Mass disposal preparedness for the poultry industries

by Rod Jenner, Angela Scott, Margaret Sexton, Wayne Mossop and Kevin Wilinson
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Foreword

The Australian chicken meat industry is continually investing in research, development and extension of production practices that improve animal welfare, animal health, food safety, product quality and cost effectiveness associated with chicken meat production. The chicken meat and egg industries have mutually recognised that emergency disease mitigation and management is a cross-industry priority, and have invested in developing systems and materials to improve preparedness in the event of an emergency animal disease (EAD) in either of these industries.

This project focusses on developing guidelines and management tools for producers that can be utilised in the formulation of on-farm emergency management plans. Disposal of large volumes of biomass, in the form of carcasses, litter and feed, create significant biosecurity, environmental and logistical issues for those in charge of managing the operation. By undertaking pre-emergency planning and identifying all the options available for a particular property, response time to an EAD can be significantly improved, thus enabling a more rapid business recovery.

Whilst there are a number of options for biomass disposal presented in the Australian Veterinary Emergency Plan (AUSVETPLAN), not all of these are suitable for large scale disposal, as would be the case with most commercial chicken farms in Australia. It was determined that composting and burial are the most viable alternatives for mass disposal in the Australian context. Both of these disposal methods create significant environmental implications. Composting is a technically complicated process requiring expertise and knowledge in order for it to be successful. This project has developed guidelines to assist with understanding and options for creating a viable composting system. Deliverables from this project include a biomass calculation tool and a decision questionnaire, with the outcome of these being a printable disposal report for an individual property. With this report, producers can develop an emergency management plan which incorporates the disposal of biomass in a biosecure and environmentally safe manner.

This project was jointly funded by AgriFutures Australia and Australian Eggs Limited, with generous in-kind support by Primary Industries and Regions South Australia (PIRSA).

This report for the AgriFutures Chicken Meat Program is an addition to AgriFutures Australia’s diverse range of over 2000 research publications and it forms part of our Growing Profitability arena, which aims to enhance the profitability and sustainability of our levied rural industries. Regional communities and the broader Australian economy depend on profitable farms. For the Australian chicken meat industry research, development and extension supports the industry to provide quality wholesome food to the nation.

Most of AgriFutures Australia’s publications are available for viewing, free downloading or purchasing online at: www.agrifutures.com.au.

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Acknowledgments

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### Abbreviations

<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>ABARES</td>
<td>Australian Bureau of Agricultural and Resource Economics and Sciences</td>
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<tr>
<td>ACGC</td>
<td>Australian Chicken Growers Council</td>
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<tr>
<td>AEL</td>
<td>Australian Eggs Ltd</td>
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<td>AHA</td>
<td>Animal Health Australia</td>
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<td>AHC</td>
<td>Animal Health Committee</td>
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<td>AI</td>
<td>avian influenza</td>
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<td>AUSVETPLAN</td>
<td>Australian Veterinary Emergency Plan</td>
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<tr>
<td>BIOMASS</td>
<td>All organic material that may be the subject of disposal</td>
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<tr>
<td>CCEAD</td>
<td>Consultative Committee on Emergency Animal Disease</td>
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<tr>
<td>EAD</td>
<td>emergency animal disease</td>
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<tr>
<td>EADRA</td>
<td>Emergency Animal Disease Response Agreement</td>
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<tr>
<td>EADRDP</td>
<td>Emergency Animal Disease Response Plan</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>GIS</td>
<td>geospatial information system</td>
</tr>
<tr>
<td>HPAI</td>
<td>Highly pathogenic avian influenza</td>
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<tr>
<td>IBDV</td>
<td>infectious bursal disease virus</td>
</tr>
<tr>
<td>MCAS-S</td>
<td>Multi-Criteria Analysis Shell for Spatial Decision Support tool</td>
</tr>
<tr>
<td>NASOP</td>
<td>Nationally Agreed Standard Operating Procedures</td>
</tr>
<tr>
<td>ND</td>
<td>Newcastle disease</td>
</tr>
<tr>
<td>OACVO</td>
<td>Office of the Australian Chief Veterinary Officer</td>
</tr>
<tr>
<td>SOP</td>
<td>standard operating procedure</td>
</tr>
<tr>
<td>vvIBD</td>
<td>very virulent infectious bursal disease virus</td>
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Executive summary

What the report is about

Disposal of infected material is a core component of the process of eradication and recovery from an EAD. Prior planning will make for a much more structured and efficient decision-making process in the event of an EAD.

The Australian Veterinary Emergency Plan (AUSVETPLAN) stipulates the requirements for disposal of carcasses and related infected material for an EAD. Sections 2.1 and 2.2 of AUSVETPLAN Disposal Manual specifically state: ‘Disposal of animal carcasses, materials and equipment (fomites) used in the husbandry of animals, and products and by-products created by the enterprises involved is a major concern in an EAD response… Prior planning should be undertaken by animal health authorities, in conjunction with all stakeholders, including environment protection agencies, local government, and other agencies and service providers (e.g. excavation and transport contractors, waste disposal operators). This is particularly relevant for enterprises with large numbers of livestock…’

The AUSVETPLAN recommendations for preplanning of disposal of animal carcasses, materials, equipment, products and byproducts for an EAD or other mass mortality event that may occur in the poultry industry are yet to be actioned. Australian Eggs and AgriFutures Australia have jointly commissioned a project, with the support of PIRSA, to address industry’s requirement to be actively involved in EAD preplanning. Because it is a cross-jurisdictional undertaking, the project necessarily needs to satisfy the requirements and obligations of a wide range of stakeholders in all tiers of government as well as private businesses.

Who is the report targeted at?

The tools developed out of this project will provide farmers with the means to be able to self-assess their property and develop a report that outlines options available to them to dispose of large volume mass mortalities on or off their property. This preparedness report will also be useful for decision makers to assess disposal options for an EAD, thus increasing the efficiency of the response.

Where are the relevant industries located in Australia?

This report has been written for the chicken meat and egg industries in Australia, but also has relevance for other poultry industries, such as duck and turkey.

Background

The Australian poultry industries have experienced a number of avian influenza (AI) and Newcastle disease (ND) EADs in the recent past. Each outbreak was eradicated by adopting a ‘stamping-out’ policy based on slaughter, disinfection and movement controls, using the AUSVETPLAN as the template for the emergency response.

There is concern among industry experts that EADs will become more prevalent in Australia due to the rapid expansion of free-range poultry production driven by consumer demand. Even though studies have shown that large-scale commercial Australian poultry producers largely understand and abide by good biosecurity practices, there is a higher risk as new, unskilled producers join the industries. It is therefore prudent that ongoing preparedness occurs during peace time. Governments have requested that industry become more proactive in preparing for mass carcass disposal as they recognise that farmers and industry personnel can provide a significant contribution in local knowledge and expertise in outbreak management.
Aims/objectives

A key objective of the project will be to develop tools and resources for processors and farmers to develop individual operational plans to dispose of carcasses, materials, products and byproducts from a farm on- or off-site by providing guidance information and lists of available resources. This will also provide them with the ability to fulfil their on-farm biosecurity obligations under various state biosecurity and environmental legislatures.

Methods used

Stage one of this project was a gap analysis of resources needed for a poultry farmer to prepare a mass disposal management plan. Stage two took the identified gaps and developed tools that can be used to prepare a mass disposal plan as part of a greater enterprise emergency management plan.

Stage one identified that any information and available resources about mass disposal of poultry industry biomass is fragmented, with various gaps in required knowledge. It identified the strong need for the development of emergency disposal plans for individual producers. This requires detailed scoping of local resources available in different regions, and awareness of different EPA considerations across jurisdictions.

Stage two involved collecting and collating resources and tools for producers so they could develop their own mass disposal management tool as part of their emergency management plan. The key output from this information is an online decision questionnaire and biomass calculator that links a property’s geographical information with environmental and biosecurity regulations in order to pre-emptively provide readily available information to stakeholders to prepare for a mass mortality event.

Results/key findings

The general findings of this project have highlighted that while there is significant activity towards EAD preparation with state agriculture departments, there is little coordination between state departments, industry and other key stakeholders in preparing for EAD responses. However, there is widespread support from key parties to develop mass disposal plans.

Governments may prefer on-site disposal due to logistical, resource, biosecurity, cost and other such considerations. Because the Consultative Committee on Emergency Animal Disease (CCEAD) ultimate decides on an EAD disposal method, it is important for producers to be able to provide information on their property’s key parameters, such as water table levels, suitable burial sites, and nearest landfill sites, in the event of an EAD.

Over the last decade, outbreaks of AI in the USA have highlighted the absolute necessity for governments and industries to develop a comprehensive, coordinated response plan that incorporates all components of eradication and resolution.

During the project, it was determined that composting and burial are likely to be the most suitable option for most large-scale poultry producers in Australia. For off-site composting, communication and establishment of relationships with commercial composting facilities during peacetime is recommended to determine the capability to perform large-scale composting in their facilities for an EAD. Rendering and incineration are less likely methods of disposal in poultry in Australia. However, for emergency disposal plans for individual producers, it should still be scoped if large-scale rendering facilities exist in their region. Communication and planning during peacetime is recommended to determine what will happen to the rendered product to avoid it being sent to landfill.

Geographic information systems (GIS) are a strong tool for collecting data and information relevant to a farming enterprise. A significant amount of publicly available data for GIS mapping is held within multiple datasets at Commonwealth and state levels. However, the data cannot be retrieved and collated into a single summary for farm-level analysis. The most appropriate websites for finding the relevant
information for an on-farm mass disposal plan have been identified and provided in the mass disposal preparedness questionnaire that is intended to be available online, along with instructions on navigating around the sites. Unfortunately, drilling down to farm-level data, as would be needed for planning of suitable on-farm disposal options, is not always available. In these instances, the producer might have to contact their local EPA or primary industries office for clarification or more detailed information. After the decision questionnaire tool is completed, a downloadable report will be generated that will, at least, provide significant guidance to producers and decision makers on the characteristics of the disposal site. It will then enable more timely decisions on the site’s suitability and the disposal methods that can be used.

**Recommendations**

In light of the findings of the project, the following recommendations and next steps can advance mass disposal preparedness in the Australian poultry industries further:

- Continue to develop and implement the Decision questionnaire and Biomass calculator tools online for producers on both Australian Eggs and AgriFutures Australia platforms
- Provide extension services to advise stakeholders of the online tools and how to use them
- Develop standard operating procedures (SOPs) for composting and burial that meet the requirements of AUSVETPLAN and NASOP (Nationally Agreed Standard Operating Procedures), administered by Animal Health Australia on behalf of Animal Health Committee, for each state, given the wide disparity of EPA requirements. The literature review and guidelines for composting that have been developed from this project can be used as a framework for the development of state-specific SOPs.
- Produce legally valid Memoranda of Understanding (MOUs) between poultry industry bodies, government agriculture and EPA departments, and private disposal-related service providers, such as composters, landfill operators, and transport operators.
- Progress the collaboration between state government agriculture and EPA departments to develop guidelines for on-farm burial and composting for intensive animal industries across all jurisdictions, as done by QLD (DAF, 2016).
- Work with GIS developers to create a GIS tool that consolidates all data that addresses the AUSVETPLAN and environmental criteria for mass disposal in the Australian poultry industry. At present, this data is dispersed and requires navigation through various GIS tools and websites.
Introduction

AgriFutures Australia has commissioned this project, in conjunction with Australian Eggs and with the support of PIRSA, to address industry’s requirement to be actively involved in EAD preplanning. Because it is a cross-jurisdictional undertaking, the project must satisfy the requirements and obligations of a wide range of stakeholders in all tiers of government as well as private businesses.

Disposal of infected material is a core component of the process of recovery from an EAD or mass livestock mortality event. In the past 30 years, the Australian poultry industries have experienced outbreaks of Newcastle disease (ND) and avian influenza (AI), all of which have been eradicated through slaughter, disposal and decontamination processes, managed under the AUSVETPLAN. Planning will make for a much more structured and time-efficient decision-making process for an EAD.

AUSVETPLAN contains the nationally agreed approach for the response to EAD incidents in Australia. The plan is captured in a series of manuals and supporting documents. The ‘Operational Manual – Disposal’ Version 3.1, 2015 is the document relevant to managing the disposal of infected and suspect infected material in an EAD (Animal Health Australia, 2015).

AUSVETPLAN stipulates the requirements for disposal of carcasses and related infected material for an EAD. Sections 2.1 and 2.2 of AUSVETPLAN specifically state: Disposal of animal carcasses, materials and equipment (fomites) used in the husbandry of animals, and products and by-products created by the enterprises involved is a major concern in an emergency animal disease (EAD) response... Prior planning should be undertaken by animal health authorities, in conjunction with all stakeholders, including environment protection agencies, local government, and other agencies and service providers (e.g. excavation and transport contractors, waste disposal operators). This is particularly relevant for enterprises with large numbers of livestock... (Animal Health Australia, 2015).

The AUSVETPLAN recommendations for preplanning of disposal of animal carcasses, materials, equipment, products and byproducts for an EAD or other mass mortality event that may occur in the chicken meat and egg industries has been actioned by the industries, in part by way of this project. The objectives of this project are to develop the systems and plans that are needed to meet AUSVETPLAN recommendations. It will also provide tools for processors and farmers to fulfil their biosecurity and environmental obligations under various state biosecurity and environmental legislature. In addition, farmers will have the tools to identify the most appropriate disposal methods, either on-farm or off-farm, for a non-emergency mass mortality incident. Supporting material on the correct procedures for composting on-farm are also provided.

Objectives

A key objective of the project will be to develop tools and resources (guidance information and available resources) for processors and farmers to develop individual operational plans for on- or off-site disposal of carcasses, materials, products and byproducts from a farm. This will also provide them with the ability to fulfil their on-farm biosecurity obligations under various state biosecurity and environmental legislatures. The tools that will be developed will be suitable for chicken meat and egg industries, and be suitable for all types of enterprises. Workshops and training programs will be developed to help producers use these tools.

The tools will give farmers the means to be able to self-assess their property and develop a report that outlines available options for disposal of large volume mass mortalities on or off their property. This preparedness report will also be useful for decision makers to assess disposal options for an EAD, thus making the response more efficient.
The project also includes a comprehensive literature review on the composting process and procedures from around the world. There has been a significant amount of research and analysis of composting processes for poultry waste as an outcome of the worldwide avian influenza (AI) outbreaks of the last decade. This literature review brings together all the knowledge gained from these scenarios.

Also from the literature review, standard guidelines for emergency poultry mass mortality composting have been developed. These guidelines form the basis of and are a key tool for investigating the feasibility of on-farm composting as part of an on-farm emergency mass disposal preparedness plan.

Farm disposal represents only a section of the Australian poultry industries. Disposal options from operations, such as chicken processing plants, egg grading floors, hatcheries (Glatz et al., 2011) and feedmills, all have unique characteristics and specific requirements that must be evaluated. These have not been specifically addressed in this report.

**Methodology**

Stage one of this project was a gap analysis of resources needed for a poultry farmer to prepare a mass disposal management plan. Stage two took the identified gaps and developed tools that can be used to prepare a mass disposal plan as part of a greater emergency management plan.

Stage one identified that any information and available resources regarding mass disposal of poultry industry biomass is fragmented, with various gaps in required knowledge. It identified the strong need for the development of emergency disposal plans for individual producers. This requires detailed scoping of local resources available in different regions, and awareness of different EPA considerations across jurisdictions. The specific details on the findings, general discussion and disposal management tools and resources are outlined below.

Stage two involved collecting and collating resources and tools for producers so they could develop their own mass disposal management tool as part of their emergency management plan. The key output from this information is an online decision questionnaire and biomass calculator that links a property’s geospatial information with environmental and biosecurity regulations in order to pre-emptively provide readily available information to stakeholders to prepare for a mass mortality event.
Background

Mass mortality events due to exotic and EADs

The Australian poultry industries have experienced a number of AI and ND EADs in the recent past.


Seven outbreaks of highly pathogenic AI (HPAI) have occurred in poultry in Australia (Scott, 2018):

1. 1976: H7N7 outbreak in Keysborough, VIC
2. 1985: H7N7 outbreak near Bendigo, VIC
3. 1992: H7N3 outbreak near Bendigo, VIC
4. 1994: H7N3 near Lowood, in south-eastern QLD
5. 1997: H7N4 near Tamworth in NSW
6. 2012: H7N7 near Maitland in NSW
7. 2013: H7N2 near Young in NSW.

Each outbreak was eradicated by adopting a ‘stamping-out’ policy based on slaughter, disinfection and movement controls, using the AUSVETPLAN as the template for the emergency response.

In 2018, an incursion of *Salmonella* Enteritidis, which, although it is categorised as a notifiable disease, did not invoke a national slaughter response because no cost sharing agreement was in place. However, as a result of a loss of markets for the eggs, flocks were voluntarily slaughtered, leading to the disposal of hens without the direction of an Emergency Animal Disease Response Plan. Poultry producers were fully responsible for the environmentally safe disposal of their flocks.

Risks of mass mortality events

There is concern among industry experts that EADs will become more prevalent in Australia due to the rapid expansion of free-range poultry production driven by consumer demand (Scott et al., 2017). The increasing popularity of hobby farmers and smaller niche operators that usually have minimal biosecurity knowledge, coupled with the increasing trend towards highly intensive commercial regions, e.g. Port Wakefield in South Australia (SA) and Griffith in NSW, also adds to the possibility of a major EAD incursion. In a survey of more than 1,500 semi-intensive free-range poultry farmers in 2017, biosecurity was found to be suboptimal, with 8 of 10 suggested biosecurity actions implemented by <50% respondents (Scott et al., 2017). The highly intensive commercial regions, in particular, become problematical due to disposal issues related to environmental concerns, urban encroachment and finite resource availability. Even though studies have shown that large-scale commercial Australian poultry producers generally understand and abide by good biosecurity practices (East, 2007; Hamilton et al., 2009), there is an increased risk as new, unskilled producers join the industries. It is therefore prudent to ensure ongoing preparedness during peacetime. Governments have asked industry to become more proactive in preparing for mass carcass disposal because they recognise that farmers and industry personnel can contribute significantly to local knowledge and expertise in outbreak management.

Some of Australia’s poultry industries mass mortality events are not caused by exotic or emergency disease. Natural events, such as drought, bushfires, floods, and breakdown of equipment (power failure, road accident), along with endemic disease outbreaks, have led to unexpected mass flock mortalities.

During an EAD outbreak in the industry, carcass disposal requires a rapid, coordinated response that involves many stakeholders to mitigate and prevent the risk of further spread to neighbouring poultry
enterprises, and to minimise any potential risks to public health or environmental contamination, particularly of groundwater and air pollution. Disposal activities must not exacerbate or further disperse the EAD through subsequent actions. Therefore, responses are coordinated activities involving all affected parties to ensure that national, state, local and industry needs are met. To limit the number of ‘on-the-run’ decisions during an EAD, pre-planning of as many known response activities as possible will contribute to smooth and rapid response times.
Project phases 1 and 2

Initially, the project team completed an extensive literature review and collated historical reports and current project reports. The literature review involved resources drawn from state government SOPs, overseas procedures, and journal articles. Resources were also collected from the SA carcass disposal working group and the Animal Health Committee (AHC)’s 3D task group. Previous work by these groups on disposal of carcasses during a hypothetical foot and mouth disease outbreak in SA were an excellent reference source. The project team also sought input from a composting company and an incinerator supplier.

To investigate the availability and gaps in resources necessary for the development of an on-farm preparedness plan, a hypothetical scenario of an EAD in a highly intensive commercial broiler farming region was created. The scenario was an outbreak of HPAI in the Port Wakefield region of SA, which contains eight farms with about six million chickens within a five-km radius. In the scenario, the decision was made to depopulate all farms within this radius. The calculated total disposal was about 15,000 tonnes of poultry carcasses, and 2,000 tonnes each of poultry litter and feed.

This scenario was presented to the Environmental Protection Agency (EPA), Geographic Information Systems (GIS) specialists at PIRSA and the Australian Chicken Growers Council (ACGC) to gain their insights and knowledge of optimal disposal of carcasses and contaminated material, while keeping in mind the bigger picture and the applicability of this strategy to other regions. While this was only a small representation of the Australian poultry industry, their knowledge and experience was considered to be adequate for this exercise.

A comprehensive demonstration of the tools and resources were publicly available during analysis of options for disposal on-farm. This included the MCAS-S tool (ABARES\(^1\) Multi-Criteria Analysis Shell for Spatial Decision Support – Department of Agriculture and Water Resources) and following on with local (South Australian) resources such as AgInsight SA.

Phase 2 of this project aimed to identify, gather and consolidate all regulatory requirements, and identify any available resources to help producers evaluate opportunities and identify limitations of on-farm disposal options. Other resources are to help producers evaluate off-farm disposal options. Different scenarios could require different responses on the one property, depending on factors such as biosecurity and zoonotic risks, weather, biomass limitations, environmental restrictions, public amenity, equipment and material availability. For this reason, the project has developed a decision questionnaire tool that considers a range of factors relevant to the producer’s situation, and produces a conclusion on a number of disposal options, dependent on the scenario.

Each state has its own laws and regulations relating to disposal of biomass. Because these laws are not consistent between states, it is necessary to take a state-by-state approach.

Composting of carcasses and other potentially infected organic material (collectively called ‘biomass’) is one viable option in many scenarios. However, composting of large volumes of biomass is quite a technical task, and requires specific resources and knowledge in order to get a good result. This was identified as a gap in resources during phase 1 of the project. As a result, Dr Kevin Wilkinson was commissioned to complete a literature review on poultry mortality composting and to develop guidelines for poultry waste composting.

To be able to assess the viability of a site for disposal, by any means, it is important to be able to estimate the weight of material to be disposed of, including any supplementary carbon sources that could be needed for composting. In this context, biomass is any organic material to be disposed of for biosecurity or public discourse reasons. It includes carcasses, litter, manure, feed, contaminated soil, and

\(^1\) Australian Bureau of Agricultural and Resource Economics and Sciences
supplementary carbon for composting. When an estimate of biomass on a property is to be calculated, a worst-case scenario should be used, to achieve a maximum possible biomass weight. This allows for disposal of all materials up to and including the maximum expected.

A biomass calculator has been developed to enable inputting the total weight of organic material on-farm that will be displayed on a simple report. Inputs deemed to be needed for the calculator were evaluated and included if found to have a material impact on the overall biomass for the property. The producer must input some variables that are then incorporated into the decision questionnaire and final property report.

After the property’s biomass has been calculated, it can be matched against a wide range of criteria that govern the options available on a property. Each state has its own set of criteria against which the property’s individual situation must be evaluated (Tables 1 and 3). A decision questionnaire has been developed that allows a producer to assess their property against the criteria for their state. Its interactive design provides answers and directions to websites with relevant information (Appendix A).

Output from this questionnaire is a downloadable report with available options for on-site or off-site disposal of the biomass on the property (Appendix C).
Findings

General

Creating emergency disposal plans for individual producers has been identified as fundamental. This will help ensure a smooth process in disposal of carcasses and infected organic matter quickly and efficiently to minimise spread of disease, as well as lead to fewer future consequences from poor decisions in the past. In the hypothetical HPAI outbreak in Port Wakefield, the gap analysis found that available information and resources were fragmented. At the farm level, there is limited readily available resources for producers to develop on-site disposal plans. Online national mapping and GIS resources are complex and difficult to use, and most producers don’t know they exist. At the industry level, government agencies and industry need to cooperate strongly to produce preparedness plans.

Each state biosecurity authority is actively involved in EAD preparedness within its jurisdiction, but active industry engagement is often not sought. Jurisdictional preparedness is more aligned with large-scale response activities, whereas the activities associated with this project are targeted at on-farm activities, highlighting the segregation of roles and responsibilities between government and private enterprise in an EAD response. State departments could collaborate to ensure policies and procedures are consistent across jurisdictions and to eliminate overlap of projects or discrepancies between guidance documents. The 3D Group (Destruction, Disposal, Decontamination Group, administered by AHC) has a role too, but its clearly defined terms of reference do not address all areas of this project’s scope.

State environmental department policy must be acknowledged as a resource and a key consideration in the decision-making process. For example, QLD Department of Agriculture and Fisheries states it ’may implement a policy whereby carcass and animal byproduct disposal (including contaminated material from infected premises) will occur at purpose-built biosecure, mass burial facilities in preference to ad-hoc, smaller on-site disposal operations occurring on numerous premises in declared areas’ (Queensland DAF, 2016). While the NSW DPI provides an online website of consolidated resources and publications on emergency management, it provides no clear direction for poultry producers in relation to EAD preparedness. There appears to be significant disparity between states when referring to environmental regulatory and licensing requirements for poultry farming. While interstate discrepancies might not affect the individual producer developing preparedness plans, they could affect interstate trade, national response activities and business recovery post-EAD. If an EAD were to cross state borders, there would be discrepancies in the immediate response activities, which can delay and cause confusion during the response.

Identifying and assessing local resources, including staffing, will always be a difficult component of preplanning. Private enterprise, such as composting facilities, landfill sites and transport companies, where needed for an EAD response, rarely have surplus reserve resources available, so can therefore understandably be reluctant to commit to providing resources, which would disrupt their normal business. The potential risk of contamination with exotic or zoonotic infectious agents also contributes to reluctance and possible refusal to provide off-site disposal services and facilities.

Site selection

During preplanning for mass disposal, the first option to be considered is whether disposal is on or off-site. To manage wider disease dissemination risks, on-site disposal is the preferred option. However, it could lead to delays in enterprise recovery until the site can be declared free of the infectious agent involved. Landholders might be reluctant to embrace this option subsequently.

Criteria that must be considered when assessing the suitability of a site for on-site disposal should also be compared with the logistics of conducting off-site disposal. Some properties will not have the option of on-site disposal due to environmental, property, public risk, or other constraints. However, many
properties will be able to develop disposal plans so that the best option at the time considers factors such as weather conditions, outbreak size, and resource availability.

The same factors that relate to selecting the method of disposal would apply for site selection. They are outlined in the AUSVETPLAN Disposal Manual and in Figure 1, below. Table 1 shows the key selection criteria, the resources available to address the criteria, and the associated gaps identified in the site selection decision.

![Diagram of factors affecting disposal methods](image)

**Figure 1: Summary of factors affecting disposal methods (Animal Health Australia, 2015)**
<table>
<thead>
<tr>
<th>Site selection criteria (as per Figure 1)</th>
<th>Resources</th>
<th>Gaps identified</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disease in question</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Zoonotic risk</td>
<td>AUSVETPLAN disease strategies for poultry:</td>
<td>All in various stages of revision</td>
</tr>
<tr>
<td>- Environmental survivability</td>
<td>AI manual dated 2011, under review – draft pending endorsement (Animal Health Australia, 2011a)</td>
<td></td>
</tr>
<tr>
<td>- Transmissibility</td>
<td>NDV manual dated 2014, under review (Animal Health Australia, 2014a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IBD manual dated 2009 (Animal Health Australia, 2011b)</td>
<td></td>
</tr>
<tr>
<td><strong>Legislative requirements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Legislation and guidelines that apply</td>
<td>Western Australia:</td>
<td>Various discrepancies in the legislation between the states. Not all states provide consideration to all key selection criteria.</td>
</tr>
<tr>
<td>- Approvals required</td>
<td>Environmental Protection Regulations 1987</td>
<td></td>
</tr>
<tr>
<td>- Local council considerations</td>
<td>Department of Agriculture and Food – Emergency animal disease Standard operating procedure 2016, Version 1.0.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Composting guidelines (2016), the Department of Environment Regulation. Western Australia.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>South Australia:</strong></td>
<td>Across all states, guidelines unavailable and inconsistent for environmental management of poultry farming, including emergency planning for carcass disposal.</td>
</tr>
<tr>
<td></td>
<td>Environment Protection Act 1993</td>
<td></td>
</tr>
<tr>
<td>Site selection criteria (as per Figure 1)</td>
<td>Resources</td>
<td>Gaps identified</td>
</tr>
<tr>
<td>------------------------------------------</td>
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<tr>
<td></td>
<td>EPA 682/16 <em>On-farm disposal of animal carcasses.</em> Environmental Protection Authority. South Australia</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Composting guideline</em> (2016), the Environmental Protection Authority. South Australia</td>
<td></td>
</tr>
<tr>
<td><strong>Queensland:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Environmental Protection Act 1994</em></td>
<td></td>
</tr>
<tr>
<td><strong>New South Wales:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Protection of the Environment Operations Act 1997</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Disposal of dead stock, New South Wales Department of Primary Industries</em> (2017).</td>
<td></td>
</tr>
<tr>
<td><strong>Victoria:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site selection criteria (as per Figure 1)</td>
<td>Resources</td>
<td>Gaps identified</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------</td>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Environment Protection Act 1970</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Designing, constructing and operating composting facilities</em> (2017). Environment Protection Authority. Victoria</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tasmania:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Environmental Management and Pollution Control Act 1994</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Environmental guidelines for the design and operation of an offal pit for the disposal of slaughter waste</em> (2013). Food and Textiles Unit, Environment Protection Authority. Tasmania</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local By-laws</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian Local Government Association</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Council requirements/considerations about poultry carcass disposal in general not clear or not defined.</td>
<td>Some councils may have prepared guidance on this issue but generally the assessment would be on its merits and considering state-based guidelines.</td>
<td></td>
</tr>
</tbody>
</table>
## Site selection criteria (as per Figure 1)

<table>
<thead>
<tr>
<th>Site characteristics</th>
<th>Resources</th>
<th>Gaps identified</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site characteristics</strong></td>
<td>Various GIS and mapping data across the states, e.g.:</td>
<td>Data is available in various formats, not consolidated, and sometimes missing across the states.</td>
</tr>
<tr>
<td></td>
<td>WA: <a href="https://maps.agric.wa.gov.au/nrm-info/">https://maps.agric.wa.gov.au/nrm-info/</a></td>
<td>National data such as from <a href="http://www.bom.gov.au/">http://www.bom.gov.au/</a> is not as detailed as state websites where various factors to be considered during a poultry mass mortality event are missing.</td>
</tr>
<tr>
<td></td>
<td>QLD: <a href="https://qldglobe.information.qld.gov.au/">https://qldglobe.information.qld.gov.au/</a></td>
<td>Data does not necessarily drill down to farm level, making it less useful as a planning tool.</td>
</tr>
<tr>
<td></td>
<td>TAS: <a href="https://dpipwe.tas.gov.au/">https://dpipwe.tas.gov.au/</a></td>
<td></td>
</tr>
<tr>
<td><strong>Time constraints</strong></td>
<td>Consultative Committee on Emergency Animal Diseases (CCEAD)</td>
<td>Size of outbreak, availability of resources and current weather conditions affect CCEAD decision-making process. These are incorporated into an EADRP and are outside the scope of this project.</td>
</tr>
<tr>
<td><strong>Speed of disposal required</strong></td>
<td>Biosecurity Queensland composting SOP:</td>
<td>No Australian SOPs validated or approved for use nationally.</td>
</tr>
<tr>
<td></td>
<td><em>Standard Operating Procedure Composting of Birds (2012)</em></td>
<td>Overseas information is available but untested in Australian conditions.</td>
</tr>
<tr>
<td>Site selection criteria (as per Figure 1)</td>
<td>Resources</td>
<td>Gaps identified</td>
</tr>
<tr>
<td>------------------------------------------</td>
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</tr>
</tbody>
</table>
| **Volumes and types of materials required** | Draft SOP exists for NSW and VIC, respectively:  
*The biosecurity of mass poultry mortality composting* (Wilkinson et al., 2014) | No clarity on approval processes for SOPs. |
| • Carbon content, size of carcasses  
• Biosecurity risk  
• Compostability | | |
| **Availability of local resources** | Composters  
Australian Organics Recycling Association | Local composters can be reluctant to accept infected material; unknown capacity of commercial facilities to deal with mass volumes (and also biosecurity risk). |
| • Personnel skilled in constructing compost windrows, burial pits, pyres or incineration pits  
• Machinery and other equipment  
• Carbon material for composting and incineration | Renderers  
Australian Renderers Association | Local renderers have limited capacity to deal with large volumes in narrow time frame. |
| | Landfill sites  
Waste Management and Resource Recovery Association Australia | Not defined if commercial landfills that are approved arrangement sites would be willing to accept waste resulting from an outbreak. Licence conditions would need to |
<table>
<thead>
<tr>
<th>Site selection criteria (as per Figure 1)</th>
<th>Resources</th>
<th>Gaps identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Landfill Owners Association</td>
<td>be exempted for extraordinary events in some instances. No MOU in place</td>
<td></td>
</tr>
<tr>
<td>Incineration</td>
<td>Commercial incinerators have low capacity, but some are licensed to dispose of quarantine material. Lack of trained personnel to perform on-farm incineration. Large fuel requirements to perform on-farm incineration.</td>
<td></td>
</tr>
<tr>
<td>Worker Health and Safety</td>
<td>Risk assessments are conducted at the time and place of an EAD to consider the immediate scenario. Outside the scope of this project.</td>
<td></td>
</tr>
<tr>
<td>Transport availability – on-site, off-site</td>
<td>Availability of transport operators to dispose of large amounts of infected carcasses would need to be determined at the time of an event.</td>
<td></td>
</tr>
<tr>
<td>Site selection criteria (as per Figure 1)</td>
<td>Resources</td>
<td>Gaps identified</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Published literature</td>
<td>Routes to be taken to prevent spread of disease; consider farm to road distances</td>
</tr>
<tr>
<td></td>
<td>Government literature</td>
<td></td>
</tr>
<tr>
<td><strong>Cost considerations</strong></td>
<td>CCEAD (Consultative Committee on Emergency Animal Disease)</td>
<td>Considered by CCEAD at the time of the event. Outside the scope of this project.</td>
</tr>
<tr>
<td><strong>Industry considerations</strong></td>
<td>Poultry industry standards and agreements</td>
<td>Proprietary company differences or company concerns about disposal methods would need to be considered.</td>
</tr>
<tr>
<td></td>
<td>Australian Chicken Meat Federation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Australian Eggs Ltd</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual poultry company policies</td>
<td></td>
</tr>
<tr>
<td><strong>Social considerations</strong></td>
<td>Local community engagement</td>
<td>Impact on local amenity would need consideration during planning; no guidelines exist.</td>
</tr>
<tr>
<td><strong>Local and international communities</strong></td>
<td>Feedback from past outbreaks in Australia and internationally</td>
<td></td>
</tr>
</tbody>
</table>
Method of disposal decision

Detailed review of the disposal methods used the AUSVETPLAN Disposal Manual as the guiding document and discussion of the scenario in Phase 1. Composting and burial were found to be the most likely methods of disposal for large-scale commercial poultry operations in Australia in a mass mortality event. Other disposal methods, such as rendering and incineration, have not been discounted, but were less likely due to problems in previous disposals. They could be options for smaller-scale scenarios with smaller volumes of biomass. For all methods, whether the disposal is on- or off-farm must be decided, which involves considerations from the EPA, local councils and availability of local resources.

The various methods of disposal of carcasses as listed in the AUSVETPLAN disposal method are outlined in Figure 2. For the vast majority of disease outbreaks in poultry in Australia, anaerobic digestion, ocean disposal, refeeding, and alkaline hydrolysis would be impractical, too costly, difficult to execute, and limited by available resources. ‘Destroy and let lie’ was considered if resources were completely overwhelmed, potentially in an extensive outbreak affecting multiple jurisdictions.

Therefore, the most practical and likely disposal methods are:

- Composting
- Burial/landfill
- Rendering
- Incineration.

All poultry disease outbreaks in Australia have involved at least one of these disposal methods.

Figure 2: Methods of disposal of carcasses (Animal Health Australia, 2015)

As listed in Table 1, site selection criteria are dependent on the method of disposal options. The options available for particular sites must be quickly scoped, with the chosen method satisfying as many factors as possible. The following subsection details the issues and gaps in the written procedures, EPA considerations and available local resources for the four disposal options.
Composting

Written procedures

Draft SOPs from NSW Department of Primary Industries in 2008, the Victorian Department of Primary Industry (Wilkinson et al., 2014) and QLD DAF (Cooper, 2012) have not been endorsed at a national level and are not entirely consistent in their methodologies. The *AUSVETPLAN Disposal Manual* provides a general overview of the composting procedure and outlines various factors to be considered.

Methods used in the USA have been documented (Flory GA et al., 2006; USDA Composting Technical Committee, 2016; USDA Composting Technical Committee, 2017). However, these guidelines are designed to manage the AI virus, and do not refer to other diseases, such as very virulent infectious bursal disease (vvIBD), which is a much harder virus than AI in the environment (Eterradossi & Saif, 2008). The earlier report (Wilkinson et al., 2014) used ND as the study virus. It has been demonstrated that composting can deactivate IBD virus (Guan et al., 2010) by reaching a temperature of 55°C for 8.8 days over a 14-day period. Any development of SOPs for EAD disposal should incorporate these parameters. Novel and unique methods of carcass composting are being reported regularly, and may have merit in certain circumstances (Glanville et al., 2006).

For Australian poultry disposal, Wilkinson’s composting guidelines have been developed in conjunction with this report and are provided in Chapter 5.

EPA considerations and site selection

Each state’s legislation has differing limits on the amount of material to be composted on a site that triggers a requirement to have an EPA licence and be categorised as a scheduled premise. The Acts contain a clause that refers to the ability to grant exemptions of licences in emergencies, if required. Various guidelines on the location and distances of where compost works should be built are also available from state environmental departments, except QLD and TAS. The compost limits and guidelines are listed in Table 2.
<table>
<thead>
<tr>
<th>Relevant state legislation</th>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composting limits</strong></td>
<td>1000 tonnes per year</td>
<td>200 tonnes per year</td>
<td>200 tonnes of organic material in a year.</td>
<td>200 tonnes of organics on-site at any one time (2000 tonnes for facilities outside regulated area); or,</td>
<td>1800 tonnes of material per year or, accept more than 100 tonnes of organic waste in any month, or accept more than 70 tonnes of organic waste in a month and produce more than 50 tonnes of compost in any month (the latter 2 factors have exemptions if premises retain the processed waste on the premises).</td>
<td>100 tonnes per year excluding backyard composting for domestic use; on-farm composting for use on agricultural land having the same owner as the land on which the compost is produced; and works in respect of silage for use on agricultural land.</td>
</tr>
<tr>
<td>Note: Does not include—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) manufacturing mushroom growing substrate; or</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) the composting of organic material from agriculture or livestock production if the organic material is either—</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(i) composted at the site where it was produced; or</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(ii) transported to another site, where agriculture or livestock production</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>SA</td>
<td>QLD</td>
<td>NSW</td>
<td>VIC</td>
<td>TAS</td>
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</tr>
<tr>
<td>Is carried out, and composted at that site</td>
<td></td>
<td></td>
<td>Resource recovery framework in this instance would be at the responsibility of the commercial composter.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevant guidelines for the site location of composting works</td>
<td>Composting guidelines (2016) of the Department of Environment Regulation, Western Australia</td>
<td>Composting guideline (2016) of the Environmental Protection Authority, South Australia</td>
<td>No suitable guidelines on compost site location found.</td>
<td>EIS Guideline: Composting and Related Facilities (1996). NSW Department of Urban Affairs and Planning.</td>
<td>Designing, constructing and operating composting facilities (2017). Environment Protection Authority, Victoria</td>
<td></td>
</tr>
<tr>
<td>Specific location information for composting extracted from the guidelines</td>
<td>The minimum distance from the composting facility must be: 3 m (vertical separation) from the base of any infrastructure to the</td>
<td>Composting should be avoided in areas with the following properties:</td>
<td></td>
<td>Composting facilities should not be situated on land liable to flooding and should be sited at least 100 metres from surface waters. It provides guidance on separation distances</td>
<td>No suitable guidelines on compost site location found.</td>
<td></td>
</tr>
</tbody>
</table>

Compost in the definition of the composting orders and exemptions does not include animal carcasses but the same process would apply.

Specific location information for composting:

- **Composting** should be avoided in areas with the following properties:
  - Sites located within an area of significant environmental or conservation value identified under

Composting facilities should not be situated on land liable to flooding and should be sited at least 100 metres from surface waters. It provides guidance on separation distances.
<table>
<thead>
<tr>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>highest historic water level</td>
<td>1,000 m to land that is for sensitive use</td>
<td>Relevant legislation or a planning instrument</td>
<td></td>
<td></td>
<td>depending on the type and size of material being composted.</td>
</tr>
<tr>
<td>1,000 m from wetland of conservation value</td>
<td>Within the floodplain known as the 1956 River Murray Floodplain or any floodplain subject to flooding that occurs, on average, more than one in every 100 years</td>
<td>Sites within an identified drinking water catchment (surface water or groundwater)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 m from watercourse, drain (surface or subsurface), or wetland</td>
<td>Within the floodplain known as the 1956 River Murray Floodplain or any floodplain subject to flooding that occurs, on average, more than one in every 100 years</td>
<td>Sites located in an area overlying an aquifer which contains drinking water quality groundwater which is vulnerable to pollution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 m from high-water mark of estuaries</td>
<td>Within the Mount Lofty Ranges Water Protection Area and the South East Water Protection Area as declared under Part 8 of the EP Act</td>
<td>Sites where the substrata are prone to land slip or subsidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 m from public drinking water source well/bore and surface water sources that supply drinking water</td>
<td>Within 100 m of a bank of a major watercourse (e.g. Murray, Torrens and Onkaparinga Rivers), or within 500 m of a high-water mark.</td>
<td>Sites on floodplains which may be subject to washout during major flood events.</td>
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</tbody>
</table>
Availability of local resources

Discussions with local commercial composters identified a likely gap with on-farm composting – the lack of skilled personnel to construct and monitor the windrows, as well as a lack of machinery. Some commercial composting sites could instead accept carcasses in an EAD. Availability of equipment and skilled personnel to construct the compost windrows are the main advantages of sending carcasses to a commercial composter. Training in biosecurity is an identified gap for the compost workers. Also, some poultry farmers currently perform small-scale on-site composting for their mortalities, but the same limitations apply to training in biosecurity and composting to eliminate pathogens. The need for transport is the main disadvantage in sending to commercial composting sites but the capacity could be available through other livestock vehicles or from commercial composters and poultry companies. When purpose-built vehicles are not available, sealed shipping containers to transport and store carcasses is a viable option. Again, training in biosecurity is an identified gap for the truck drivers, and directions on routes to take to minimise aerosol spread to other farms will have to be discussed.

For carbon material, the required amounts should be available at commercial composting sites. Floor-based poultry farms have a ready source of carbon in the form of floor litter; however, environmental considerations must be evaluated, including leaching, odour, and groundwater contamination (Kelleher et al., 2002). Local carbon sources will need to be received for on-farm composting. These can include plant material where, for example, local tree mulchers can be contracted to make the carbon available. Availability and willingness to supply must be determined because this carbon source already has a market. Biochar as a suitable carbon source appears to have ideal properties (Steiner et al., 2011), but reliable availability must be determined.

Burial

Written procedures

In the AUSVETPLAN Disposal Manual, the overview of burial processes includes trench burial, commercial landfill, mass burial, and mounding. Other factors to be considered during the decision process include cost comparisons, especially for building burial pits on-farm or sending carcasses to a commercial landfill.

EPA considerations and site selection

For all states, there are no formal guidelines for on-farm mass burial of intensive livestock operations. In WA and QLD, this information is available from agricultural departments in collaboration with their respective environment departments. South Australia and VIC offer guidance on small-scale burial of dead stock after bushfires. Specifically, this information is not intended for mass burials. Tasmania provides no information on on-farm burial of livestock, but has guidelines on the operation of an offal pit to dispose of slaughter waste. For this project, this guidance in the form of SOPs, factsheets, and guidelines across the states has been extracted to address the site selection criteria of the AUSVETPLAN Disposal Manual (Table 3).

The ND outbreaks in the Mangrove Mountain region of NSW in the late 1990s has had ongoing issues associated with the burial many poultry carcasses, where the groundwater is still monitored for contamination from the leachate of the carcasses (NSW Department of Primary Industries, 2017).
Table 3: Site selection criteria of the *AUSVETPLAN Disposal Manual* addressed by the relevant state legislation and guidelines for on-farm burial.

<table>
<thead>
<tr>
<th>Site selection criteria</th>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximity to drinking water supply</strong></td>
<td>- At least 2 m separation from bottom of proposed pit to groundwater level</td>
<td>- The site should be at least 500 m from the nearest bore.</td>
<td>The site will not be within 10 km of a town water supply intake; the site will not be within 300 m of a borehole used for drinking water.</td>
<td>- At least 200 m from any surface water (creek, river, lake, spring, dam)</td>
<td>- Greater than 200 m from any groundwater supply (stock and domestic bore)</td>
<td>At least 100 m separation distance from the pit to bores</td>
</tr>
<tr>
<td></td>
<td>- Located at least 200 m from surface waters and groundwater supply bores</td>
<td></td>
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</tr>
<tr>
<td><strong>Proximity to human habitation</strong></td>
<td>- Located at least 300 m from a dwelling (sensitive use)</td>
<td>- The site should be at least 500 m from the nearest residential building.</td>
<td>The site will be more than 2 km from a town. The site will be more than 1 km from any dwelling.</td>
<td>- Greater than 300 m from any sensitive use (such as a neighbouring house)</td>
<td>- Well away from the view of the general public.</td>
<td>At least 500 m separation distance from the pit to neighbours</td>
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<tr>
<td><strong>Soil characteristics</strong></td>
<td>- Located in soil type of low permeability (avoid highly permeable sands,</td>
<td>- Soils with clay subsoil are most suitable for burial trenches or</td>
<td>The site will be located on soil of low permeability and good stability</td>
<td>On heavier soil of low permeability and good stability</td>
<td>- On heavier soil of low permeability and good stability</td>
<td>The pit must be located on a site that has deep, fine-textured soils (such as</td>
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22
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<thead>
<tr>
<th>Site selection criteria</th>
<th>WA</th>
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</thead>
<tbody>
<tr>
<td>Topsoil assessment</td>
<td>gravels, substrata, Karst geology)</td>
<td>composting areas. Soils with high leaching properties (sand, gravelly or rocky soils) are to be avoided where possible.</td>
<td>permeability and good stability</td>
<td>- Cover the carcasses with at least 2 m of soil</td>
<td>- Slightly mound pits after backfilling to allow for subsidence and promote runoff rather than infiltration</td>
<td>clay and silt) with underlying geology that has low risk for groundwater contamination.</td>
</tr>
<tr>
<td>Subsoils assessment</td>
<td>- Using available mapping or local knowledge, locate test sites in areas of gravelly and loamy soils in upper 30% of landscape where expected subsoil depth is minimum of 5 m</td>
<td>- The ideal profile is white sandy clays to a depth of target (plus 1 m)</td>
<td>- At least 2 m separation from bottom of proposed pit to groundwater level</td>
<td>- At least 200 m from any groundwater supply (stock and domestic bore)</td>
<td>- The base of the trench should be at least 2 m above the water table.</td>
<td>- The deepest point of the pit must maintain a minimum height of 1.5 m above groundwater at peak level.</td>
</tr>
<tr>
<td>Groundwater depth</td>
<td>- Located at least 200 m from surface waters and</td>
<td>- The base of the trench should be at least 2 m above the water table.</td>
<td>Groundwater depth at the site will be at least 5 m from the bottom of the pit, i.e. minimum 5 m pit plus 5 m buffer = 10 m surface to groundwater level</td>
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<tr>
<td>Site selection criteria</td>
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</tr>
<tr>
<td>Proximity to surface water</td>
<td>groundwater supply bores</td>
<td>- Disposal sites should be at least 500 m from defined depressions, watercourses and surface water catchments (such as streams, rivers, creek beds and wetlands).</td>
<td>- The site will be more than 500 m from any watercourse.</td>
<td>- The site will be outside known flood zones.</td>
<td>Above the one in 100 year flood level</td>
<td>- At least 2 m from the bottom of pit to the water table level</td>
</tr>
<tr>
<td>Proximity to coast</td>
<td>The site will be more than 2 km from the coast.</td>
<td></td>
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<td>At least 200 m separation distance from the pit to water courses</td>
</tr>
<tr>
<td>Proximity to protected and other areas</td>
<td>- Located at least 300 m from a dwelling (sensitive use)</td>
<td>- Not specified. As per SA Environment Protection (Waste to Resources) Policy 2010 under the Environment Protection Act 1993 (see comments) “in a manner that (does not) results in site contamination or an environmental nuisance”</td>
<td>- The site will not be within 1 km of a World Heritage Area.</td>
<td>- The site will not be within 250 m of a national park or conservation area of Indigenous cultural site.</td>
<td>- Greater than 300 m from any sensitive use (such as a national park)</td>
<td>- At least 300 m from any sensitive use (e.g. a neighbouring house)</td>
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<td></td>
<td>- Located safe working distance from underground infrastructure (power, telephone, gas, water, sewerage)</td>
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<td>- a safe distance from underground and above-ground infrastructure (such as a power lines, telephone lines, gas lines, water pipes, sewerage)</td>
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<td></td>
<td>- Located away from public view</td>
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<td></td>
<td>- Not located in a flood-prone area, i.e. &gt; 1 in 100 years flood level</td>
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<td></td>
<td>- Complementary to native flora and fauna planning controls, i.e.</td>
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<tr>
<td>Site selection criteria</td>
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<tr>
<td>significant wetlands, tidal areas, wildlife habitats</td>
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<tr>
<td>- Complementary to heritage overlays, native title and other covenants</td>
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<tr>
<td>- Complementary to any other regulatory requirements</td>
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<tr>
<td>Site accessibility</td>
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<tr>
<td>- Not located in areas subject to instability, i.e., susceptible to landslip or excessive erosion, geological fault</td>
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<tr>
<td>- Preferably on elevated land with moderate slope (less than 5%)</td>
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<tr>
<td>Preferred sites:</td>
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<tr>
<td>- Areas free of exposed granitic rocks (shallow depth, waterlogging, recharge)</td>
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<tr>
<td>Site terrain</td>
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<tr>
<td>- Not specified.</td>
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<tr>
<td>- The site should be free of underground services (pipelines, power and telephone lines) and should not interfere with access to roads.</td>
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<tr>
<td>- The site should be accessible to earthmoving plant, stock and operators. Soils must be stable enough to take the weight of equipment used to construct and fill trenches.</td>
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<tr>
<td>- The site will be accessible to multiple large trucks and earthmoving equipment, allowing unhindered entry-exit and space for decontamination of vehicles and large machinery</td>
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<tr>
<td>- The site will be more than 250 m from underground and aboveground infrastructure (such as a powerline, telephone line, gas line, water pipes, sewerage)</td>
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<tr>
<td>- The site will be on elevated land but with a slope of less than 5%.</td>
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<tr>
<td>Site terrain</td>
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<tr>
<td>- Where necessary, excavate cut-off drains upslope of the burial pits to direct surface runoff away from the pits</td>
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<tr>
<td>- Where possible, plan destruction activities close to burial site</td>
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<tr>
<td>- Have good, safe access to site for machinery</td>
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<tr>
<td>Stock access to the pit area must be prevented by a stock exclusion fence or other means.</td>
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<tr>
<td>- A record and site plan must be kept showing areas where offal pits have been established.</td>
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<tr>
<td>- The pit must be located to reduce...</td>
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<tr>
<td>Site selection criteria</td>
<td>WA</td>
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<tr>
<td>- Elevated locations on erosional lateritic surfaces (deep soils of low permeability)</td>
<td></td>
<td>As per SA Environment Protection (Waste to Resources) Policy 2010 under the Environment Protection Act 1993 (see comments)</td>
<td>a slope of less than 6% (3.50) (preferably less than 2%) (1.150))</td>
<td>than 5% (preferably less than 2%)</td>
<td>than 5% (preferably less than 2%)</td>
<td>surface runoff draining toward the pit. Cut-off drains must be dug around the pit to prevent surface runoff from entering the pit.</td>
</tr>
<tr>
<td>- Convex landforms, no drainage lines (prevention of erosion and waterlogging)</td>
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<tr>
<td>- Near remnant vegetation (dry soils, erosion protection, soil biologic activity)</td>
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<td></td>
<td>“in a matter that does (not) cause or has potential to cause unstable geotechnical conditions”</td>
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<tr>
<td>- Remote from housing (own, neighbours)</td>
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<tr>
<td>- Remote from water supplies (dams, bores, soak, creeks, saline areas)</td>
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<tr>
<td>- Proximity to tracks and laneways (access)</td>
<td></td>
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</tr>
</tbody>
</table>

**References**

- Department of Agriculture and Food – Emergency animal disease Standard operating procedures, Western Australia
- EPA 682/16 On-farm disposal of animal carcasses, Environmental Protection Authority, South Australia
- Guidance Document – Establishing a mass burial facility for disposal of carcasses and material contaminated with an infectious emergency
- Disposing of deceased stock, New South Wales Department of Primary Industries (2017)
- Waste management (2017), Agriculture Victoria
- Environmental guidelines for the design and operation of an offal pit for the disposal of slaughter waste (2013), Food and textiles Unit
<table>
<thead>
<tr>
<th>Site selection criteria</th>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>animal disease agent</em> (2016). Department of Agriculture and Fisheries. Queensland.²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Environment Protection Authority. Tasmania³</td>
</tr>
</tbody>
</table>

² Contact Biosecurity Queensland office for a copy.
³ Contact the EPA Tasmania for a copy.
Availability of local resources

The Australian Government Department of Agriculture and Water Resources is the approval body where post-entry quarantine activities and treatments may be performed. There are listed sites that have approved arrangements for deep burial in all states except NSW (Table 4). Although these arrangements are in place, a site may not necessarily accept material. As with composting, variables relating to transport are likely to be the major limiting factors when sending carcasses to commercial landfill operations.

Because some poultry operations bury normal mortalities on-farm, the skills and equipment for creating burial pits exists to some degree. If on-site burial is pursued, these skills must be refined to include training in biosecurity, to create pits for mass burial; extra equipment may also be needed. Engineering and technical support would likely need to be sought from commercial landfill companies.

On-farm burial is an unlikely option for regions with shallow groundwater depth and current prohibition of burial for normal mortalities by the local council. Other poultry regions cannot bury normal mortalities on-farm because specialised machinery – rock-breakers – are needed to dig pits in the ground.

Incineration

The AUSVETPLAN Disposal Manual provides an overview of disposal via incineration, including pyre construction and air curtain incinerators. Phase 1 of this project determined that on-farm incineration was an unlikely disposal method for large-scale mass mortalities in the Australian poultry industries and, therefore, was not explored in detail by all states.

EPA considerations and site selection

During the Mangrove Mountain outbreaks in NSW in the late 1990s, open-air incineration was reported to have created a convection current, with hot air rising from the incineration heaps and carrying unburned fomites onto neighbouring poultry farms, thus potentially spreading the outbreak.

The SA Environment Protection (Air Quality) Policy 2016 lists requirements for incineration outside of commercial incinerators for the disposal of agricultural or forestry waste. Incineration inside metropolitan Adelaide and townships requires council approval (by individual permit or general notice published in a newspaper). No permit is needed for incineration outside metropolitan Adelaide and townships. However, where relevant, incineration is to be conducted in accordance with the SA Country Fire Services (CFS) Broad Acre Incineration Code of Practice for 2015. This code can declare days of total fire bans and, in this case, incineration is not permitted unless a permit is issued under the Fire and Emergency Services Act 2005.

Availability of local resources

In SA, one commercial incinerator, Veolia, is licensed by the Environment Protection Authority (EPA) to receive and incinerate chemical, medical, veterinary and quarantine wastes only.

The Department of Agriculture also lists commercial incinerators that have approved arrangements to deal with waste in a biosecure manner. These are present in all states except WA and TAS (Table 4). The capacity of the commercial incinerator in SA is low at about 15 tonnes per day. Therefore, it would not be able to deal with the hypothetical outbreak alone.
Chicken carcasses are difficult to burn because they contain relatively high volumes of water. Air curtain incinerators require large amounts of dry timber or coal to maintain sufficient heat, and are also quite slow and inadequate to accommodate large volumes of waste. One commercial incinerator that was investigated needed the equivalent of double the weight of timber to carcass weight, e.g. burning 700 tonnes of poultry needs 1400 tonnes of timber. Another form of incinerator uses diesel fuel, but as the primary fuel source, diesel generates high levels of benzene, therefore the generated ash has to go to landfill or some other treatment facility. These types of incinerator are in limited supply and are generally only small scale, with a capacity of up to 4 tonnes/day. While some states have gas-fired incinerators, they are generally of limited capacity and availability, so are useful for only small-scale disposal.
Table 4: Burial and incineration sites with approved arrangements with the Australian Government Department of Agriculture, Water and the Environment to deal with waste in a biosecure manner.

<table>
<thead>
<tr>
<th>Burial or incineration facility</th>
<th>Registered name</th>
<th>Trading name</th>
<th>Address</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burial</td>
<td>City of Darwin</td>
<td>Shoal Bay Waste Management Facility</td>
<td>Shoal Bay Access Road Karama NT 0812</td>
<td>NT</td>
</tr>
<tr>
<td>Burial</td>
<td>Veolia Environmental Services (Australia) Pty Ltd</td>
<td>Ti Tree Bioenergy</td>
<td>Champions Way Willowbank QLD 4306</td>
<td>QLD</td>
</tr>
<tr>
<td>Burial</td>
<td>FGF Developments Pty Ltd and Remondis Australia Pty Ltd</td>
<td>Springmount Waste Management Facility</td>
<td>Lot 123 Springmount Road, Arriga QLD 4880</td>
<td>QLD</td>
</tr>
<tr>
<td>Burial</td>
<td>Acquista Investments Pty Ltd and Veolia Environmental Services (Australia) Pty Ltd</td>
<td>Integrated Waste Services</td>
<td>Port Wakefield Road, Lower Light SA 5501</td>
<td>SA</td>
</tr>
<tr>
<td>Burial</td>
<td>Waste Management Pacific (SA) Pty Ltd</td>
<td>Transpacific Waste Management</td>
<td>Primes Road Inkerman SA 5550</td>
<td>SA</td>
</tr>
<tr>
<td>Burial</td>
<td>Southern Waste Resource Co Pty Ltd</td>
<td></td>
<td>Lot 2605 Main South Road, McLaren Vale SA 5171</td>
<td>SA</td>
</tr>
<tr>
<td>Burial</td>
<td>Copping Refuse Disposal Site Joint Authority</td>
<td>Southern Waste Solutions</td>
<td>Blue Hills Road and Fazackerleys Road Copping TAS 7174</td>
<td>TAS</td>
</tr>
<tr>
<td>Burial</td>
<td>Suez Recycling and Recovery Pty Ltd</td>
<td>Sita Environmental Services</td>
<td>274 Hallam Road Hampton Park VIC 3976</td>
<td>VIC</td>
</tr>
<tr>
<td>Burial</td>
<td>Hanson Landfill Services Pty Ltd</td>
<td></td>
<td>55 Bridge Inn Road Wollert VIC 3750</td>
<td>VIC</td>
</tr>
<tr>
<td>Burial</td>
<td>Landfill Operations Pty Ltd</td>
<td></td>
<td>1100-1152 Christies Road Ravenhall VIC 3023</td>
<td>VIC</td>
</tr>
<tr>
<td>Burial</td>
<td>City of Cockburn</td>
<td></td>
<td>920 Rockingham Road Henderson WA 6166</td>
<td>WA</td>
</tr>
<tr>
<td>Burial</td>
<td>Shire of Esperance</td>
<td></td>
<td>77 Windich Street Esperance WA 6450</td>
<td>WA</td>
</tr>
<tr>
<td>Burial</td>
<td>City of Rockingham</td>
<td></td>
<td>Lot 2170 Millar Road West</td>
<td>WA</td>
</tr>
</tbody>
</table>
Approved arrangements, previously Quarantine Approved Premises and Compliance Agreements, are voluntary arrangements entered into with the Department of Agriculture, Water and the Environment. These arrangements allow operators to manage biosecurity risks and/or perform the documentary assessment of goods in accordance with departmental requirements, using their own sites, facilities, equipment and people, and without constant supervision by the department and with occasional compliance monitoring or auditing. Sites do not need to have this prior arrangement before disposal occurring at the site, and those with approved arrangements are not under any obligation to accept disposal material.
Rendering

The Australian Renderers Association Inc indicated that the capacity of rendering plants to deal with mass mortality events is unlikely to be possible at short notice. The Association indicated that most rendering plants work at full capacity and have started to no longer accept rendering of mortalities. Due to export markets, rendering plants may also not want to process material infected with disease. Rendering was used in the 2014 HPAI outbreak in Young, NSW. However, the processed material was subsequently not accepted anywhere as a commercial product, possibly due to fear of the product’s sterility from infectious agents, and therefore the material was ultimately sent to a commercial landfill. The Australian Standard for the Hygienic Rendering of Animal Products AS 5008-2007⁴, which is not legislated in every jurisdiction, does not specify that the heat treatment must meet requirements for destruction of exotic disease pathogens, therefore would not be an acceptable alternative for the disposal of infected carcasses in those circumstances.

Poultry mortality composting – a literature review

Summary

Composting is a natural biological decomposition process that takes place under aerobic, thermophilic conditions (i.e. >45°C). It can be used for the routine (day-to-day) management of mortalities on farms and for carcass disposal in EAD outbreaks. In routine mortality composting systems, carcasses are placed in piles or bins with supplemental carbon sources, such as sawdust, litter, straw or wood shavings. In EAD outbreaks, composting can be either inside or outside the poultry shed after euthanasia. In-shed mass mortality composting is particularly effective because containment of the carcasses inside the poultry shed minimises the spread of the virus by minimising transmission pathways such as via aerosols and vehicle movements.

Composting is a well-established pathogen-reduction technology that is widely applied in urban and agricultural organic waste treatment. It is known to control almost all pathogenic viruses, bacteria, fungi, protozoa (including cysts) and helminth ova to acceptably low levels. Exceptions are the endospore-forming bacteria (e.g. *Bacillus anthracis* and *Clostridium botulinum*) and prions, such as bovine spongiform encephalopathy. Multiple mechanisms are known to be involved in the inactivation of pathogens during composting, such as exposure to heat, microbial antagonism (including antibiotic production and direct parasitism), production of organic acids and ammonia, and competition for nutrients. Temperature, considered the most important factor in pathogen inactivation, is relatively easy to measure during composting.

Temperatures above 55°C within a few days of setup can be readily achieved when mass mortality composting piles are constructed. During pile or windrow (an elongated pile) construction, poultry carcasses are usually layered between, or mixed with, poultry litter and a supplementary carbon source, such as sawdust. This is then covered with a thick blanket of clean carbon source so that the carcasses are completely encased. High temperatures speed up the decomposition process and kill pathogens. After about 2-3 weeks of composting, temperatures might start to decline but there should be little evidence of carcass remaining within the pile. At this point, the compost is turned to promote mixing and aeration so that the second stage of high temperature composting can begin. Over the course of a few weeks, more windrow turnings ensure that, as far as possible, all compost particles are exposed to high temperature composting.

Research has consistently shown that mortality composting effectively destroys avian viruses. For example, recent work in Australia has shown that a vaccine strain of Newcastle disease virus (NDV V4) was unlikely to survive more than 24 hours composting. As part of that project, the researchers monitored 18 separate poultry mass-mortality composting windrows using different combinations of co-compost (poultry litter and other carbon sources) along with two different approaches to windrow construction. The inactivation kinetics of NDV V4 were found to be closely correlated with the length of exposure to temperatures in the range 25–45°C over the first three days of composting.

Although there is growing confidence about the merits of composting for emergency disposal of poultry carcasses, questions remain about the cost-effectiveness of composting for other disposal methods. For example, a lot of supplementary carbon material is typically needed to be brought in
for the compost mix and to fully encapsulate the pile. Getting access to sufficient carbon material, personnel and equipment is a major challenge during EAD outbreaks. Knowing this, researchers from Iowa and Maine (USA) examined more efficient approaches to preparing mixes. Their findings suggest that the use size reduction and mixing equipment reduces requirements for labour, supplementary carbon and other equipment compared to the traditional approach (i.e. mixing with a loader). The researchers also suggest that the use of mixers and size-reduction equipment could shorten the composting cycle enough to reduce the economic impact on affected farms.

Besides reviewing the international scientific literature, this review also covered Australian guidelines for poultry mortality composting. Though there are numerous references to composting as an option for the disposal of poultry mortalities in Australia, the coverage of the topic is typically superficial because it is usually a component of a much larger subject (e.g. environmental management or code of practice). These guidelines are also not necessarily consistent, and jurisdiction over on-farm composting can be confusing.

For standard operating procedures (SOPs), we found only a few examples from QLD, NSW and VIC, as well as a more detailed guideline from the USDA called the ‘Livestock Mortality Protocol’. These SOPs/protocols all have different formats and do not necessarily agree on the details.

Finally, areas of further work were recommended, including:

- Harmonise SOPs for emergency and routine (non-emergency) management of poultry mortalities and other poultry wastes
- Develop and implement an adoption strategy to promote these SOPs in industry and government biosecurity agencies
- Conduct large-scale simulations of mass poultry mortality composting with the participation of industry and government agencies
- Investigate the availability of expertise, equipment, and carbon sources etc. in each region to facilitate a rapid response to emergency disease outbreaks
- Further research to make the mortality composting process as biosecure and economically feasible as possible, speeding up the process, making more efficient use of carbon sources and labour etc.
- Further research on biosecurity of poultry waste composting could focus on controlling infectious bursal disease virus (IBDV), infectious laryngotracheitis (ILT) and Clostridium botulinum. IBDV is less thermotolerant than most other avian viruses and could be a good surrogate for validation of the poultry mortality composting process. ILT outbreaks are relatively common and the virus is easily transmitted through infected litter. C. botulinum is a bacterial spore-forming pathogen that should be studied for the biosecurity of routine poultry mortality composting systems.

Introduction

Composting is a natural biological decomposition process that takes place under aerobic, thermophilic conditions. It can be used for the day-to-day management of mortalities on farms and for carcass disposal in EAD outbreaks. In mortality composting, carcasses are placed in piles or bins with supplemental carbon sources, such as sawdust, litter, straw or wood shavings. Composting is particularly suitable for broiler-farm mortalities and litter.

In EAD outbreaks, composting can be conducted either inside or outside the poultry shed after euthanasia (Kalbasi et al., 2005; Mukhtar et al., 2004). According to Flory & Peer (2010), in-shed composting offers important advantages for eradicating highly pathogenic avian influenza (HPAI)
viruses: containment of the carcasses inside the poultry shed minimises the spread of the virus by minimising transmission pathways, such as via aerosols and vehicle movements. In addition, composting minimises human exposure by reducing the number of people needed to complete the job by at least 50%. Their experience in handling outbreaks in Virginia and West Virginia, USA, in 2007 demonstrated that in-shed windrows could be built by as few as two equipment operators and a labourer, compared to the seven or eight needed for a landfilling operation for the same size poultry facility.

**Conventional vs mortality composting**

**Conventional composting systems**

In conventional composting systems, raw materials are mixed to form a pile of relatively uniform nutrient content, particle size, porosity and moisture content. Mesophilic microorganisms\(^5\) first use the readily degradable substrates, such as sugars, starch and proteins. If the pile is of sufficient volume (usually >1 m\(^3\)), temperatures rise rapidly (above 45°C). The materials may be turned every few days to move the cooler outside layers into the centre of the pile, and to allow air to move more freely into the pile. In other systems, air is forced into the pile by a thermostatically controlled fan.

- This first stage of composting (6–12 weeks duration), characterised by high temperatures (45–65°C) and rapid decomposition rates, is usually termed the thermophilic stage or period of ‘intensive decomposition’ (Haug, 1993). These conditions eliminate nuisance odours and destroy pathogens and weed seeds. During this stage, substrates such as fats, hemicellulose and cellulose are degraded.

- As the composting process proceeds and the availability of substrate become more limiting, temperatures begin to fall. This second stage of composting (lasting for 4+ weeks), called the maturation or curing phase, takes place under mesophilic conditions (under 45°C). It is characterised by lower rates of biological decomposition under which aeration is no longer a limiting factor. During this stage, the biologically resistant substrates, such as lignocellulose and lignin, are degraded. The maturation phase has a large bearing on the suitability of the end product for a particular use (Brewer & Sullivan, 2003); (Wilkinson et al., 2009).

Many authors have defined various optimums for the composting process, including a carbon-to-nitrogen ratio (C:N) of between 25:1 and 30:1, moisture content in the range of 50–60% (w/w), porosity\(^6\) of 35–45%, and oxygen levels of >10% by volume (Table 5). But these optimums were developed for relatively homogenous organic materials, such as manures, green waste, food wastes and biosolids, and have questionable relevance to mortality composting.

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\(^5\) Organisms that grow at moderate temperatures, i.e. between about 20°C and 45°C.

\(^6\) Porosity is a measure of the void space in a compost pile (i.e. the free air space between particles, or pores).
Table 5. Desirable characteristics for composting (modified from Keener et al., 2006; Northeast Regional Agricultural Engineering Service, 1992).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Optimum</th>
<th>Reasonable Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon to Nitrogen Range (C:N)</td>
<td>25-30:1</td>
<td>20-40:1</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>50-60% (wet basis)</td>
<td>40-60% (wet basis)</td>
</tr>
<tr>
<td>Porosity</td>
<td>35-45%</td>
<td>30-50%</td>
</tr>
<tr>
<td>Oxygen concentration</td>
<td>&gt;10%</td>
<td>&gt;5%</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>&lt;640 kg/m³</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.5-8.0</td>
<td>5.5-9.0</td>
</tr>
</tbody>
</table>

Livestock mortality composting systems

In contrast, a livestock mortality composting pile is a heterogenous mixture, so strict application of the principles discussed above is not possible. A mortality composting pile contains animal carcasses, having a high moisture content, low C:N ratio and almost zero porosity, which is surrounded by a material (the carbon source) with a high C:N ratio, moderate moisture level and good porosity (Keener & Elwell, 2000).

Kalbasi et al. (2005) aptly described mortality composting as the above-ground burial of dead animals in a mound of supplemental carbon, such as sawdust, litter, straw or wood shavings. Sufficient supplemental carbon is needed around carcasses to absorb bodily fluids and to prevent odours from escaping from the pile.

The decomposition process is initially anaerobic in and around the carcass layer, but as odorous gases are produced and diffuse, they enter an aerobic zone where they are degraded to CO₂ and water (Keener et al., 2000). In contrast to conventional composting systems, temperatures in mortality composting are initially higher in the outer aerobic layers of the pile than in the interior (Figure 3). Oxygen diffuses only slowly into the interior of the pile as the carcass layer degrades, resulting in a delay of two to three days before thermophilic conditions are reached.
Mortality composting is generally conducted in three stages.

- In the primary stage, the pile is left undisturbed as soft tissue decomposes and bones partially soften.
- The compost is usually then moved, turned or mixed to begin the secondary stage, during which the remaining materials (the remaining meat and bones) break down further.
- The composting process is completed during a curing or storage phase.

Some bones of large mature animals may remain after completion of the secondary and/or storage stages of composting, but they are usually quite brittle, they pose no health risk and will not damage farm equipment when applied to land (Keener et al., 2006; Mukhtar et al., 2003). Nevertheless, Murphy, D. & Carr (1991) observed that the moisture content of a composting pile has a major bearing on the decomposition rate of bones from cattle mortalities. If the pile is allowed to dry out, bones become very hard and appear to cease decomposition. Continued decomposition is achieved by wetting the pile each month for about six to nine months.

The time to completion of composting varies with the size of the animal, the compost formulation (e.g. type of carbon (C) sources used) and management of the pile (e.g. mixing, turning and watering). As a general rule, the first stage is complete in as little as 10 days for small animals, such as poultry, about 90 days for medium-sized animals, such as pigs, and over six months for large carcasses (Mukhtar et al., 2004).

**Mortality composting system design and layout**

**Main systems**

In the USA, mortality composting began in the poultry industry in the early 1980s and soon spread to other industries; it has also been used for roadkill. The basic forms of mortality composting are in bins, piles/windrows, or in vessels.

**Bin composting**

Bin composting is usually conducted in a three-sided enclosure on a hard stand (e.g. concrete or compacted soil). It may or may not be covered by a roof, though a roof is usually advisable. Examples are available online for purpose-built constructions with concrete floors, roofs, and wood or concrete sidewalls (Figure 4). In their simplest form, the walls can be constructed of hay bales or any material that can adequately confine the composting pile (Mukhtar et al., 2003). Simple bins can also be built from pallets or wood and plastic mesh. They are sometimes termed ‘mini-composters’ and are suitable for small animals, such as poultry, rabbits, piglets and fish (Brodie & Carr, 1997).
At least three bins are usually in operation at any one time: one being filled, another in the primary stages of composting, and the other in the secondary stages. A pile is sometimes substituted for the secondary bin in two-bin systems (Keener, 2000). As a general guide, 10 m³ of bin space is required for every 1,000 kg of carcass (Mukhtar et al., 2004).

**Pile composting**

Piles for mortality composting are usually constructed in the open on a hard stand. When a concrete pad is not available, a plastic or geotextile liner placed under windrows as a moisture barrier is recommended. Access to the pile from all sides should be possible, and the pile is shaped to shed rainfall. Windrows are formed by continually extending the length of the pile by adding more mortalities and supplemental carbon. The length of the windrow is determined by loading rates and site layout. Mukhtar et al. (2004) described the recommended dimensions of windrows according to the relative sizes of carcasses:

- Small carcasses (<23 kg): bottom width, 3.6 m; top width, 1.5 m; and height, 1.8 m.
- Medium carcasses (23–114 kg): bottom width, 3.9 m; top width, 0.3 m; height, 1.8 m.
- Large and very large carcasses (>114 kg): bottom width, 4.5 m; top width, 0.3 m; height, 2.1 m.

New poultry operations in the USA frequently build mortality composting facilities along the side of a manure shed (Figure 5). The roofline is simply extended to create a channel down one side of the shed. Piles of compost can then be constructed under it using the manure that is stored in the main shed adjacent to it.
In-vessel composting

In-vessel composting systems have also been used for composting carcasses. These systems enclose composting materials in a sealed chamber or vessel where environmental parameters, such as temperature and aeration, can be better controlled than in a pile or windrow. Examples include rotary composters, the BiobiN™ and the Ag-Bag® in-vessel system. The BiobiN™ system is offered as a contracted service to the poultry industry in Australia. Bins of up to 9 m³ in size are delivered to the poultry facility and, when full, are transported to a licensed composting facility to complete composting. The BiobiN™ is a fully enclosed system with forced aeration, and a biofilter to control odours and leachate. The Ag-Bag® in-vessel system was used for the disposal of one million avian influenza (AI)-negative birds during an EAD outbreak in British Columbia in 2004 (Spencer, L et al., 2005). The poultry carcasses and C source were mixed together and pushed into the Ag-Bag®. In 2002, the Ag-Bag® composting system was also used to dispose of 43,000 birds in the low-pathogenic avian influenza (LPAI) outbreak in Virginia, USA. The Ag-Bag® system uses an LDPE recyclable plastic ‘sock’ into which the compost raw materials are pushed via a hopper and hydraulic ram (Figure 6). Aeration is supplied by fan through plastic pipes at the base of the compost.
Site selection and layout

The following general principles apply to site selection and layout for on-farm composting of mortalities (Keener et al., 2006; Mukhtar et al., 2004):

- The site should be in an elevated area of low permeability, at least 1–2 m above the water table and not within 100 m of surface waters (e.g. streams, lakes, wells).
- The site should have an adequate slope (1–3%) to allow proper drainage of leachate and to prevent pooling of water.
- Consideration should be given to prevailing winds and the proximity of neighbours to minimise problems associated with odour and dust.
- Runoff from the compost (e.g. from a 25-year, 24-hour rainfall event) should be collected and directed away from production areas, and treated through a vegetative filter strip or infiltration area.
- The site should have all-weather access and minimum interference from other traffic.
- Maintaining an effective cover of carbon (C) source over compost piles is usually sufficient to eliminate scavenging animals and vermin. But animals will dig into piles when they know mortalities are there, so fencing should be installed around piles and bins to minimise this problem.

Poultry mortality composting construction in detail

Carbon sources

A wide range of C sources can be used for mortality composting, including sawdust, wood shavings, green waste, chopped straw, manure, poultry litter, and other bedding materials. The three most important properties that influence the performance of different C sources in mortality composting are available energy (biodegradability), porosity, and moisture absorbency.

Sawdust is probably the most common C source used for mortality composting: it is highly absorbent, allows high temperatures to be sustained, and sheds rainwater when used for uncovered piles. Rice hulls, where available, are also a common C source in Australia. According to Imbeah (1998), C sources, such as sawdust and rice hulls, are ideal for mortality composting because their particle size allows them to settle intimately around the carcass to provide optimum contact.

Researchers rarely identify the type of C source beyond the generic term ‘sawdust’ even though the biodegradability of sawdust between timber species can differ by a factor of more than 10. Data from Allison (1965) showed that hardwoods had significantly higher biodegradability than softwoods, but there was considerable variation between various species, especially in the softwood family.

The absorbency of different types of bedding materials is also known to differ greatly (Burn & Mason, 2005; Misselbrook & Powell, 2005). In general, softwood sawdust is more absorbent than hardwood sawdust. The absorbency of a C source will influence the depth of the base layer needed to absorb liquids during composting, as well as the performance of the outer layers as a biofilter. Coarsely structured C sources, such as wood shavings or wood chips, are more likely to present problems with odour, leachate, and vector attraction (King et al., 2005).
In evaluating the suitability of various C sources for mass poultry mortality composting, Wilkinson et al. (2014) found that green waste, sawdust, and shavings all performed satisfactorily. However, windrows constructed with green waste were typically 5–8°C hotter than either shavings or sawdust in the first six days of composting. This is likely because green waste was already composting when it was added to the mix. Another notable issue was greater fly activity around windrows built with shavings, probably because the higher porosity of shavings could cause more malodours to escape from piles (Wilkinson et al., 2014).

In practice, a wide range of C sources can be successfully used in mortality composting. The choice of material is likely to be based on cost, availability, and performance. It is commonly advised to incorporate up to 50% of finished compost into the base and cover C sources (Kalbasi et al., 2005; Keener et al., 2006; Mukhtar et al., 2004). The recycling of finished compost in this manner reduces the purchase cost of raw materials, speeds up the initiation of composting conditions, and reduces the space needed to store finished compost. To facilitate faster rates of decomposition, some researchers recommend that carcasses should be added to C sources that are actively composting or those that have an ideal C:N ratio for composting (Kalbasi et al., 2005; King et al., 2005). The inclusion of too much finished compost in the initial mixture sometimes reduces decomposition rates because of a lack of available energy in the compost or less porosity in the final mix (Keener et al., 2006) (Murphy, J. et al., 2004).

**Determining requirement for carbon**

Recommendations differ on the amount of carbon needed to compost mortalities. These include:

- A 12:1 sawdust-to-mortality volume ratio for all types of mortality (Keener, 2000)
- A carcass: straw: manure volume ratio for poultry of 1:0–1.2:4–8 (Natural Resources Conservation Service, 2001)
- A 2:1 C source-to-mortality volume ratio for poultry, not including the requirement for base layer and capping (Tablante & Malone, 2005).

The requirement for C can be estimated for composting all types of mortalities in either bins or static piles/windrows when the annual mass of mortality is known. The annual sawdust requirement in m³/yr, Vs, is calculated by:

\[ Vs = YL \times 0.0116 \]

where YL is the yearly mortality loss in kg/yr (Keener, 2000). This equation gives the total annual requirement, but up to 50% of it can be met by replacing fresh sawdust with finished compost.

**Bin composting**

A base of sawdust or other suitable C source of 20–30 cm thickness should be placed on the floor of the bin to collect liquids released during composting. Mukhtar et al. (2004) suggested that the ideal base layer is preheated litter, put in place about two days before carcasses are added. Carcasses can be layered within the bin with about 15–30 cm of absorbent bulking material (e.g. litter or sawdust) placed between each layer of mortalities. Mortalities must not be placed within 20–30 cm of the sides, front or rear of the bin. A final cover of damp sawdust or litter to a depth of about 45–60 cm should be placed on the top of the pile (Figure 7). This final cover acts as a biofilter for odour control and to insulate the heap. When the cover material is too dry or too wet, odours can be released, and scavenging animals could be attracted to the pile (Keener et al., 2006).
Figure 7. Typical layout of a mortality composting bin for small animals (adapted from Keener et al., 2006; Tablante et al., 2005).

The pile is moved to a secondary bin when the last layer of mortalities is almost completely decomposed. To ensure that the pile reheats, it is watered and remixed. An extra 10 cm of co-composting cover material is added to ensure that any remaining carcass pieces are covered, and odours are minimised. When more animals are to be added to a partially filled bin, half of the cover material is removed, and a new layer of animals is placed on top. The new layer is then covered with 60 cm of damp C source.

Pile or windrow composting

Mukhtar et al. (2004) suggested that a base layer of C source should be 30 cm thick for small carcasses (e.g. poultry), 45 cm for medium carcasses (e.g. pigs), and 60 cm for large carcasses (e.g. horses and cattle). An ideal base layer for this purpose has been described as absorbent organic material containing sizeable pieces 10–15 cm long, such as wood chips (Bonhotal et al., 2002). Another layer (15–30 cm thick) of highly porous, pack-resistant bulking material can be added on top of the base layer to absorb moisture from the carcasses and to maintain adequate porosity. The dimensions of these base materials must be large enough to accommodate the mortalities with >30 cm space around the edges.

An evenly spaced layer of mortalities can then be placed on top and covered with 30–60 cm of C source. Some guidelines recommend the use of a dry cover (Bonhotal et al., 2002) whereas others claim a moist C source reduces odours and helps to break down bones (Keener et al., 2000; Murphy, J. et al., 2004).

Poultry carcasses can be layered in windrows with at least 30 cm of C source between each layer until the windrow reaches a height of about 1.8 m.

González & Sánchez (2005) found that in static piles of poultry mortalities, straw, and hen manure, there was some influence of ambient temperatures and different mixes on the progress of composting. In summer, the carcasses were exposed to temperatures above 60°C for 4–20 days, depending on the mix used. In winter, peak temperatures were lower, but still exceeded 55°C in each pile.
**Mass poultry mortality composting**

The use of mortality composting as the main method of carcass disposal on a mass-scale (known as mass mortality composting) is probably likely only for small- to medium-sized carcasses. Until recently, most mass mortality composting was conducted after catastrophic events, such as poultry flock losses due to heat stress or herbicide contamination (Malone, 2004). However, it is now increasingly being used to successfully manage the disposal of carcasses in EAD outbreaks, particularly in North America.

Composting is particularly suitable for the emergency management of broiler-farm mortalities and poultry litter. Composting can be conducted inside and outside the poultry shed after euthanasia. More litter, sawdust or other C sources can be delivered to the farm when the volume of litter in the poultry shed is insufficient to complete the composting process. As a general rule, 4–5 mm of litter is needed per kg of carcass per m² of shed floor space (Tablante et al., 2005).

Poultry carcasses can be layered in windrows using essentially the same procedure as described above for the routine management of mortalities. A skid-steer loader is used to layer carcasses in a windrow with dimensions of 3–4 m at the base, and up to 1.8 m high. Each layer of mortality should be no deeper than 25 cm, with 15–20 cm of litter/sawdust between each layer. The final windrow is capped with 15–20 cm of litter/sawdust to ensure all carcasses are covered. Each layer of birds is moistened with water at a rate of 1 L/kg of carcass (Tablante et al., 2002).

Alternatively, birds can be mixed and piled up together with the available C source. First, the birds are spread evenly across the centre of the shed. The carcasses are rolled up together with litter to form windrows 3–4 m wide at the base. The litter from along the sidewalls (or extra supply of C, if needed) is then used to cap the windrows (15–20 cm thick). Experience in the USA has shown that this method involves the least time, labour, and materials.

Wilkinson et al. (2014) reported on research investigating the feasibility of mass poultry mortality composting in Australia. In one of their experiments, the performance of the two main methods of windrow construction (‘mixing’ and ‘layering’ methods described above) was compared using a range of bedding materials as co-composting materials (poultry litter, sawdust, wood shavings and green waste). The mixing method involved the construction of windrows directly from a 1:2 mix (by volume) of carcass and co-composting material (e.g. poultry litter plus sawdust). For the layering method, windrows were constructed with alternate layers of carcass, poultry litter, and other co-composting material. Both types of windrows were built on an absorbent base-layer of co-composting material (25–30 cm deep) and both were capped with more co-composting material (20 cm deep). The windrows were left undisturbed for 2–3 weeks while composting took place.

The windrows prepared using the mixing method performed a little better than those prepared using the layering method (Wilkinson et al., 2014). In the first stage of composting, average windrow temperatures were 4–5°C higher in the mixed windrows than in the layered windrows from the second day onward (Figure 8). They also found that carcass decomposition was more advanced at turning, ‘presumably because there was better contact between carcass and co-composting materials in the mixed windrows’.

Nevertheless, the researchers noted that both mixing and layering performed satisfactorily in their study, and that both methods have succeeded in EAD outbreaks in North America.

Wilkinson et al. (2014) also found that all co-composting ingredients performed well during composting. The differences they observed in temperature development were evident only during
the first 6–8 days of composting. Green waste was initially 5–8°C hotter than either shavings or sawdust during this time, probably because it was already composting when added to the mix (Figure 9).

Figure 8. Temperature development during mass poultry mortality composting in mixed and layered windrows. Windrows were turned for the first time at the start of ‘Stage 2 composting’. (Wilkinson et al., 2014)

Figure 9. Mean daily windrow temperatures in windrows constructed with green waste, sawdust or shavings during the first 17 days of composting. (Wilkinson et al., 2014)

Reports from Australia and overseas consistently show that temperatures above 55°C are usually reached within five days of windrow construction. When temperatures begin to decline after 2–3 weeks, the windrows can either be turned inside the poultry shed, or reformed outside. If windrows are moved outside, it is best practice to cover them with a breathable film (e.g. such as geofabric). After turning, windrows are capped again with litter or other C source to a minimum depth of 10
cm. After an extra 2–3 weeks, the compost can be applied to land with the approval of the relevant authorities.

Managing environmental and public health impacts

Improper carcass disposal may cause serious environmental and public health hazards, including:

- Nuisance odour from the anaerobic breakdown of carcasses
- Leaching of nutrients from carcasses to groundwater and surface water
- Spread of pathogens from infected carcasses via equipment, personnel, air, soil, or water
- Flies, vermin and scavengers disrupting operations and acting as potential vectors of harmful diseases.

Many of these potential hazards are managed by paying careful attention to site design and layout. The biological risks associated with mortality composting are principally managed by proficient operation of the composting process.

Glanville et al. (2006) investigated the environmental impact of cattle carcass composting. Trials were conducted in 6 m x 5.5 m x 2.1 m windrow-type test units containing four 450 kg cattle carcasses on a 60 cm thick base layer of C source, which included corn silage, ground cornstalks or ground straw mixed with feedlot manure.

During the first 4–5 weeks after construction, air samples were collected each week from the surface of the test units and compared with stockpiles of cover materials (i.e. not containing mortalities). Threshold odour levels were determined by olfactometry using experienced odour panelists and standard dilution procedures. It was found that 45–60 cm of cover material was generally effective at retaining odorous gases produced during composting. Threshold odour values for the composting test units were often similar to the odour intensities found in the cover material stockpiles.

Chemical analysis of the leachate collected in PVC sampling tubes installed at the base of the test units showed that it had high pollution potential (Glanville et al., 2006). The leachate had mean ammonia concentrations of 2,000–4,000 mg/L, total organic C of 7,000–20,000 mg/L, and total solids of 12,000–50,000 mg/L. Nevertheless, the base and cover materials were highly effective at retaining and evaporating liquids released during composting as well as that contributed by seasonal rain. Following a 5-month monitoring period after the setup of the trial, the test units received almost 546 mm of rain yet released less than 9 mm of leachate each.

Wilkinson et al. (2014) also tried to collect leachate from the base of windrows being used to simulate mass poultry mortality composting. Their experiments used a 25–30 cm base layer of C source. Though 18 windrows were monitored, less than 30 mL of leachate was recovered in total. Although leachate volumes were low, individual samples had high nutrient concentrations. Total nitrogen content varied from 48–3,500 mg/L, ammonium from 48–3,500 mg/L, phosphorus <4–49 mg/L, and potassium 6–8,500 mg/L.

In Nova Scotia, Rogers et al. (2005) investigated the environmental impacts of composting pigs in sawdust and pig litter (manure plus bedding). Leachate and surface runoff were collected and analysed for various water quality parameters. Highest temperatures and better carcass decomposition were observed with sawdust in both the primary and secondary stages of composting. Compared to the pig litter treatments, the sawdust cover also had lower leachate and surface runoff volumes, and annual nutrient loadings.
Finished mortality compost should be applied to land in a manner similar to manure so that the nutrient uptake capabilities of the crop being grown is not exceeded.

Poultry mortality compost often has a higher nutrient content than other composts, probably because of the high nutrient content of poultry litter. During composting, much of the available nitrogen is converted to organic forms and becomes unavailable to plants in the short term.

Murphy, D. et al. (1991), for example, demonstrated much slower rates of N mineralisation in loamy sand amended with poultry mortality composts compared to manure. Thus, there is a lower risk of nutrient leaching with compost than with uncomposted manures and mortalities. Nevertheless, it is advisable to not spread mortality compost in sensitive areas, such as watercourses, gullies and public roads.

**Improving process efficiency**

The typical structure of a mortality composting windrow is heterogeneous, which increases the challenge of ensuring that all compost particles are subjected to lethal conditions sufficient to kill pathogens. Diseased carcasses must be formed into windrows as quickly as possible but, on the other hand, a hastily prepared mix can undermine biosecurity, delay the progress of composting, and increase costs associated with the use of composting in emergencies.

In North America, confidence appears to be growing about the merits of composting for emergency disposal of poultry, but questions remain about its cost-effectiveness compared to other disposal methods. For example, a lot of C-material is typically needed for the compost mix itself (i.e. that which is blended with the carcasses) and to fully encapsulate the pile. Getting access to sufficient C-material, personnel and equipment is a major challenge during EAD outbreaks. Therefore, some researchers in the USA have examined ways to improve the efficiency of composting in emergencies while still ensuring that the process remains biosecure.

For example, Keaten and Hutchinson (2017) found that feed mixer wagons (Figure 10) were an effective and economical means of preparing chicken mortality composting mixes. The hire of this type of equipment was largely offset by lower labour needs, C source, and other equipment compared to the traditional layering approach (Table 6). While their study was a simulation of mass mortality composting using a small-scale mixing system, they suggested that tub grinders could also be used in real outbreaks (Figure 11). These findings were supported by real-life experience from an EAD outbreak in Iowa. The researchers also suggested that the use of mixers and size-reduction equipment could shorten the composting cycle enough to reduce the economic impact on affected farms (it is unclear, though, by how much).

The benefits of shredding or crushing larger birds, such as turkeys, has also been examined. Bendfeldt et al. (2005) demonstrated that temperatures above 60°C were achieved within five days in windrows constructed with crushed or shredded turkeys, and 16 days for whole carcasses. In addition, they reported that to compost crushed or shredded carcasses, 30% less C material was needed compared to whole carcasses. Windrows formed from crushed or shredded carcasses also do not need more water to be added.
Table 6. Economic estimates for ‘conventional layering’ (CL) and mixer wagon methods for mass mortality composting of layer hens (Keaten et al., 2017).

<table>
<thead>
<tr>
<th>Methodology Used</th>
<th>Cost per 200,000 birds</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No manure</td>
<td>Low</td>
<td>High*</td>
</tr>
<tr>
<td></td>
<td>With manure</td>
<td>Low</td>
<td>High*</td>
</tr>
<tr>
<td>Mixer wagon method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days without manure, 3 days with manure (10 hrs/day) per 200,000 birds</td>
<td>$2,500</td>
<td>$3,750</td>
<td>$4,688</td>
</tr>
<tr>
<td>5 yard(^3) wheel loader making base/cap ($125/h)</td>
<td>$2,500</td>
<td>$3,750</td>
<td>$4,688</td>
</tr>
<tr>
<td>5 yard(^3) wheel loader adding birds, carbon, manure to mixer ($125/h)</td>
<td>$3,600</td>
<td>$4,500</td>
<td>$5,400</td>
</tr>
<tr>
<td>1 tractor with mixer ($180/h)</td>
<td>$3,600</td>
<td>$4,500</td>
<td>$5,400</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 laborer on the ground ($20/h)</td>
<td>$400</td>
<td>$600</td>
<td>$750</td>
</tr>
<tr>
<td>1 foreman ($40/h)</td>
<td>$800</td>
<td>$1,200</td>
<td>$1,500</td>
</tr>
<tr>
<td>Carbon material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600-1180 yard(^3) ($9-16/yard(^3))</td>
<td>$5,400</td>
<td>$9,600</td>
<td>$10,620</td>
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<tr>
<td>Total cost</td>
<td>$15,200</td>
<td>$21,850</td>
<td>$25,320</td>
</tr>
<tr>
<td>CL method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 days (10 h/day) per 200,000 birds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment (fuel, equipment, operator included)</td>
<td>$3,500</td>
<td>$4,375</td>
<td>$4,375</td>
</tr>
<tr>
<td>1 track skid loader making base/cap ($100/h)</td>
<td>$3,500</td>
<td>$4,375</td>
<td>$4,375</td>
</tr>
<tr>
<td>1 track skid loader layering carbon/litter ($100/h)</td>
<td>$3,500</td>
<td>$4,375</td>
<td>$4,375</td>
</tr>
<tr>
<td>1 track skid loader layering birds ($100/h)</td>
<td>$3,500</td>
<td>$4,375</td>
<td>$4,375</td>
</tr>
<tr>
<td>1 track skid loader layering manure ($100/h)</td>
<td>$3,500</td>
<td>$4,375</td>
<td>$4,375</td>
</tr>
<tr>
<td>Labor</td>
<td>$800</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>2 laborers on the ground ($20/h)</td>
<td>$800</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>Carbon material</td>
<td>$8,100</td>
<td>$14,400</td>
<td>$16,200</td>
</tr>
<tr>
<td>Total cost</td>
<td>$20,200</td>
<td>$29,525</td>
<td>$31,800</td>
</tr>
</tbody>
</table>

Based on recorded times and carbon amounts for each method during simulation experiments, as well as costs gleaned from HPAI outbreaks in the USA. *High estimate is 1.25 times the low end to allow for changes in supply and demand. Note: 1 yard\(^3\) = 0.76 m\(^3\)

Similarly, Flory et al. (2010) found that crushing turkeys before windrow formation raised temperatures by increasing the exposure of carcasses to composting conditions and by enhancing the release and distribution body fluids throughout the compost mix. Compared to shredding, crushing also reduced the equipment necessary for in-shed composting and eliminated the difficult process of cleaning and disinfecting the tiller.
Improvements to the process can also be made to the second stage of composting. At this point, the compost is handled more like a conventional windrow by turning and mixing. While most experience to date with mass mortality composting has involved the use of front-end loaders and large skid-steers for turning and mixing, the use of a dedicated ‘windrow turner’ shows some promise. Windrow turners are commonplace in conventional composting systems (Figure 12). They enhance composting by improving aeration, particle-size reduction, and mixing. When used in mortality composting, windrow turners can help achieve higher internal temperatures (3°C to 6°C). Flory et al. (2010) found that a large tractor-mounted turner completely mixed and aerated one windrow comprised of turkeys such that three weeks later, the only visible evidence of carcasses was leg bones, quills, and a few feathers; no other bones, flesh, or bird parts were visible.

![Figure 12. A tractor-mounted windrow turner](image)

**Biosecurity of mortality composting, including pathogen presence and inactivation**

The biosecurity of mortality composting has been reviewed by Wilkinson (2007) and Berge et al. (2009). Although composting is a well-established technology to reduce pathogens, process management and heterogenous pile conditions pose particular challenges for validating the microbiological safety of mortality composting. Biosecurity agencies in Australia, New Zealand, USA and Canada have recognised the potential benefits of using composting for both routine and emergency management of mortalities, and have identified it as a preferred method of carcass disposal (Department of Agriculture, Fisheries and Forestry, 2005)\(^7\). However, the lack of a scientifically validated process is likely to be a major barrier to its widespread adoption in many countries.

countries (Wilkinson, 2007). Research projects in the USA, Canada and Australia have attempted to bring scientific validation to a process that has been used successfully in EAD outbreaks in North America ((Bendfeldt et al., 2005; Malone, 2004; Spencer, L., 2005a; Spencer, L., 2005b). A growing body of studies and reviews of the subject (Senne et al., 1994; Wilkinson et al., 2014) (Costa & Akdeniz, 2019) is beginning to build a picture confirming that the process is a feasible and biosecure alternative to landfilling of EAD-affected poultry carcasses.

In this section, we will discuss the key biosecurity issues, drawing largely from the review published by Wilkinson (2007), together with more recent published reports.

**Inactivation of pathogens by composting – general principles**

While the thermal death point and environmental sensitivity of many pathogens are well known (Crowdy, 1984; Golueke, 1991; Haug, 1993), it is appropriate to consider some of the pathogens and issues relevant to mortality composting.

Composting is a well-established technology for reducing pathogens. It is known to control almost all pathogenic viruses, bacteria, fungi, protozoa (including cysts) and helminth ova to acceptably low levels. Exceptions are the endospore-forming bacteria (e.g. Bacillus anthracis and Clostridium botulinum) and prions, such as bovine spongiform encephalopathy (Kalbasi et al., 2005). Prions are highly resistant to physical and chemical means of inactivating pathogens. For this reason, it is assumed that composting will be ineffective in reducing infectivity of prion-infected carcasses.

Multiple mechanisms are known to be involved in the inactivation of pathogens during composting, such as exposure to heat, microbial antagonism (including antibiotic production and direct parasitism), production of organic acids and ammonia, and competition for nutrients (Epstein, 1997). Temperature, considered the most important factor in pathogen inactivation, is relatively easy to measure during composting.

The inactivation of pathogens is a function of both temperature and length of exposure. Exposure to an average temperature of 55–60°C during composting for a couple of days is usually sufficient to kill the vast majority of enteric pathogens (Haug, 1993).

It is common to observe straight lines (or nearly so) through time–temperature survival data in semilog plots. Thus, the inactivation of pathogens can be modelled using the first-order equation:

$$\frac{dn}{dt} = -k_dn,$$

where n is the viable cell population and $k_d$ is the thermal inactivation coefficient (Haug, 1993).

**Environmental sensitivity of some pathogens of interest to poultry mortality composting**

The AI virus is relatively heat sensitive but can survive for long periods in the environment under some conditions (Stallknecht et al., 1990), and there is considerable variation in heat stability between different strains (Scholtesseck, 1985); (Swayne & Beck, 2004). According to AUSVETPLAN (Animal Health Australia, 2011a), highly pathogenic AI virus (HPAI) is killed when exposed to 70°C for 30 min, 75°C for 5 min, or 80°C for 1 min.
Swayne et al. (2004) studied heat inactivation of avian influenza and Newcastle disease viruses in egg products. The ND viruses and low-pathogenic strains of AI were inactivated in all egg products when treated with industry-standard pasteurisation protocols. The protocols varied from 60°C for 210 seconds to 67°C for 15 days, depending on the egg product. The protocols were also effective in inactivating HPAIV strains in liquid egg products but not in dried egg whites. For dried egg whites, it took 15.2 days at 54.4°C to inactivate HPAI where the industry standard was deemed to be 7–10 days.

Alexander & Manvell (2004) constructed heat inactivation curves for ND virus strain Herts 33/56 in artificially infected meat homogenate. A 90% reduction in infectivity was observed after exposure to 65°C for 120 s, 70°C for 82 s, 74°C for 40 s, and 80°C for 29 s.

Infectious bursal disease virus (IBDV) is highly resistant to environmental conditions and is difficult to inactivate (Animal Health Australia, 2017). It is resistant to freezing and thawing, and is stable at pH >2 (Lukert & Saif 1997, cited in Animal Health Australia, 2017). It is also resistant to many chemical disinfectants.

Mandeville et al. (2000) studied the heat sensitivity of five IBDV strains. All five strains showed similar characteristics, with heating for one minute in vitro resulting in one, two, and three log reductions at 65°C, 71°C and 100°C, respectively. Temperatures between 65°C and 77°C were most effective. Other reports, however, have shown that IBDV has greater thermal tolerance. For example, some studies have shown little loss in infectivity of IBDV even after exposure to five hours at 56°C or 90 min at 60°C (Animal Health Australia, 2017).

Some viruses are sensitive to changes in pH or ammonia. Turner and Burton (1997) discussed the interaction of temperature and pH on the survival of viruses in pig slurry. It was thought that some of the virucidal properties of pig slurry are related to the production of ammonia that increases with temperature and at a pH over 8. It is unclear whether these factors apply to avian viruses, but high ammonia levels are commonplace in poultry mortality composting.

Risks associated with Clostridium botulinum in poultry mortality composting need further investigation. C. botulinum is a facultative anaerobic spore-forming bacterium that can persist in the environment for many years. The spores are common in soil and water. The bacterium produces a highly potent toxin that causes botulism in humans and many other animal species. The risk of botulism increases in poultry when the disposal of mortalities is delayed. Industry guidelines stipulate that if everyday mortalities cannot be disposed of immediately, they must be stored in a freezer until the day of disposal (McGahan & Tucker, 2003). In their report for AECL on composting for the egg industry, Wiedemann et al. (2008) highlight the risk of C. botulinum in chicken carcasses. They recommended the following (quoted directly from the report):

- Birds must be composted fresh (daily) or stored in a fridge/freezer before composting to avoid a build-up of pathogens. It is imperative that birds are not heaped and left to begin decomposing before composting, as this will increase the risk of Clostridium botulinum.
- Compost piles must maintain complete coverage of the birds with a significant buffer between the carcasses and the surrounding environment (minimum of 300 mm of bulking material).
- The compost must have adequate moisture, oxygen, carbon and nitrogen to compost effectively, as demonstrated by high temperatures within the compost pile (greater than 55°C).
- Compost piles or windrows must be kept aerobic.
Wiedemann et al. (2008) based these recommendations for *C. botulinum* control on a review by Chinivasagam & Runge (2008) that examined pathogen risks associated with poultry (layer) waste composting. They drew their conclusions from the findings of Böhnel and Lube (2000) showing that about 50% of ‘bio-compost’ samples in Germany contained *C. botulinum*. It was suggested that the bacteria could multiply in the anaerobic conditions found in domestic food waste containers, and possibly also under certain conditions in composting.

Along with Böhnel et al. (2000), Chinivasagam et al. (2008) state that composting is unlikely to control *C. botulinum*. There is certainly sufficient reason to be cautious, but the only study we have found in the literature that has investigated the persistence of *C. botulinum* in mortality composting (Curci et al., 2007) showed effective control of the bacterial spores and toxin present in the carcasses of cattle that had died from botulism.

Very little research has been published on this subject, and so the conditions under which *C. botulinum* could survive during composting and even perhaps multiply (for example, during curing) are largely unknown. It is true that the bacterium thrives in anaerobic environments and that it is heat tolerant. However, it is unclear whether the exact conditions favouring the multiplication of *C. botulinum* would occur in poultry mortality composting. Although anaerobic conditions are frequently seen in mortality composting systems, periods of low oxygen levels are typically associated with thermophilic temperatures (Figure 13). Though the spores of *C. botulinum* might survive thermophilic temperatures, they will likely multiply only under certain anaerobic and mesophilic conditions. Bacterial regrowth is discussed further in the next section.

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8 Bio-compost is a term used in Europe for compost made from source-separated food and green waste.
Regrowth of pathogens in compost

Enteric bacteria are known to be able to regrow in composted organic materials when temperatures decline to sublethal levels. Though this problem may not apply directly to viruses and other obligate pathogens and parasites, bacterial regrowth is an important indicator of the overall efficacy of composting in controlling pathogens.

Moisture, organic matter stability and microbiological competition are the key factors that influence the regrowth of pathogens in composts. The stability of compost is of critical importance to prevent the regrowth of pathogens (Millner et al., 1987) (De Bertoldi et al., 1988). Stability, a measure of the potential microbial activity in compost, is a function of substrate availability (Bernal et al., 1998). Sometimes compost appears to be stable, but it is so only because it is too dry to support high rates of microbiological activity. Upon rewetting of these composts, an ideal environment can be provided for pathogens to repopulate (Soares et al., 1995). Handling and transport of compost before it is stable also increases the risk of recontamination and pathogen regrowth (Millner et al., 1987) (Bagge et al., 2005).

Hussong et al. (1985) concluded that the active indigenous flora of compost establishes a homeostatic barrier to colonisation by *Salmonella* sp., and in the absence of competing flora, reinoculated salmonellae may grow to potentially hazardous densities. When inoculated in irradiation-sterilised composts, salmonellae grew at a rate of 0.65 doublings per hour for over 24 hours. For Russ & Yanko (1981), the C:N ratio served as a long-term nutritional indicator of *Salmonella* regrowth potential in biosolids composts. Thus, when the C:N ratio was under 15:1, available carbon was limiting, and repopulation did not occur.

The conditions of storage and curing may have a major impact on the regrowth of pathogens. Millner et al. (1987) showed that *Salmonella* was not suppressed in compost taken from 70°C compost-pile zones. With different microbiological flora in compost taken from cooler zones (25–55°C), *Salmonella* was either suppressed or killed. Yet, when compost was stored for a very long time (e.g. two years), it became more likely to promote *Salmonella* regrowth, probably as a result of the declining effect of indigenous antagonistic microorganisms (Sidhu et al., 2001).

Compost bypassing thermophilic conditions

The percentage of composting material bypassing thermophilic conditions (hereafter ‘percentage bypass’) is potentially more important to the overall efficiency of pathogen reduction than the application of any given time–temperature treatment (Gale, 2002) (Papadimitriou & Stentiford, 2003). In a fully enclosed composting system such as an in-vessel reactor, high temperatures can be achieved from the centre of the composting mass to within a few centimetres of the edge. In piles or windrows, there is greater variation in the temperature profile from the cool outside layers to the hot central mass. As a result, piles and windrows are usually turned periodically to expose the outer layers of the pile to high-temperature composting.

The effect of turning on pathogen destruction can be modelled by assuming that a compost pile has an outer cooler zone where temperatures are sublethal and pathogens are not destroyed, and an inner hotter zone where complete thermal inactivation occurs. When the pile is turned at time intervals ofDt and a random redistribution of material occurs, the number of pathogens surviving (n) can be described as:
\[ n_t = n_0 \left( f_1 + f_h e^{-k_d \Delta t} \right)^N, \]
given that
\[ f_1 + f_h = 1, \]
where \( n_0 \) is the number of pathogens initially present, \( f_1 \) is the fraction of compost in the sublethal temperature zone, \( f_h \) is the fraction of compost in the lethal temperature zone, and \( N \) is the number of pile turnings (Haug, 1993). Assuming that a given proportion (c) of pathogens survive the high-temperature zone, \( n_t \) can also be given as (Gale 2002):
\[ n_t = n_0 (f_1 + f_h^c)^N. \]

There are currently no methods available to determine percentage bypass with an adequate degree of precision and reliability (Papadimitriou et al., 2003). The percentage bypass would need to account for spatial and temporal changes in temperature profiles within a heap, requiring many temperature readings to be taken. The percentage bypass has been estimated by representing compost pile temperature data in cross-sections, using XYZ contour fill charts and calculating the proportion of surface area falling in any given temperature range (Joshua et al., 1998) (Wilkinson et al., 2003). Using this approach, Joshua et al. (1998) showed that >60% of the cross-sectional area of windrows was exposed to temperatures above 55°C in 7 of 15 days. The windrows, comprising green waste, measured 2.5 m high by 3.5–4.5 m wide at the base, were turned only once during this period.

Similarly, Wilkinson et al. (2003) studied the effect of turning on the windrow temperature profiles of poultry litter. Trials were conducted with unamended litter (i.e. the litter was not adjusted for moisture content or C:N ratio) formed in windrows 1.6 m high and 3 m wide. The static windrow had only 7% of the cross-sectional area, with temperatures exceeding 45°C between weeks 3–9 of the trial. In the turned windrow during the same period, about 54% of the litter was exposed to temperatures above 45°C.

**Pathogen inactivation in large clumps of solids**

Large clumps of solids (e.g. a whole carcass or parts of one) reduce the efficiency of heat inactivation in a composting pile because they take longer to heat than smaller particles. Taking the worst-case scenario of a particle of high density, specific heat and low thermal conductivity, Haug (1993) showed that the time taken in hours, \( t \), for the centre of a particle to reach a temperature close to the surrounding temperature, could be given as:
\[ t = 0.001 R^2, \]
where \( R \) is the radius of the particle (mm), given that
\[ \frac{T - T_0}{T_1 - T_0} = 0.9, \]

53
where \( T_0 \) is the temperature of the particle when it goes into the compost, \( T_1 \) is the temperature of the surrounding compost material, and \( T \) is the desired temperature for pathogen destruction. Thus, an FMD-infected leg of pork (\( R = 200 \) mm), at room temperature (\( T_0 = 20^\circ \text{C} \)) when introduced into the compost pile, would need to be exposed to \( 60^\circ \text{C} \) (\( T_1 \)) for about 2 days (40 h) to be considered safe, assuming that the desired temperature for destruction (\( T \)) of the virus was \( 56^\circ \text{C} \) (Gale, 2002).

**Pathogen inactivation during poultry mortality composting**

In an Australian study designed to simulate mass mortality composting, Wilkinson et al. (2014) demonstrated that NDV V4 was particularly susceptible when exposed to the full range of composting conditions. They compared the two windrow-construction methods, as described above (‘mixed’ and ‘layered’), along with different methods for inoculating the virus into chicken carcasses before composting. The first inoculation method used dialysis cassettes, which ensured that the virus was subjected to the full effects of potentially toxic liquids and gases produced during composting. Chickens inoculated this way were buried on the outside edge of windrows (under the capping layer) and were recovered for virus testing no later than after five days of composting. In the second method, virus suspensions were contained in plastic vials, placed inside carcasses, buried in the middle of the compost windrow, and then recovered after 14 days (at turning). The virus in the plastic vials was therefore exposed only to the temperature effects of composting. Temperature probes were also buried with each inoculated chicken (Figure 14).

![Figure 14. Location of chickens with inserted temperature probes (T) and carrier for NDV V4. The shaded portion represents the base-layer and capping. One inoculated chicken was recovered from each level (Y) under the capping on each of four sampling occasions (after 12, 36, 60 and 108 hours of composting). Three inoculated chickens were located in the centre of the windrows because they were all sampled after 14 days (324 hours), before turning. (Wilkinson et al., 2014)](image)

The mean virus titres in both layered and mixed windrows were still high (Log10 8.9 and 9.2, respectively) after 12 hours of composting. After 36 hours (second day), virus titres were about four logs lower in the mixed windrows than the layered piles: Log10 7.44 and 3.19, respectively (\( p<0.05 \); Table 7). By 60 hours of composting (third day), virus titres were Log10 3.00 and 1.00 in the mixed and layered windrows, respectively, though these differences were not statistically significant (\( p=0.063 \); Table 7). By the fifth day (108 hours), NDV V4 could no longer be detected.
in any sample. The virus samples recovered from the centre of windrows on day 14 also tested negative.

Table 7. Effect of composting on survival of NDV V4 (Wilkinson et al., 2014). Data are means of virus titre Log10.

<table>
<thead>
<tr>
<th>Day</th>
<th>Windrow type</th>
<th>Edge of windrow</th>
<th>Centre of windrow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Base</td>
<td>Middle</td>
</tr>
<tr>
<td>One</td>
<td>Layered</td>
<td>8.33</td>
<td>9.01</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>9.00</td>
<td>9.00</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>8.67</td>
<td>9.00</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>0.53</td>
<td>0.53</td>
</tr>
<tr>
<td>Two</td>
<td>Layered</td>
<td>7.67</td>
<td>7.33</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>6.57</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>1.92</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>7.12</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>0.53</td>
<td>0.53</td>
</tr>
<tr>
<td>Three</td>
<td>Layered</td>
<td>7.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>5.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>LSD (p&lt;0.05)</td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>Five</td>
<td>Layered</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Fourteen</td>
<td>Layered</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The inactivation of virus was faster in the middle-edge and upper-edge layers of the windrows where temperatures were typically higher than at the base. In mixed piles, the middle/- and upper-edge layers were 17–21°C hotter than the corresponding base layer after 36 hours composting (Figure 15). The difference between these layers in the layered windrows was 8–13°C at the same point in time (Wilkinson et al., 2014).
Figure 15. Temperature development during the first 3 days of composting in the outside edges of the mixed windrows, as reported in Wilkinson et al. (2014). Positions corresponding to Figure 14: Base—just above the base layer (Y= 30 cm); Middle—half the windrow height (Y=60 cm); Upper—two-thirds windrow height (Y=90 cm).

The inactivation kinetics of NDV V4 were found to be closely correlated with the length of exposure to temperatures in the range 25–45°C over the first three days of composting. This relationship (Figure 16) is a first order decay model for hours of exposure above 30°C.

From this study, the researchers concluded the following:

- Although the mixing method was objectively superior to the layering method from a biosecurity perspective, it made little difference to the inactivation of NDV V4 because the virus was extremely sensitive to composting conditions.
- NDV V4 was probably killed during composting after one day of exposure to temperatures above 45°C. More than 85% of temperature probes in all compost piles recorded at least one day above 45°C in their study. If avian viruses are unlikely to survive much more than 24 hours at 45°C, then the vast majority of probing positions monitored in their study were subjected to these conditions more than ten times over.
- A small percentage of probes recorded less than 24 hours at 45°C; these were typically located at the base of the windrows. The researchers proposed that this risk could be managed three ways; by:
  - using clean (uncontaminated) co-compost in the base and cover layers
  - monitoring temperature in different parts of the compost
  - turning the pile at least twice before the compost is approved for release.

Senne et al. (1994) investigated the effects of poultry carcass composting on the survival of HPAIV and the adenovirus that causes egg drop syndrome-76 (EDS-76). Tissues collected in dialysis bags from 8-week-old chickens inoculated with one of these viruses were composted in alternating layers of straw, goat manure, and chicken carcasses. After the first 10 days of composting, HPAIV had
been totally inactivated, and only one of 20 tissue samples yielded the adenovirus of EDS-76. A further 10 days of composting eliminated both viruses.

Glanville et al. (2006) investigated the survival of vaccine strains of poultry viruses placed inside compost piles constructed with cattle carcasses and different carbon sources. Survival times of viruses were much shorter when they were exposed to the full range of environmental conditions (not just heat) within the composting pile. When housed in vials (i.e. isolated from the full range of composting conditions), avian encephalomyelitis (AE) survived 1–7 weeks, and NDV two days to four weeks. When the viruses were exposed to the full range of composting conditions, seasonal ambient temperatures had little effect because both viruses were generally inactivated in about seven days.

![Figure 16. Inactivation of NDV V4 in mass poultry mortality composting as a function of exposure to temperatures above 30°C (Wilkinson et al., 2014).](image)

Glanville et al. (2006) also evaluated the biosecurity of uncovered composting windrows containing eggs inoculated with NDV and AE. Specific-pathogen-free (SPF) sentinel chickens were stationed in cages about 3 m from the windrows. Of 72 SPF sentinel birds stationed around the windrows, only one bird showed a positive immune system response for AE antibodies, indicating a possible release from the carcass composting trials. In another trial, exposure to compost dust from the excavation of a completed mortality windrow did not elicit an antibody response to either virus in any one of 23 sentinel birds. However, when the external surfaces of windrows were contaminated with liquid containing live vaccine strains of NDV and AE, six of 22 birds produced serologic antibodies to NDV only.

Conner et al. (1991) investigated the microbiological safety of poultry farm mortalities composted in bins. Daily poultry mortalities from a broiler farm were placed between layers of litter (manure and shavings) and wheat straw to a final depth of 1.5 m and held for 8–10 days after filling. The
compost was then transferred to a secondary bin for another 17–21 days. Enteric bacteria (S. Typhimurium, S. Enteritidis, S. Senftenberg, Pasteurella multocida, Listeria monocytogenes and Escherichia coli 0157:H7) were either inoculated directly onto carcasses or into tubes of brain-heart infusion with 0.5% agar. Salmonella Typhimurium was eliminated within six days of primary composting in two of three tests with inoculated carcasses. In the third test, S. Typhimurium was not eliminated until the early stages of secondary composting (after 9–10 days in the primary bin and another 5–10 days in the secondary bin). Test tubes containing the other pathogens were placed into hot and cooler zones of the bins. Attempts to recover the pathogens failed at the end of 14 days of primary composting, and again after another 14 days of secondary composting.

Infectious bursal disease virus (IBDV) has been suggested as a good surrogate to study the survival of avian viruses during mortality composting because it is known to be relatively resistant to a wide range of pH, temperatures and chemical disinfectants. Guan et al. (2010) investigated the survival of a vaccine strain of IBDV in the bursa of Fabricius and splenic tissue from experimentally infected chickens, and in splenic tissue and manure that had been inoculated with the virus. The specimens buried in compost were contained within nylon mesh bags, and the tissues were enclosed within the abdominal cavity of chicken carcasses. Extracts of composted specimens were inoculated into Vero cell cultures, and real-time reverse transcriptase PCR was used to quantify the virus in the cultures. By day 7 in compost, the temperature had been slightly above 55°C for 2.6 days. IBDV had been inactivated in specimens inoculated with virus, but had survived in tissues taken from infected chickens. By day 14, the temperature had been above 55°C for 8.8 days, and the virus was inactivated in all specimens (Table 8).

**Table 8. Survival of IBDV in various specimens placed in compost or outside of compost as ambient temperature controls (Guan et al., 2010)**

<table>
<thead>
<tr>
<th>Day collected</th>
<th>Treatment</th>
<th>Temp. (C) at collection</th>
<th>Days over 55°C</th>
<th>Specimens tested for IBDV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>From infected chickens&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0</td>
<td>Compost</td>
<td>18.5</td>
<td>0</td>
<td>+, +, (±)</td>
</tr>
<tr>
<td>7</td>
<td>Compost</td>
<td>36.2</td>
<td>2.6</td>
<td>+, +, (±)</td>
</tr>
<tr>
<td>14</td>
<td>Compost</td>
<td>57.8</td>
<td>8.8</td>
<td>−, −, (−)</td>
</tr>
<tr>
<td>21</td>
<td>Compost</td>
<td>54.8</td>
<td>16.6</td>
<td>−, −, (−)</td>
</tr>
<tr>
<td>35</td>
<td>Compost</td>
<td>44.3</td>
<td>16.8</td>
<td>+, +, (±)</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>13.2</td>
<td>9</td>
<td>−, −, (−)</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>10.8</td>
<td>0</td>
<td>−, −, (−)</td>
</tr>
</tbody>
</table>

<sup>a</sup>The bursae and spleens that were tested for virus had been taken from chickens that had been inoculated at 3 wk of age with 9000 TCID<sub>50</sub> of IBDV via oral and nasal routes.

<sup>b</sup>The manure and spleens were from an IBDV-free flock of chickens. These specimens had been inoculated with 2.9 × 10<sup>5</sup> TCID<sub>50</sub> of IBDV just prior to being buried in compost or being held at ambient temperatures.

<sup>c</sup>TriPLICATE compost and control specimens were collected on each sampling day. Two specimens were used for isolation of IBDV in Vero cell cultures and one specimen for chicken bioassay. Plus and minus signs indicate that virus was detected or was not detected by RRT-PCR in the cell cultures. Signs in parentheses indicate that virus was detected or was not detected by RRT-PCR in the bioassay.

Crespo et al. (2016) reported on an interesting study conducted during a real-life outbreak of very virulent IBDV at a pullet farm in Washington State in 2014. They investigated the composting of litter from the affected shed using an aerated static pile to inactivate the virus. Two weeks before the affected pullet flocks were moved to the layer house, 25 three-week-old specific-pathogen-free (SPF) birds were placed in the house. Ten days later, 30% of the SPF birds tested positive for the virus while 3 died. After the pullets were moved, at 20 weeks of age, the litter in the shed was composted using the aerated static pile method (Figure 17). The pile was maintained at above 55°C for 4 weeks. After this time, another 30 SPF birds were placed on the composted material. Two weeks later, the birds were healthy and there was no evidence of IBDV. The subsequent pullet flock did not break out with IBDV.
Validation of pathogen inactivation during composting

While pathogen inactivation has been the focus of much research, very little attention has been given to the development of strategies to validate the microbiological safety of composting systems (Christensen et al., 2002). It could be argued that process validation in mortality composting systems poses even greater challenges than for conventional composting.

Direct process evaluation is often used to assess pathogen inactivation in composting (Christensen et al., 2002) (Lens et al., 2004). This involves the inoculation of test organisms into the composting environment to test their ability to survive. It is a valuable tool for identifying parameters for process optimisation in different zones of compost (e.g. the outer edge of a pile), or for investigating the environmental susceptibility of specific pathogens during composting. But direct process evaluation can be an unreliable indication of the overall efficacy of the process, especially in heterogeneous mixtures of compost (Christensen et al., 2002). They concluded that taking spot samples of compost after the thermophilic stage of composting for pathogen testing was potentially more reliable and cost-effective than direct process evaluation.

Regulations in Germany require ongoing validation and supervision of anaerobic digestion and composting plants for hygienic safety (Lens et al., 2004). Direct process evaluations are conducted with the thermally tolerant organisms Salmonella Senftenberg W 775 (H2S negative), Plasmodiophora brassicae, tobacco mosaic virus, and tomato seeds. The end product is also monitored for the presence of Salmonella in 50 g of product. The test organism, S. Senftenberg W 775 (H2S negative), represents pathogens of human and veterinary interest because it can be quantitatively detected and differentiated to species level with PCR techniques. S. Senftenberg is also believed to be more thermo-tolerant than a range of notifiable pathogens, such as FMD, ADV, CSFV, swine vesicular disease virus, and African swine fever virus (Moss & Hass, 2000).

Given the importance of temperature to the inactivation of pathogens, temperature monitoring is an essential part of process evaluation. Using thermal death curves derived from Crowdy (1984) for numerous pathogens, Vinneras et al. (2003) developed a method to mathematically evaluate and estimate the safety margins of pathogen inactivation during composting. The method was based on a mathematical calculation of the number of times total inactivation (defined by at least a 12 log10 reduction) would have theoretically been achieved in laboratory-scale composting experiments. For example, a faeces-food waste mix achieved a calculated safety margin of more than 37 times the total die-off of enteroviruses, and 500 times that of Ascaris.
Similarly, intensive temperature monitoring can be used to estimate the probability that a particular time-temperature regime has been achieved. Burge et al. (1978) did this for 15 aerated static piles by composting a mixture of raw biosolids and wood chips. Temperatures were monitored throughout the composting process from the centre of the pile, lateral portions extending out from the centre, as well as just below the outer blanket at the lower edge of the pile. This latter area is usually exposed to the lowest temperature during composting. Despite the lower temperatures in the lower edges of the 15 piles surveyed, there was a high level of confidence that any particular time-temperature regime would be achieved. For example, there was a 99.9% chance that temperatures above 55°C would be achieved for 9.4 days. Confidence levels will vary between operations; therefore, proficient design and operation are needed to establish confidence that all material achieves an adequate time-temperature profile.

Similar approaches have also been used for mortality composting. For example, Wilkinson et al. (2014) monitored 18 separate poultry mortality composting windrows using different combinations of co-compost with the two windrow-construction methods (mixing and layering). Each windrow had up to 27 functioning temperature probes recording temperature each hour during the first stage of composting (before the first turn). This meant that almost 200,000 individual temperature readings were collected. These data were analysed to determine the length of time that different parts of the windrows were exposed pile to various temperature thresholds (37°C, 45°C and 50°C).

They found that more than 85% of probes recorded at least one day above 45°C in all windrows constructed during their study (Table 9). In addition, 66–94% of temperature recordings were above 50°C for one day or more. On average, each probe recorded a temperature above 45°C for 254–338 hours in succession (Table 10). Only a small percentage of probes recorded less than 24 hours at 45°C; these were typically in the base of the windrows. They concluded that the suboptimal conditions in these positions are difficult to avoid completely, and are therefore best dealt with by turning the compost.
Table 9. Effect of compost treatment on the percentage of temperature probes recording at least one day above 45°C, 50°C, and 55°C in mass poultry mortality composting (Wilkinson et al., 2014).

<table>
<thead>
<tr>
<th>Co-compost</th>
<th>Construction</th>
<th>% probes recording at least 1 day at:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt;45°C</td>
</tr>
<tr>
<td>Green waste</td>
<td>Mixed</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>92</td>
</tr>
<tr>
<td>Shavings</td>
<td>Mixed</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>91</td>
</tr>
<tr>
<td>Sawdust</td>
<td>Mixed</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>85</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td></td>
<td>95</td>
</tr>
<tr>
<td>Layered</td>
<td></td>
<td>89</td>
</tr>
</tbody>
</table>

Table 10. Effect of composting treatment on temperature recordings above 45°C for the first 17 days of mass poultry mortality composting (Wilkinson et al., 2014).

<table>
<thead>
<tr>
<th>Co-compost</th>
<th>Construction</th>
<th>Hours &gt;45°C per probe</th>
<th>% probes &lt;24 h at &gt;45°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Min</td>
</tr>
<tr>
<td>Green waste</td>
<td>Mixed</td>
<td>338</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>295</td>
<td>0</td>
</tr>
<tr>
<td>Sawdust</td>
<td>Mixed</td>
<td>312</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>254</td>
<td>0</td>
</tr>
<tr>
<td>Shavings</td>
<td>Mixed</td>
<td>321</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Layered</td>
<td>296</td>
<td>0</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td></td>
<td>324</td>
<td>0</td>
</tr>
<tr>
<td>Layered</td>
<td></td>
<td>282</td>
<td>0</td>
</tr>
<tr>
<td>Green waste</td>
<td></td>
<td>317</td>
<td>0</td>
</tr>
<tr>
<td>Shavings</td>
<td></td>
<td>309</td>
<td>0</td>
</tr>
<tr>
<td>Sawdust</td>
<td></td>
<td>283</td>
<td>0</td>
</tr>
</tbody>
</table>
Monitoring composting conditions

The progress of composting is monitored primarily with a temperature probe. Temperature is the single most important indicator of the stage of degradation, the likely pathogen kill, and the timing of turning events (Keener et al., 2006). Temperatures should be taken at several points near the carcasses in a pile, e.g., using a stainless-steel temperature probe 90–100 cm in length. A logbook should also be used to record data, such as the mass of carcasses, temperature, amount and types of C sources, and the date when compost is turned (Mukhtar et al., 2004).

Australian guidelines for poultry mortality composting

There are numerous references to composting as an option for the disposal of poultry mortalities in Australia.

The National EMS for the Chicken Meat Industry (McGahan et al., 2003) and the Egg Industry Environmental Guidelines (McGahan et al., 2018) provide an overview of spent litter and dead bird composting. Coverage in these documents is at an appropriate level because it is within the overall context of environmental management at poultry facilities. A key issue they identify is to check with local regulations whether composting is a feasible option. Most state governments have a processing threshold above which a licence or ‘works approval’ is needed (e.g. 100 t/month of organic waste processed in VIC, but 200 t/annum in SA). These thresholds usually apply only to waste brought onto a facility from outside, not to the waste generated at the facility itself. Local governments may also have local laws on dead stock disposal. Planning permits can sometimes specify disposal options applicable to a given local government area.

Agriculture Victoria administers the Victorian Code of Practice for Broiler Farms (Broiler Code Vic 2009). Enshrined in the Victorian Planning Provisions, the Code has some regulatory weight, though the actual regulatory status of on-farm composting is a little unclear. It covers composting of spent litter and dead birds; it states that uncomposted manures and litter must not be fed to stock or spread on or near poultry farms (as per the ruminant feed ban that applies Australia-wide). The Code states that composting must comply with the EPA Victoria’s Guideline 1588.1: Designing, constructing and operating composting facilities (EPA Vic 2017).

The case in Victoria is a good example of how jurisdiction over on-farm composting can sometimes be confusing. The EPA Victoria guidelines (EPA Vic 2017) were not meant to apply to composting of wastes derived on-farm, nor for facilities processing less than 100 t/month. Furthermore, the EPA guidelines classify animal mortalities at the highest risk level, which means they must be composted in an enclosed system with odour control systems. This could be beyond the capacity of many growers, though the BiobiN could qualify as a suitable system because it is containerised and has a biofilter for odour control (Figure 23, left).

One major Australian meat chicken integrator reports that most of their growers who compost mortalities use a BiobiN9. Another major integrator reported that they generally discourage mortality composting, though one grower reportedly uses the Ecodrum system (Figure 23, right)10. Ecodrum, an in-vessel system, does not appear to have an odour control system though one could possibly be retrofitted.

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9 personal communication.
10 personal communication.
As well as the EPA VIC guidelines, other states (e.g. SA, NSW, QLD, and WA) also have published guidelines to regulate commercial composting industries in those states (not on-farm composting). These are typically concerned with the siting of compost facilities and general approaches to feedstock control, odour, dust, litter and noise. They contain little technical detail about composting processes of relevance to poultry waste composting.

EPA guidelines specific to stock disposal from SA (EPA SA, 2016) refer to the mortality disposal methodologies outlined in AUSVETPLAN (Animal Health Australia, 2015). The South Australian guidelines are thin on detail, but state that the practice of mortality composting is well established in SA, and that those interested in adopting the process should consult an ‘expert’. As expected, the coverage of composting in AUSVETPLAN is also limited to high-level information, but provides a useful outline of factors to consider in the context of emergency disease management.

Wiedemann et al. (2008) gives a detailed treatment of poultry waste composting for the egg layer industry. As a result of this work, Australian Eggs published an Enviro Fact Sheet on the subject (Australian Eggs, undated). The fact sheet offers good detailed advice about composting poultry industry wastes, and that composting operators should ‘ensure the process has adequate oxygen at all times’ to ‘reduce the risk of botulism’. As discussed earlier, this is not very practical advice because the main performance issue is that thermophilic temperatures are sustained long enough to kill pathogens. Low oxygen levels in composting are regularly observed during the thermophilic stage of composting in windrow systems, but that does not necessarily affect process performance.

**Standard operating procedures (SOPs) for mass poultry mortality composting**

We have identified SOPs written for mass mortality composting. These all have different formats and do not necessarily agree on the details. The purpose of the next stage of our study is to compare these SOPs in detail to develop an SOP that can be adopted at the national level. The SOPs we have identified include the following:

- Two SOPs, written by Kevin Cooper for the Biosecurity QLD and NSW Department of Primary Industries, with similar content.
- A series of SOPs also prepared as part of the RIRDC project entitled Biosecurity of Mass Poultry Mortality Composting. The first covered the setting up of windrows; the second, process monitoring and control; and the third covered turning and sampling compost.
- A more detailed USDA guideline called the Livestock Mortality Protocol. This protocol includes procedures for poultry and larger farm animals (e.g. pigs and cattle). Interestingly, the protocol states upfront that:

  successful mortality composting requires the following:
  - A qualified composting expert to guide windrow construction.
  - Trained equipment operators.
  - Sufficient carbon, water, and space.

  And that, if any of these components are lacking, composting is NOT recommended.

**Conclusions**

Research and practice have repeatedly shown the potential of composting for inactivation of avian viruses in litter and mortalities. Studies to validate the process have been conducted in Australia (Wilkinson et al., 2014), and SOPs are available in different states and in the USA, but the lack of a nationally agreed approach hampers its potential application in emergencies. Furthermore, there
is some regulatory confusion, and some corporate industry players are reluctant to support the
process even for routine management of mortalities because of biosecurity concerns.

There is legitimate concern about the proportion of compost material exposed to lethal temperatures
in any composting system. This highlights the importance of turning compost to ensure all parts
are exposed to thermophilic conditions. It could be argued that turning is even more critical when
the mix is inherently heterogeneous, like the mixes typically seen in mortality composting.

Recent developments include the use of large-scale size-reduction equipment (e.g. tub grinders and
mixing wagons) to improve the homogeneity of mix preparation. These approaches appear to offer
real promise in achieving a biosecure and cost-effective outcome. Another approach demonstrated
by Crespo et al. (2016) also shows the potential of using aerated static pile (ASP) composting to
ensure that litter is properly sanitised. ASP could also be considered for mortality composting
because lower temperatures in parts of piles are likely to be associated with lack of aeration.11

We have also seen how pathogen destruction can be modelled when the thermal sensitivity of a
pathogen is known, and information on temperature distribution in a composting system is
available. Using this type of modelling approach, and assuming that >80% of compost at any point
is exposed to lethal temperatures (>45°C) and the proportion of pathogens surviving lethal
temperatures is 0.05%, two turns would be necessary to achieve a 10-log reduction in virus counts.
Given the extensive data set of Wilkinson et al. (2014), these assumptions are not unreasonable.
Their study found that 85% of all temperature probes recorded temperatures >45°C for at least one
hour. Furthermore, viruses cannot regrow outside their host, so the proportion surviving prolonged
exposure even to sub-lethal temperatures (e.g. 40–45°C) is likely to be very low. Two turns could
easily be incorporated into a mass mortality composting operation when windrows are turned to
begin a short period of curing or storage (e.g. two weeks) after the second stage of composting is
complete.

It could be argued that the number of turns needed to eliminate bacterial pathogens is greater than
for viruses because they can recolonise parts of the pile when conditions are favourable. A good
rule of thumb for a 99.9% reduction in bacterial pathogen counts is between three and five turns.
In fact, the USEPA 503 rule for ‘processes that further reduce pathogens’ incorporates at least five
turns for windrow composting over a 15-day period (USEPA, 2003). Similar principles have also
been shown between survival of weed seeds and number of turns during composting (Churchill et
al., 1996).

Although two turns might theoretically be sufficient to eliminate avian viruses in mass mortality
composting, the biosecurity of the process could be further strengthened by improving mix
preparation processes (e.g. using grinders and mixers) and by incorporating more turns, especially
with a windrow turner during the second stage of composting.

**Further work**

Further work is recommended in the following areas:

- Harmonise SOPs for emergency and routine (non-emergency) management of poultry
  mortalities and other poultry wastes.

11 ASP helps to minimise anaerobic, cool pockets during composting, and redistributes heat more evenly throughout a
  pile. This notion would need to be established by further research.
• Develop and implement an adoption strategy to promote these SOPs in industry and government biosecurity agencies. The strategy should also include upskilling/training of people in each production region to prepare for an emergency disease outbreak.
• Large-scale simulations of emergency mortality composting, with industry and government agencies participating, because there is little direct experience in Australia.
• Investigate the availability of expertise, equipment, and C sources etc. in each region to facilitate a rapid response to emergency disease outbreaks.
• Improve the process: make it as biosecure and economically feasible as possible; speed up the process: make more efficient use of C sources and labour etc.
• Pathogen activation, including IBDV, ILT (Infectious laryngotracheitis) and *Clostridium botulinum*. IBDV is less thermotolerant than most other avian viruses; it could be a good surrogate for process validation. ILT outbreaks are relatively common and the virus is easily transmitted through infected litter. *Clostridium botulinum* is a bacterial spore-forming pathogen that should be studied for the biosecurity of routine poultry mortality composting systems. Evidence is mounting on the biosecurity benefits of composting chicken industry waste streams.
Guidelines for poultry waste composting

Introduction to the science of composting

Definitions and scope

Composting can be defined as the controlled biological decomposition of organic materials under aerobic and thermophilic conditions. Composting is a controlled process, like any other manufactured product. It is also an aerobic process in that the organic materials decompose in the presence of air. Composting is a thermophilic process, meaning that it takes place at temperatures above 45°C for extended periods during processing. Thermophilic composting is desirable for a few reasons – faster decomposition speeds up the composting process and helps to eliminate pathogens and weed seeds that might be present in the raw material. Composting transforms organic materials into a safe, reusable product called compost.

Process control is the distinguishing feature of composting because it enables operators to meet their biosecurity and environmental management goals and obligations. In this guideline, process control is emphasised because the term ‘compost’ has often been wrongly attributed to many different types of organic materials derived from uncontrolled processes.

In poultry operations, a major factor to consider is the predominant raw materials (‘feedstock’) to be composted. For example, due to biosecurity risk factors, mortalities must be handled differently compared to other feedstock.

With a basic understanding of the biology of composting, operators will be better placed to exert control over the process. The biology of composting will therefore be covered briefly in the next section.

Temperature and microorganisms

The temperature reached during composting is primarily the result of microbiological activity, which in turn is governed by moisture content, aeration and substrate (food) availability. Heat builds up in compost because of the insulating properties of the mass, i.e. when the rate of heat gain is greater than heat loss. Small volumes of organic materials (<1–2 m³) might not heat up because the heat generated is quickly lost to the atmosphere.

Temperature has a self-limiting effect on microbiological activity and, thus, on the rate of organic matter decomposition. Few microorganisms remain active and survive above 65°C, therefore the composting rate rapidly declines. Thermophilic conditions begin at temperatures above 45°C. The highest rates of decomposition usually occur at 45–55°C mainly because of the activity of thermophilic bacteria and the high speed of biochemical processes in this temperature range.

The different phases of composting are shown in Figure 18. Low temperature (i.e. near ambient) can indicate that the composting process is completed, but keep in mind that temperatures can also fall during composting as a result of other factors, such as limited moisture or air.

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12 For example, poultry litter that self-heats in a stack without further management controls cannot be called compost.
Temperature affects organic matter decomposition by directly influencing the make-up of the microbiological population. In a compost pile, a dynamic food-web is at work: there is a succession of organisms that predominate, depending primarily on temperature and the types of food available for consumption. Bacteria, fungi and actinomycetes all play major roles during composting. Some types of invertebrates, such as nematodes, mites, earthworms, snails and slugs, consume organic residues, but they are active at lower temperatures towards the end of the composting process.

Compost feedstock is a complex mix of organic materials ranging from simple sugars and starches to more complex molecules, such as cellulose and lignin. The decomposition of organic matter is a dynamic process because different microorganisms have the capacity to break down compounds of varying complexity and resistance to degradation. Compost microorganisms first consume compounds that are easier to break down than more-resistant compounds (Table 11). Hence, the degradation of sugars, starches and amino acids often marks the initial stages of the composting process. The soft tissue (protein) of poultry mortalities is thus easily degradable in composting, though the larger bones (e.g. beaks) take longer to break down. In addition, layer manure and poultry litter are highly degradable and are therefore excellent additions to any compost mix.

After the easily degradable compounds have decomposed, microbiological activity decreases and temperature falls to below 45°C. Lignin, being more resistant to decomposition, is degraded more slowly, predominantly by fungi growing at these lower temperatures. Materials such as pine sawdust and shavings have high lignin contents and are therefore poorly compostable on their own.
Table 11: Relative susceptibility of organic compounds to decomposition during composting (adapted from Epstein 1997).

<table>
<thead>
<tr>
<th>Organic compound</th>
<th>Susceptibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugars</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Starches, glycogen, pectin</td>
<td></td>
</tr>
<tr>
<td>Fatty acids, lipids, phospholipids</td>
<td></td>
</tr>
<tr>
<td>Amino acids</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Usually susceptible</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td></td>
</tr>
<tr>
<td>Lignocellulose</td>
<td>Resistant</td>
</tr>
<tr>
<td>Lignin</td>
<td></td>
</tr>
</tbody>
</table>

During the curing or maturation phase, temperature declines further until it becomes identical to the ambient temperature, and compost quality improves significantly. Mature compost is safe to use and is a versatile product for many different applications.

**Oxygen**

Without oxygen, the aerobic microorganisms responsible for composting cannot survive and grow. ‘Aerobic’ means living or occurring in the presence of oxygen. For this reason, we often use the term ‘aerobic thermophilic composting’ to describe the fundamental elements of the process.

When microorganisms feed on the carbon component of organic materials for their energy, oxygen is used up and carbon dioxide is produced. The oxygen concentration in air is about 21%, but considerably lower in composting materials. The oxygen level is governed by microbiological activity and the efficiency of the aeration system. Ideally, oxygen concentrations of about 10–14% are needed for optimum composting conditions.

Aerobic microorganisms cannot function effectively at concentrations below about 5% in compost. Under anaerobic conditions (i.e. at or close to 0% oxygen), composting processes release methane, a highly odorous compound and potent greenhouse gas.

In a compost matrix, water and air are both held in the pore spaces between compost particles. Good compost porosity strikes the right balance between water content (around 50%)\(^{13}\) and air content (>10%). Because this is difficult to achieve in the early stages of poultry mortality composting, compensatory measures need to be taken, as we shall see later.

In most composting systems, the compost is turned with either front-end loader or a specialised windrow turner (Figure 19) to provide aeration. Another reason for turning compost is to move the outside portions of the pile into the middle to ensure exposure of all materials to the conditions necessary to eliminate pathogens and weed seeds.

\(^{13}\) That is, 50 g water plus 50 g dry matter.
In poultry mortality composting, biosecurity considerations override the usual practice of frequent turning until after most soft tissue has decomposed. As microbiological activity and, hence, oxygen demand diminish towards the end of the composting process, so does the need for turning.

Other aeration mechanisms include forced aeration that delivers air with a fan. A feature of high-technology systems, forced aeration is not usually viable in on-farm composting operations.

**Water**

Moisture is essential to all living organisms, but during composting, moisture is lost by evaporation. The compost cools to prevent overheating, but care must be taken to ensure that the compost does not dry out too quickly. The optimum moisture content for composting is generally 50–60% (wet weight basis). Below about 30%, microbiological activity is severely restricted. Above about 60%, compost can become anaerobic and odorous.

**Carbon-to-nitrogen ratio**

In organic matter, carbon (C) is the energy source and the basic building block for microbial cells. Nitrogen (N), also important, and along with C, is the most commonly limiting element.

Microorganisms need about 25–30 parts of C by weight for each part of N used for protein production. A C:N ratio of 20–40:1 is often suitable to start composting, depending on the make-up of the raw material. As composting proceeds, the C:N ratio gradually decreases to between 10 and 20:1 (depending on the C:N starting point).

Preparing and mixing the raw materials to an optimum C:N ratio results in the fastest rate of decomposition – provided that other factors are not limiting. In general, a high C:N ratio slows the decomposition rate so that the temperature increase is limited, and the total length of composting is extended. Raw materials of low C:N ratios (<15:1) may decompose rapidly, but odour can become a problem because of the complete and rapid usage of oxygen without replenishment. Furthermore, under these conditions, N can be lost as gaseous emissions of ammonia, reducing the nutrient value of the compost. Ammonia is also a highly odorous gas.
Other important factors

Organic wastes vary widely in pH without greatly affecting their suitability for composting. The optimum pH range for composting is somewhere in the range of 5.5 to 8.5. Odours from ammonia production are often a problem when the pH exceeds 9.

Apart from C and N, compost microorganisms need an adequate supply of other nutrients, such as phosphorus, sulphur, potassium and trace elements. These nutrients are usually present in ample concentrations in compost, though phosphorus (P) can sometimes be limiting. A C:P ratio of 75–150:1 is required.
Site design and composting systems

Environmental management is the number one factor governing the success or failure of a composting operation. To prevent significant environmental problems, all composting facilities, even on-farm operations, should be built and operated according to sound environmental management and planning principles.

This section discusses site design and composting systems with respect to managing environmental impacts. Other aspects of environmental management (e.g. odour control) are discussed in another section.

Compost management plan

Good environmental management begins with careful planning. When a poorly planned facility is up and running, there are limited available options for addressing environmental problems. It is recommended that poultry facility operators wanting to proceed with composting should develop a compost management plan (CMP). A CMP details how the proposed composting operation complies with your environmental management plan as well as other relevant policies and procedures (e.g. codes of practice for biosecurity, animal welfare and health and safety). A CMP should also identify potential hazards and critical control points.

The CMP must be regularly updated to reflect changes made to any part of the operation, following an established performance management process such as ‘plan, implement, monitor and review’.

Regulations and codes of practice

The CMP sits under a facility’s overarching environmental management plan (EMP), codes of practice, and other relevant policies. These documents should outline the relevant regulations that must be complied with for waste treatment and disposal.
As part of a poultry facility’s licence to operate, on-farm composting facilities must comply with all government environmental regulations, but they are not usually regulated separately from the farm businesses under which they operate. Unlike commercial composting facilities, on-farm composting operations are not classified as licensed operations or ‘scheduled premises’. Exceptions to this general rule may apply if an on-farm operation:

- Plans to take in a significant proportion of waste for composting from other sources (e.g. other farms, agribusiness or municipalities). This would apply if the poultry facility provides a regular waste disposal service for other businesses or municipalities.
- ‘Value adds’ to the end-product for the commercial market (by pelletising or bagging the compost), and
- Actively markets the end-product rather than disposing of it ‘as required’ or casually.

To determine which specific regulations might be needed, check with the relevant state-based environmental or agricultural authority and local government department before proceeding.

**Site design**

The location of a composting site has a major influence on its environmental and economic performance. Inadequate site selection for poultry composting can also cause a higher risk of biosecurity breaches.

It is most important to match the feedstock to be composted with the appropriate technology and the needs of the site. Because most poultry wastes are potentially highly odorous, strict biosecurity protocols must apply.

Other considerations are:

- The capacity of the proposed technology to manage odour and dust emissions
- The scale of the proposed operation
- The distance of the proposed site to residential areas, other poultry facilities or other sensitive land uses (‘buffer distances’)
- The prevailing wind direction, wind speed and cold air flows
- The distance of the proposed site to surface waters (should be >100 m) and
- The vulnerability of groundwater to leaching and pollution.

An important feature of any facility is the separation of functional areas for the performance of similar tasks. Functional areas reflect the main activities of composting.

These can be broken broadly into the following areas:

- Preparing compost mix
- Composting
- Curing and
- Machinery washdown space.

Each functional area has different organisational and technical characteristics depending on the proposed feedstock, scale of operation, and composting technology.
An example of a suitable layout for an on-farm open windrow/pile composting operation is shown in Figure 20. The entire site should be bunded to divert stormwater outside the composting area. The surface should be made from graded and compacted soil or gravel (minimum 15–20 cm thick).

The example layout has a holding pond to collect leachate and rain from the bunded area. Water in the holding pond can be used to irrigate the compost piles when necessary. An alternative to a holding pond is a professionally designed vegetation strip, like those used for the treatment of effluent from septic systems.

Figure 20: Example layout for an on-farm composting operation.

In this example, the curing area is small compared to the main composting area because it assumes that compost will be stacked here in deep piles for a brief period only (e.g. 4 weeks or so). After this, the compost can be stored outside the facility boundary without issue.

In addition, the following characteristics should be considered:

- The site should be at least 100 m from waterways, at least 200 m from other farm buildings and more than 2,000 m from neighbouring poultry farms.
- The installation of fencing is recommended to keep out scavengers.
- The mix preparation area should be separately contained (e.g. by more bunding or walls) to prevent cross-contamination between feedstock and finished compost. If mortalities are composted, sufficient absorbent organic material, such as sawdust or spent poultry litter, should be stored here to quickly cover incoming carcasses.
- The composting process in the composting area should follow a set directional flow, with ‘fresh’ compost at one end and finished compost at the other.
- Some compost facilities for mortalities are designed with roofing. While this is ideal, it is not necessary in all cases, but it may be prudent in high-rainfall climates.
- A machine washdown space ensures that cross-contamination does not occur when using machinery in different operational areas around the site and the rest of the farm.

14 These are general guidelines. Check with your state EPA, agriculture department or local government for regulations and/or guidance specific to your plans.
Composting systems

This section outlines the distinguishing characteristics of the main types of composting systems that could be suitable for poultry waste composting. Because all systems aim to control the composting process by manipulating temperature, oxygen and moisture, they are variations of a common theme.

The most common type of system is the turned windrow or pile (Figure 21). It is adequate for processing many types of organic wastes, including mortalities. To maintain optimum composting conditions, windrows are managed by turning the mass with either a front-end loader or a specialised windrow turner.

The windrow system is particularly suitable for on-farm composting for several reasons. It is simple and relatively cheap to set up and operate. Windrows need more space than other systems, and in rural areas, likely suitable sites are easier to find for space and buffer distances. On-farm composting operations often have another advantage over commercial operations in urban areas – more time. In windrowing, composting for extended periods helps the process performance.

Figure 21: Turned windrows or piles (photos courtesy of J. Biala, University of Queensland).

- Low capital and processing costs
- Flexible for a range of wastes; suitable for mortalities, subject to appropriate controls
- Aeration by specialised turner (left) or front-end loader (right)
- Compost can be finished in about 6 weeks\(^{15}\)
- Windrows can be outdoors or under a roof
- Care needed for effective control of odour and leachate.

Although mortalities can be composted in open windrows or piles, most poultry operations find that a bin system is ideal for regularly disposing of small quantities of carcasses (Figure 22).

\(^{15}\) If the compost is to be on-sold to another user, a longer composting period (at least 12 weeks) is recommended.
Figure 22: Examples of mortality composting bin designs.
Source: https://blancharddemofarms.org/practices/animal-mortality-composting

- Most widely used system for mortalities where the bins are progressively filled over 1–2 weeks as carcasses are collected
- Significant capital cost because a roof is usually needed to protect from heavy rainfall
- Low processing costs (simple to operate)
- Aeration by moving compost from one bin to the next in succession
- Compost can be moved out and stored after about 6 weeks composting.

Forced aeration systems (i.e. with fans for aeration) improve process control. They do not necessarily produce compost of higher quality than mechanically turned windrows, but they usually do it faster.

Specialised mortality composting services are also available in some areas. These typically involve a period of composting at the poultry facility, then the process is completed at a commercial facility. The most common example of this approach is offered with the BiobiN™ (Figure 23, left). It is delivered for the poultry farm to fill over an agreed period, after which the bin is exchanged for an empty one. The BiobiN is fully containerised, and aeration is controlled by fan. An odour control system is fitted.

Many variations of fully controlled and scalable containerised composting systems are available commercially. For instance, the Ecodrum system has also been used for poultry mortality composting in Australia. It is an example of a rotating drum system that is designed to improve mixing and aeration during composting (Figure 23, right).
Figure 23: Examples of containerised composting systems with the BiobiN (http://www.biobin.net) and the Ecodrum (http://www.ecodrumcomposter.com/media.php).

- Often called ‘in-vessel’ composting, these are scalable systems typically with aeration and odour control
- Significant capital cost to buy outright unless the container is leased under a service agreement (as for the BiobiN)
- Medium to high operating costs
- Aeration by fans and, for the Ecodrum, by rotation of the drum.

Highly sophisticated forced aeration systems are commercially available. Though these can be used in on-farm composting operations, the expense can be difficult to justify for all but the largest farm operations. Two examples of such systems are shown in Figures 24 and 25.
The choice of composting system or technology is generally governed by the following key factors:

- Types of material processed
- Location of the proposed operation and proximity to neighbours (distance, topography, prevailing winds)
- Potential problems from dust, odour or bio-aerosol emissions
- Size of available land and desired processing capacity
- Investment and operating costs.

Although on-farm poultry operations most commonly use a windrow/pile system or bin systems (particularly in North America), farms and agribusinesses near small towns or peri-urban areas may need to consider other options with better biosecurity and odour controls.
Composting systems process control

This section outlines the main elements of process control as it might apply to on-farm poultry waste composting systems. We will use the different functional areas identified in the section above for a typical site to identify critical control points. These different functional areas are:

- Preparing compost mix
- Composting
- Curing
- Machinery washdown.

Compost mix preparation

Poultry wastes that can be composted include:

- Poultry litter
- Layer manure
- Waste feed
- Daily mortalities
- Dead chicks from hatcheries
- Broken egg waste\(^\text{16}\).

Previously, the desirable specifications for compost mixes to promote optimum composting conditions discussed earlier can be summarised (Table 12).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Optimum</th>
<th>Reasonable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-to-nitrogen ratio (C:N)</td>
<td>25–30:1</td>
<td>20–40:1</td>
</tr>
<tr>
<td>Moisture content</td>
<td>50–60% (wet basis)</td>
<td>40–60% (wet basis)</td>
</tr>
<tr>
<td>Porosity</td>
<td>35–45%</td>
<td>30–50%</td>
</tr>
<tr>
<td>Oxygen concentration</td>
<td>&gt;10%</td>
<td>&gt;5%</td>
</tr>
<tr>
<td>Bulk density</td>
<td>&lt;640 kg/m(^3)</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.5–8.0</td>
<td>5.5–9.0</td>
</tr>
</tbody>
</table>

A mix containing poultry waste can theoretically be co-composted with a whole range of different organic materials (Table 13), but poultry producers are most likely to buy products, such as sawdust and shavings, as per established practice. In any case, poultry waste streams must be blended with clean, high-carbon co-composting material for the following reasons:

1. Poultry waste streams all have high nitrogen (N) contents. A high-carbon (C) co-composting material is blended to increase the C:N ratio to within a reasonable range for

\(^{16}\) Whole eggs should be broken open to ensure that their contents decompose. Although the shell will not decompose, it will contribute a useful quantity of calcium to the mix.
composting. For poultry composting, a minimum C:N ratio of 20:1 is recommended (Table 12).

2. Poultry wastes are odorous and can also represent a biosecurity risk if they are not handled appropriately. Dry poultry litter or other co-composting material (e.g. sawdust) is used to cover these materials to minimise odour and bio-aerosol emissions.

3. As mortalities break down, fluids are released. The co-composting material absorbs these fluids and prevents their release into the environment.

Table 13: Physico-chemical properties of a range of organic waste streams.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Moisture</th>
<th>Structure</th>
<th>C:N</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed tree and shrub prunings</td>
<td>dry to moist</td>
<td>good</td>
<td>70-90</td>
<td>0.5-1</td>
</tr>
<tr>
<td>Eucalyptus bark</td>
<td>dry</td>
<td>good</td>
<td>250</td>
<td>0.2</td>
</tr>
<tr>
<td>Eucalyptus sawdust</td>
<td>dry</td>
<td>average</td>
<td>500</td>
<td>0.1</td>
</tr>
<tr>
<td>Pinus radiata bark</td>
<td>dry</td>
<td>good</td>
<td>500</td>
<td>0.1</td>
</tr>
<tr>
<td>Pinus radiata sawdust</td>
<td>dry</td>
<td>average</td>
<td>550</td>
<td>0.09</td>
</tr>
<tr>
<td>Grass clippings</td>
<td>moist to wet</td>
<td>poor</td>
<td>9-25</td>
<td>2-6</td>
</tr>
<tr>
<td>Mixed food organics</td>
<td>moist to wet</td>
<td>average</td>
<td>14-16</td>
<td>1.9-2.9</td>
</tr>
<tr>
<td>Vegetable produce</td>
<td>wet</td>
<td>poor</td>
<td>19</td>
<td>2.7</td>
</tr>
<tr>
<td>Fruit</td>
<td>wet</td>
<td>poor</td>
<td>20-49</td>
<td>0.9-2.6</td>
</tr>
<tr>
<td>Fish</td>
<td>moist to wet</td>
<td>poor</td>
<td>2.6-5</td>
<td>6.5-14.2</td>
</tr>
<tr>
<td>Biosolids</td>
<td>moist to wet</td>
<td>poor</td>
<td>5-16</td>
<td>2-6.9</td>
</tr>
<tr>
<td>Tannery waste (hair)</td>
<td>dry to moist</td>
<td>average</td>
<td>3.1-4.3</td>
<td>11.7-14.8</td>
</tr>
<tr>
<td>Mixed abattoir wastes</td>
<td>moist to wet</td>
<td>poor</td>
<td>2-4</td>
<td>7-10</td>
</tr>
<tr>
<td>Wool scour waste:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) raw decanter sludge</td>
<td>moist</td>
<td>poor</td>
<td>(1) 13.8</td>
<td>(1) 0.81</td>
</tr>
<tr>
<td>(2) raw flocculated sludge</td>
<td>moist</td>
<td>poor</td>
<td>(2) 19</td>
<td>(2) 1.61</td>
</tr>
<tr>
<td>Grease trap sludges</td>
<td>moist to wet</td>
<td>poor</td>
<td>0.7-4</td>
<td>9-91</td>
</tr>
<tr>
<td>Flocculated dairy solids</td>
<td>moist to wet</td>
<td>poor</td>
<td>0.08-8.5</td>
<td>5-715</td>
</tr>
<tr>
<td>Ice cream solids</td>
<td>moist to wet</td>
<td>poor</td>
<td>1.5-2.2</td>
<td>24-41</td>
</tr>
<tr>
<td>Chicken manure (layers)</td>
<td>dry to moist</td>
<td>poor</td>
<td>3-10</td>
<td>4-10</td>
</tr>
<tr>
<td>Chicken manure (broiler)</td>
<td>dry to moist</td>
<td>poor</td>
<td>12-15</td>
<td>1.6-3.9</td>
</tr>
<tr>
<td>Newsprint</td>
<td>dry</td>
<td>poor</td>
<td>398-852</td>
<td>0.06-0.14</td>
</tr>
<tr>
<td>Paper</td>
<td>dry</td>
<td>poor</td>
<td>127-178</td>
<td>0.2-0.25</td>
</tr>
<tr>
<td>Wheaten straw</td>
<td>dry</td>
<td>good</td>
<td>100-150</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Seaweed (kelp)</td>
<td>dry to moist</td>
<td>average</td>
<td>25</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Sources: Rynk et al. (1992); Handreck and Black (1994); DPI Victoria, unpublished data; Coker (2006).

Note for Table 13: ‘Structure’ is a descriptive term for the physical property of compost materials. ‘Good’ structure denotes the right particle size distribution to maintain porosity and prevent compaction when stacked in a pile. ‘Poor’ structural material usually has too many fine particles, producing a mix that restricts airflow. This occurs when the pore spaces in the pile are too small to allow free drainage of water, or when a pile slumps under compaction.

Raising the C:N ratio above 20:1 with dry co-composting material can make the mix too dry for composting, so water must be added to compensate. If mortalities are included in the mix, less water is needed than when manure or litter are composted on their own.

Calculating the C:N ratio of a mix made up of more than one feedstock can be a daunting mathematical task for many people. Moisture content must also be calculated simultaneously with C:N ratio to ensure that the mix falls within the recommended range for both attributes. Fortunately,
a spreadsheet for the simultaneous calculation of C:N ratio and moisture content is available online from Cornell University.¹⁷

The specifications in Table 12 were developed for commercial composting operations to minimise environmental breaches (e.g. odour emissions), promote thermophilic conditions, and to produce a safe end-product for the consumer. For these specifications, there is a little more flexibility for on-farm composting operations because it should not increase the odour impact of poultry farms¹⁸. Furthermore, in most cases, the end-product is unlikely to be sold because composting on poultry farms is mainly used to manage waste rather than to produce a saleable product.

There is a range of approaches for preparing compost mixes. Mostly, a simple bay-like structure should suffice (Figure 26), but a mixer wagon could produce better results (Figure 27). Recent research shows that a mixer wagon in mortality composting reduces the need for more high-carbon co-composting material (Keaten et al., 2017).

In commercial composting, the usual approach is to prepare a mix that is as uniform as possible for the distribution of particle size, water and nutrients. Because most composting operations on poultry farms will involve at least some mortalities, this principle can be difficult to achieve in practice. As discussed in the next section, mortalities are traditionally layered in a compost pile between alternate layers of poultry litter and/or sawdust (or similar C source). However, more recent research has shown that mortality composting performs better when the carcasses are mixed in a 1:2 to 2:3 ratio (by volume) with poultry litter and/or sawdust or similar C source (Wilkinson et al., 2014).

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¹⁷ http://compost.css.cornell.edu/calc/simultaneous.html

¹⁸ Poultry farms already have challenging odour issues associated with manure and litter. Effective composting should reduce odour emissions, not increase them.
In summary, we can identify the following critical control points for preparing compost mix:

- Take a consistent approach to mix preparation – one that has been shown invariably to work. Some trial and error is needed to achieve consistent results, though. Adjusting the composition of the mix may be necessary if there is excessive odour, for example, or where high-risk materials are slow to decompose.
- Ensure that highly absorbent, co-composting material is available in the designated mix preparation area to quickly cover high-risk materials, e.g. mortalities, until they can be processed.
- When mortalities (or chicks or broken eggs) are placed in the mix preparation area, cover them with at least 1.5x their volume with litter or sawdust (or similar C source). Alternatively, mortalities can be applied directly to piles in the composting area as they are collected (this process is discussed in the next section). In this case, the mix preparation area would be used only to store and prepare other, less hazardous, compost feedstock (such as poultry litter and sawdust).
- Mix the material as thoroughly and as uniformly as practicable by loader or mixer wagon before transferring to the composting area. During the mixing process, add water as necessary. In a heterogeneous mix containing mortalities, it can be difficult to practically assess moisture content, but it is usually sufficient to lightly spray the carcasses with water during mixing.
- Generally, incorporate high-risk materials into composting within 24 hours. Any material in poor condition (e.g. partly decomposed birds) should be incorporated sooner than that.
- Keep equipment (e.g. loader) used in the mix preparation area separate from the curing area. If this is not possible, clean the equipment before using it in the clean area or elsewhere on the farm.

As discussed, there is some flexibility in mix preparation for on-farm composting of poultry waste. With this in mind, key performance criteria for adequate compost mix preparation can be summarised as follows:

- The mix consistently reaches thermophilic conditions quickly (typically within 12 hours) when incorporated into a composting pile.
- The composting process is easily managed with few problems.
- The whole process clearly improves whole-of-site environmental management and biosecurity.
Three main aspects of composting will be covered in this section. Firstly, the generic principles of managing conventional (i.e. non-mortality) composting with turned windrows or piles will be discussed because this type of technology is used extensively throughout Australia. Secondly, we will cover the specific case of mortality composting to dispose of routine carcasses from poultry facilities. These two systems are significantly common because mortalities can also be composted in windrows, but different approaches to setting up and managing the process are needed. In the third section, process monitoring and troubleshooting will be covered.

Setting up and managing turned windrows for conventional composting

Windrows are horizontally extended piles, the shape and dimensions of which depend on the space available, the feedstock composted (type and quantity), and the equipment available for turning. We will use the terms ‘windrow’ and ‘pile’ interchangeably here because there is little difference in how these heaps are managed in principle.

The length of windrows is limited only by the space available. They are typically 1.5–2 m high\(^{19}\) and 3.5–5 m wide at the base. In high rainfall climates, windrows can be protected from rain with a breathable cover, or they can be formed under a roof. Excessively large heaps can easily overheat, and if they are dry, spontaneous combustion (i.e. compost fires) can occur.

Although large heaps often retain more heat and are more effective in destroying pathogens and weeds relative to smaller ones, odour emissions are common because not enough air can diffuse and aerate the core of the pile. A compromise between pile height and the ability of the pile to retain heat and destroy pathogens and weeds (occurring over 55°C) is needed in managing such piles.

The shape of a pile influences its capacity to absorb water. Creating a concave shape in the top helps water absorption so that rainfall can replenish some of the moisture lost from the compost as steam. In contrast, piles formed into a peak will help to minimise water absorption by shedding water in prolonged wet conditions.

The main reasons for turning compost piles are to move the outside portions of a windrow into the middle and to loosen and fluff the material so that air can move more freely into the windrow. Turning ensures that all parts of a composting mass are exposed to the conditions necessary to eliminate pathogens and weeds. The agitation of composting particles that occurs during turning also stimulates higher rates of decomposition by exposing new surfaces to microbiological attack.

Windrows are turned by a variety of means. Windrow turners are usually more efficient than front-end loaders or excavators because turners are specifically designed for the job. Higher efficiency has a price; a windrow turner is a substantial investment.

PTO-driven windrow turners (Figure 28) are ideal for on-farm composting operations, and they are much cheaper than self-propelled turners (Figure 29).

\(^{19}\) Windrows/piles containing mortalities are typically a maximum of 1.8 m high.
Turning with a front-end loader involves flipping the top of the windrow over just beyond the existing windrow. Then the remaining compost from the base of the windrow is lifted onto the top of the new windrow (Figure 30).

Windrows should be turned when temperatures exceed about 65°C, or when they fall below 45°C, unless the compost has already reached the curing stage. Usually, windrows are turned at least once a week in the first 4–6 weeks, and then less regularly (e.g. fortnightly or less) after that.

Each operation must find its optimum turning strategy because turning is the major cost for operating a windrow system. One advantage of many on-farm operations is that plenty of time and space is available to allow composting for extended periods (e.g. 9–12 months). In this case, relatively few turns are possible provided that appropriate environmental controls are in place.

Turning facilitates the composting process by various means but could also release high peak odour emissions. The turning of windrows may in fact be the most critical activity contributing to odour emissions. Operators should take this into account, and schedule turnings when the wind is moderate, steady and away from sensitive receptors.
Moisture is lost during composting through evaporative cooling and must be replaced by watering. The optimum moisture content for composting is generally considered to be 50–60%. Below about 30%, microbiological activity is severely limited. Water can be added during composting by hose, sprinklers, or soaker hoses. When a windrow turner is used, it can be connected to a water source and added during turning (Figure 31 & 32).

Water must be added slowly to ensure it penetrates the pile rather than running off the surface. Take care to minimise pooling during watering by providing adequate drainage and water (runoff) collection systems. Collected water and leachate should be reused, where possible. If water is discharged to the sewer, land or water, it may need treatment to comply with relevant wastewater discharge regulations.

![Figure 31: A windrow turner connected to a mobile water tank.](http://jphequipment.com.au/)

![Figure 32: A windrow turner with water tank installed on top.](www.frontierturners.com/)

**Setting up and managing mortality composting piles**

Mortality composting is usually conducted in windrows/piles out in the open, or in purpose-built bays under a roof (Figure 22). We will focus this discussion on setting up these types of systems because all other approaches (e.g. in-vessel containers and rotating drums) are essentially variations on the same theme. Though mortality composting is used to dispose of poultry carcasses, the same general approach could be used for disposing of other hazardous waste streams, such as broken eggs and chicks.

Mortality composting is essentially a two-stage process:

- **Stage 1**: The carcass compost mix is fully encased in clean, high-carbon co-composting material (e.g. sawdust or shavings). This material acts as a biofilter, preventing odours and bioaerosols from escaping from the compost. The use of the casing also maximises the likelihood that all bio-hazardous compost materials are exposed to thermophilic composting conditions (>45°C) before the compost is moved or turned. When set up, these piles should be left undisturbed until most of the carcass tissue has decomposed (usually about 10–14 days). Disturbing the pile too early is a health and biosecurity risk.

- **Stage 2**: Begins when the pile is turned (e.g. into the adjacent bay) and ends when the compost is ready for curing (about 4 weeks). The clean casing material is mixed in with the rest of the compost during the first turn. In this stage, piles are essentially handled like conventional compost. A small amount of tissue might be evident early in this stage, but it would have already been exposed to extended periods (e.g. min 7 days, probably more) of high-temperature composting (45–65°C). The sight of remnant tissue may be unpleasant, but it should be safe enough to handle in a prudent manner.

---

20 It is not classified as finished or mature compost at this stage. But the compost can be safely matured in storage over a period of months.

21 Usual hygienic practices still apply, e.g. using personal protective gear, washing hands and equipment, and minimising dust dispersal during turning etc.
When setting up a windrow or pile, a base layer of clean, high-carbon co-composting material is first placed on the ground. If the pile is under a roof, then a 300-mm deep layer of a material such as sawdust should suffice. If the pile is in the open, then this layer should be about 450 mm deep.

The carcass-compost mix can then be transferred from the mix preparation area onto the base layer. Ideally, the carcass-compost mix already comprises a 2:3 ratio (by volume) of carcass and co-compost. The pile can be built up to a height of about 1.5 m, after which the top and sides are covered with clean, high-carbon co-composting material (the ‘capping’). The capping layer should be 300 mm deep for piles built under cover, and 450 mm for those in the open. The total height of the pile should not exceed 1.8 m. The width at the base will typically be 3–4 m for windrows. For those in bays, the width of the pile is governed by the size of the loader bucket.

Sometimes it is more convenient to layer mortalities in a compost bay as they are collected (Figure 33). Note how clean co-compost material is recommended for the base and capping layers while the co-compost between layers of carcasses can include poultry litter (if available).

The recommended layering process in a covered compost bay is as follows:

1. Place the base layer of clean co-compost material down, as described above.
2. Place a layer of carcasses on top of that (at about 200 mm thick).
3. Cap the pile with 300 mm of clean co-compost material.
4. Lightly moisten the capping layer.
5. When a new layer of carcasses is to be added, scrape away 100 mm of the capping and place the dead birds on top. Now there should be a 200-mm co-compost layer between the two carcass layers.
6. Place the excess capping that was scraped away on top of the new layer, topping up with more clean co-compost material to a depth of 300 mm.

At least three bins are usually in operation at any one time—one being filled, another in Stage 1 composting, and the other in Stage 2. A pile is sometimes substituted for the second bin in two-bin systems. As a general guide, 10 m³ of bin space is needed for every 1,000 kg of carcass (Mukhtar et al., 2004).

![Diagram of composting process](image)

**Figure 33: Example of a layering method for poultry mortality composting in bays.**

When compost bays are used, fresh compost mixes are established at one end of the facility with more advanced stages of composting occurring at the other end. When windrows are used, one end of the windrow may contain fresh compost, while at the other end the compost is ready to be moved to the curing area.

In summary, critical control points for mortality composting include the following:
• Use only clean co-compost material for encasement.
• Use deeper layers of co-compost material for encasement when piles are out in the open.
• Turn or move the compost only after Stage 1 composting ends (when the carcasses have had time to decompose – check before proceeding).
• Stage 1 composting is not deemed to have begun until the last carcass layer has been added to a pile (when carcasses are added in layers, a pile may take a week or two to complete).
• Turn or move the compost in sequence – oldest first, freshest last. This reduces the risk of cross-contamination between piles of different ages.

**Process monitoring and troubleshooting**

Effective control of composting and troubleshooting with confidence require the following:

1. Some knowledge of the biology and the mechanics of composting.
2. Applying this knowledge in practice. Through practice one can predict the outcome when different management actions are taken and can also anticipate potential problems.
3. Having effective process monitoring protocols and using them.

Fortunately, monitoring of composting is a relatively simple process. Pile temperature is the best indicator of progress. Temperature must be monitored and recorded for three reasons:

1. To provide information on the progress of composting
2. To support operational decisions about how to manage the composting process (e.g. when to turn and water)
3. To ensure that temperatures are high enough to eliminate pathogens and/or weed seeds.

The vast majority of pathogens are highly susceptible to composting (see Wilkinson (2007) for specific details to poultry mortality composting). The general pathogen-reduction guidelines stipulate that the entire compost mass has been subjected to temperatures above 55°C for a minimum of 3 consecutive days (USEPA, 2003). This guideline should generally be achieved within about 21 days, provided the compost has been turned a minimum of 5 times.

In a new operation, a thorough temperature profiling is needed to establish the ‘typical’ temperature pattern for the entire composting process of a given feedstock. A typical pattern should emerge after only 2 or 3 batches have been composted. When this is established, an operator can follow a simplified monitoring procedure to ensure that a given batch proceeds according to the typical pattern.

For routine temperature monitoring, follow these general procedures:

![Figure 34: Options for monitoring temperature include (left) a bimetal thermometer (Source: REOTEMP Instrument Corporation), and (right) a digital thermocouple thermometer (Source: Cole-Parmer Instrument Company).](image-url)
• Insert the temperature probe horizontally into a compost pile at half-height in at least 3 different places. Windrows longer than 10 m may need more readings, e.g. every 4 or 5 m of windrow length.
• Ideally, at each location, take temperature readings at three depths in the horizontal plane (e.g. 40, 70 and 100 cm).
• Monitor temperatures every 2 days at the start of composting to ensure the heap reaches thermophilic conditions quickly. When thermophilic conditions are reached, twice weekly monitoring is usually enough because temperature changes slowly.
• In on-farm operations, composting for extended periods (e.g. 9–12 months), temperature monitoring can be much less frequent (e.g. every few weeks until the process is complete).

When windrows dry out and start overheating, temperature measurements alone can be misleading. Therefore, monitor moisture levels alongside the prevailing temperature regime.

With a little practice, moisture content can be estimated quite accurately with the feel of the compost in the hand. This method is used routinely to estimate moisture content in the raw mix, as well as for monitoring moisture content during composting²².

A good analogy for compost at 50% moisture content is that of a wrung-out moist sponge – it is obviously moist, but water should not run from it if it is squeezed in the hand.

Follow this procedure for monitoring compost moisture content (Figure 35):

1. Take a handful of compost and close your hand around it to make a fist.
2. Tightly hold your fist closed. Observe whether any water runs between the fingers or falls to the ground. If this happens, the compost is too moist.
3. Open your hand. If the compost has not formed into a ball on the hand, it is too dry. If it forms a ball on the hand and breaks up under light pressure, it will be at the correct moisture content.

²² It will not be possible to use this method in the early stages of mortality composting – only when composting is well advanced.
As discussed, compost operators should become quickly familiar with how their process performs. The general pattern of performance typically looks something like this (Figure 36):

1. When compost starts out at near ambient temperature, it reaches thermophilic conditions (>45°C) usually within 12–24 hours. The pile heats from the inside out.
2. In the core of the pile, the hot zone gradually expands over a few days, reaching peak temperatures often above 65°C. At this point, the core temperature may start to fall as the supply of oxygen to the microbes becomes limiting. The pile is typically turned at this point.
3. After turning, there is often a short period (a few hours) of lower temperatures before high temperatures are quickly re-established due to oxygen being replenished.
4. Temperatures around 45–65°C can be maintained for three months or more (depending on feedstock).
5. At this point, peak temperatures slowly begin to decline, and the maturation phase of composting begins. Technically, composting might not be complete for another 12 weeks or more. But the compost can usually be safely stored (with little further management) when peak temperatures are within 10°C of ambient.
Figure 36: A typical temperature profile for turned windrows in relation to turning events and stage of composting.

The performance pattern for mortalities can be a little different (Figs. 39 & 40):

1. In contrast to conventional composting, mortality compost piles heat up first in the outside layers. The edge of a fully constructed pile should reach >45°C within the first 2–3 days of composting. The core might take a few days to a week longer. Temperatures tend to converge after about 7–10 days.
2. Peak temperatures well above 55°C should be expected after about 7–10 days composting.
3. The compost just above the base layer will almost always be cooler than the upper layers of the pile. The coolest part is therefore typically at the base in the core of the pile, which could take 10 days to reach >45°C.
4. In the upper layers, temperatures may fall gradually after about 7–10 days composting, even before the base layer temperatures begin to plateau.
5. After the pile has been turned for the first time, the pattern of temperature development should begin to look more like a conventional compost pile.

These performance indicators were developed after extensive Australian research (Wilkinson et al., 2014).
Figure 37: Pattern of temperature development for mortality composting. Edge – temperature taken just below capping layer, halfway up pile height; Core – in the centre of the pile in the same horizontal plane; Mid-way – between edge and core. Based on research by Wilkinson et al., (2014).

Figure 38: Schematic showing what a typical temperature profile could look like for poultry mortality composting (Wilkinson et al., 2014).

Keep in mind that these performance patterns are most relevant for mortality composting piles set up to completion in one hit. Piles that are constructed in layers over time may behave a little differently.

When a simple monitoring process has been established for temperature and moisture content, many common problems can be diagnosed and rectified by examining pile conditions (Table 14).
Table 14: Guide for diagnosing and treating temperature-related problems during composting (adapted from Rynk et al. (1992)).

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible reason</th>
<th>Other clues</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piles fail to heat up</td>
<td>Materials too dry</td>
<td>Can't squeeze water from materials</td>
<td>Water or add wet ingredients</td>
</tr>
<tr>
<td></td>
<td>Materials too wet</td>
<td>Pile looks soggy and slumps</td>
<td>Add dry ingredients and remix; Form windrows to shed rainfall</td>
</tr>
<tr>
<td>Not enough N, or slowly degrading or stable materials</td>
<td>Very high C:N ratio; wood feedstock</td>
<td>Pile compacted; few large particles; not too wet</td>
<td>Add high N ingredients</td>
</tr>
<tr>
<td>Poor structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small pile size</td>
<td>Height &lt;1 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature falls too soon</td>
<td>Low oxygen; need for aeration</td>
<td>Temperature declines gradually, not sharply</td>
<td>Turn pile</td>
</tr>
<tr>
<td></td>
<td>Low moisture</td>
<td>Can't squeeze water from materials</td>
<td>Add water</td>
</tr>
<tr>
<td>Uneven temperature in pile</td>
<td>Materials mixed</td>
<td>Visible differences in materials along pile</td>
<td>Turn or remix pile</td>
</tr>
<tr>
<td></td>
<td>poorly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature falls gradually; doesn’t reheat after turning</td>
<td>Composting nearing completion</td>
<td>Approaching expected composting time period; adequate moisture available</td>
<td>None required</td>
</tr>
<tr>
<td>Low moisture</td>
<td></td>
<td>Can't squeeze water from materials</td>
<td>Add water</td>
</tr>
<tr>
<td>Pile overheating (&gt;65°C)</td>
<td>Insufficient aeration</td>
<td>Pile is moist</td>
<td>Turn pile</td>
</tr>
<tr>
<td>Moderate to low moisture</td>
<td>Pile damp but not wet or dry</td>
<td></td>
<td>Add water and turn</td>
</tr>
<tr>
<td>Pile too large</td>
<td>Height &gt;2.5 m</td>
<td></td>
<td>Shorten pile</td>
</tr>
<tr>
<td>Very high temperatures (&gt;75°C)</td>
<td>Pyrolysis or spontaneous</td>
<td>Materials dry; interior looks or smells charred, smell of ammonia</td>
<td>Decrease pile size; maintain proper moisture content; break down pile and add water to charred or smouldering sections</td>
</tr>
<tr>
<td></td>
<td>combustion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Curing

The curing phase is an integral part of the composting process, especially for those wanting to make quality composts. Lignin is degraded most rapidly during curing, and compost is enriched with complex humus compounds.

Curing begins when temperatures are sustained below 45°C even after turning. It is complete when temperatures decline to within 5°C or so of ambient. Curing completes the composting process and produces a mature end-product. Immature compost can be toxic and have negative effects on plant growth, which are alleviated by a suitable curing phase of 3–6 weeks.

The curing phase can be shorter (e.g. 3–4 weeks) when composting is just to dispose of waste. In this case, the main purpose of curing would be to make the compost safe to store elsewhere on the farm.

Compost is cured in a separate functional area of the composting facility to avoid recontamination with pathogens. The use of the same machinery with cured compost directly after handling the raw material is to be avoided for the same reason (unless it is thoroughly washed).
Turning is less frequent during curing – perhaps once a week to begin with but as the temperature drops below 40°C, the pile may be left undisturbed for long periods provided that aerobic conditions are maintained. Limiting piles to about 2.5 m in height and 6 m in width is usually enough to prevent the buildup of anaerobic conditions during curing. If the pile continues to reheat above 45°C after turning, more frequent turnings may be needed to maintain aerobic conditions. Alternatively, consider reducing the size of the pile.

Properly cured compost has a low rate of microbial activity, and should therefore not develop anaerobic conditions during storage. Very large storage piles increase the risk of fire from spontaneous combustion. The height of fully cured compost in storage should not exceed 3.5 m, though the reach of front-end loaders or other equipment often determines maximum pile height.

**Machinery washdown**

This area of the facility is used to limit cross-contamination between the raw feedstock, compost in advanced stages of composting, and cured compost. With strict washdown protocols in place, machinery used in the composting site could also be safely used elsewhere on the farm. In any case, trucks, loaders, and trailers hauling bio-hazardous material from the production area of the farm should be cleaned before leaving the site.

The washdown space should be separately bunded to prevent the wash water reaching other areas of the compost site. On the other hand, wash water could potentially be used to irrigate feedstock in the mix preparation area (but not elsewhere). A high-pressure hose should be used to clean all equipment after use. The use of disinfectant should be minimised because it could affect microbial activity during composting.
**Summary checklist**

These guidelines have identified many issues to consider when planning a poultry waste composting operation. Careful planning and process monitoring are the main keys to success. Avoid technology suppliers that promote solutions that appear ‘too good to be true’. Composting does not need to be a complex process, but at the same time, taking too many short cuts can have serious consequences to biosecurity and your licence to operate. We can briefly summarise the main steps as follows:

- ✓ Study the science of composting
- ✓ Make better decisions with sound knowledge
- ✓ Identify all relevant regulations
- ✓ Talk to your local EPA/regulatory agency and local government
- ✓ Develop a Compost Management Plan
- ✓ Plan for success
- ✓ Identify a suitable site for composting
- ✓ Is the site appropriate for the intended composting system and feedstock?
- ✓ Pay careful attention to site design
- ✓ No short-cuts
- ✓ Identify critical control points for composting
- ✓ Do not take short-cuts
- ✓ Establish a robust monitoring protocol
- ✓ Keep records to comply with regulations and to improve processes
- ✓ Take a consistent approach to process control
- ✓ You cannot improve what you cannot control. Avoid haphazard ‘management’
- ✓ Manage process performance
- ✓ Continuous improvement. Plan, implement, monitor and review
Implications

The general findings of this project have highlighted that while there is a significant amount of activity towards EAD preparation with state agriculture departments, there is little coordination between the state departments, industry and other key stakeholders in preparing for EAD responses. However, there is widespread support from key parties to develop mass disposal plans. Current resources are largely government-driven and not necessarily developed with industry. Industry contribution and engagement is a strong, and yet underused, resource. The incentive of poultry industries to plan for EAD needs to be promoted to individual producers, including those who are not contracted to processors, or members of industry associations.

Governments may prefer on-site disposal due to logistical, resource, biosecurity, cost and other considerations. Because the ultimate decision for the disposal method in an EAD lies with the CCEAD, it is important for producers to be able to provide information on key parameters associated with their property, such as water table levels, suitable burial sites, and nearest landfill sites.

Jurisdictional management issues

Information about EPA requirements and local resources is very fragmented, not consistent across jurisdictions, and not easily accessed. This information can be used to some degree to make it possible that emergency disposal plans are developed for individual producers and tailored to their location. The EPA in one state was reluctant to make decisions on some scenarios put to them during discussions, implying that decisions during an outbreak are flexible, and could be inconsistent, depending on local conditions and scenarios at the time. Discussions with key personnel in one government biosecurity department indicated that EPA consultation during an outbreak relied heavily on verbal communication and good relationships between the biosecurity and EPA parties. While this allows for flexibility and rapid response, it is not a robust decision-making process, and is subject to individual interpretation of the laws and regulations at the time. It also presents a risk that skills bases within departments are diluted as key decision makers change their roles and responsibilities. This highlights the importance of producers developing an emergency management plan for their property to protect business continuity.

The outbreaks of AI in the USA in the last decade have highlighted the absolute necessity for governments and industries to develop a comprehensive, coordinated response plan that incorporates all components of eradication and resolution into a single response plan (USDA, 2017).

Disposal methods

For the specific disposal methods of composting, burial, rendering and incineration, it was determined that composting and burial are likely to be the most suitable options for most large-scale poultry producers in Australia. For off-site composting, communicating and establishing relationships with commercial composting facilities during peacetime is recommended to determine the capability to perform large-scale composting in their facilities in an EAD. However, the outcomes of the AHA workshop ‘Lessons learnt from highly pathogenic avian influenza incidents in NSW’ state clearly that there is a need to develop and implement SOPs as part of peacetime preparedness and that an SOP for large-scale biosecure composting is vital (Animal Health Australia, 2014b).

One of the gaps identified in Phase 1 of the project was the disparity of information on poultry mortality composting, which has been addressed through a literature review. Phase 1 and the literature review identified a lack of guidance on poultry mortality composting. It is difficult to develop nationally consistent SOPs with enough detail to be considered as an operational document due to the wide disparity of EPA requirements and restrictions between states. Therefore, guidelines for composting have been developed from which state-specific or standard operational procedures can be developed. Local issues that must be considered include:

- Types of material being processed
- Location of the proposed operation and its proximity to neighbours (distance, topography, prevailing winds)
• Potential problems from dust, odour, or bio-aerosol emissions
• Size of available land and desired processing capacity
• Investment and operating costs.

Queensland, NSW and Victorian agricultural departments have SOPs that could be consolidated and validated to develop a nationally acceptable composting SOP.

The sites approved by the Department of Agriculture, Water and the Environment for post-entry quarantine activities and treatments are useful for large-scale off-site burial. Again, communicating and establishing relationships is recommended during peacetime to discuss the use of the sites in an EAD. Large-scale on-farm burial is regarded as difficult, needs technical expertise and specialised equipment, and has long-term implications and EPA considerations for the soil, groundwater, and business continuity. On-farm burial does not effectively decompose carcasses; the long-term presence of carcasses buried in the ground has had implications in the USA, with lower land prices for properties that have buried poultry during the 2015 HPAI outbreaks (Schaal, 2016). The implications in the USA have also been experienced in the ND outbreak in the Mangrove Mountain of NSW (NSW Department of Primary Industries, 2017). It is recommended that emergency disposal plans for individual producers include scoping to determine whether on-farm burial is suitable for their location. However, there is an obvious gap – there are no formal guidelines or procedures from the EPA in all jurisdictions that outline on-farm burial for intensive farming operations.

Rendering and incineration are less likely disposal methods in an EAD in poultry in Australia. However, for emergency disposal plans for individual producers, large-scale rendering facilities should be scoped in their region. Communication and planning during peacetime is recommended to determine what will happen to the rendered product to avoid it being sent to landfill. EAD eradication attempts using incineration have been largely disappointing. They have potentially raised the risk of disease spread by disseminating infected fomite material into the atmosphere through the generation of convection currents leading to downwind infection of subsequent flocks. On-farm incineration is considered an unsuitable mass carcass disposal method for poultry carcasses. Off-site commercial incinerators are also less likely to be able to handle the capacity needed during an EAD outbreak in poultry, but should be scoped and identified in emergency disposal plans.

GIS (geographical information system) spatial data and data mapping

There is a significant amount of publicly available data for GIS mapping held within multiple datasets at both commonwealth and state level, however the data cannot be retrieved and collated into a single summary for farm-level analysis. For example, the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool, which is available on the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) website, requires software to be downloaded and specialised training in order to be properly utilised and as such is not designed for the casual user. The terminology used and the presentation of data in the various state-based mapping systems is also not consistent making it difficult for the casual user to find relevant information.

Decision questionnaire tool

The most appropriate websites for finding the relevant information for an on-farm mass disposal plan have been identified and provided in the mass disposal preparedness questionnaire that is intended to be available online, with instructions on navigating the sites. See Appendix A for the decision questionnaire outline. Unfortunately, farm-level data, as would be needed to plan suitable on-farm disposal options, is not always available. In these instances, the producer might have to contact their local EPA or primary industries office for clarification or more detailed information. A downloadable report that will be generated after the decision questionnaire tool is completed will at least offer significant guidance to producers and decision makers on the characteristics of the disposal site. It will then enable more timely decisions on the site’s suitability and appropriate disposal methods. Appendix C is an example of a report that will be generated once a producer completes the decision question tool.
Biomass calculator tool

The calculation or estimation of maximum possible biomass on a farm at any one time is a fundamental parameter in considering suitable disposal options, as is the type and mix of material in the biomass. Because poultry carcasses will degrade in a different way and time to litter, manure, and feed, the mix of biomass on a particular farm must be determined as part of the preplanning process. Inputs are needed for each method of on-farm disposal. It is critical to be able to accurately estimate the tonnage of biomass during the planning phase to ascertain the viability of resource availability for each possible scenario. See Appendix B for a sample of the biomass calculator tool, which is intended to be available online as an integrated component of the decision questionnaire tool.
Recommendations

In light of the findings of the project, the following points are provided as recommendations and next steps to advance mass disposal preparedness in the Australian poultry industries:

- Continue to develop and implement the Decision questionnaire and Biomass calculator tools online for producers on both Australian Eggs and AgriFutures Australia platforms
- Provide extension services to advise stakeholders of the online tools and how to use them
- Develop Standard Operating Procedures (SOPs) for composting and burial that meet the requirements of AUSVETPLAN and NASOP (Nationally Agreed Standard Operating Procedures, administered by Animal Health Australia on behalf of Animal Health Committee) for each state, given the wide disparity of EPA requirements. The literature review and guidelines for composting developed from this project can be used as a framework to develop state-specific SOPs.
- Produce legally valid Memoranda of Understanding (MOUs) between poultry industry bodies, government agriculture and EPA departments, and private disposal-related service providers such as composters, landfill operators, transport operators.
- Progress the collaboration between state government agriculture and EPA departments to develop guidelines for on-farm burial and composting for intensive animal industries across all jurisdictions, as conducted by QLD (Queensland DAF, 2016).
- Work with GIS developers to create a GIS tool that consolidates all data that addresses the AUSVETPLAN and environmental criteria for mass disposal in the Australian poultry industry. At present, this data is dispersed and requires navigation through various GIS tools and websites.
Appendix A: Decision questionnaire

**General questions**

<table>
<thead>
<tr>
<th>Introductory text of the questionnaire in general</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome to the mass disposal preparedness questionnaire for the Australian poultry industry.</td>
</tr>
<tr>
<td>This questionnaire was built to help Australian poultry producers in developing a mass disposal plan to better prepare themselves in case of an emergency.</td>
</tr>
<tr>
<td>This questionnaire will take about 30–60 minutes to complete. It involves answering questions about a potential disposal site. The questions were based on the site selection criteria of the AUSVETPLAN Disposal Manual with reference to guidance documents from the relevant environmental protection authority.</td>
</tr>
<tr>
<td>The questionnaire involves visiting external websites if information about your potential disposal site is unknown. You do not have to complete the questionnaire in one setting; you can save where you are up to and come back to the questionnaire at any time. It will also automatically save as you go to the next question.</td>
</tr>
<tr>
<td>At the end of the questionnaire, you will receive a report about your mass disposal options. You will be able to download and print this report, and use it as a document to give to government decision makers in an emergency or mass mortality.</td>
</tr>
<tr>
<td>It is recommended that you use Google Chrome or Mozilla Firefox browsers.</td>
</tr>
<tr>
<td>Please click next to begin.</td>
</tr>
</tbody>
</table>

**Farm details**

| Name |
| Position |
| Company |
| Farm address |

<table>
<thead>
<tr>
<th>1</th>
<th>Which state are you located in?</th>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW/ACT</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>What is your farm type in each production area on the farm? (multiple options available)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) Layer production farm
b) Layer rearing farm*
c) Broiler farm*
d) Turkey farm*
e) Duck farm*
f) Breeder rearing farm*
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2b</td>
<td>What other livestock do you have on the property?</td>
<td>Open text box where producer can type in response</td>
</tr>
<tr>
<td>3a</td>
<td>Fill out the total approximate weight (in tonnes) for each type of material on-farm.</td>
<td><em>Insert fields from mass disposal preparedness waste calculator</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Answers of table are placed in the report.</td>
</tr>
<tr>
<td></td>
<td>If the results of the questionnaire indicate that on-site burial can be conducted, the following text is produced at the end of question 12:</td>
<td>Note that before conducting on-farm burial, as a general guide, the total weight in tonnes to be buried is equal to the total volume of waste (m³). Specific machinery and work, health and safety requirements apply. Earthmoving machinery operators may also specify burial pit dimensions based on soil and machinery types.</td>
</tr>
<tr>
<td></td>
<td>If the results of the questionnaire indicate that on-site burial can be conducted, the following text is produced at the end of question 12:</td>
<td>Composting does not require much space as carcasses are layered within each heap. As a general rule, you need 1 metre of windrow per 1 tonne of carcass (based on a windrow that is 4.5 m wide and 1.8 m high). For information on how to construct a composting heap, see the poultry guidelines for composting.</td>
</tr>
</tbody>
</table>
| 3b | Please indicate the number of machinery available on each farm. | □ Tractors  
□ Bobcats/skid steers  
□ Front-end loaders  
□ Telehandlers  
□ Earthmoving machinery |
| 4a | Has a potential disposal site area been identified on or near the property? | a) Yes  
b) No* |
<p>| 4b | Please describe where the disposal site area is (e.g. in relation to the farm) or enter the address. | Open text box where producer can type in response |</p>
<table>
<thead>
<tr>
<th>4c</th>
<th>What is the distance from the disposal site to another poultry farm?</th>
<th>Open text box where producer can type in response (in km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If unknown, go on Google Maps (<a href="https://www.google.com/maps">https://www.google.com/maps</a>) and use the measuring tools to measure to the closest shed or range (for free range farms) of the other farm.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4d</th>
<th>What is the size of the disposal site in hectares?</th>
<th>Open text box where producer can type in response (numbers only)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If unknown, go on Google Maps (<a href="https://www.google.com/maps">https://www.google.com/maps</a>) and use the measuring tools to obtain an estimated size of the disposal site.</td>
<td></td>
</tr>
</tbody>
</table>

---

### Questions for on-site burial (as per the site selection criteria of the AUSVETPLAN Disposal Manual)

**Trigger responses**

If any answer with an * is selected in this section (questions 5–12) or question 4a (for Queensland only), the following text is produced. This is followed by dot points of the specific triggered text of each of questions 5–12. The exception is question 8, where the response for this question is to be at the bottom of all the dot points produced for this section. Following these triggered texts, the off-site burial responses for the specific state chosen in question 1 is produced.

**It is recommended that you cannot mass bury on your disposal site based on your answers of the following:**

- Text for question 4a (if triggered)
- Text for question 5 (if triggered)
- Text for question 6 (if triggered)
- Text for question 7 (if triggered)
- Text for question 9 (if triggered)
- Text for question 10 (if triggered)
- Text for question 11 (if triggered)
- Text for question 12 (if triggered)
- Text for question 13 (if triggered)

**Text for question 8**

**Off-site burial response for the specific state**

If there are no answers with an * selected in this section, then the following text is produced. The response for question 8 is also to be at the bottom of this text. The off-site burial responses for the specific state chosen in question 1 is also produced below this, except for the first paragraph marked with an *.

---

100
Based on your answers to the questions, you should be able to perform mass burial on your disposal site. However, please note that the factors highlighted in the table above, such as the distance to the nearest poultry farm and machinery available on the farm, have not been considered in this automatic process. These factors need to be properly considered by the decision-maker. Also note that the site must be easily accessible using machinery.

Text for question 8

Off-site burial response for the specific state (without first paragraph marked with an *)

The following questions are specific to the jurisdiction answered in Question 1.

WA

5a Proximity to drinking water supply

What is the distance of the disposal site to the nearest bore?

If unknown, go to:

Zoom to where your disposal site is located. Check the box 'Browse Mode' (it may take a few seconds to load). Find which bore is closest to your disposal site.

Options:
- a) Greater than 200 m
- b) Less than 200 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 200 m. It is advised that burial sites should be located at least 250 m from groundwater supply bores.1

SA

If unknown, go to:

Zoom to where your disposal site is located. Check the box 'Browse Mode' (it may take a few seconds to load). Find which bore is closest to your disposal site.

Options:
- a) Greater than 250 m
- b) Less than 250 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 250 m. It is advised that burial sites should be located at least 250 m from groundwater supply bores.1

QLD

If unknown, go to:
https://qldwaterinformation.qld.gov.au/Zoom to where your disposal site is located. Click on 'layers' on the left menu. Scroll to 'Inland waters' and tick 'Groundwater.' Bores will pop up on the map. Click on the blue spanner icon on the map, and then click on the ruler to measure the distance from the closest bore to the property boundary.

Options:
- a) Greater than 300 m
- b) Less than 300 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 300 m. It is advised that burial sites should be located at least 300 m from groundwater supply bores.1

NSW/ACT?

If unknown, go to:

Zoom to where your disposal site is located. Select ‘All bores’ under ‘bores’ (ensure ‘bores’ is ticked). Find which bore is closest to your disposal site.

Options:
- a) Greater than 200 m
- b) Less than 200 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 200 m. It is advised that burial sites should be located at least 200 m from groundwater supply bores.1

VIC

If unknown, go to:

Zoom to where your disposal site is located. Ensure ‘Bores – FedUni’ and ‘Bores – WMBS’ under the ‘Bores and Springs’ folder on the right-hand side are ticked. Use the ruler under the ‘tools’ section to measure the distance from the closest bore to the property boundary.

Options:
- a) Greater than 200 m
- b) Less than 200 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 200 m. It is advised that burial sites should be located at least 200 m from groundwater supply bores.1

TAS

If unknown, go to:

Zoom to where your disposal site is located. Select ‘All bores’ under ‘bores’ (ensure ‘bores’ is ticked). Find which bore is closest to your disposal site.

Options:
- a) Greater than 100 m
- b) Less than 100 m*

*a triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest bore is less than 100 m. It is advised that burial sites should be located at least 100 m from groundwater supply bores.1

5b Water catchment areas

What catchment area is your disposal site located in?

To get an idea, go to:
http://www.water.wa.gov.au/.../大きいまちの新築住宅
Download and retain this report as part of your disposal records.

Open textbox where producer can enter answer

To get an idea, go to:

Go to Data Search;
Search for Surface Water Catchments. Click on Zoom to the extent of this dataset. Zoom to where your disposal site is located and view the boundaries of the catchment area.

To get an idea, go to:

Go to Data Search;
Search for Surface Water Catchments. Click on Zoom to the extent of this dataset. Zoom to where your disposal site is located and view the boundaries of the catchment area.

To get an idea, go to:

Find which catchment area your disposal site is located in using the map or drop down menus, and note this in your response.

Open textbox where producer can enter answer

To get an idea, go to:

Use the interactive map to find the closest catchment management authorities and note this in your response.

Open textbox where producer can enter answer

101
### 6a Proximity to human habitation

What is the distance of the disposal site to the nearest neighbouring residential building?

If unknown, you can go on Google Maps ([https://www.google.com/maps](https://www.google.com/maps)) and use the measuring tools to measure the distance between the disposal site and the nearest neighbouring residential building.

**Options:**
- a) Greater than 300 m
- b) Less than 300 m*

*triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest neighbouring residential building is less than 300 m. It is advised that burial sites should be located at least 300 m from the nearest neighbouring residential building. 

- a) Greater than 500 m
- b) Less than 500 m*

*triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest neighbouring residential building is less than 500 m. It is advised that burial sites should be located at least 500 m from the nearest neighbouring residential building.

- a) Greater than 1 km
- b) Less than 1 km*

*triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest neighbouring residential building is less than 1 km. It is advised that burial sites should be located at least 1 km from the nearest neighbouring residential building.

**6b Specific question for NSW and VIC only**

Is the disposal site well away from the view of the general public?

**N/A**

**6c Specific question for QLD only**

What is the distance of the disposal site to the nearest neighbouring town?

If unknown, you can go on Google Maps ([https://www.google.com/maps](https://www.google.com/maps)) and use the measuring tools to measure the distance between the disposal site and the nearest neighbouring town.

**Options:**
- a) Greater than 2 km
- b) Less than 2 km

*triggers the following text in the final report:

You indicated that the distance from the disposal site to the nearest neighbouring town is less than 2 km. It is advised that burial sites should be located at least 2 km from the nearest neighbouring town.

**7 Soil characteristics**

Please provide a short description of the soil at the disposal site. How water-repellent is the soil?

What is the soil type at the disposal site?

What is the soil type at the disposal site?

What is the soil type at the disposal site?

If unknown, download and print the following map and keep as part of your report.

What is the soil type at the disposal site?
**Groundwater depth**

What is the groundwater depth of the disposal site in metres?


Zoom to where your disposal site is located. Click on the 5th layer icon on the top right 'Soil – Land Qualities'. Tick the box 'Land Qualities – Water Repellence Susceptibility.'

Open textbox where producer can enter answer

If unknown, go to: http://www.aginsight.sa.gov.au/

Click on 'Geoscientific', then 'Soil' and check the box for 'Soil group (soil type)'.

Then click on 'Active layers' at the top, and click on the icon that represents dot points and a list, which will show what the colours represent.

Open textbox where producer can enter answer

If unknown, go to: http://www.aginsight.sa.gov.au/

Click on 'Map Data' (on right-hand side), then 'Water Resources', then 'Shallow Groundwater depth'.

Go to where your disposal site is located. Click on 'Legend' (on left-hand side) and match the corresponding colour over your disposal site with the groundwater depth in metres.

Open textbox where producer can type in response (numbers only) 

If unknown, go to: https://www.environment.nsw.gov.au/eS agreement=Agree+and+Continue

Click on 'Map layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'. Click on the 'Identify' tool, then 'GWIMS features' and click 'Ok'. Click on the bar of the map. Tick the box 'GWIMS features' and click 'Okay'.

Zoom to where your disposal site is located. Click on 'Custom layers' on the right-hand side. Select 'Modelled Soil Properties', then 'Clay (%)', then 'Clay 7%, 30-100cm'. A coloured layer will appear over the map.

Open textbox where producer can enter answer


Zoom to where your disposal site is located. Click on 'custom layers' on the right-hand side. Select 'Modelled Soil Properties', then 'Clay (%)', then 'Clay 7%, 30-100cm'. A coloured layer will appear over the map.

Open textbox where producer can enter answer

Not specified

If unknown, go to: https://www.qvg.org.au/vvg_map.php?agreement=Agree+and+Continue

Zoom to where your disposal site is located. Click on 'custom layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'. Click on the 'Identify' tool, then 'GWIMS features' and click 'Okay'.

Zoom to where your disposal site is located. Click on 'custom layers' on the right-hand side. Select 'Modelled Soil Properties'. Select 'Clay (%)', then 'Clay 7%, 30-100cm'. A coloured layer will appear over the map.

Open textbox where producer can type in response (numbers only) 

If unknown, go to: https://wrt.tas.gov.au/groundwater-info/

Zoom to where your disposal site is located. Click on 'custom layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'.

Open textbox where producer can enter answer


If unknown, go to: https://www.vvg.org.au/vvg_map.php?agreement=Agree+and+Continue

Zoom to where your disposal site is located. Click on 'custom layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'.

Open textbox where producer can enter answer

If unknown, go to: https://www.vvg.org.au/vvg_map.php?agreement=Agree+and+Continue

Zoom to where your disposal site is located. Click on 'custom layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'.

Open textbox where producer can enter answer

If unknown, go to: https://www.vvg.org.au/vvg_map.php?agreement=Agree+and+Continue

Zoom to where your disposal site is located. Click on 'custom layers' on the top bar of the map. Tick the box 'GWIMS features' and click 'OK'.

Open textbox where producer can enter answer

To get an idea, contact the Tasmanian EPA about the soil type on your farm and record the answer.

Open textbox where producer can enter answer

8

The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.

The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.

The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.

The following text is produced in the report:

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The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.

The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.

The following text is produced in the report:

You answered that the groundwater depth of the disposal site is __ metres.
machinery with minimal slope of the land.

You answered that the groundwater depth of the disposal site is __ metres.

It is advised that there should be at least a 10 metre separation from the bottom of the burial pit to the groundwater level.1

Please also note that the disposal site must be easily accessible to earthmoving machinery with minimal slope of the land.

9a Proximity to surface water

What is the nearest distance of the disposal site to any defined depressions (e.g. cliffs), watercourses or surface water catchments (e.g. farm dams, streams, rivers, creek beds and wetlands)?

If unknown, go to Google Maps: https://www.google.com/maps

Zoom to where your disposal site is located. Measure the distance from your disposal site to the closest waterbody, using the Google Maps measuring tools. Note: Google Maps might not identify your farm dam so you will have to measure this separately.

Options:

a) Greater than 200 m
b) Less than 200 m*

*triggers the following text in the final report:

You indicated that the disposal site is less than 200 m from defined depressions (e.g. cliffs), watercourses or surface water catchments (e.g. farm dams, streams, rivers, creek beds and wetlands). It is advised that burial sites should be located more than 200 m from these features.1

9b Specific question for QLD only

What is the nearest distance from the disposal site to the coast?

If unknown, go to Google Maps: https://www.google.com/maps

Zoom to where your disposal site is located. Measure the distance between your disposal site and the coast using the Google Maps measuring tools.

Options:

a) Greater than 2 km
b) Less than 2 km

*triggers the following text in the final report:

You indicated that the disposal site is less than 2 km from the coast. It is advised that burial sites should be located more than 2 km from the coast.1

10 Site accessibility & site terrain

Are underground services (e.g. pipelines, power and telephone lines) or above-ground utilities at least 250 m from the disposal site?

For major energy and water supply infrastructure, go to:

If unknown, call 1100 or lodge an enquiry at https://www.1100.com.au/
<table>
<thead>
<tr>
<th>infrastructure a safe distance from the disposal site?</th>
<th>Options:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Yes</td>
<td>b) No*</td>
</tr>
<tr>
<td>*triggers the following text in the final report:</td>
<td></td>
</tr>
<tr>
<td>You indicated that the site is not a safe distance from underground services (e.g. pipelines, power and telephone lines) or above-ground infrastructure. Disposal cannot occur where it can interfere with underground services or above-ground infrastructure.</td>
<td></td>
</tr>
</tbody>
</table>

Click on 'Infrastructure' then 'Pipelines and gas' and check the box for 'Licences, gas pipeline (petroleum)'.

Click on the downward arrow next to 'Location search' and click on 'Infrastructure' again.

Click on 'Water' and check the box for 'SA power networks underground distribution lines' and 'Water mains (pipelines)'

Confirm that there is no underground infrastructure:

- Calling 1100, or lodge an enquiry at https://www.1100.com.au/
- Options:
  - c) Yes
  - d) No*

*triggers the following text in the final report:

You indicated that the site is not a safe distance from underground services (e.g. pipelines, power and telephone lines) or above-ground infrastructure. Disposal cannot occur where it can interfere with underground services or above-ground infrastructure. 1

---

<table>
<thead>
<tr>
<th>Proximity to protected and other areas</th>
<th>Options:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Yes</td>
<td>b) No</td>
</tr>
<tr>
<td>*triggers the following text in the final report:</td>
<td></td>
</tr>
<tr>
<td>You indicated the site is not a safe distance from underground services (e.g. pipelines, power and telephone lines) or above-ground infrastructure. Disposal cannot occur where it can interfere with underground services or above-ground infrastructure.</td>
<td></td>
</tr>
</tbody>
</table>

Click on 'Infrastructure/energy and water supply'.

Confirm that there is no underground infrastructure:

- Call 1100, or lodge an enquiry at https://www.1100.com.au/
- Options:
  - a) Yes
  - b) No*

*triggers the following text in the final report:

You indicated the site is not a safe distance from underground services (e.g. pipelines, power and telephone lines) or above-ground infrastructure. Disposal cannot occur where it can interfere with underground services or above-ground infrastructure. 1

---

<p>| 11a Proximity to protected and other areas | Options: |</p>
<table>
<thead>
<tr>
<th>Is the disposal site within a flood-prone area, such as a one-in-100 years flood area?</th>
<th>Options:</th>
</tr>
</thead>
<tbody>
<tr>
<td>If unknown, go to:</td>
<td>If unknown, go to:</td>
</tr>
</tbody>
</table>

Zoom to where your disposal site is located. Click on the layer icon on the top right ‘Soil – Land Qualities.’ Tick the box ‘Land Qualities – Flood Hazard.’

If your disposal site is within a coloured region of the map (i.e. light yellow to purple), then it is in a flood-prone area.

Options: |
| a) Yes* |
| b) No |

Not specified

If the disposal site is within or close to the Hawkesbury-Nepean Valley, you can determine your risk by going to:


Zoom to where your disposable site is located, select ‘medium likelihood’ on the left-hand side. If the disposal site is covered by any depth of flooding, it is within a flood-prone area.

If the disposal site is not within the Hawkesbury-Nepean Valley, contact your local council to determine whether the area is within a one-in-100 years flood area.

Options: |
| a) Yes* |
| b) No |

**Not specified**

If your disposal site located in a flood-prone area? |

If unknown, go to: |


Zoom to the disposal site location. Click ‘layers’ on the right-hand side. Click ‘add layer.’ Search for ‘flood’. Click the green plus button next to ‘Floodplain.’ If your disposal site is located in a pink-red area highlighted on the map, then it is located in a flood-prone area.

Options: |
<p>| a) Yes |
| b) No |</p>
<table>
<thead>
<tr>
<th>1b</th>
<th>Specific question for QLD</th>
<th></th>
<th></th>
<th>11b</th>
<th>Specific question for QLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the distance from the disposal site to any protected areas?</td>
<td>If unknown, go to: <a href="https://qldglobe.information.qld.gov.au/">https://qldglobe.information.qld.gov.au/</a> Zoom to where your disposal site is located. Under ‘All Layers,’ scroll down and check ‘Matters of state environmental significance’ (MSES). Then scroll down to ‘Parks,’ then check ‘Protected areas.’ Measure distance from your disposal site to any coloured area. Options: a) &gt;250 m b) &lt;250 m*</td>
<td>*triggers the following text in the final report: You indicated that the disposal site is less than 250 m of a protected area. It is advised that burial sites should not be within 250 m of a protected area.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Questions for on-site composting**

**Trigger responses**

The questionnaire ends for QLD and TAS, unless the producer answers any of b) to f) in question 2a (see below). The text in question 12 is produced for these states.

For WA, SA, NSW and VIC, if any answer with an * is selected in this section (questions 13–15), the following text is produced. This is followed by dot points of the specific triggered text of each question from questions 13–15.

*It is recommended that you cannot mass compost on your disposal site, based on your answers of the following:*

- Text for question 13 (if triggered)
- Text for question 14 (if triggered)
The following questions are specific to the jurisdiction answered in Question 1.

<table>
<thead>
<tr>
<th>WA</th>
<th>SA</th>
<th>QLD</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
</tr>
</thead>
</table>
| 12 | How far is your disposal site (farm) from a wetland of conservation value? | Is your disposal site (farm) within any Water Protection Areas (these include the Murray River Floodplain, the Mount Lofty Ranges and South East water protection areas)? | Is your disposal site within an area of significant environmental or conservation value? | Is your disposal site (farm) on land prone to flooding? | Contact your state EPA to confirm whether on-site composting can be conducted on your disposal site.

### WA

Zoom to where your disposal site (farm) is located (or click My Location in the bottom left, which will locate your current position). Click on the ‘layer’ list

### SA

Please refer to the following guideline: [https://environment.des.qld.gov.au/__data/assets/pdf_file/0037/88939/pr-gl-open-windrow-composting.pdf](https://environment.des.qld.gov.au/__data/assets/pdf_file/0037/88939/pr-gl-open-windrow-composting.pdf)

which states that “The site should be sited in a location so that the risk of impact from odour, dust and water...”

### QLD
on the top right. Under the ‘environment’ dropdown, check ‘Directory of Important Wetlands in Australia – Western Australia.’ Ensure ‘Environment’ is also checked. Measure the distance using the ruler on the top right.

Options:

a) Greater than 1,000 m
b) Less than 1,000 m*

* triggers the following text in the final report:

You indicated that the site was less than 1,000 m from a wetland of conservation value. It is advised that composting sites should be at least 1,000 m from a wetland of conservation value.2

Observe the highlighted areas that are known as Water Protection Areas, and note whether your disposal site (farm?) is located in any of these regions.

Options:

a) Yes
b) No*

* triggers the following text in the final report:

You indicated that the site was within a Water Protection Area. It is advised that composting sites should be outside of these Areas.1

Contact your state EPA to confirm whether on-site composting can be conducted on your disposal site.

Alternatively, go to: https://nationalmap.gov.au/ and explore the data to identify conservation areas around your site.

Options:

a) Yes
b) No*

* triggers the following text in the final report:

You indicated that the site was within an area of significant environmental or conservation value. It is advised that composting sites should be outside of these Areas.1

Open the folder ‘Climate and Environment’ and then ‘Flood.’ Tick the boxes ‘1 in 100 year flood’ and ‘Historic flood extent’. Zoom to where your disposal site (farm?) is located. If your disposal site (farm?) is within the coloured regions, then it is in a flood-prone area.

Options:

a) Yes
b) No*

* triggers the following text in the final report:

You indicated that the disposal site is within a flood-prone area. It is advised that composting sites should not be within a flood-prone area, i.e. >1-in-100 years flood level.1

The closest distance from the disposal site (farm?) to any watercourse, drain (surface or subsurface), minor wetland or estuary?


Zoom to where your disposal site (farm?) is located (or, click on the geolocator in the top right, which will locate your current position). Find which bore is closest to your disposal site (farm?).

Options:

Further composting text for NSW (produced if the farmer answers Yes to question 12, i.e. is able to compost on farm):

For NSW, please also note that composting must not be performed in any lands nominated as special or protected areas by local water supply authorities (such as Sydney Water, Hunter Water, councils) or in the vicinity of a groundwater bore used as drinking water. Composting should also not occur on floodplains that may be subject to washout during major flood events. Contact your local council for information about significant water and flooding events in your area.

How far is the disposal site (farm?) to surface water?

Go to: http://www.vic.waterwatch.org.au/water-watch_map

Tick ‘GA Surface Hydrology – Major and Minor Rivers’ under the ‘Waterways’ folder and ‘Victorian wetland environments (2013)’ under the ‘Wetlands’ folder. Measure the distance from highlighted surface water to the disposal site (farm?) using the ruler found under ‘tools’.

Options:

a) Greater than 100 m
b) Less than 100 m*

* triggers the following text in the final report:
<table>
<thead>
<tr>
<th>Options</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Greater than 500 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Less than 500 m*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* triggers the following text in the final report:

You indicated that the site was less than 500 m from any watercourse, drain, minor wetland or estuary. It is advised that composting sites should be at least 500 m from any watercourse, drain, minor wetland or estuary.²

<table>
<thead>
<tr>
<th>Options</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Greater than 300 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Less than 300 m*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* triggers the following text in the final report:

You indicated that the site was less than 200 m from a potable supply well/bore. It is advised that composting sites should be at least 200 m from a potable supply well/bore.²
## Online calculator tool for on-site disposal

<table>
<thead>
<tr>
<th><strong>Off-site burial response</strong></th>
<th><strong>Online calculator tool for on-site disposal</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Given the location of your disposal site, you do not meet the recommended burial guidelines. However, you may wish to contact the state Environmental Protection Authority (EPA) to confirm this.</em></td>
<td><em>Given the location of your disposal site, you do not meet the recommended burial guidelines. However, you may wish to contact the state Environmental Protection Authority (EPA) to confirm this.</em></td>
</tr>
<tr>
<td>The EPA was contacted about the landfill site _______________. The EPA confirmed the landfill site could/could not accept putrescible waste carcasses based on their licence.</td>
<td>When you have selected a potential landfill site, contact the EPA to confirm the site is suitable to accept poultry carcasses based on their licence. You may also wish to contact the landfill site itself to see if they would be willing to take poultry carcasses. Record your communications below:</td>
</tr>
<tr>
<td>The landfill site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.</td>
<td>The EPA was contacted about the landfill site _______________. The EPA confirmed the landfill site could/could not accept putrescible waste carcasses based on their licence.</td>
</tr>
<tr>
<td>The landfill site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.</td>
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</tr>
<tr>
<td>The landfill site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event.</td>
<td>Contact the EPA at 1300 372 842 to find the closest landfill that can accept poultry carcasses.</td>
</tr>
<tr>
<td>When you have selected a potential landfill site, contact the EPA to confirm the site is suitable to accept poultry carcasses based on their licence. You may also wish to view the licence documentation. See if the site can take poultry carcasses by finding ‘Putrescible waste’ under ‘Permitted Wastes Disposal’.</td>
<td>Please note that the EPA must be contacted before any burial.</td>
</tr>
<tr>
<td>To find the closest landfill, contact your EPA or go to: <a href="https://www.epa.sa.gov.au/data_and_publications/search-public-licences/search-location-area">https://www.epa.sa.gov.au/data_and_publications/search-public-licences/search-location-area</a> Select any landfills that come up, and view the licence documentation. See if the site can take poultry carcasses by finding ‘Putrescible waste, animal waste, or similar, under limit conditions – Waste’.</td>
<td>To find the closest landfill, contact your EPA or go to: <a href="https://apps.epa.nsw.gov.au/prpoeoapp">https://apps.epa.nsw.gov.au/prpoeoapp/</a> Click on the Fee-based activity dropdown menu and select ‘Waste disposal by application to land.’</td>
</tr>
<tr>
<td>The landfill site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept putrescible waste carcasses in a mass disposal event.</td>
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</tr>
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</tr>
<tr>
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</tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
</tbody>
</table>

110
Off-site composting response

*Given the location of your disposal site, you do not meet the recommended composting guidelines. However, you may wish to contact the state Environmental Protection Authority (EPA) to confirm this.

*Given the location of your disposal site, you do not meet the recommended composting guidelines. However, you may wish to contact the state Environmental Protection Authority (EPA) to confirm this.

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The landfill site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

The composting site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

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The composting site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

The EPA was contacted about the composting site. The EPA confirmed the site could/could not accept poultry carcasses based on their licence.

Select any composting sites that come up, and view the licence documentation. See if the site can take poultry carcasses by finding ‘Animal Mortalities’ in the table under ‘Waste acceptance’ or similar.

When you have selected a potential composting site, contact the EPA to confirm the site is suitable to accept poultry carcasses, based on their licence. You may also wish to contact the composting site itself to see if they would be willing to take poultry carcasses. Record your communications below:

The EPA was contacted about the composting site. The EPA confirmed the site could/could not accept poultry carcasses based on their licence.

When you have selected a potential composting site, contact the EPA to confirm the site is suitable to accept poultry carcasses based on their licence. You may also wish to contact the composting site itself to see if they would be willing to take poultry carcasses. Record your communications below:

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The EPA was contacted about the composting site. The EPA confirmed the site could/could not accept poultry carcasses based on their licence.
poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

not accept poultry carcasses in a mass disposal event.

not accept poultry carcasses in a mass disposal event.

The composting site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

The composting site was contacted to see if they would be willing to take poultry carcasses in a mass disposal event. The site stated they could/could not accept poultry carcasses in a mass disposal event.

EPA considerations for composting

Please note that under the Environmental Protection Act 1986, a licence is needed if composting over 1,000 tonnes or more per year. Please contact the state EPA to ensure the appropriate requirements are met.

Please note that under the Environment Protection Act 1993, a licence is needed if composting over 200 tonnes per year. Please contact the state EPA to ensure the appropriate requirements are met.

Please note that under the Environmental Protection Act 1994, a licence is needed if composting over 200 tonnes per year. Please contact the state EPA to ensure the appropriate requirements are met.

Please note that under the Environment Protection Act 1997, a licence is needed if composting over 1,800 tonnes of material per year or accept more than 100 tonnes of organic waste in any month, or accept more than 70 tonnes of organic waste in a month and produce more than 50 tonnes of compost in any month. There are exemptions if premises retain the processed waste on the premises. Please contact the state EPA to ensure the appropriate requirements are met.

Licence requirements

A composting site will need a licence if:

(a) where it takes place inside the regulated area, or takes place outside the regulated area but receives organics from inside the regulated area (whether or not it also receives organics from outside the regulated area):

(i) it has on site at any time more than 200 tonnes of organics received from off site, or

(ii) it receives from off-site more than 5,000 tonnes per year of non-putrescible organics or more than 200 tonnes per year of putrescible organics, or

(b) where it takes place outside the regulated area and does not receive organics from inside the regulated area:

(i) it has on site at any time more than 2,000 tonnes of organics received from off site, or

(ii) it receives from off-site more than 5,000 tonnes per year of non-putrescible organics or more than 200 tonnes per year of putrescible organics.

The regulated area of NSW that comprises the Sydney metropolitan area, the Illawarra and Hunter regions, the central and north coast local government areas to the QLD border, as well as the

Resource recovery orders and exemptions

If carcasses are composted for end-use product on-site, the NSW composting orders and exemptions (as part of the resource recovery framework to facilitate the lawful re-use of recovered wastes) apply to any amount of material taken off-site.

If raw materials or pre-composted material is taken off-site to a licensed commercial composter, the resource recovery framework in this instance would be at the responsibility of the commercial composter.


References

Have these references available as a footnote of the report

1Department of Agriculture and Food – Emergency animal disease Standard operating procedure (Bowyer, 2016, Version 1.0). Western Australia

2Composting guidelines (2016) of the Department of Environment Regulation. Western Australia


4EPA 682/16 On-farm disposal of animal carcasses. Environmental Protection Authority, South Australia

5Composting guideline (2016) of the Environmental Protection Authority, South Australia

6Guidance Document – Establishing a mass burial facility for disposal of carcasses and material contaminated with an infectious emergency animal disease agent (2016). Department of Agriculture and Fisheries. Queensland


10Designing, constructing and operating composting facilities (2017). Environment Protection Authority. Victoria

11Environmental guidelines for the design and operation of an offal pit for the disposal of slaughter waste (2013). Food and textiles Unit, Environment Protection Authority, Tasmania
Appendix B: Biomass calculator

Fill out the total approximate weight (in tonnes) for each type of material in the blue cells below.

The calculators below this table help to estimate the weights of litter in sheds and eggs + cardboard trays, if you are unsure.

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Number</th>
<th>Average weight (kg)</th>
<th>Total Weight (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter in sheds</td>
<td></td>
<td></td>
<td>1440</td>
</tr>
<tr>
<td>Manure in sheds*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter stored outside of sheds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed</td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Eggs + cardboard trays</td>
<td></td>
<td></td>
<td>2340</td>
</tr>
<tr>
<td>Poultry (maximum carrying capacity and weight)</td>
<td>40000</td>
<td>2.2</td>
<td>88</td>
</tr>
<tr>
<td>Total tonnes</td>
<td></td>
<td></td>
<td>3883</td>
</tr>
</tbody>
</table>

*applies to slatted sheds. Leave blank if the shed is non-slatted, and manure is incorporated in the litter (e.g. broiler farms).

### Litter calculator for inside sheds

<table>
<thead>
<tr>
<th>Shed Size</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sheds on farm</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Average depth of litter, in cm</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Total m³</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>1440 tonnes (based on 0.48 m³ per tonne)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Eggs + cardboard trays

Note: if you use only plastic egg trays, please input 0 for cardboard egg tray weight (orange cell).

<table>
<thead>
<tr>
<th>Number</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs per tray</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Cardboard trays per pallet</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Pallets per farm</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Average egg weight (grams)</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Average cardboard tray weight (grams)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Eggs on farm at any point in time</td>
<td>36000</td>
<td></td>
</tr>
<tr>
<td>Tonnes of eggs + cardboard trays on-farm at any point in time</td>
<td>2340</td>
<td></td>
</tr>
</tbody>
</table>

As a guide, the total volume of waste (m³) is equal to the total weight in tonnes

Machinery available on farm:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractors</td>
<td></td>
</tr>
<tr>
<td>Bobcats/skid steer</td>
<td></td>
</tr>
<tr>
<td>Front-end loader</td>
<td></td>
</tr>
<tr>
<td>Telehandler</td>
<td></td>
</tr>
<tr>
<td>Earthmoving machinery</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Sample mass disposal report for completed questionnaire

Hypothetical poultry operator in SA who is able to conduct on-farm burial and on-farm composting based on answers to questionnaire.

Questionnaire answers

<table>
<thead>
<tr>
<th>Farm details</th>
<th>Name: Joe Bloggs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position: General farm manager</td>
</tr>
<tr>
<td></td>
<td>Company: Eggs for you</td>
</tr>
<tr>
<td></td>
<td>Farm address: 1234 Egg St, Adelaide</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>State</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>Farm type</td>
<td>Layer production farm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer rearing farm</td>
</tr>
<tr>
<td>2b</td>
<td>Other livestock on property</td>
<td>Sheep</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3a</th>
<th>Mass disposal calculator</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of material</td>
<td>Number</td>
</tr>
<tr>
<td>----</td>
<td>--------------------------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td>Litter in sheds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manure in sheds*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Litter stored outside of sheds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eggs + cardboard trays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poultry</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

| 3b | Machinery available on-farm | 2 x tractors |
|    |                              | 1 x front-end loader |

<table>
<thead>
<tr>
<th>4a</th>
<th>Disposal site identified</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4b</td>
<td>Disposal site description</td>
<td>Large paddock 5 km away from the farm</td>
</tr>
<tr>
<td>4c</td>
<td>Closest poultry farm</td>
<td>10 km</td>
</tr>
<tr>
<td>4d</td>
<td>Disposal site size</td>
<td>5 hectares</td>
</tr>
<tr>
<td>5a</td>
<td>Distance to bore</td>
<td>&gt;250 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>5b</td>
<td>Within water catchment area</td>
<td>550 m</td>
</tr>
<tr>
<td>6a</td>
<td>Distance to residential building</td>
<td>&gt;500 m</td>
</tr>
<tr>
<td>6b</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>6c</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>7</td>
<td>Soil type</td>
<td>Clay</td>
</tr>
<tr>
<td>8</td>
<td>Groundwater depth</td>
<td>20 m</td>
</tr>
<tr>
<td>9a</td>
<td>Distance to surface water</td>
<td>&gt;500 m</td>
</tr>
<tr>
<td>9b</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>10</td>
<td>Site accessibility</td>
<td>Underground services and above-ground infrastructure are at a safe distance from the disposal site</td>
</tr>
<tr>
<td>11a</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>11b</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>12</td>
<td>Is the disposal site within any water protection areas?</td>
<td>No</td>
</tr>
<tr>
<td>12#</td>
<td>Is the farm within any water protection areas?</td>
<td>No</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>N/A for SA</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>N/A for SA</td>
</tr>
</tbody>
</table>

**Recommendations based on questionnaire answers**

**On-site burial**

Based on your answers to the questions, you should be able to perform mass burial on your disposal site. However, please note that the factors highlighted in the table above, such as the distance to the nearest poultry farm and machinery available on the farm, have not been considered in this automatic process. These factors need to be properly considered by the decision-maker. Also note that the site must be easily accessible using machinery.

You answered that the groundwater depth of the disposal site is 20 metres.

It is advised that there should be at least a 5-metre separation from the bottom of the burial pit to the groundwater level.

**Off-site burial**

To find the closest landfill, contact your EPA or go to: [https://www.epa.sa.gov.au/data_and_publications/search-public-register#/search?location=area](https://www.epa.sa.gov.au/data_and_publications/search-public-register#/search?location=area)

Select ‘licence’ from Record type, type the closest suburb, select ‘landfill depot’ from activity.

Select any landfills that come up, and view the licence documentation. See if the site can take poultry carcasses by finding Putrescible waste under Permitted Wastes Disposal.
When you have selected a potential landfill site, contact the EPA to confirm the site is suitable to accept poultry carcasses based on their licence. You may also wish to contact the landfill site itself to see if they would be willing to take poultry carcasses. Record your communications below:

The EPA was contacted about the landfill site.

The EPA confirmed the landfill site could/could not accept poultry carcasses based on their licence.

The landfill site was contacted to see if they would be willing to take poultry carcasses for mass disposal. The site stated they could/could not accept poultry carcasses for mass disposal.

On-site composting

Based on your answers to the questions, you should be able to perform mass composting on your disposal site. However, please note that the factors highlighted in the table above, such as the distance to the nearest poultry farm and machinery available on the farm, have not been considered in this automatic process. These factors need to be properly considered by the decision-maker. Composting can also contaminate shallow groundwater and water catchment areas. Also note that the site must be easily accessible using machinery.

Based on your farm type and location, composting inside your sheds has been identified as a potential option.

Off-site composting

To find the closest off-site composting facility, contact your EPA or go to: https://www.epa.sa.gov.au/data_and_publications/search-public-register#/search?location=area

Select ‘licence’ from Record type, type the closest suburb, select ‘composting’ from activity.

Select any sites that come up, and view the licence documentation. See if the site can take poultry carcasses by finding ‘Compostable Organic Waste’ under ‘Permitted Feedstock’ or ‘Permitted wastes receipt.’

When you have selected a potential composting site, contact the EPA to confirm the site is suitable to accept poultry carcasses based on their licence. You may also wish to contact the composting site itself to see if they would be willing to take poultry carcasses. Record your communications below:

The EPA was contacted about the composting site:

The EPA confirmed the landfill site could/could not accept poultry carcasses based on their licence.

The composting site was contacted to see if they would be willing to take poultry carcasses for mass disposal. The site stated they could/could not accept poultry carcasses for mass disposal.
**EPA considerations**

Please note that under the Environment Protection Act 1993, a licence is needed if composting over 200 tonnes per year. Please contact the state EPA to ensure the appropriate requirements are met.

**References**


2. EPA 682/16 On-farm disposal of animal carcasses. Environmental Protection Authority. South Australia

3. Composting guideline (2016) of the Environmental Protection Authority. South Australia
References


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Mass disposal preparedness for the poultry industries

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