Bioaerosol risk assessment and associated risk of legionellosis

Assessment of the information provided by the Te Mata Mushroom Company Ltd for the resource consent hearing July 2019

Background

On 23rd July 2019, the Hawkes Bay Medical Officer of Health requested advice on the legionellosis risk associated with the large scale composting operations of the Te Mata Mushroom Company Ltd situated at 174-176 Brookvale Road, Hastings. The site of the composting operations associated with mushroom growing is near a residential community a risk assessment of the

A risk assessment has been carried out from the following information:

- The publically available information submitted to the Hawkes bay Regional Council by the Te Mata Mushroom Company Ltd as part of the resource consent application. The information was obtained from the supporting documentation and was viewed on line at https://w–ww.hbrc.govt.nz/our-council/news/archive/article/327/te-mata-mushroom-company-ltd-submissions-closed on 24th July 2019;
- Surveillance data related to notified legionellosis cases for the Hawkes Bay DHB area;
- Published peer-reviewed scientific articles related to bioaerosols and the associated link to legionellosis.

Bioaerosols

An aerosol consists of particles small enough to be suspended in the air and remain airborne. There is particulate material in every breath taken and in healthy people the respiratory system is very efficient in removing this. These particles are generally between 0.01 µm (1/1000 mm) to 100 µm in diameter. The site and extent of deposition of particles in the respiratory tract are primarily affected by particle size, charge and hygroscopic properties. Large particles (>6 µm) tend to mainly deposit in the upper airway, while small particles (<2 µm) deposit mainly in the alveolar region and are probably the most apt to act systemically, whereas the particle in the size range 2-6 µm deposit in the central and small airways (Darquenne, 2012). Aerosolised particles of less than 5 µm in diameter behave very similarly to bulk air and can be deeply inhaled (Fitzgeorge *et al*, 1983).

Bioaerosols are defined as airborne material from any *biological* source, such as animals, plants, insects or micro-organisms. They are produced wherever biological material is being processed, milled, shredded or chopped and should be regarded as ubiquitous. Examples of work sites where significant bioaerosols are produced include oxidation ponds at sewage works, windrowing at composting facilities, harvesting agricultural crops, and log processing at timber mills.

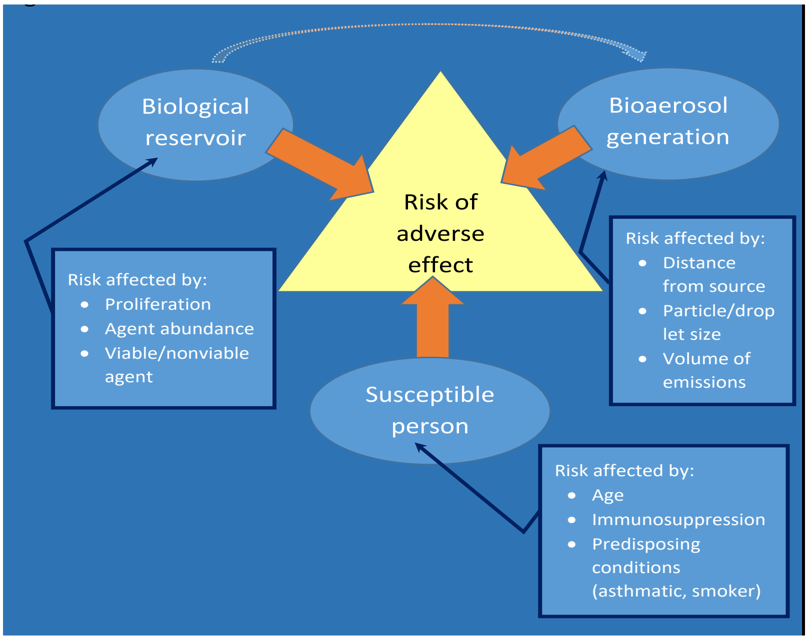
There are two different classes of biological material that contribute to the makeup of bioaerosols that can pose a potential health risk to susceptible persons: those that contain viable micro-organisms (such as bacteria, viruses, fungi or fungal spores) that can potentially cause infections; and those that contain non-viable material (for example, animal dander, pollen, or endotoxins) that act as an allergen. Generally bioaerosols are made up of a combination of these classes of material. Since it is not pragmatic to eliminate their production in the composting process, steps need to be put in place to sensibly manage any adverse risk that can arise.

Micro-organisms forming bioaerosols are generally reversibly bound to particulate matter and because of their small size are easily dispersed by wind. Bioaerosols can stay suspended in the air for prolonged periods and potentially travel long distances from their source (Nygard *et al*., 2008) and as a result may pose health hazards to nearby communities with elevated exposures.

Composting and the associated bioaerosol risks

The figure below shows that for an adverse effect to occur following exposure to a bioaerosol, three interdepended events need to align:

1. there has to be a contaminated source where *the biological agent* is produced and multiplying (*Biological reservoir*);
2. there has to be a means for a person to come into contact with the source; the prerequisite being the biological agent in an aerosolised state (*Bioaerosol generation*);
3. the person has to be susceptible to the disease caused by the biological agent (*Susceptible person*).



Biological reservoir

Wherever there is organic material there will be micro-organisms present. The composting process is dynamic and influenced by many different microbiological and environmental factors, but the principle action is carried out by the micro-organisms present in the organic material. The microbial population, growth, and activity are primarily effected by the make-up of the compost feedstock, moisture levels, heat and pH. The levels of different pathogenic micro-organisms, if present, will not be static during the composting process. Enteric pathogens such as Salmonella, Campylobacter and faecal coliforms are likely to be present in high numbers at the beginning of the composting process when food, animal or sewage waste are part of the feedstock, and usually decrease during the composting process. *Legionella* bacteria are likely to be low at the start of the process, but will be present in higher numbers during the maturation process where temperatures are more likely to suit its growth and the growth of the *Legionella* hosts (nematodes and protozoa). Aspergillus fungi are another potential pathogen and allergen and can be found in compost at any stage at significant numbers. At no stage can it be assumed that the compost material is completely pathogen-free, so steps to reduce pathogen load, minimise and contain bioaerosols generated or exposure to any bioaerosols need to be followed.

Bioaerosol generation

Bioaerosols will be generated wherever finely chopped biological material is exposed to the air. A review of the composting production processes at the Te Mata Mushrooms Company site indicates the potential for bioaerosols to be produced from the composting process at the following stages:

- filling and emptying of bunkers and loaders (bulk movement and handling of compost or its component materials);
- wetting of baleage with the recycled water prior to shredding;
- the initial shredding and mixing of the baleage, chicken litter and gypsum;
- formation and placement of the Phase 1 compost into static beds;
- formation and placement of the Phase 2 compost into static beds;

- the physical turning of the material in the static pile during the maturation stage;
- the removal and transport of the spent compost from the growing sheds;
- agitation of the recycled water in the pond.

Once generated the bioaerosol can remain suspended for considerable time, from minutes to hours. Bioaerosol concentration reduces the further the distance from the activity generating it due to particle settling and the dilution affect from bulk air movement. Prevailing weather, humidity and wind conditions will affect the dispersement and spread of any bioaerosol.

Susceptible person

Aerosolised particles of less than 5 µm in diameter can be deeply inhaled and behave very similarly to bulk air. Particle deposition patterns are different in healthy lungs compared to diseased lungs due to changes in lung physiology. These differences may play a role in the factors predisposing the immunocompromised and those with underlying lung issues to infections from airborne pathogens suspended in bioaerosols. Pathogen concentration and composition of the bioaerosols and the length of time and frequency that an individual is exposed to the bioaerosol influence the outcome of an exposure event. Particle deposition patterns are different in healthy lungs compared to diseased lungs due to changes in lung physiology.

Approximately 50-60% of domestically-acquired legionellosis cases in New Zealand in any given year have resulted from close exposure to compost material. Infection can result from the inhalation of aerosolised dust from the compost material for distances up to 10 metres from the material.

Review of current knowledge of bioaerosol risks from composting activities

Composting activities result in elevated concentrations of bioaerosols primarily generated during activities where there is a mechanical agitation and movement of the compost material (Taha et al., 2006). Bioaerosol concentrations and emissions are influenced by a number of biotic and abiotic factors (air temperature, relative humidity, wind speed) (Brągoszewska et al., 2017).

The limited number of studies undertaking microbial analysis of aerosols generated at these various stages of compost maturation have either not looked specifically for *Legionella*, or failed to detect it, except for one from Switzerland (Conza *et al*, 2013). The study identified the presence of *Legionella* in both the compost material and bioaerosol samples collected from four composting facilities, indicating the potential of both compost and bioaerosols at composting facilities to be sources of legionellosis. A total of 16.6% (5/47) samples were culture-positive for *Legionella* bacteria. However the bioaerosol sampling was undertaken at five metres from the compost pile and therefore the data cannot be used to predict either bioaerosol behaviour or survival of any suspended microorganisms at distances further from the compost pile.

A more recently published study (Nasir *et al*, 2018) used controlled conditions to generate bioaerosols from compost and then measure the physico-chemical and biological characteristics of the emissions. Although culture methods did not detect the presence of *Legionella* bacteria in either the compost or bioaerosol samples, it was detected in both sources using qPCR methods. Again, although this study's findings again shows the potential of both compost and bioaerosols generated from it to be sources of legionella bacteria, there was no detail on how far *Legionella* can be spread and remain viable.

In the domestic setting, the action of opening compost bags and the emptying of their contents probably pose the most significant risk for transmission of *Legionella,* since these activities have the greatest potential for the production of aerosols from the compost and occur when the user is physically close (less than 1-2 metres) to the compost material. Because *Legionella* is relatively sensitive to drying (Katz & Hammel, 1987), it is unlikely that it is transmitted unassociated with particulate matter, as a free organism. It is more likely to be spread as a vesicle-associated particle emitted from amoebae or attached to the aerosolized dust from the compost.

A national study in the UK that analysed hospital admission data due to respiratory illness for people living or working beyond 250 metres of outdoor composting facilities did not identify any increased risks (Douglas *et al*, 2016).

A systematic review to evaluate the current evidence relating to possible health impacts associated with bioaerosol emissions from composting facilities was limited by the small number of studies, the short time frames under which the studies were carried out, and cross-sectional studies with limited interpretation of causality (Pearson *et al*, 2015). The study concluded that although the evidence base on health effects of bioaerosol emissions from composting facilities is still limited, there is sufficient evidence to support a precautionary approach for regulatory purposes. Bioaerosol concentrations were highest on-site during agitation activities (turning, shredding, and screening). In the systematic review, six studies detected concentrations of either *Aspergillus fumigatus* or total bacteria above the UK Environment Agency's recommended threshold levels beyond 250 m from the composting site. Occupational studies of compost workers suggested elevated risks of respiratory illnesses with higher bioaerosol exposures. Elevated airway irritation was reported in residents near composting sites, but this may have been affected by reporting bias (Pearson *et al*, 2015). An update to the 2015 systematic review made by Pearson *et al* was published in February 2019 (Robertson *et al*., 2019) did not add any significant findings although there was increased use of molecular methods in some studies to describe the microbial populations making up the bioaerosols being generated from the composting sites.

Legionellosis cases attributed to aerosolised spread beyond a composting facility in New Zealand

It is acknowledged that the most likely transmission route for *Legionella* bacteria from compost material to the lungs is via breathing in aerosolised dust generated from the compost. There is a theoretical risk that the aerosolised spread of *Legionella* bacteria from either open windrows or heaped compost piles may travel to persons more than 250 metres from the source, although there is no evidence to either support or refute this scenario. Modelling of aerosolised spread of Legionella bacteria has primarily been carried out using *Legionella pneumophila* in water aerosols, where it has been shown that the *Legionella* can travel long distances (>10 km) and remain viable (Nygard *et al*., 2008).

Although there is a theoretical risk of aerosolised spread of *Legionella* bacteria from compost facilities beyond the immediate area of their physical location (that is, more than 250 metres away), there have been no incidents of legionellosis acquired by this exposure route identified in New Zealand to date.

Legionellosis cases notified in the Hawkes Bay DHB area from 2014 until July 2019

Legionellosis due to compost exposure is usually due to infection with *Legionella longbeachae*. Other pathogenic strains of *Legionella* are also isolated from compost, although less frequently. In New Zealand, legionellosis is a notifiable disease and accurate disease surveillance data is maintained within the EpiSurv database. A review of notified legionellosis cases in the Hawkes Bay DHB area over the last five years shows a total of 16 laboratory-diagnosed cases notified. There has been a significant drop in case numbers over that period from a high of eight cases in 2015, to no cases in 2018 and a single case reported to date in 2019.

Since 2014, 10 of the 16 notified cases report a compost exposure to *Legionella longbeachae*, with five of these having a confirmed exposure from the home use of compost or potting mix and *Legionella longbeachae* being isolated from the implicated compost material. A further three cases have a probable compost exposure due to self-reporting of compost use during the incubation period for the disease, but either no environmental samples were collected for testing or legionellae other than *Legionella longbeachae* were isolated from the compost material.

Source tracing and temporal-spatial analysis of the 16 notified legionellosis cases identified three that resided within a 5 km radius of Te Mata Mushroom Company's premises, and with the closest case residing within two kilometres of the Te Mata Mushroom Company's premises. The source of this case's legionellosis was proven to be due to inadequate control of the home hot water system and could not to be attributed to aerosolised compost material.

Assessment of the potential for bioaerosol generation after implementation of proposed activities				
Process	**Activity**	**Associated risk**	**Potential for bioaerosol generation**	**mitigation**
Bale wetting (Bale spiking)	Injection of recycled water	Recycled water potentially contaminated with Legionella bacteria	low	n/a
Use of recycled water	Water collects into sump and returns to storage reservoir	Recycled water potentially contaminated with Legionella bacteria	low	Aerate storage reservoir to maintain low BOD
Preparation of Phase 1 compost	Moving/dumping premixed chicken litter & gypsum	Chicken liter potentially contains pathogenic enteric bacteria and Legionella bacteria	moderate	Material stored covered
	Bale breaking and mixing with chicken litter/gypsum mix	Aerosol production	high	Carry out under cover using bale breaker machine
	Movement of material by loader or/and conveyer belt	Creation of dust	high	
Phase 1 compost maturation	Compost sitting in bunker	nil	very low	contained in enclosed bunker
				screening of extended eaves
				air extraction to biofilter
Phase 2 compost set up	Movement of material by loader or/and conveyer belt	Creation of dust	high	contained in enclosed bunker
				screening of extended eaves
				air extraction to biofilter
Phase 2 compost maturation	Compost sitting in bunker	nil	very low	contained in enclosed bunker
				screening of extended eaves
				air extraction to biofilter
Mushroom bed set up	Movement of material by loader or/and conveyer belt	Creation of dust	high	contained in enclosed bunker
				screening of extended eaves
				air extraction to biofilter
Mushroom bed dismantle	Movement by loader or/and conveyer belt	Creation of dust	high	
Storage and disposal of spent compost	Movement by loader or/and conveyer belt	Dry material	moderate	stored in covered shed

Assessment of the bioaerosol risk at the Te Mata Mushroom Company site

A desk top assessment of the proposed composting processes at the Te Mata Mushroom Company Brookvale Road, Hastings, as detailed in the submissions to the Hawkes Bay Regional Council did not identify any activity where there would be an increased risk of bioaerosol generation and consequently, an increased risk of legionellosis to either worker or visitors to the Te Mata site or persons at properties neighbouring the site. These have been summarised in the table, above.

The assessment has been based on specialist knowledge of the biology and physiology of *Legionella* and our understanding of the growth and persistence of *Legionella* in complex biological matrices such as compost and recycled water. These include our understanding that:

- Dry baleage does not support the growth of *Legionella*;
- Recycled water at temperatures below 20°C does not encourage the growth of *Legionella* bacteria with any *Legionella* present remaining viable but dormant;
- Green compost does not contain high levels of *Legionella* bacteria;
- The level of *Legionella* bacteria increases with compost maturation;
- Spent compost will have the same potential to contain Legionella bacteria as mature compost.

Activities where there is mechanical agitation and movement of the mature and spent compost (use of conveyors and front end loaders) is likely to be where material is aerosolised. This material is also likely to have the highest microbial concentration, and the highest risk of containing *Legionella* bacteria since mature compost has the potential of containing relatively high levels of *Legionella* bacteria compared to green compost. On balance, when the proposed mitigations as listed in the table above are in place, there is no perceived increased risk of bioaerosol generation or the bioaerosol spread of *Legionella* bacteria beyond the immediate area where the compost material is being used.

Summary of findings

A review of recent literature shows there does not appear to be an increased risk of legionellosis from residing or working more than 250 metres of a composting facility.

A review of EpiSurv data shows there is no evidence of any legionellosis cases that can be traced to the Te Mata Mushroom Company site over the last five years.

The mitigation activities planned or already implemented by the Te Mata Mushroom Company are not expected to increase the risk of the aerosolised spread of Legionella bacteria from the site.

The greatest risk for exposure to pathogenic bacteria (Legionellae and enteric bacteria) would be to workers on site closely involved with the movement and handling of the chicken litter, and the compost material.

There will also be a risk of exposure to aerosolised bacteria from the recycled water used for wetting the baleage.

It is expected that workers will adhere to safe work practices and will wear PPE when undertaking processes that involve the handling or moving of the chicken litter and compost material on site.

Author details

Author: David Harte

Position: Senior Scientist, Health & Environment Group, ESR Ltd

Expertise: 20 years' experience managing and working in the Legionella Reference Laboratory and the Environmental Microbiology Laboratory at ESR.

Contact: Email: David.Harte@esr.cri.nz
Tel: 04 914 0755

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