their efforts currently, and where more effort needs to be exerted. Figure 2 shows the average scores for each of the general risk assessment attributes. However, as the maximum score for each attribute varied (Table 1), it was necessary to examine the average attribute score as a percentage of the maximum score for that attribute (Figure 3). The results reveal that the attributes that are adequately covered include “logical/transparent”, “identification of other emissions”, “problem definition” and “options appraisal”. Further examination of the results shows that the majority of the risk assessments (30, n=42) were classified as logical, and identified other emissions such as odour (29). In addition, most practitioners provided a full (17) or partial (13) description of the problem. Most practitioners also included a full (16) or partial (13) appraisal of mitigation or control measures (options appraisal), although the effort was related to the risk in only 19 of the risk assessments considered.

Risk screening and prioritisation is an area where further work is required, with 20 (n=42) of the risk assessments providing only a partial description and only seven providing a full description (Figure 3). Although the magnitude of the consequences was either partially (14) or fully examined (7), for the majority of the risk assessments, the probability of the consequences was either not estimated (17) or underestimated (12) (Figure 3).

The first area identified as requiring more effort is the diagrams, where the majority were either not useful (11, n=42) or there were no diagrams (21) (Figure 3). One of the key issues was the absence of a scale on diagrams, which prevented accurate assessment of the proximity of sensitive receptors. The other common issue was the lack of detail of site plans, particularly information such as location of activities and any trees or screens around the site that could mitigate emissions. Diagrams should provide a scaled, accurate plan of the site, showing buildings, screens, bunding, location of on site activities and compost windrows. In addition, a scaled, topographical diagram showing the location of sensitive receptors in relation to the site is required. A conceptual model of the site is valuable, but rarely present, in the risk assessments.

Stating the limitations and uncertainties within a risk assessment explains why some aspects may have been covered and others not. It should describe where the author of the risk assessment knows data is lacking, for example, in the reliability of the data gathered. The overwhelming majority (35, n=42) of assessments undertaken by practitioners did not state or discuss any limitations or uncertainties of their work (Figure 3). In addition, not one risk assessment provided any evidence of stakeholder

involvement in the process. Stakeholder involvement, although not mandatory, does provide the practitioner with local knowledge, such as the location and activities of particularly sensitive receptors. This information could be useful in designing mitigation measures, for example, not undertaking agitation activities under periods when high wind speeds would direct emissions towards sensitive receptors. In addition, consulting with local stakeholders can provide a sound basis for future relationships by involving them in the decision making process.

Stating the limitations and uncertainties, involving stakeholders, and the use of appropriate diagrams and site plans, have therefore been identified as the main general attributes of composting risk assessments that require improvement.

3.3. Bioaerosol composting attributes

Examination of the bioaerosol attributes (Figure 4) revealed that, in general, these attributes are given less attention than the general attributes. The only adequately described composting attribute was the identification of sensitive receptors within 250 m of the facility, with 18 (n=44) providing a full identification and a further 21 providing at least a partial identification of sensitive receptors (Figure 5). Lack of stakeholder involvement suggests the identification of sensitive receptors may give rise to bias.

Bioaerosol and composting risk assessments should contain a description of the process and a site specific identification of all sources, pathways and receptors. Of the risk assessments analysed, only eight (n=44) provided a full, accurate and site

specific description of the sources, pathways and receptors, with the majority providing either inaccurate or partial (i.e. not site specific) descriptions only (Figure 5).

In terms of bioaerosol sampling, 24 (n=44) of the risk assessments did not provide any description of the sampling methods, 21 sampled fewer organisms than suggested by the Composting Association (1999), and 27 did not use the culture techniques suggested by the Composting Association (1999) (Figure 5). Although other sampling techniques do exist, the Composting Association (1999) method is the standard protocol recommended within England and Wales, and as such should be used as a minimum. Practitioners using other methods should be able to demonstrate comparability with the Composting Association (1999) standard protocol. In addition, 28 did not discuss the assumptions regarding their sampling strategy and 31 (Figure 5) did not identify any other potential sources of bioaerosols that could have contributed to the overall emissions, for example, agricultural activities nearby. A high proportion of practitioners (25) had not monitored the background (e.g. upwind) concentration of bioaerosols; and in 19 of the risk assessments, the information presented was not relevant to that facility. The majority of practitioners (29) did not give any indication that they intended to revisit the risk assessment. Finally, 24 of the risk assessments gave no summary of the health risks associated with bioaerosols at the composting facility.

The absence of details regarding sampling methodology restricts the interpretation of the bioaerosol concentrations. Conditions on-site during sampling can affect bioaerosol concentrations, for example, agitation activities have been shown to

increase bioaerosol concentrations (Taha *et al.*, 2006). Meteorological conditions will also affect bioaerosol emission and dispersion. Higher winds will carry bioaerosols further downwind, while turbulent conditions will enhance drop-out and dilute concentrations. Therefore bioaerosol concentrations presented without this information may be interpreted out of context.

The results of this analysis suggest that while most practitioners are capable of undertaking a generic risk assessment, there is a distinct lack of site specific information and a disregard for the importance of bioaerosols in composting risk assessments. In many cases, the limitations are associated with a reluctance to undertake full bioaerosol monitoring, possibly due to the costs associated with monitoring. Many of the risk assessments were therefore based on data monitored at other sites, where conditions are unlikely to be the same. In the case of new or non-operational sites, this may be the only data available. However it is still important to monitor background concentrations to establish the baseline conditions. The absence of bioaerosol monitoring data in composting risk assessments results in inaccurate estimates of the risks of that particular site. In addition, risk assessments based on information from different sites are unlikely to provide an accurate picture of the risk associated with the site in question, due to differences in meteorology and topography, which will have an impact on bioaerosol concentrations. Therefore, on-site monitoring is essential, not only for the implementation of appropriate management techniques, but also to allow for fair and consistent regulatory decision making.

4. CONCLUSIONS

This analysis illustrates that the majority of composting risk assessments do not adequately examine the risk associated with bioaerosols, although the descriptions of the general risk assessments attributes are adequate, as evidenced by the number of attributes (7 out of 11 attributes) that were adequately covered in most risk assessments. Although the aim of this exercise was to identify good and bad practice, no ideal examples were identified. Instead, we found that the majority of risk assessments consisted of both good and bad parts, with many scoring rather poorly. In order to find a perfect example of good practice, parts of different risk assessments would need to be collated. Sections of different risk assessments that display good practice have been highlighted in a series of workshops held for EA personnel. This information is being used to develop guidance to assist EA officers in assessing risk assessments.

The most important problem with the risk assessments was the lack of site specific data. Given that bioaerosol concentrations vary greatly depending on local conditions, season, sampling methods and on-site activities (ADAS, 2005; Taha *et al.*, 2006; 2007), it is difficult to justify using data from a site that is unlikely to have similar bioaerosol sources. However, where sites are not yet operational, it is still useful to monitor for bioaerosols to gain an understanding of the baseline data associated with other activities in the area. Admittedly, this would probably only be a single snapshot, but in the absence of more advanced methods for monitoring bioaerosols, this would be the best available background data for a new composting facility. Furthermore, practitioners need to follow the existing guidance in terms of sampling procedures at the very minimum, and clearly describe their practice,

including any assumptions and limitations within the risk assessment. The data and information presented should be relevant and concise. Describing the general process of undertaking a risk assessment for example is not necessary, as this is provided in the guidance documents.

In summary, the key elements of composting risk assessment where additional information should be provided are:

- site specific information, specifically bioaerosols monitored upwind (preferably 50-100m), adjacent to both static compost windrows and to compost agitation activities, downwind and at sensitive receptors within 250m;
- detailed descriptions of conditions during sampling (on-site activities, age of compost, moisture content of compost and meteorological conditions such as season, wind speed, wind direction and relative humidity); and
- appropriate expert interpretation to justify the decisions reached, including stating any limitations, uncertainties and assumptions.

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TABLES

Table 1. Attribute scoring system. Note: major attributes are shown in bold.

GENERAL ATTRIBUTES	1	2	3	4
Problem definition	Not present	Partially described	Fully described	
Limitations/uncertainties	Not present	Partially described	Fully described	
Stakeholder involvement	None	Limited	Full consultation	
Logical/transparent	Illogical	Not transparent	Logical	
Risk screening and prioritisation	Not present	Partially described	Fully described	
Magnitude of consequences	Not examined	Poorly examined	Partially examined	Fully examined
Probability of consequences	Not estimated	Underestimated	Overestimate	Accurately estimated
Diagrams (available, useful)	No diagrams	Some diagrams, not useful	Many diagrams, not useful	To scale, topographical diagrams
Effort related to risks	No	Yes		
Options appraisal	No	Partially described	Yes	
Identification of other emissions, e.g. odour	No	Yes		
BIOAEROSOL/COMPOSTING ATTRIBUTES				
Process description and SPR	Not present	Inaccurate descriptions	Process/SPR description only	Fully described and accurate
Sampling description	Not present	Partially described	Fully described	
Organisms sampled	Less than CA protocol	CA protocol	More than CA protocol	
Culture techniques	Less than CA protocol	CA protocol	More than CA protocol	
Assumptions	Not stated	Stated, not supported	Stated and supported	
Appreciation of health risks	Not appreciated	Some appreciation	Fully appreciated	
Plans to revisit risk assessment	No	Yes		
Relevance of information	Irrelevant	Relevant	Site-specific	
Background information	Not monitored	Monitored upwind	Monitored pre-facility	
Identification of sensitive receptors (within 250m)	No attempt	Selective identification	Full identification	
Identification of other sources	No	Yes		

FIGURES

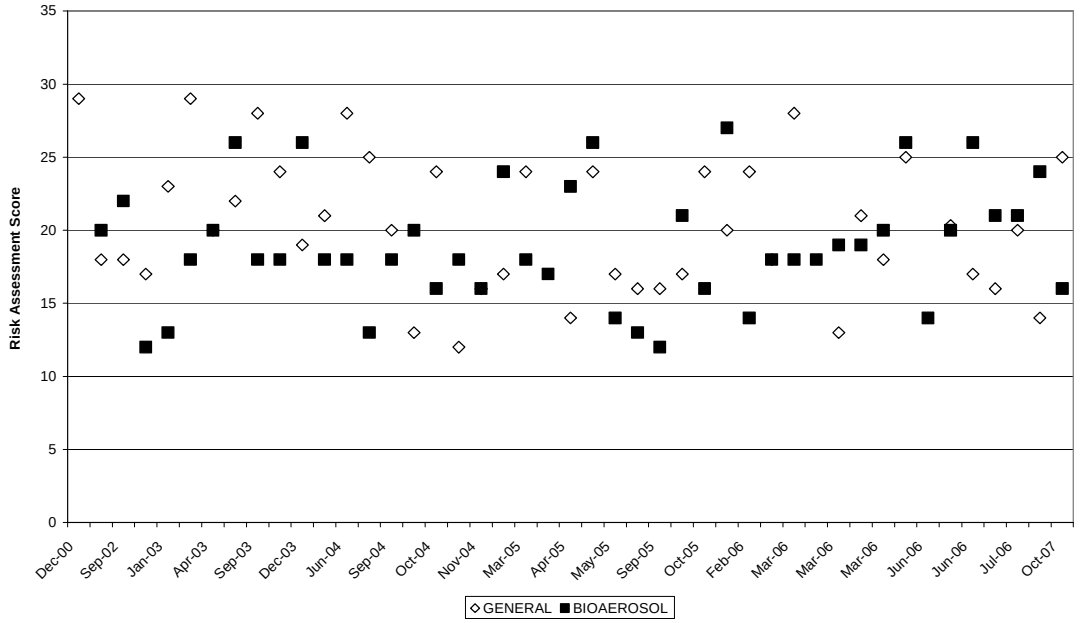

Figure 1. The overall score for the general and bioaerosol attributes in relation to the time period that the risk assessment was undertaken, showing the variation with time and the lack of improvement in the quality of the risk assessments submitted.

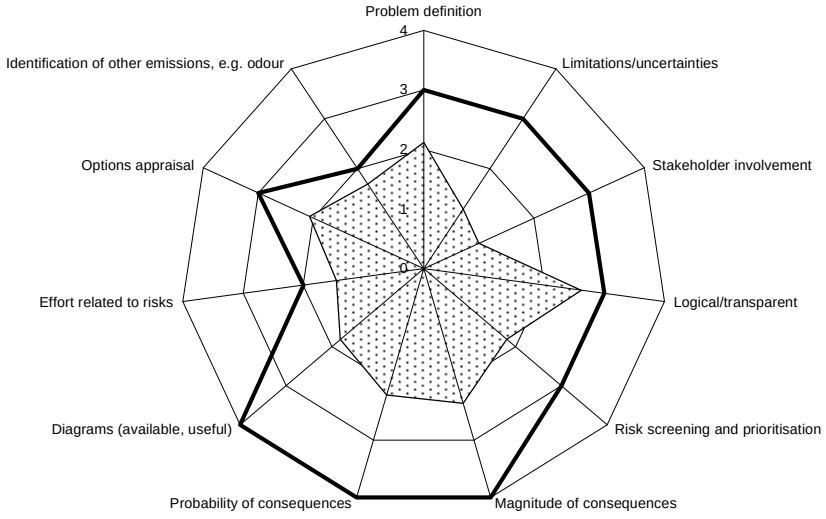

Figure 2. Radar diagram showing the average scores (1-4) for the general attributes. The bold line shows the maximum possible score for each attribute (see Table 1).

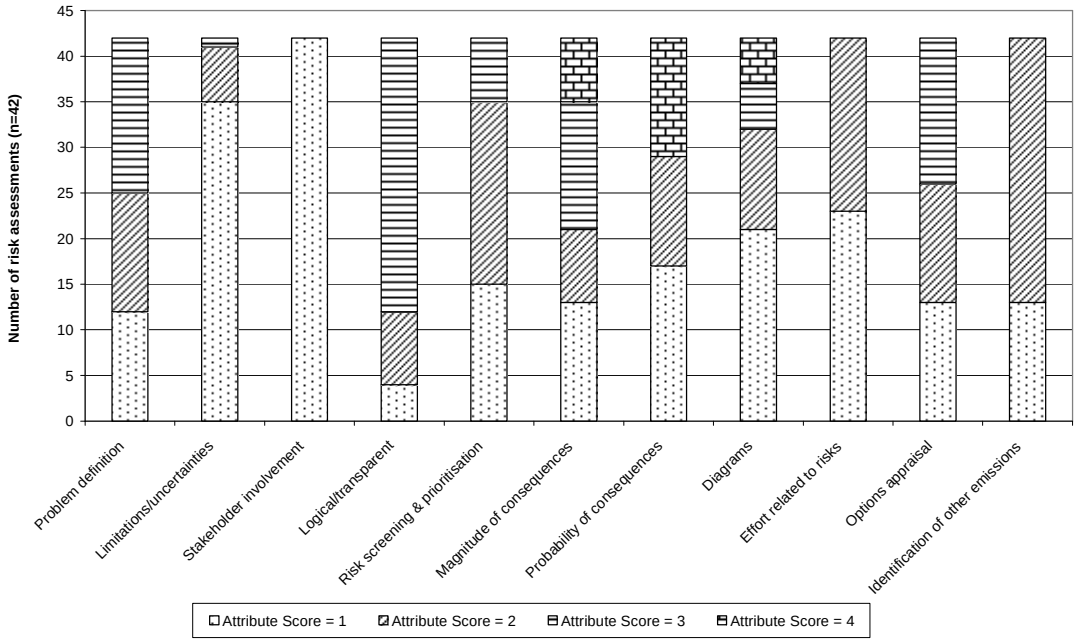

Figure 3. Stacked bar graph showing the number of risk assessments that achieved an attribute score of 1 to 4 for each of the general attributes. This graph highlights the areas where further work is required (where majority of risk assessments have an attribute score = 1), in particular, stakeholder involvement and limitations/uncertainties.

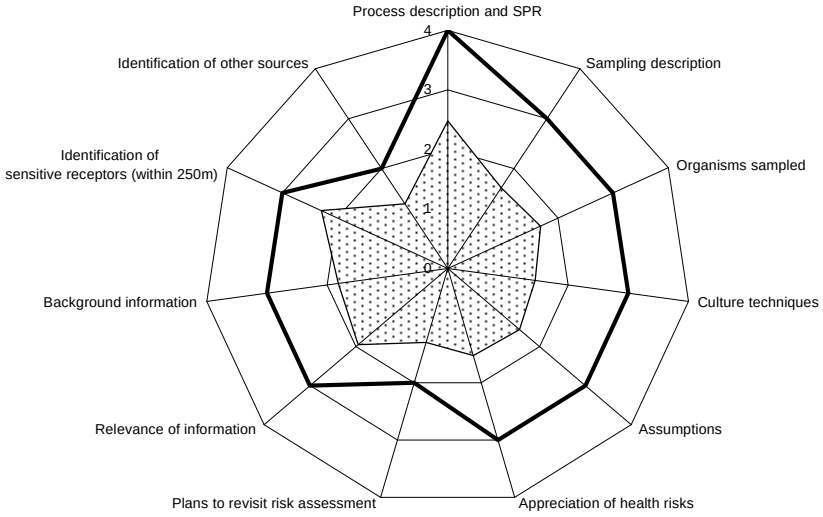

Figure 4. Radar diagram showing the average scores (1-4) for the bioaerosol attributes. The bold line shows the maximum possible score for each attribute (see Table 1).

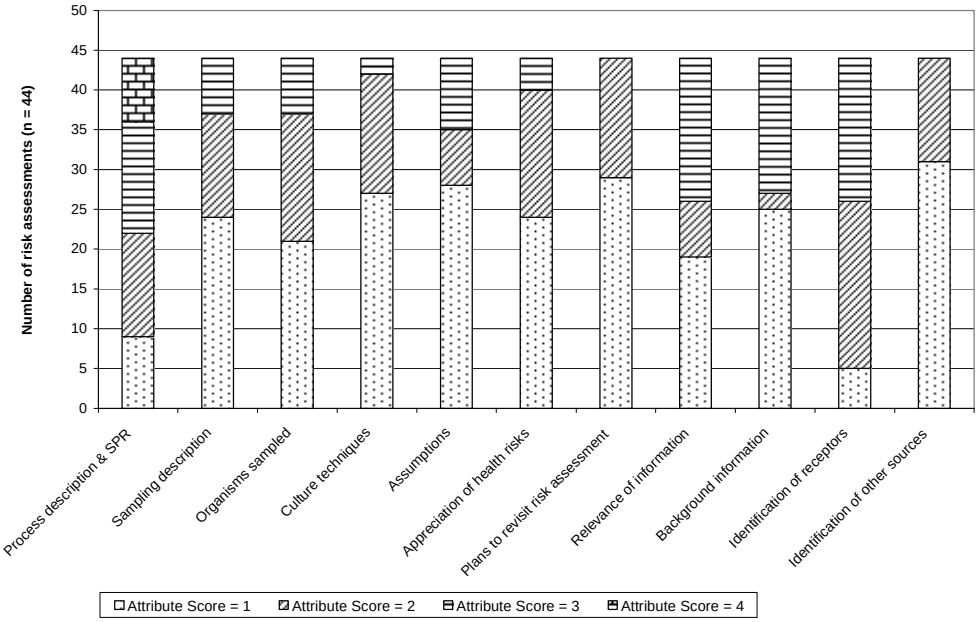

Figure 5. Stacked bar graph showing the number of risk assessments that achieved an attribute score of 1 to 4 for each of the bioaerosol attributes. This graph highlights the areas where further work is required (where majority of risk assessments have an attribute score = 1).