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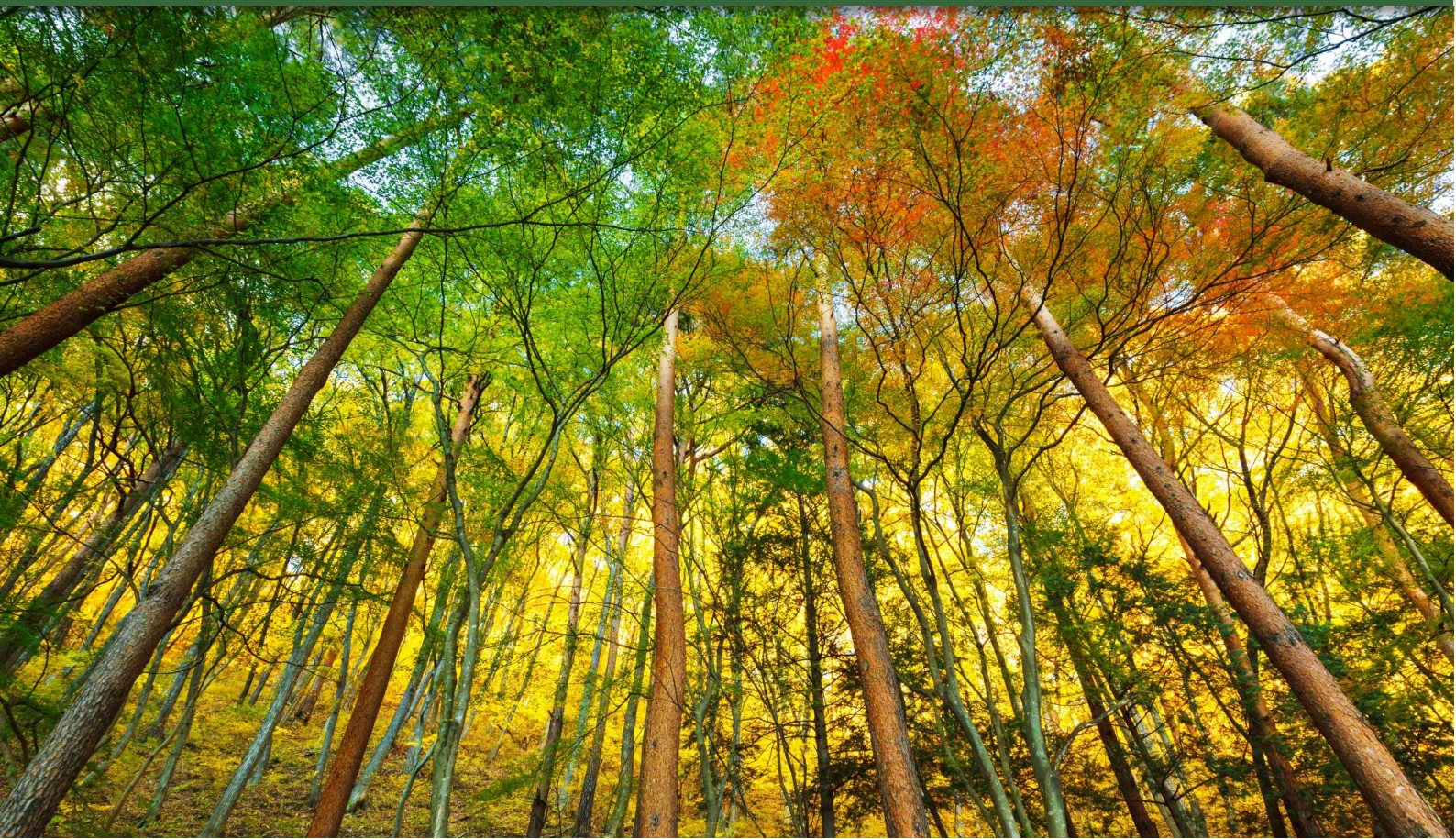
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Bioaerosols Risk Assessment

v1.2

Environmental and sustainability solutions provided to
Haworth Scouring Company Limited



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Document Title	Bioaerosols Risk Assessment	
Client	Haworth Scouring Company Limited	
Revision	v1.2	
Date	05/02/2026	
Document Reference	EPR-A04	
Project Reference	1538/F05	
Author: Ellen MacCallum	Reviewer: Martin Ropka	
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REVISION LOG

Revision	Details	Date
0.1	Initial draft	29/10/2025
0.2	Internal review	31/10/2025
1.0	Final for submission	14/11/2025
1.1	Draft update following first submission	04/02/2026
1.2	Internal review	05/02/2026

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1.0 INTRODUCTION

This report provides an assessment of the operations of a wool scouring and proposed Anaerobic Digestion (AD) facility at Haworth Scouring Company Limited (HSC) in Bradford, West Yorkshire. The intention of this report is to carry out an independent bioaerosol risk assessment of the operations for the purposes of Environment Agency (EA) permitting requirements.

With reference to the Environmental Permitting Regulations 2016 Schedule 2 Part 2 Chapter 6 Part A(1)(a), the site currently holds an environmental permit (reference EPR/BS60251F/V005) for the 'pre-treating (by operations such as washing, bleaching or mercerisation) or dyeing fibres of textiles in a plant with a treatment capacity of more than 10 tonnes per day'. HSC are looking to install an anaerobic digestion processing unit in order to break down the organic elements within the wash water produced by the scouring process.

1.1 Definitions

Bioaerosols

"Aerosols are liquid or solid particles suspended in a gaseous medium with size ranges from 0.001 to 100 μ m. Bioaerosols consists of aerosols containing microorganisms (bacteria, fungi, viruses) or organic compounds derived from microorganisms (endotoxins, metabolites, toxins ad other microbial fragments)...Bioaerosols vary in size (20nm to 100 μ m) and composition depending on the source, aerosolization mechanisms, and environmental conditions prevailing at the site."

Anaerobic Digestion

"Anaerobic Digestion (AD) is defined as a complex biological process that transforms organic material into biogas, primarily methane (CH₄) and Carbon Dioxide (CO₂), through the coordinated actions of various microorganisms under strict anaerobic conditions. It consists of four primary stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis."

Wool Scouring

"Wool scouring is the industrial cleaning process that removes grease (lanolin), dirt, and contaminants, such as vegetable matter, from raw fleece. It is the essential first step in preparing strong wool for high value uses."

1.2 Bioaerosols

Bioaerosols are defined as aerosols, aeroallergens, or particulate matter of microbiological, plant or animal origin. Bioaerosols can interact with living systems through infective, allergenic and/or toxic mechanisms. The biological agents that have been examined in relation to bioaerosol exposures associated with waste handling and treatment processes include pathogenic or non-pathogenic spores, live (viable) or dead (non-viable) bacteria, fungi, viruses, bacterial endotoxins, mycotoxins, and peptidoglycans. Although other types of biological component may also be present as airborne particles such as algal fragments, protozoa and nematodes, these have not been considered in studies of bioaerosols emitted by the waste industry.

The potential for particulates to be liberated from organic waste treatment sites does exist. Airborne dusts and so bioaerosols are likely to be aerosolised by the handling of the waste materials accepted on site, their storage and movement and by meteorological conditions (presence or absence of precipitation, wind, etc.). Bioaerosols are aerosolised as clumps, aggregates and attached to larger mineral particles in the TSP size range. Hence, they generally settle fairly rapidly, i.e. within a minute or two and within 250m of the point of generation. Weather conditions can also affect generation and aerosolisation. Viability can deteriorate according to temperature, humidity and sunlight. Die off is generally exponential, although non-viable (dead) microorganisms may still be able to cause health effects (allergenic/toxic effects in sufficient concentrations). However, the M9 standard for England and Wales and the majority of data at present utilises counts of viable microorganisms.

It is important to note other activities and environments can affect local concentrations of bioaerosols. In terms of published scientific literature, a range of authors report natural concentrations of bacteria and fungi routinely range from 1000 to 100,000 (10³ to 10⁵) cfu/m³ air. An investigation of an anaerobic digestion site reported high measurements of fungi off-site in wet woodland comparable to on-site. Additionally, it was reported that mowing a nearby meadow also significantly affected results of viable fungi and bacteria (160 and 480 respectively prior to mowing, 15.0 x 10³ cfu/m³ and 17.6 x 10³ cfu/m³ after).

The objective of this assessment is to appraise the potential for significant risks to human health in the workplace, dwellings or other buildings within the vicinity of the existing treatment facility from the operations on the HSC site, and to demonstrate that bioaerosol risks can be maintained at acceptable levels taking into account the proposal to install an AD processing unit.

2.0 REGULATORY POSITION

Currently, EA policy requires license/permit applications to provide a site specific bioaerosol risk assessment where the proposed facility will be within 250 metres of sensitive receptors. These risk assessments need to demonstrate that the process measures employed at the facility adequately prevent, or where this not possible significantly reduce, the risk of bioaerosol release and that the resulting activity will be unlikely to expose the nearest sensitive receptor to elevated concentrations of bioaerosols.

There is minimal regulatory guidance available for assessing bioaerosol emissions from AD facilities. The EA Regulatory Position Statement (RPS) on composting and potential health effects from bioaerosols states that bioaerosol concerns would normally be associated with composting activities, defined as “the biological decomposition of biodegradable waste under conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat”. The RPS also defined operations which are likely to result in the uncontrolled release of high levels of bioaerosols as ‘including the shredding of waste and the turning of waste in the sanitisation, stabilisation and maturation stages of composting where these operations are not contained or are not subjected to exhaust ventilation and scrubbing/filtering.’ These activities will not occur at HSC, as the biological decomposition of the waste will occur under controlled, anaerobic conditions. Therefore, the site is unlikely to be a high-risk site for bioaerosol emissions. This is supported by the EA’s ‘Guidance for developments requiring planning permission and environmental permits’ which states that they “do not consider bioaerosols from anaerobic digestion a serious concern”.

2.1 Reference Levels

Based on open windrow composting systems, the EA has set reference levels for micro-organisms in air derived from values for an 8-hour working day. These levels are presented in Table 1 below. It should be noted that process on site is a fully sealed anaerobic digestion system and as such the reference levels below are likely to be an over estimation.

Table 1 – EA set reference levels for micro-organisms

Reference Pollutant	Threshold Level (cfu/m3)	Result if dose-response exceeded
Bacteria	10,000	Not stated
	1,000	Not stated

Fungi	5 x 10 ⁴	Work related respiratory disorders at cont. exposures over 10 ⁵
	Background	Not stated
	1,000	Not stated
Actinomycetes	2 x 10 ⁴	Work related respiratory disorders at cont. exposures over 10 ⁵
Aspergillus fumigatus	10 ⁵ - 10 ⁶	Sensitisation if exposed repeatedly
	10 ⁸	Hypersensitivity Pneumonitis
Gram-negative Bacteria	300	Not stated
	1 x 10 ³	Work related respiratory disorders at cont. exposures over 10 ⁵
	2 x 10 ⁴	Work related respiratory disorders at cont. exposures over 10 ⁵
Endotoxins	1-2 x 10 ² (ng/m ³)	Not stated
	50 (eu/m ³)	Based on no-effect-level of 90 eu/m ³ in clinical trials
	1,000-2,000 (ng/m ³)	Organic dust toxic syndrome
	100-200	Bronchorestriction
	20-50	Mucous membrane irritation

2.2 Health Impacts

Bioaerosols are a mixture of micro-organisms which generate products ubiquitous in rural environments. Bioaerosols can travel up to 250m due to their small size of generally less than 10 μ m (fungi, bacteria and actinomycetes) and are not filtered out by specialised nose cells lining the nose and nose hairs thus penetrating deep into the lungs. These bioaerosols can cause diseases relating to the respiratory system (coughs and fevers), eye irritation, dermatitis and gastro-intestinal symptoms.

Aspergillus fumigatus is of particular concern, as it can cause severe infections which can be fatal particularly for immunocompromised individuals. Another acute disease associated with exposure is Organic Dust Toxic Syndrome (ODTS) with symptoms including acute irritation of the airways and eyes.

High concentrations and long exposure times can affect the health of an individual who is vulnerable with lower natural defences. Bioaerosols and toxins could overwhelm an individual's immune system and cause some of the symptoms mentioned above. However, in a normal healthy person there is no increased health risk in the natural environment. There is no evidence to suggest that occupiers who live in proximity to waste sites have suffered ill health. However, one report by Dehghani et al., (2012) states that distances of composting sites to residential properties must be observed as 600 species of *Aspergillus* fungus is enough to cause infections of the internal organs and skin, and can damage human eye, ear and fingernails.

3.0 RISK ASSESSMENT METHODOLOGY

The starting point for every risk assessment is to identify the different aspects, namely the hazards, sources of those hazards, sensitive receptors and the pathways between the source and the receptors. Figure 1 identifies the risk assessment framework with each tier of risk assessment presented to which the methodology within this risk assessment is based.

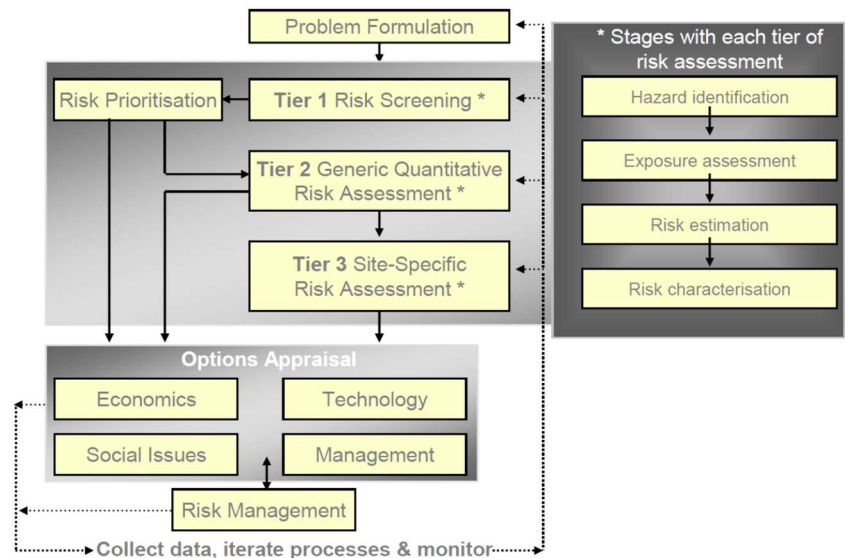


Figure 1 - The Environmental Risk Assessment Framework

The four stages within each tier of risk assessment are identified below.

Hazard identification: The situation that could lead to harm. Including what sources of hazard(s) are present and what are their properties/what data is available? Is this substance toxic (or situation hazardous) and how toxic (hazardous) is it?

Exposure assessment: Evaluate the plausibility of the hazard being realised at the receptor - by which mechanisms, allowing an assessment of the probability, magnitude and duration of exposure. Who (or what) is exposed, how long and often?

Risk estimation: Of what relative scale is the probability and extent of possible harm? How big a risk is this? This includes the probability and frequency of a hazard being present, potential pathways and possible harm, e.g. dose-response relationships. (Dose-response relationships in turn depend on duration and concentration of exposure).

Risk characterisation: How significant is the risk and what are the uncertainties? Is this something I need to worry about and if so, how much should I worry? The probability and

magnitude of consequences are placed in context, and an evaluative judgement is made in response to the data that is available currently.

4.0 SITE DESCRIPTION AND INFORMATION

Haworth Scouring Company is situated 1.3km east of Bradford city centre and comprises an irregular area of approximately 8 acres. The site is surrounded by mixed industrial units and some residential properties and by minor roads on four sides, with the fifth (south) side being the boundary of main Leeds-Bradford railway line.

The installation is a textiles plant which washes and dries raw fleece wool to produce clean, dry wool fibre for sale or onward processing. The main activities are receipt of raw materials and fuels, product processing (heating, drying, washing, and cleaning) and despatch of finished product. Ancillary processes include on-site treatment of effluents and recovery of wool grease.

The effluent from the raw wool scouring process at HSC is characterised by extremely high Chemical Oxygen Demand (COD) and high solids content. These parameters not only impact upon the environment when discharged to public sewer but are also used to determine the cost of discharge. Lowering these parameters before discharge therefore not only benefits the environment but also reduces operational costs. HSC has put in place efficient wool grease capture from effluent and a physico chemical effluent treatment plant to reduce COD and solids by around 90% but are hoping to reduce these further with the insertion of an AD stage to their existing effluent treatment system. An additional CHP unit will be co-installed at the anaerobic digestion site. Digestion of the effluent will produce a biogas that will be burned in the CHP to produce electricity and heat which will be used on the site.

The combination of physico-chemical and anaerobic treatment, as well as the production of biogas for on-site power generation, will render the aqueous effluent easier to treat in the existing treatment system, reduce chemical usage and also reduce the amount of sludge solid waste being produced.

5.0 DESCRIPTION OF PROCESS

5.1 Wool Scouring

The scouring process is described in these steps:

- Greasy wool containing wool grease (lanolin), dirt and other vegetable material is loaded onto a large conveyor and pre-blended in an accumulator bin.
- Excess dirt and vegetable matter are removed from the wool prior to washing without damage to the fibre.
- Effluent Treatment Plant (ETP) treats effluent and grease prior to discharge to sewer (emission point S1), listed as Directly Associated Activity AR4.
- The greasy wool is conveyed through a series of temperature-controlled wash bowls containing biodegradable detergent which removes the wool greasy and dirt and debris from the fibres before going through a series of rinse bowls.
- A series of specific temperature-controlled dryers dries the wool, and a moisture management system provides a best fit for specified moisture regain values requested by a customer.
- Wool is press packed in bales of approximately 300-350kg and stored for export to the customer.

5.2 AD Feedstock Reception

The effluent is conferred into the pre-digestion effluent tank following completion of the wool scouring process via sealed pipework. Process parameters are carefully monitored at all times through the SCADA system.

5.3 Digestion Phase

The plant operates a one-stage digestion process. Six tanks, each with a theoretical capacity of 135m³ each, and working volumes of 123m³ are split into two parallel treatment lines with three tanks, with each set of tanks operating in series to one another. The actual fill level of a seventh digester shall vary to meet demand from HSC's decanter.

The delivery of feedstock to the digesters is carefully controlled using the SCADA system, determining the waste input rate to comply with the fermenter 'recipe'. This controls the C/N ratio and the input rate of feedstock in order to manage biogas yield. The amount of feed from each feedstock source is determined in line with the loading rate calculations in order to maintain optimal conditions in the digester.

Substrate is mixed in the digesters by rotating paddles to ensure the best distribution of feedstock within the digester, with gas bubble generation also providing a mixing effect. This prevents the formation of localised volatile fatty acids (VFA) which can cause bubbling and make conditions unstable.

The digester tanks are stirred and heated for three days. The temperature of the digesters is maintained between 36°C and 46°C, and the tanks are fully sealed. This allows the AD of the feedstock to take place, releasing a methane-rich gas (biogas) and producing a material with some nutritional content (digestate).

Biogas is collected and distributed to the onsite Combined Heat and Power (CHP) engine that is co-installed at the AD site via collection pipework. The collected biogas is comprised principally of Methane (CH₄) and Carbon Dioxide (CO₂) (typically 55% methane and 45% carbon dioxide) with trace amounts of other gases, including Hydrogen Sulphide (H₂S) and Nitrogen (N₂). The biogas is collected until the substrate has reached a residence time of no less than three days. The entire digestion process is enclosed, with no release point to the atmosphere, meaning no emissions should be released during this process.

5.4 Solid Sludge/Digestate Removal

Following completion of the digestion process, the effluent is transferred to the existing effluent treatment plant on site where dewatering takes place and the solid sludge/digestate is conferred to a roll-on roll-off skip which is removed from site daily. The residual water from the process is discharged to the mains sewers under a permitted discharge consent.

5.5 Biogas Generation

The biogas produced is collected via pipework attached to each digester tank. The collected biogas undergoes "scrubbing"; to remove contaminants using a carbon filter on the CHP's gas intake line. The gas is subsequently dried and cooled before being combusted in the CHP engine to produce electricity from renewable sources to displace the electricity and gas currently used to power the site. The heat generated will provide hot water for the wool washing process.

5.6 Climate Data

The following section identifies the prevailing weather conditions on site, in particular the wind direction in order to predict the path of likely aerial dispersion of odours generated on site.

Wind data for Bradford has been collated over the last 30 years (Meteoblue weather data). This data is illustrated in Figure 2, showing that the prevailing wind direction is towards the west (270°).

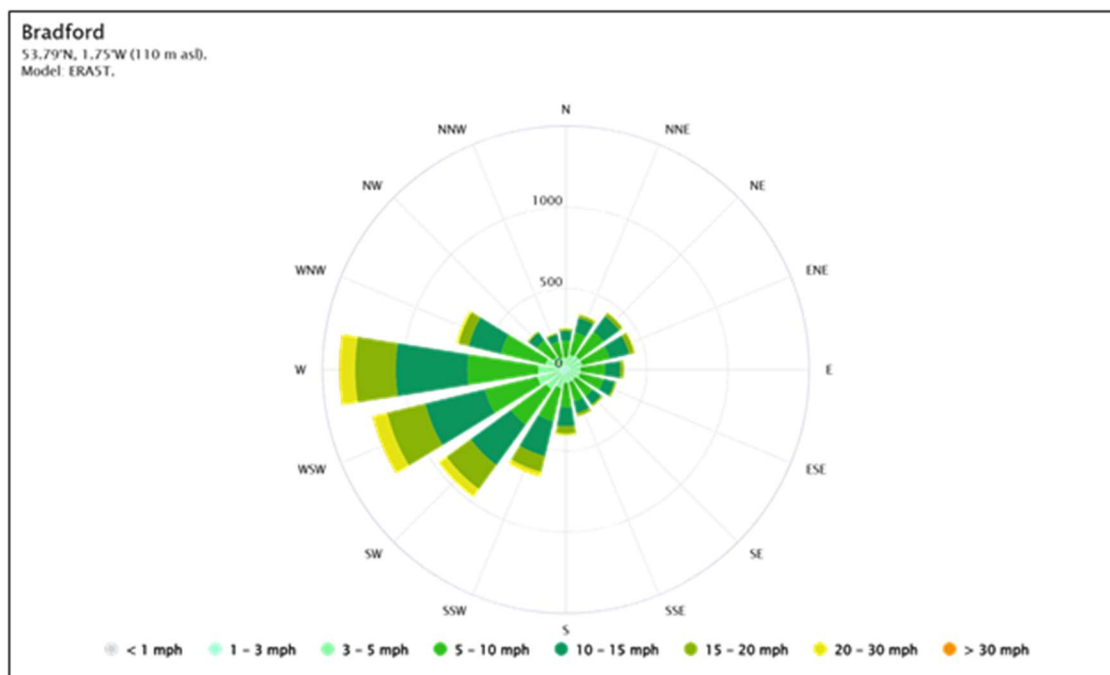


Figure 2 – Windrose showing wind direction over a 30-year period

Site operatives use an online weather report and a weather station installed on site for recording weather conditions as required on monitoring forms. The weather information will identify wind strength, direction, temperature and atmospheric pressure as a minimum.

5.7 Potentially Sensitive Receptors

The EA refers to Receptors as a 'workplace' or a 'dwelling'. A dwelling includes a garden boundary, and a workplace is where workers are frequently present (a workplace does not normally include areas where workers are present for short periods). The EA does not explicitly class transient receptors including footpaths, recreational open spaces, bridleways, highways, roads, railways or livestock as potentially sensitive receptors to bioaerosols.

DEFRA ranks the sensitivity of potential receptors to general waste management activities as given in Table 2. There are minor differences in sensitivity categories to bioaerosols and dust. In the latest EA position statement duration of exposure was also mentioned as:

'Sensitive receptors refer to people likely to be within 250 metres of the composting operation for prolonged or frequent periods. This term would therefore apply to dwellings (including any associated gardens) and to workplaces where workers would frequently be present'.

Table 2 – Ranking of Sensitive Receptors

Sensitivity Ranking	Category of Receptor
<p>High</p> <p>Individuals living and/or working in the vicinity for prolonged frequent periods.</p>	Houses and residents (schools, hospitals etc.).
<p>Medium</p> <p>Individuals working in the vicinity for prolonged frequent periods.</p>	Trade premises and factories (offices, industrial premises).
<p>Medium/Low</p> <p>Individuals in the area for frequent periods.</p>	Public footpaths (local environmental areas).
<p>Low</p> <p>Individuals unlikely to be in the area of direct exposure for prolonged or frequent periods.</p>	Other amenities (minor roads and open public spaces).

5.8 Site Specific Sensitive Receptors

Site specific sensitive receptors that are located within 250m of the site boundary are identified in Table 7 below. Distances to receptors are given from the site boundary.

Table 3 – Sensitive Receptors Within 250m of Site Boundary

Receptor Reference	Receptor Description/Land-use Type	Direction From Site (From true North)	Approximate Distance to Site Boundary (m)
1	Residential Receptor – Garden	Northwest	58
2	Residential Receptor – Garden	Northwest	105
3	Residential dwelling	Northwest	87
4	Residential dwelling	Northwest	72
5	Residential dwelling	Northwest	63

6	Residential dwelling	West-northwest	74
7	Residential dwelling	North	51
8	Residential dwelling	North-northeast	65
9	Residential Receptor – Garden	North-northwest	68
10	Residential Receptor – Garden	North	50
11	Residential Receptor – Garden	Northeast	63
12	Residential Receptor – Garden	East-northeast	100
13	Redmire Van Hire	West-southwest	50
14	Brownie Points	West-southwest	72
15	Adams Foodservice Mount Street	South-southeast	178
16	Industrial Unit	South-southeast	164
17	Womenszone	East-northeast	39
18	Chaiiwala	Northeast	180
19	Abaseen	Northeast	202
20	Dzire Lounge	East-northeast	207
21	Continental Kitchen and Bar	East-southeast	116
22	Commercial premises and café cluster	Northwest	150
23	Café and Autoworks vehicle repair shop	West-northwest	220

24	Commercial premises	North-northeast	141
25	Commercial and Retail premises	Northeast	247
26	Co-op Academy Pennyoaks	East-northeast	39

6.0 RISK ASSESSMENT

The AD process is a biological process that takes place under controlled conditions in a sealed environment. Although the site presents a low risk for bioaerosol emissions (as described in Section 2.0 above), some of the processes undertaken have the potential to release bioaerosols, such as sludge reception and distribution, sludge treatment, and biogas combustion. Certain assets also have the potential to release bioaerosols, such as the sludge reception point, sludge holding tanks, digester tanks, and post-digestion storage tanks.

This risk assessment has been informed by the risk assessment techniques presented in the following guidance: 'An Environmental Risk Management Framework for Composting Facilities in England & Wales', together with the iterative risk assessment technique described by Defra. Whilst consideration has been given to the fact that the site process is one of AD and not composting, the above guidance has been judged as the most comprehensive and best available risk assessment model to apply to the biological process.

6.1 Hazard Identification

In order to assess the potential risks from bioaerosols, emission sources need to be considered. Table 4 sets out the source-pathway-receptor linkages for exposure of local sensitive receptors to emissions from airborne bioaerosols at the site.

Table 4 – Source-Pathway-Receptors Identified for Bioaerosol Emissions

Source Process	Potential Emission Source	Pathway	Receptor
Reception of material	Material reception area	Aerial dispersion then inhalation, ingestion, absorption/contact	Those within 250m of the site
Effluent reception and distribution	Effluent reception pump house	Aerial dispersion then inhalation, ingestion, absorption/contact	Those within 250m of the site
Effluent treatment	Anaerobic digesters	Aerial dispersion then inhalation, ingestion, absorption/contact	Those within 250m of the site
	Buffer storage tank		
Biogas combustion	Gas holder	Aerial dispersion then inhalation,	Those within 250m of the site
	CHP		

	Boilers	ingestion, absorption/contact	
Roadways and vehicles, material transportation and storage, on-site maintenance	Roadways into and out of site Vehicles entering and leaving site	Aerial dispersion then inhalation, ingestion, absorption/contact	Localised to within 50m of the activity

Fugitive dusts are likely to be liberated by the handling of the materials accepted on site, their storage and movement and by meteorological conditions (presence or absence of precipitation, but particularly wind). Vehicles on site may exacerbate this situation at sites with hard standing where surfaces dry out.

Bioaerosols are mostly likely to be released when materials are agitated or processed such as during the deposition of waste in the waste reception area.

6.2 Exposure Assessment

An assessment necessarily requires the consideration of potential routes of exposure of individuals to bioaerosols should they escape from the site. Potential pathways of exposure are:

- **Inhalation:** breathing via nose or mouth;
- **Ingestion:** eating or swallowing;
- **Absorption:** through skin or via the eyes (directly or indirectly);
- **Contact:** with the surface of the skin or eyes; and,
- **Injection:** by high pressure equipment/contaminated sharp objects.

It is assumed the most important potential route of any exposure for a sensitive receptor in the vicinity of a site will be airborne inhalation as other routes would involve direct contact with the material (which is more of an occupational issue). The conceptual model for the exposure assessment is outlined in Figure 3.

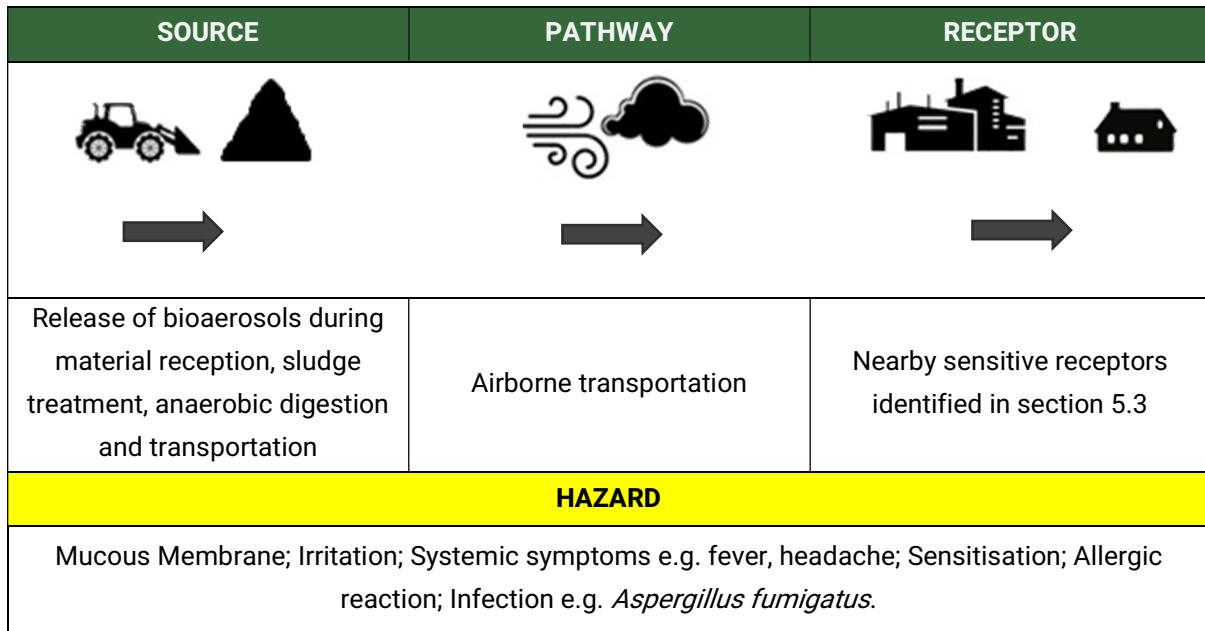


Figure 3 – Site Conceptual Model for Pollutant Exposure

The conceptual model requires further refinement in terms of the duration of exposure and other issues such as whether effects are likely to be acute (short-term) or chronic (long-term) i.e. the consequences, which will be explored below.

6.3 Emissions Classification

In terms of reported concentrations at biological treatment sites, many reports specify that concentrations are elevated during agitation only, and during periods of little to no activity concentrations are similar to background. Indeed, the EA state that bioaerosol release is episodic with reception movement potentially generating the highest releases. An emissions classification can therefore be drawn from the site activities considered to potentially contribute to bioaerosol release.

Emission Class	Site Activities	Comments
Low	Site maintenance	Site operates in accordance with robust maintenance schedule
	Material storage	Constant activities but low level of material agitation Waste processed within a maximum of 72 hours following receipt onto site AD Feedstock is stored in an enclosed tank

Emission Class	Site Activities	Comments
Low to Medium	Waste Reception	Raw wool for the scouring process is received in a designated, enclosed waste reception area Effluent for the AD process is conferred into the pre-digestion effluent tank via sealed pipework
	Vehicle loading and transportation of product offsite	Vehicles are inspected before entering/leaving site Skips and vehicles are regularly cleaned Loads are damped down before sheeting to prevent airborne emissions All wool products are transported offsite in covered vehicles/skips
High	Release of fugitive emissions owing to poor waste reception	Potential release of bioaerosols in immediacy of activities which are actively agitating materials Unlikely due to effective management systems and processes, enclosed processes, and quick processing times Effluent for the AD process is conferred into the pre-digestion effluent tank via sealed pipework
Very High	Accidents during digestion phase leading to elevated release events	Rare due to effective management systems and processes
	Malfunction or ineffective utilisation of filters	Rare due to effective management systems and processes Filters are regularly maintained in line with manufacturers guidance

7.0 MONITORING METHODOLOGY

The following monitoring methodology for the site bioaerosol monitoring has been developed following the M9 Technical Guidance Note¹.

7.1 Sampling Locations

The following sections, which are based on CEN TS 16115-2, describe approaches that must be considered when designing a sampling strategy.

A number of different sample locations are required to assess the levels of bioaerosol emitted from a facility. It is necessary to locate these at specified distances, which are dependent on the distance from the centre of the active operational area.

Upwind

Sampling shall be carried out upwind of the site. Upwind data shall provide information on the concentration of specified bioaerosols that are present in the air blowing onto the operational area of the site. Upwind data indicates the concentration of bioaerosols that would be present, irrespective of whether the facility was there or not. This effectively represents the background concentration of bioaerosols.

The sample location of the upwind concentration measurement shall be measured at a distance of 50m from the centre of the active operational area where possible. If a neighbouring operation, structure or installation prevents sampling at this location, then sampling shall be carried out at a location, which is at a distance as far upwind as is possible between the active operational area and the neighbouring operation, structure or installation.

Whenever these samples are collected, a note shall be made of any upwind activities that may affect the concentration of bioaerosols.

Downwind

Sampling shall be carried out downwind of the site, using a fan like shape arrangement to detect the position of the plume. The orientation of the measurement area is determined by the prevailing mean wind direction at the time of monitoring.

This approach is used to ensure that measurements are made in the emission plume, during the sampling campaign. If there are any buildings, installations or structures between the

¹ [M9 environmental monitoring of bioaerosols at regulated facilities - GOV.UK](#)

downwind location and the centre of the active operational area, then sampling shall be carried out upwind of that structure or installation, at a distance greater than twice its height.

7.1.1 Fan Like Shape Sampling Arrangements

The sampling arrangement is designed to assess bioaerosol levels at the nearest sensitive receptor to the site. Sampling shall be carried out at 1 upwind and 3 downwind locations in a fan like arrangement simultaneously.

The distance of the downwind locations from the centre of the active operational area shall be the same as the distance of the nearest sensitive receptor from the source of bioaerosols i.e. the AD plant. This approach measures the potential bioaerosol exposure at the nearest sensitive receptor, assuming the wind was blowing in the direction of the receptor and the terrain is similar. At HSC, the nearest sensitive receptor is located approximately 50m from the centre of the AD plant. This is the Bradford MOT Centre to the southwest of the AD plant.

Figure 4 shows this approach applied to a facility with a single point source. A central traverse is determined based on the mean wind direction. A sampling traverse line is run through these points at an angle of 30° (± 3) to the centre traverse. Any restrictions to the line of sight with the AD plant in locating the sampling points caused by topography or vegetation shall be noted in the sample strategy and final monitoring report.

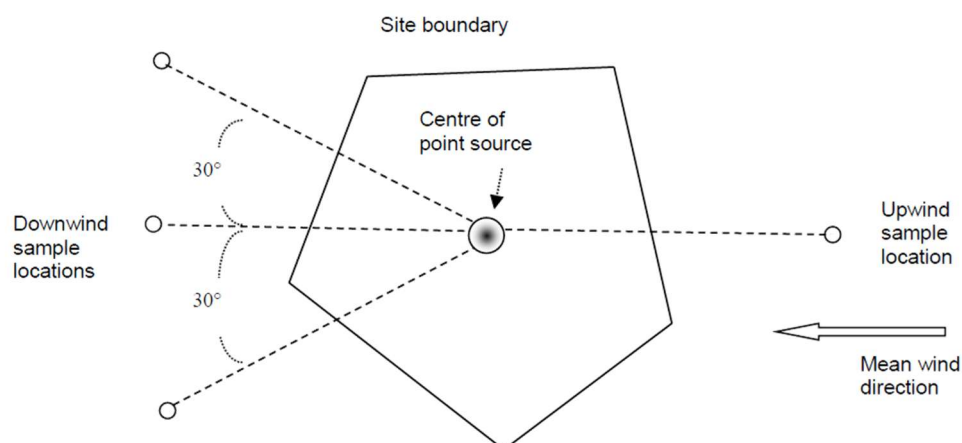


Figure 4 - Simplified fan like shape sampling arrangement

7.2 Modifications to the Fan Shape

In practice it is not always possible to comply with the fan like shape sampling arrangement. Access to the exact required sample locations may not always be possible. Under these

circumstances it is acceptable to sample a few degrees off axis from the required locations. If this is not possible, the fan shape arrangement will be adapted. The fan like shape arrangement will also need to be adapted if topography has a significant impact on meteorological conditions e.g. the presence of buildings which may affect the flow of wind from the site. This may affect the position of some or even all of the sample locations. Health and safety must always be considered at the earliest point in the monitoring strategy and must be given the highest priority. Such considerations may lead to modification of the fan like shape sampling arrangement. A sample location that would meet the requirements of the fan like shape sampling arrangement will not be used, if it introduces an unacceptable safety risk. For example, a location that falls within the facilities' operational boundary shall not be used because of on-site hazards, such as site traffic.

7.3 Carrying Out the Measurements

The bearing from true north of the sample locations from the centre of the active operational area shall be measured (in degrees) and recorded. This bearing can be estimated from a scale map of the site. As mentioned above, the monitoring points are not fixed and the location of each monitoring point shall be determined by the wind direction on the day of monitoring.

In order to determine the bioaerosol process contribution from the site, sampling at the upwind and downwind locations shall be carried out concurrently, so that the results can be compared. A sample is considered to be concurrent if the sample times overlap by a minimum of 10% of each other.

Sampling shall not be carried out during rain, sleet or snow (as this obstructs the air jets in the sampler and may damage the vacuum pump); or if the ambient temperature falls below 3°C (as this causes unacceptable levels of condensation to form in the sampler and tubing).

7.4 Meteorological Conditions

7.3.1 Wind Speed and Wind Direction

The average wind speed and average wind direction shall be calculated for the duration of the sampling period for each sample. A weather station will record the direction the wind has blown from. This should then be converted into the direction the wind blows to, by adding or subtracting 180° to the calculated true north average wind direction bearings.

The difference between the bearing of the samplers and the average bearing to which the wind blows during the sampling period shall be calculated. The difference for the upwind samples should be 180°. The difference for the downwind sample in the centre of the fan like

shape should ideally be 0° (a difference of up to ±30° is acceptable). The wind flow direction should be from the source toward the samplers within the ±30° sector for over 80% of the sampling duration. Deviations from this shall be noted in the monitoring report and discussed in context with the results.

7.3.2 Temperature and Relative Humidity

The arithmetic mean of the air temperature and relative humidity should be calculated and recorded for the duration of each sampling period. This data provides information on potential survival rate (tenacity) of bioaerosols, which can have a major influence on the measurement results. It is known that warmer temperatures aid growth of bioaerosols, while a relative humidity of 80% or more means they remain viable longer. Similarly, it is necessary to record cloud cover because ultraviolet light reduces the survival rate of bioaerosols.

It is necessary to assess and record the weather conditions because this provides information about dispersion conditions, especially potentially unfavourable dispersion conditions, which can lead to an increased impact locally.

7.5 Number of Samples

The fan-shape configuration has four sample locations. At each location a minimum of 3 measurement results of *Aspergillus fumigatus* and mesophilic bacteria are required.

7.6 Sample Time

After calibration, the pumps shall be operated for 60 minutes at each location.

7.7 Equipment Utilised

Sampling shall be carried out using IOM personal samplers attached to a pump as allowed in M9 TGN (2018).

7.7.1 Calibration

Prior to each site visit, the pumps are to be calibrated with a certified reference volume meter – ‘rotameter’ which has an accuracy rating of more than ±2 per cent expressed in operational cubic meters, referenced to ambient air conditions. The rotameter head is to be connected to the filter head, which is then to be connected to the pump which is set at 2000ml/minute and is run for 10 minutes. The flow rate is to be adjusted if required.

7.6.2 Viable Counts – Filters

The sampling shall be undertaken following the approach set out in the M9 TGN (2018). The SKC IOM cassettes shall be loaded with a 25mm 0.8µm polycarbonate filter. The IOM pump shall be operated at a flow rate of 2.0 ± 0.1 litre/min. Pumps are to be charged until full and calibrated to within ± 2 per cent of 2l/min (SKC Group). To provide field blanks, two controls shall be loaded into the IOM head and handled in the same way as the field samples only without being exposed and without air being drawn through them. The twelve filters across the monitoring points (three filters in three sampling heads at each of the four monitoring locations) are to be sampled for 60 minutes. The start and stop times of each are to be recorded for accuracy. Each sampling head shall be mounted on a tripod in a horizontal hanging position at a height of 1.5m as per the technical guidance note and each IOM head shall be approximately 20cm apart.

7.8 Laboratory Enumeration

The filters shall be kept at a temperature of $5^{\circ}\text{C} \pm 3^{\circ}\text{C}$ during transportation to the laboratory. Processing shall take place within 24 hours of monitoring.

The IOM heads containing a polycarbonate filter are to be used to determine the bioaerosol exposure under the test conditions. Upon arrival at the laboratory the bioaerosols impacted on each filter shall be recovered in 5ml maximum recovery diluent. The target micro-organisms are to be cultured using appropriate dilutions on the following media:

- Nutrient Agar (NA) agar plates for total mesophilic bacteria.
- Malt extract agar (MEA) agar plates for *Aspergillus fumigatus*.

Samples shall be incubated for 7 days at 37°C (total mesophilic) and 2 days at 41°C (*Aspergillus fumigatus*). Identification of *Aspergillus fumigatus* is to be performed by microscopy.

All filters are to be extracted from the cassettes (including the two blanks which shall be retained from the visit) as per the protocol in a controlled and sterilised environment. After the incubation period of 48 hours (see above) the number of colonies are to be counted, and the total number of colonies are to be expressed as colony-forming units (cfu/m³). Colony-forming units shall also be counted after 7 days, in line with the M9 TGN. Bioaerosol recovery shall be conducted in line with the IOM operating instructions, 5ml of recovery solution shall be utilised to wash the filters in. The blank filters are to be loaded onto plates in the same way as the filters which had undergone bioaerosol monitoring. The blank filters will show any contamination errors which could occur during sampling.

8.0 RISK ESTIMATION

As bioaerosols monitoring has not been conducted at the site, monitoring results from a similar site have been utilised in the following sections to provide an estimation of risk. The site chosen was a much larger AD facility receiving a much broader range of liquid wastes and it is therefore considered that it represents a worst-case scenario. The site chosen also has sensitive receptors very close and is therefore considered to be representative. To overcome potential difficulties with the uncertainty of information such as source emission rates or micro-organism decay, conservative assumptions have been made. Risk estimation uses deterministic and probabilistic techniques that offer a way of dealing with the inherent variability and uncertainties in exposure estimation.

The risk estimation calculated within this risk assessment is based upon a calculation of the probability of exposure and the magnitude of the consequence. Semi-quantitative scoring is assigned to each factor and combined in order to score the risk to each potential receptor from operations on site due to bioaerosol release.

8.1 Magnitude of Consequences

Table 6 indicates the magnitude of consequences based on DEFRA (Negligible to Mild) and EA (Moderate to Extremely Severe) categories and their descriptions. These broad categories provide a mechanism for comparative assessment. The category of consequence is therefore assigned to the magnitude of risk for assessment based upon levels of micro-organisms monitored at or adjacent to the source.

Table 6 – Magnitude of Consequences from Source Emissions

WRM Classification	Category	Indicative Range	Category and Consequence	Level of Consequences compared to natural levels
Low	Negligible	<300	No observable effect on individuals or populations. No effect on local ecosystem, individual species or local features.	Low range of natural environmental levels.
Low/Medium	Mild	300 - 1000	No observable effect on health of individuals.	Mid-range of natural environmental levels.

WRM Classification	Category	Indicative Range	Category and Consequence	Level of Consequences compared to natural levels
			No observable effect at the population level or on local ecosystem.	
Medium	Moderate	1000 - 3000	Health effects generally not noted. Short term: no significant impacts on robust individuals, populations or ecosystems. Potential minor health or nuisance impacts for vulnerable individuals (frail/elderly/sick). Continuous long term: robust individuals unaffected. Potential health effects on vulnerable individuals (frail/elderly/sick). No observable effect on local ecosystem.	Upper-range natural environmental levels.
High	High	3000 - 10,000	Short-term: no significant impacts on robust individuals. Vulnerable individuals affected including welfare and nuisance. Continuous long term: vulnerable individuals affected including health, welfare and nuisance. Potential effects on population structure or size and local ecosystem impacts possibly detectable. Equivalent to occupational exposure levels.	High range of natural environmental levels.
Very High	Severe	10,000 - 30,000	Short term and long term: some robust individuals affected including health, welfare, and nuisance. Local dysfunction of communities if continuous. Local ecosystem changes detectable.	Short term highest natural environmental levels for specific events e.g. harvesting.

WRM Classification	Category	Indicative Range	Category and Consequence	Level of Consequences compared to natural levels
Very High	Very Severe	30,000 - 100,000	Probable effects on robust individuals. Widespread effects on the functioning of communities and ecosystems.	Rare natural environmental levels.
Very High	Extremely Severe	>100,000	Widespread health effects. Impacts on the functioning of regionally important ecosystems.	Maximum of natural environmental events.

It is difficult to ascribe a consistent source emission rate as values quoted are highly variable and masked by variations in ambient concentrations. Detailed estimation would require the use of dispersion models with appropriate modules for calculation of airborne and deposited particulate. The EA indicates that there are 'numerous uncertainties' with air quality modelling and refers to the use of deterministic or probabilistic models. The EA uses a simple straight-line fit to estimate the downwind distance to meet the reference level.

8.2 Mesophilic Bacteria

The results from the site that was chosen as an appropriate example/comparator showed that the median UW result for Mesophilic Bacteria (<139 cfu/m³) fell below the EA Permitted Limit (1,000 cfu/m³). The median results for the DW, DW-30 monitoring locations were 139 cfu/m³. The median result from the DW+30 monitoring location was 416 cfu/m³. All of these are below the EA Permitted Limit.

This demonstrates that the upwind result for Mesophilic Bacteria is considered to be low to low/medium using the classification in Table 6. The downwind result is also considered to be low.

8.3 Aspergillus Fumigatus

The results from the site that was chosen as an appropriate example/comparator showed that the median UW result for Aspergillus Fumigatus (<139 cfu/m³) fell below the EA Permitted Limit (1,000 cfu/m³). All median results for the DW, DW+30 and DW-30 monitoring locations (all <139 cfu/m³) fell below the EA Permitted Limit.

This demonstrates that the upwind result for *Aspergillus Fumigatus* is considered to be low using the classification in Table 6. The downwind result is also considered to be low.

Based on the analysis of these results, Table 7 demonstrates how varying emission levels impact upon the magnitude of consequences. Whilst it is clear that an emission event labelled as 'Very High' would cause a high magnitude of consequences, a very high emission event is unlikely based on the results presented within this risk assessment. Low emissions result in a low magnitude of consequences.

Table 7 – Risk Assessment Factor A – Magnitude of Consequence

Receptor	Emission Classification				
	Low	Low/Medium	Medium	High	Very High
1 - Residential Receptor – Garden		X			
2 - Residential Receptor – Garden		X			
3 - Residential dwelling		X			
4 - Residential dwelling		X			
5 - Residential dwelling		X			
6 - Residential dwelling		X			
7 - Residential dwelling		X			
8 - Residential dwelling		X			
9 – Residential Receptor - Garden		X			
10 - Residential Receptor - Garden		X			
11 - Residential Receptor - Garden		X			
12 - Residential Receptor - Garden		X			

Receptor	Emission Classification				
	Low	Low/Medium	Medium	High	Very High
13 - Redmire Van Hire		X			
14 - Brownie Points		X			
15 - Adams Foodservice Mount Street		X			
16 - Industrial Unit		X			
17 - Womenzone		X			
18 - Chaiiwala		X			
19 - Abaseen		X			
20 - Dzire Lounge		X			
21 - Continental Kitchen and Bar		X			
22 - Commercial premises and café cluster		X			
23 - Café and auto works vehicle repair shop		X			
24 - Commercial premises		X			
25 - Commercial and Retail premises		X			
26 - Co-op Academy Pennyoaks		X			

8.4 Probability of Exposure

Simple factors can be used to generate indicative probabilities of an event occurring. Each can be the product of several variables. For example, the fraction of the time that the wind blows towards a receptor multiplied by fraction of time that material is disturbed.

Conservative (i.e. 'worst case' conditions) probability factors for the occurrence of a release event have been derived and are described in Table 8.

Table 8 – Factor Determining the Probability of Exposure

Factor	Description
Receptor	<p><i>The proportion of time that a receptor is present at the identified location.</i></p> <p>The receptor is only affected when present. In residential properties and hospitals, a value of 1 is assumed; equivalent to continual occupancy. At commercial/school properties, a value of 0.25 is equivalent to slightly more than a 40-hour week. At amenity and other facilities, a value of 0.01 is equivalent to 2 hours a week for any individual.</p>
Wind Direction	<p><i>The proportion of time averaged over 1 year that wind blows towards the receptor – no modification is made for wind speed.</i></p> <p>Probability factors are calculated as the proportion of the time that the wind blows to the receptor from any part of the biological activity for all release cases. Average climatic data is used to calculate wind direction probabilities.</p>
Activity Classification	<p><i>Classification as to the frequency of bioaerosol release from each identified site activity.</i></p> <p>Classification as identified within Table 6 with hours per week of operations for each site activity.</p>

Criteria for probability as a function of frequency and duration are defined below in Table 8. These are conservative and are based upon site activity duration.

Table 8 – Criteria for Probability of Exposure Occurrence

Probability Criteria	Description of Probability
Negligible	Exposure of less than 25 hours per year (½ hour per week).
Low	Exposure of 25-100 hours per year (<2 hours per week).
Medium	Exposure of 100-250 hours per year (<5 hours per week).
High	Exposure of >250 hours per year (>5 hours per week).

Based on these factors, the probability of conditions occurring to affect each receptor has been estimated for the probability criteria defined above. The results are shown in Table 9 for possible exposure to emissions from operations on site. The potential probability of consequences given below is based on criteria as identified in Table 8 above but using the classification in Table 6.

Table 9 – Risk Assessment Factor B – Probability of Consequence

Receptor	Emission Classification				
	Low	Low/Medium	Medium	High	Very High
1 - Residential Receptor – Garden		X			
2 - Residential Receptor – Garden		X			
3 - Residential dwelling		X			
4 - Residential dwelling		X			
5 - Residential dwelling		X			
6 - Residential dwelling		X			
7 - Residential dwelling	X				
8 - Residential dwelling	X				
9 – Residential Receptor - Garden	X				
10 - Residential Receptor - Garden	X				
11 - Residential Receptor - Garden	X				
12 - Residential Receptor - Garden	X				
13 - Redmire Van Hire	X				

Receptor	Emission Classification				
	Low	Low/Medium	Medium	High	Very High
14 – Brownie Points	X				
15 - Adams Foodservice Mount Street	X				
16 - Industrial Unit	X				
17 - Womenzone	X				
18 - Chaiiwala	X				
19 - Abaseen	X				
20 - Dzire Lounge	X				
21 - Continental Kitchen and Bar	X				
22 - Commercial premises and café cluster	X				
23 - Café and auto works vehicle repair shop	X				
24 - Commercial premises	X				
25 - Commercial and Retail premises	X				
26 - Co-op Academy Pennyorks	X				

8.5 Significance of Risks

To provide an estimation of the risk of bioaerosol release on site, an assessment combining the following risk assessment factors are required:

- Risk Assessment Factor A: Magnitude of Consequence – Table 7
- Risk Assessment Factor B: Probability of Consequence – Table 9

There is no single formula for combining the frequency and magnitude of exposure and simple intuitive methods are therefore employed. A risk matrix is generally considered to be an accepted method of identifying the magnitude and probability of the potential risk. A general matrix to estimate the magnitude and the probability of a potential risk is given in the table below.

Table 10 – Risk Estimation Matrix

Probability (Factor B)	Magnitude (Factor A)				
	Low	Low/Medium	Medium	High	Very High
Low	1	2	3	4	5
Low/Medium	2	4	6	8	10
Medium	3	6	9	12	15
High	4	8	12	16	20
Very High	5	10	14	18	25

Applying the above risk estimation matrix, the significance of the risk to the sensitive receptors located near the site are calculated as below in Table 11. The significance of the risk for all sensitive receptors is classified as Low.

Table 11 – Significance of Risk from Site Operations

Receptor	Emission Classification				
	Low (Less than 5)	Low/Medium (Less than 10)	Medium (Less than 15)	High (Less than 20)	Very High (20 or above)
1 - Residential Receptor – Garden	2				
2 - Residential Receptor – Garden	2				
3 - Residential dwelling	2				
4 - Residential dwelling	2				

Receptor	Emission Classification				
	Low (Less than 5)	Low/Medium (Less than 10)	Medium (Less than 15)	High (Less than 20)	Very High (20 or above)
5 - Residential dwelling	2				
6 - Residential dwelling	2				
7 - Residential dwelling	1				
8 - Residential dwelling	1				
9 - Residential Receptor - Garden	1				
10 - Residential Receptor - Garden	1				
11 - Residential Receptor - Garden	1				
12 - Residential Receptor - Garden	1				
13 - Redmire Van Hire	1				
14 - Brownie Points	1				
15 - Adams Foodservice Mount Street	1				
16 - Industrial Unit	1				
17 - Womenzone	1				
18 - Chaiiwala	1				
19 - Abaseen	1				
20 - Dzire Lounge	1				
21 - Continental Kitchen and Bar	1				

Receptor	Emission Classification				
	Low (Less than 5)	Low/Medium (Less than 10)	Medium (Less than 15)	High (Less than 20)	Very High (20 or above)
22 - Commercial premises and café cluster	1				
23 - Café and auto works vehicle repair shop	1				
24 - Commercial premises	1				
25 - Commercial and Retail premises	1				
26 - Co-op Academy Pennyoaks	1				

8.6 Significant Risks

The most significant risks identified at site are as follows:

1. Containment Failure: The AD process is enclosed and takes place within a number of sealed tanks, making the risk of bioaerosol emissions very low. However, if the integrity of the tanks were to be compromised (i.e., if the tank was damaged and there was a leak), the tanks could no longer contain any bioaerosols that have arisen during the AD process. To minimise this risk, the site operates a strict inspection and maintenance schedule and conducts daily inspections to ensure the integrity of all site plant and equipment.

2. Malfunction or ineffective utilisation of filters: failure of, or loss of efficiency in, the filters has the potential to lead to increased bioaerosol emissions from on site processes. To minimise the risk, the filters are maintained in accordance with manufacturing and servicing agreements, and regular emissions testing is undertaken on the biofilter to demonstrate its efficacy.

9.0 CONCLUSION

In conclusion, a variety of studies have shown different dispersal distances and have used differing reference values for estimating effects on health to local populations. The results in this report indicate that the risk of bioaerosols emissions to sensitive receptors is Low.

Furthermore, individual monitoring events indicate the risk of bioaerosol emissions to sensitive receptors is Low. Therefore, the intended activities to be carried out on site are acceptable and tolerable in terms of risk tolerability.

Although there are potentially emissive operations on site with respect to waste handling, the control measures that the site have in place, the low to moderate occurrence of wind being in the direction of sensitive receptors, and the nature of the AD process (as a predominantly closed operation) reduces the overall exposure potential.

10.0 RISK MITIGATION MEASURES

The following good practice operation and mitigation measures are currently adopted in order to control activities that may generate or affect the release of bioaerosols.

- a) Waste treated in AD site is liquid waste only and reception occurs in a sealed tank which minimises the release of bioaerosols and odour to the atmosphere.
- b) A filter is fitted to which serves to reduce potential bioaerosol emissions to atmosphere.
- c) Inspections of buildings and infrastructure are undertaken to ensure that requisite maintenance is regularly undertaken. Checks include fencing, gates, building facilities and drainage systems.
- d) The site is swept and kept clear of all loose material on a regular basis.
- e) Plant and machinery are well maintained in line with the sites maintenance schedule to avoid dust generation.

The site also employs the following measures as necessary to further mitigate the aerosolisation of bioaerosols.

1. Daily housekeeping measure are employed to keep the site levels of dust and other loose materials as low as possible. Site operatives will frequently tour the site to check its condition. If the site is not up to suitable standards, operatives will be instructed to perform further housekeeping work such as the dampening of roadways or the sweeping of dusts.
2. The site operates under a robust maintenance schedule, which includes regular checks on key process equipment. Tanks are checked at regular intervals to ensure their continued effectiveness and integrity, as failure of a key item of plant such as a storage tank would be a large source of bioaerosols.
3. The site proactively monitors weather conditions, including wind direction and these are recorded.