# General Rules for Decontamination Following an Outbreak of Avian Influenza or Newcastle Disease

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Maria Serena Beato and Paola De Benedictis

## 12.1 Introduction

Rapid application of strict biosecurity measures is the first step to prevent and control the introduction of avian influenza (AI) or Newcastle disease (ND) viruses. Biosecurity comprises two elements: bio-exclusion and bio-containment. Bio-exclusion includes all measures aimed at excluding infectious agents from uninfected premises. It requires the prevention of direct and indirect contact of infected animals or contaminated inanimate carriers (*fomites*) with poultry. Bio-containment includes all measures aimed at maintaining the infection within the premises from where the diagnosis was first obtained. Decontamination of the infected farm is one of the actions that must be adopted during the bio-containment process (EFSA 2005). Secondary spread of AI and ND is achieved mainly through human-related activities, such as the movement of staff, vehicles, equipment and other fomites. Further outbreaks may occur following restocking of birds in establishments that have not been adequately sanitised. It therefore follows that if decontamination of premises, footwear and clothing, vehicles, crates, farm equipment and other materials is not carried out properly, infection will persist in the avian population. Thus, the concurrent damage to the poultry industry and, in many instances, the public health threat will not be removed. For this reason, cleaning and disinfecting must be considered as an essential part of AI and ND control programmes. Decontamination is the combination of physical and chemical processes that kill or remove pathogenic microorganisms and is of crucial importance for disease eradication. Decontamination involves close cooperation between property owners and the personnel involved in the procedures. Natural processes, such as time, dehydration, warm temperature and sunlight, favour decontamination. Since most disinfectants have reduced effectiveness in the presence of fat and organic matter, preliminary cleaning is needed invariably before any disinfection, in order to achieve effective chemical decontamination.

## 12.2 Choice of Disinfectant

When a disinfection programme is to be implemented, many factors must be taken into account in order to achieve the goal of decontaminating the infected area and, in the meantime, limiting spread of infection to uninfected farms. Knowledge of the characteristics of infectious agents plays a key role in the selection of the disinfectant. AI and ND viruses are multiplied and released at a high concentration by their host species and are able to persist in the environment (Beard and Hanson 1984; De Benedictis et al. 2007). Nevertheless, their resistance to common disinfectants is relatively low, according to the Noll and Youngner classification (1959). Both AI and ND viruses are medium-sized, single-stranded (ss) RNA, enveloped viruses. They are classified as Category A viruses (Noll and Youngner 1959).

However, when planning a disinfection programme, other factors also need to be taken into account, namely the properties of disinfectants, external factors that can influence the activity of the disinfectants and the characteristics of the premises to be decontaminated. Choice of the appropriate disinfectant relies on its proven efficacy against AI and ND viruses. The assessment should also include sustainability under certain circumstances (i.e. pH and temperature for optimal activity, stability in the presence of organic material or in hard water, con-

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tact time and safety for personnel). Products should be used at a concentration of proven efficacy against the selected agent. Most disinfectants require a minimum contact time, usually not less than 30 min, depending on environmental conditions. The toxicity of some chemical agents limits the range of choice. The use of a compound with a high toxicity should be avoided although compounds with mild toxicity may be used under controlled circumstances. It is of primary importance that the staff members are trained in disinfecting procedures in order to achieve optimal results and avoid adverse consequences to operators, equipment and the environment. Corrosiveness can be limited by diluting the compound whilst taking into account the minimum concentration necessary to maintain viricidal activity. In many instances, the cost and availability, at a local level, of the disinfectant product are the main limiting factors.

The best inactivating agents for Category A viruses, including AI and ND viruses, are considered to be detergents, alkalis, oxidising agents, and aldehydes (Ausvetplan 2007). The use of soaps and detergents is recommended only for preparatory clean-up procedures before proper decontamination. Alkalis are ideal decontaminating chemicals for animal housing, yards, drains, effluent waste pits and sewage collection areas. Sodium hydroxide, caustic soda and sodium carbonate washing soda are readily available, cost-effective and have a saponifying action on fats and organic matter. In contrast, oxidising agents are not recommended for decontamination procedures. The effectiveness of household bleach (sodium hypochlorite) and hypochlorite powder decreases markedly in the presence of organic matter; these compounds are also not stable chemically and decompose rapidly at temperatures above 15°C. Commercial products are highly effective, although expensive, and should be used according to the manufacturer's instructions. Within the aldehyde family, gluteraldehyde is efficacious, stable and partially active in the presence of organic matter, although it is a mild corrosive for metals. Despite these positive characteristics, the cost of gluteraldehyde for large-scale decontamination is high.

Gaseous formaldehyde is still used for the decontamination of air spaces. However, many parameters have to be assessed to achieve a complete and effective decontamination, including gas concentration, temperature, humidity, contact time and evenness of distribution (see Appendix A for practicalities of formaldehyde gas use).

Other external factors that should be considered to achieve optimal efficacy of the decontamination process are the calcium concentration in the water used to prepare the disinfectant solution and the environmental temperature, both of which influence the efficacy of the disinfectant. In general, disinfectants are most efficacious at high temperatures, reaching optimum efficacy above 20°C (e.g. the optimum range for formaldehyde activity is 24–38°C) (Samberg and Meroz 1995). Some products effective against AI have been tested in combination with antifreeze compounds and shown to retain their activity (Davison et al. 1999). During the winter or in case of low environmental temperatures, the efficacy of certain disinfectants may be reduced. It is essential that the product to be used under these conditions is still efficacious at low temperatures or retains its activity when combined with an antifreeze product.

A summary of disinfectants to be used in decontamination procedures is summarised in Tables 12.1 and 12.2.

**Table 12.1** Disinfectant/chemical selections and procedures for avian influenza andNewcastle disease (modified from Ausvetplan 2007)

| Item to be disinfected | Disinfectant/chemical/procedure |
|---|---|
| Live bird | Kill humanely |
| Carcases | Bury, burn or render |
| Animal housing/equipment | Soaps and detergents, oxidising agents, alkalis |
| Environs | N/A |
| Humans | Soaps and detergents, citric acid |
| Water | |
| – Tanks | Drain to pasture where possible |
| – Dams | Drain to pasture if practicable, otherwise N/A |
| Electrical equipment | Formaldehyde gas |
| Feed | Bury, burn |
| Effluent, manure | Bury or burn, alkalis and acids |
| Human housing | Soaps and detergents, oxidising agents |
| Machinery, vehicles | Soaps and detergents, alkalis |
| Clothing | Soaps and detergents, oxidising agents, alkalis |
| Aircraft | Soaps and detergents, oxidising agents |

**Table 12.2** Chemical products available for disinfecting procedures and principal recommendations of use (modified from De Benedictis et al. 2007). Recommended products are highlighted in bold type

| Chemical product | Recommended concentration | Method of action | Recommended contact time | Recommended use | Limitations | Other information |
|---|---|---|---|---|---|---|
| **Soaps and detergents** | | Surfactant propriety against lipid components | 10 min | During cleaning | | Used also with disinfectants |
| **Alkalis** | | Protein denaturation | | | Activity increases at high temperature; not efficacious at room temperature | |
| Sodium hydroxide (caustic soda) | 2–5% for clothes 10% at 60° C for floors | | 10 min | Floors and clothes | Do not use in the presence of aluminium and derived alloys | Do not allow contact with organic tissues |
| Sodium carbonate | 10% | | 30 min | In the presence of high concentrations of organic material | Thermolabile; light-sensitive | |
| Calcium hydroxide | 3% | | | Walls, floors | | |
| **Acids** | | Inhibition of enzymatic reactions; denaturing of proteins and nucleic acids | | | | |
| Hydrochloric acid (inorganic acid) | 2–5% | | 10 min | Floors | Corrosive; do not use for disinfecting metals | |
| Citric acid (organic acid) | 0.2% | | 30 min | Clothing and body | | |
| **Chlorine compounds** | | Protein denaturation and oxidising | | | Corrosive; inhibited by organic materials and by basic pH | Low cost and non toxic |
| Calcium hypochlorite | 2–3% | | 10–30 min | Floors, clothes | | |
| Sodium hypochlorite (household bleach) | 2–3% | | 10–30 min | Equipment | | |
| **Oxidising agents** | | Denaturing activity on lipids and DNA | | | Decreasing efficacy in the presence of organic compounds; corrosive | |
| Hydrogen peroxide | 3–6% | | | | | Rinse after use |
| **Aldehydes** | | Alkylation of amino and sulphydryl groups of protein and of nitrogen of purine bases | | | Decreasing efficacy in the presence of organic compounds; corrosive | |

(*continued*)

**Table 12.2** (*continued*)

| Chemical product | Recommended concentration | Method of action | Recommended contact time | Recommended use | Limitations | Other information |
|---|---|---|---|---|---|---|
| Formalin | 8% | | 10-30 min | | Toxic gas; unstable | Efficacious in the presence of propylene glycol |
| Glutaraldehyde | 1–2% | | 10–30 min | | pH 7.5–8.5: mildly corrosive for metals, not for use on plastic and rubber | Irritating for eyes, nose and throat; a rinse after use |
| Formaldehyde | 40% | | 15–24 h | | | |
| **Phenol compounds** | | Inactivation of enzymatic system and loss of metabolites through cellular membrane | | | Irritating due to their residual activity: rinse after use | Efficacious in the presence of organic matter; low cost |
| Cresolic acid | 2% | | | Floors | | High cost |
| Synthetic phenols | 2% | | 10 min | Floors | | |
| Phenol crystal | 0.4–0.2% | | 12–18 h | | | |
| **Quaternary ammonium compounds** | | Activity with –NH4+ groups | | Personal use | Do not use with hard water, e.g. > 32 F°; efficacious in the presence of antifreeze compounds | Accurate cleaning of surfaces is recommended before use |
| **Alcohols** | | Protein denaturising in the presence of $H_2O$ | | Clothes and equipment | Do not use for plastic and rubber | Flammable, evaporable |
| Ethanol | 70% | | 5–15 min | In association with other compounds in hand-wash disinfectants | | Used also in association with other molecules or as a thinner in disinfectant solutions |

## 12.3 Decontamination Procedures

Effective property decontamination will be achieved as a result of appropriate assessment of the contaminated areas and extensive knowledge of the characteristics of the infectious agent. Further requirements are the availability of adequate equipment, disinfectants and personnel to undertake the tasks. As a preliminary good practice, all exhaust fans must be turned off in the case of an outbreak occurring in an intensive poultry farm. This is of primary importance to avoid uncontrolled dispersion of the agent by aerosol (Ausvetplan 2007).

A decontamination strategy consists of:

- Property assessment
- Preliminary disinfection
- Initial clean-up
- Full disinfection followed by inspections

This includes disinfection of personnel leaving the contaminated areas as well as infected areas and machineries. Special attention must be paid to areas at high risk of contamination, such as animal waste effluents and animal feed. The latter must be destroyed.

Both cleaning and disinfection procedures of the infected premises must be performed systematically from back to front and from top to bottom of the farm. The roof-wall-floor method should be adopted in each building and the building should be cordoned off with marking tape when disinfection is concluded in order to avoid re-contamination of a decontaminated area (De Benedictis et al. 2007; Ausvetplan 2007).

Preliminary disinfection should be undertaken immediately after confirmation of the disease, as it will reduce the amount and distribution of infectious agent during culling and disposal. This preliminary disinfection should be performed in any contaminated area, with particular attention paid to culling and at disposal sites. In particular, the culling site should be continuously disinfected at every break during the day (Ausvetplan 2007).

After slaughter and disposal, a clean-up process should be undertaken to remove all manure, dirt, detritus and contaminated items that cannot be disinfected, e.g. insulation material, wood, contaminated feedstuff and litter. The use of water and disinfectant should be avoided at this stage, to reduce both the volume and the weight of the material to be disposed of (dry cleaning). After disposal, all surfaces should be scratched, scraped, and then sprayed with low-pressure water and detergent to remove any visible contamination. Earthen floors should be broken and soaked in disinfectant (wet cleaning). The viricidal activity of the majority of disinfectants is inhibited partially or totally by interaction with organic material. For this reason, thorough clean-up should be considered an essential initial step for an efficacious disinfection.

During full disinfection procedures, the goal should be the inactivation of all infectious particles. Portable equipment (platforms, feeding-trough, egg rollers, egg conveyors, egg collectors) must be cleaned and then disinfected indoors to prevent any contact with uninfected livestock. Water pipes must be flushed with high-pressure water and then all parts of the pipes filled with a water solution of disinfectant for at least 48 h. Pipes have to be rinsed with a further water jet. Water pipes that can be dismantled must be cleaned individually with cleaning solutions collected directly into containment vessels. To decontaminate iron fittings, the use of high temperature and, if safety considerations allow, the application of a flame are recommended.

A thorough inspection provides an assessment of the efficacy of decontamination. Important aspects to be checked are:

- Complete disposal of all contaminated woodwork not suitable for cleaning and disinfection
- No organic material is left behind fixtures and fittings
- No encrustation on any exposed surface is observable
- All contaminated feedstuff has been destroyed
- All grossly contaminated sites (culling and disposal) have been cleaned effectively and disinfected
- All fluid that has been disinfected has been released into drains or septic tanks
- The conditions of quarantine, especially at exit/entry points, and warning notices are maintained.

The second disinfection is a repeat of the first and can be started approximately 14 days after the completion of the first disinfection. Final inspection is carried out in the same way as the first inspection. The workforce is to be withdrawn from the premises only if the inspection yields positive results and there are no doubts on its effectiveness and completeness. If there is any degree of uncertainty, the procedure must be repeated. The efficacy of the disinfection process may be tested by introducing sentinel animals or by collecting environmental swabs for virus isolation attempts.

## 12.4 Personal Decontamination

During an AI or ND outbreak, people may spread the virus by acting as mechanical carriers. For this reason, it is necessary that all staff members taking part in the decontamination procedures change clothing, use disposable shoes and overalls before entering the farm and shower when they leave the infected premises. Heavy personal contamination occurs inevitably whilst working on infected/contact premises, particularly during physical inspection of living animals, at culling and carcase disposal sites, and when removing manure, bedding and detritus. A personal decontamination site (PDS) must be arranged near the exit point of an infected premise (IP), and moved into the IP when necessary. The PDS should be placed at the limit of the total area defined as infected in order to avoid secondary contamination of people leaving the PDS. The PDS should be easily disinfected and have an impervious surface; alternatively, the floor area may be covered with a large plastic ground cover. Treatment (usually spraying) with an efficacious disinfectant should be undertaken before any procedures are started. Clean water and good drainage are crucial to avoid recontamination of clean areas. If adequate drainage is not available, a pit may be used as an alternative to ensure that no effluent escapes beyond the decontamination site. Personal decontamination procedures must be followed strictly by all personnel leaving the IP. On arrival at the PDS, warm soapy water should be available for washing the hair, face and skin. The pH of the water solution can be varied to enhance its antiviral action, with the addition of sodium carbonate or citric acid. Heavy-gauge plastic garbage bags should be used for the storage of all contaminated items. Plastic bags are easily disinfected by spraying their external surfaces; this procedure avoids further contamination of personnel leaving the IP to burn and bury waste or to clean and disinfect non-disposable items. When available, the use of disposable overalls must be favoured over other clothes. Plastic overalls should first be washed with a low-pressure pump to remove gross material. Particular care must be taken to clean the back, under the collar, the zipper and inside the pockets. Cotton overalls and sprayed plastic overalls are removed and placed in disinfectant. Underwear also should be placed in disinfectant, especially if cotton overalls are used. In this case, washing of the entire body is also necessary. Boots must be scrubbed, particularly the soles. Personnel leaving the PDS should walk across the areas, treat the boots again and finally change them for street shoes. Personnel are recommended to continue a second phase of cleaning at home. It is compulsory that they do not have direct or indirect contact with other susceptible animals, premises and poultry farms for a minimum of 3 days. Disinfected overalls must be placed in a plastic bag, the outside of the bag disinfected and then placed at the outer limit of the area for removal. The disposed items should be autoclaved or treated in a hospital laundry.

Visitors on properties where AI or ND is suspected should also be considered as contaminated. They should remain preferably in the suspected area until outbreak confirmation and the start of decontamination procedures. Otherwise, common household disinfectants should be used to minimise the risk of disease transmission. In this case, the following information should be recorded and advice given:

- Name and address of the people concerned
- Assessment of the degree of exposure and contact with the suspected disease agent
- Advise a change of clothing if possible
- Recommend putting the clothes suspected of contamination in a plastic bag for appropriate treatment
- Efficacious domestic chemicals, in default of approved disinfectants, are:
  - Domestic washing soda (10 parts in 100 parts hot water)
  - Soap and hot water for scrubbing
  - Household concentrated chlorine bleach (1 part in 3 parts of water, corresponding to 2–3% of available chlorine). This is not recommended for decontamination of the skin.

## 12.5 Vehicle and Car Decontamination

All vehicles that enter the IP, and their drivers, carry a disease dissemination risk. No vehicle may leave the IP before its decontamination. Additionally, all vehicles that have been in contact with the disease agents before the outbreak must be traced to avoid secondary and uncontrolled spread of the infection. A carwash facility is ideal for the decontamination of vehicles. It has the advantage of allowing the undercarriage of the vehicles to be very easily washed, thus cleansing the most contaminated part of the vehicle.

Any rubber floor mats should be removed and scrubbed with disinfectant. The dashboard, steering wheel, handbrake, gear stick and seats should be wiped with appropriate disinfectant. The contents of the boot must be removed and both the contents and the interior of the boot wiped with disinfectant. The wheels, wheel arches and undercarriage of the car should be sprayed with disinfectant. Cleaning using disinfectant/soap and water with brushing to dislodge encrusted dirt and organic matter is preferable to washing with strong water streams.

All solid debris should be removed from the vehicle. Livestock vehicles are then soaked in disinfectant using a detergent, and scrubbed down to bare metal or wood. The outside dual wheels and spare wheels must be removed to ensure adequate decontamination of wheel hubs and to inspect the spare wheel hangers. All animal faecal matter and bedding must be removed. All organic material must be considered as contaminated and then disinfected and burnt or buried. All fixtures and fittings must be dismantled to ensure that infected material has been removed. All surfaces must be cleaned and then disinfected. The wheels, wheel arches, bodywork and undercarriage must be cleaned of detritus and disinfected. The driver's cabin and the sleeping compartments also need to be cleaned and disinfected.

## 12.6 Disposal of Carcases

This section of the chapter briefly describes and then summarises the main methods for the disposal of animal carcases. Interesting and specific literature based on field experience gained during the management of outbreaks such as the 1984 AI outbreak in Virginia (US) and the 2001 FMD outbreak in the UK is available (Berglez 2003; UK Environment Agency 2001). Readers should take into account that all such information has to be applied flexibly, as carcase disposal is a part of an emergency management plan based on the specific options for disposal. Decision-makers should be knowledgeable about the various disposal technologies, understand their principles of operation, and be aware of the equipment needed, costs, environmental impact and logistic details for each technology. This expertise is best achieved by the formation of an *ad hoc* team of experts.

The primary aim in the disposal of carcases and animal products is to limit disease spread. In view of this, the disposal of carcases should be considered as an essential component of animal disease control and eradication programmes. To maintain biosecurity standards and decrease the risk of disease spread, it is necessary to know the epidemiology of the infectious agent as this will affect the choice of disposal methods. Regardless of the chosen method, rapid disposal and the classification of wastes according to their potential infectivity are of primary importance.

The methods used to dispose of animals and animal products and the selection of disposal sites must be based on the following principles. Before a particular plan of action is decided upon, a decision-making process incorporating these principles should be undertaken (Ausvetplan 2007):

- Prevention of disease spread
- Speed
- Cost effectiveness
- Local legislative requirements
- Community and operator safety
- Local environmental conditions and resource availability.

Selection of an expert team can be evaluated to analyse the field situation and to guide a decision-making process that yields recommendations allowing application of the best practicable solution at a local level.

After the carcases have been disposed of, long-term factors must be considered and planned, such as maintenance, monitoring and the rehabilitation of disposal sites. Carcases may be buried, incinerated, composted or rendered.

### *12.6.1 Burial*

There are three burial techniques: (1) trench burial, (2) landfill and (3) mass burial sites.

#### 12.6.1.1 Trench Burial

This approach involves excavating a trench, placing carcases in it and then using the excavated material to cover them. Since little expertise is required, this method is used widely. It is relatively inexpensive as most of the equipment necessary is readily available. Trench burial is generally adopted on-farm or on-site for daily mortalities and is probably more discrete than other methods such as open burning. Cost estimates of use of on-site trench burial may differ considerably when carried out in an emergency situation. In choosing this method of disposal, it is necessary to determine the suitability of a site for burial. Soil properties, topography, hydrological properties, proximity to water bodies, public areas, roadways, municipalities and property lines as well as accessibility affect the choice and thus the use of a site for burial. The disadvantages of this method include potential environmental contamination, especially of water. Regions where the water table is deep and the soil relatively impermeable are suitable for trench burial disposal. This method has been identified as a means of placing carcsses "out of site out of mind" (NABC 2004) while they decompose, but it does not ensure elimination of the infectious agent. Indeed, it has been shown that the residue within a burial site can persist for many years (NABC 2004) such that the ultimate elimination of carcases remains a long-term process.

The use of trench burial for carcase disposal was adopted during the 1984 AI outbreak in Virginia, US (Mixston 2003), during which 5,700 tons (5,170,953 kg) of carcase material were disposed of, with an estimated cost of $US25 per ~1000 kg (Berglez 2003). On-site burial was the primary method used and accounted for approximately 85% of the disposed carcases. Towards the end of the outbreak, the burial trenches were standardised at a width of 20 ft (6 m), a depth of 10 ft (3 m) and a length able to accommodate the carcases. This meant approximately 20 $ft^3$ were required per 800 lbs (about 363 kg) of poultry carcases.

#### 12.6.1.2 Landfills

Landfills have been widely used as a means of carcase disposal in many disease eradication efforts, such as the 1984 and 2002 AI outbreaks in Virginia (Berglez 2003) and the 2002 outbreak of ND in southern California (Riverside County Waste Management Department 2003). The advantages of this method include:

- Landfill sites may be licensed to accept animal waste, hence dual purpose
- On-site facilities
- Large capacity
- Already existing and immediately available
- Environmental protection measures have been already designated and implemented

Among the disadvantages of landfills are:

- They may not be close to the source of the waste to be disposed of, thus risking the spread of disease agents during the transport of infected carcases (common to any off-site disposal methods).
- Commitment to site maintenance is long-term and hence expensive over an extended period.
- The process does not produce a usable by-product.
- The primary by-products resulting from decomposition of wastes in the landfill are leachate and landfill gas.

Leachate is defined as “liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste” (US EPA 1995). The amount of leachate generated depends on the amount of liquid originally contained in the waste (primary leachate) and the quantity of precipitation that enters the landfill through the cover or that falls directly on the waste (secondary leachate) (US EPA 1995). The composition of leachate depends on the decomposition phase (acetic vs methanogenic phase). If the leachate is not properly managed, it can be released from the landfill and will result in environmental pollution. Landfill gases, typically 50% methane and 50% carbon dioxide, are the products of the anaerobic decomposition of organic material in landfill sites. If left unmanaged, landfill gas can vent to the atmosphere or migrate underground. Active control systems that rely on gas recovery wells or trenches and vacuum pumps to check the migration of landfill gas have been employed.

Modern Subtitle D landfills are designed to prevent the leakage of leachate from the site. The key features of these landfills include a composite liner, leachate containment systems and gas collection systems.

During the 1984 AI outbreak in Virginia, approximately 15% of the poultry carcase material was disposed of in landfills (Berglez 2003). The landfill used at that time was an unregulated dump, making potential groundwater and surface water contamination an issue. The environmental concerns resulted in only limited use of the site. In the 2002 AI outbreak in Virginia, commercial landfills played a more important role. During that outbreak, 16,900 tons of carcases were disposed of, 85% in landfills (Berglez 2003). Transportation of the waste proved to be the main bottleneck.

In October 2002, an outbreak of ND was confirmed in a backyard flock in southern California and spread to other, mainly backyard, flocks. During eradication approximately 3,160,00 birds were depopulated from 2,148 premises. Landfills were the primary method used to dispose of the carcases. The cost was estimated at about $US40 per ton (Hickman 2003). During the outbreak, the Riverside County Waste Management Division developed a training video for landfill operators on how to properly handle potentially infected waste (Riverside County Waste Management Division 2003).

#### 12.6.1.3 Mass Burial

A large number of carcases can be accommodated in mass burial sites, which incorporate systems to collect, treat and dispose of leachate and gas. Mass burial sites played a key role in the 2001 outbreak of foot-and-mouth disease (FMD) in the UK and much of the information on this method was gained from that event. As shown by the UK experience, to minimise operational difficulties it is crucial that a site assessment is carried out prior to the initiation of site development. The total amount of land required depends on the volume of carcases and the space needed for operational activities. The most important advantage of mass burial is the capacity to dispose of a large number of carcases. However, the UK experience generated negative reactions to this method by the public. Among the disadvantages of mass burial, long-term costly monitoring and management of the facilities are the major issues.

#### 12.6.1.4 Additional Remarks

For all the burial techniques described, the location of the sites should be recorded accurately. Site selection must include the following considerations: access to the site; environment (water table, proximity of municipalities, etc.) and construction (stability of soil, necessity of fencing and banks, etc.) (Ausvetplan 2007). Moreover, regular inspection of the burial site is recommended, with the aim of preventing problems and to return the site to its original condition. Correct site selection will affect the amount of time required for buried animal carcases to decompose as this depends on temperature, moisture and burial depth as well as on soil type and drainage.

The environmental impact of livestock burial has been poorly investigated (Freedman & Fleming 2003) and further studies are needed. The main environmental impact of mass burial is associated with the risk of potential contamination of groundwater with the chemical products of carcase decay. With reference to burial techniques of birds, two reports have provided evidence for these occurrences. The amount and type of contaminants released from two shallow pits containing 62,000 lbs of turkey carcases were evaluated by Glanville (1993, 2000). High levels of ammonia, total dissolved solids, biochemical oxygen demand (BOD) and chloride were observed in the monitoring well closest to the burial site. Studies by Ritter and Chrinside (1995, 1990) considered the impact of dead-bird disposal pits on groundwater quality. Over a 3-year monitoring period, some pits had impacted groundwater quality, with nitrogen being a greater problem than bacterial contamination.

### *12.6.2 Incineration*

Historically, incineration played an important role in the disposal of carcases. However, increased awareness of public health issues and advances in technology have resulted in a reduction of its use. There are three categories of incineration techniques: (1) open-air burning, (2) fixed-facility incineration and (3) air-curtain incineration (NABC 2004).

#### 12.6.2.1 Open-Air Burning

The burning of carcases in the open air, including on combustible heaps known as pyres, has been replaced by other disposal methods in many countries. The volume of ash produced can be massive (NAO 2002), with the potential for groundwater and soil contamination by the hydrocarbons used as fuel (Crane 1997).

Open-air burning is not permitted in every country or region and in most cases permission by local authorities has to be obtained. In a declared animal carcase disposal emergency, it may be possible to overcome local policy (Ellis 2001). Open-air burning is time-consuming and can be considered the most lengthy of the three incineration processes. The species of animal burned influences the length of the process. According to Berglez (2003), the greater the percentage of animal fat, the more efficiently a carcase will burn.

Open-air burning causes significant public awareness, often generating a negative image of the management of an outbreak. It is crucial during the site selection process to first communicate with local communities about open-air burning intentions (Widdrington FMD Liaison Committee).

#### 12.6.2.2 Fixed-Facility Incinerators

These include small on-farm incinerators, small and large incineration facilities, crematoria and powder plant incinerators (NABC 2004). In contrast to open-air burning, the use of fixed-facility incinerators allows highly controlled and contained disposal. Fixed-facility incinerators are fuelled generally by diesel, natural gases or propane. Many incinerators are fitted with afterburner chambers that burn hydrocarbon gas completely. Compared to open-air burning, the ash produced is considered safe and may be disposed of in landfills (Ahlvers 2003). Fixed incinerators are more suitable for the disposal of small amounts of material and their lack of mobility results in their practicability being compromised (Ausvetplan 2007).

#### 12.6.2.3 Air-Curtain Incineration

A relatively new technology for carcase disposal is air-curtain incineration. Here, a fan forces a mass of air through a manifold, creating a turbulent environment in which incineration is greatly accelerated, up to six times faster than open burning (NABC 2004; Ford 1994). The fans deliver high-velocity air down into either a metal refractory box or burn pit. Materials needed for the air-curtain system include wood (e.g. pallets in a wood-to-carcase ratio varying between: 1:2 and 2:1) fuel for the fire and an air-curtain fan (Ford 2003). Air-curtain facilities can vary in size and be constructed as mobile units. Other advantages are that they are designed to achieve high temperatures, resulting in an extremely efficient combustion, yielding better fire control and fuel economy than obtained with pyres (Ausvetplan 2007). However, they require active monitoring during operation and there must be a suitable location available in which to construct the pit.

#### 12.6.2.4 Additional Remarks

Experience has shown that some disadvantages may be encountered during incineration, such as operation during atmospheric inversions (daily and weather front related); this has resulted in hanging smoke and odour and the high potential for equipment fires and other malfunctions. Immediate sources of back-up equipment should be identified and extensive air monitoring is necessary to ensure the safety of local residents (Flory et al. 2006). All of the methods described pose a fire hazard and yield ash.

### *12.6.3 Composting*

Composting is a natural process during which microorganisms decompose biological material in the presence of oxygen, transforming the material into a safe and stable product (Ausvetplan 2007; NABC 2004; Mukhtar et al. 2004). Aerobic composting has been shown to be a valuable disposal technology. Carcase composting offers several advantages—from a reduced environmental impact to the generation of a valuable by-product and the destruction of pathogens.

The process of composting consists of two phases. During the first phase, the temperature increases, soft tissues decompose and bones begin decomposition. This phase may last from 3 weeks to 3 months (Haug 1993). In the second phase, decomposition of the remaining material, mainly bones, occurs. The compost turns into a black soil (humus) containing primarily nonpathogenic bacteria and plant nutrients. This phase takes approximately one month. The end of the second phase is marked by an internal temperature of 25–30°C. For this phase it is necessary to move the composting pile from a primary to a secondary bin.

In the composting of animal carcases, microorganisms convert the body of the dead animal and carbon source into a stable mixture of bacterial biomass and organic acids (Keener et al. 2000). Carcase composting systems need and rely on the availability of carbonaceous material. Carbon sources can include poultry litter, manure, cereal crop straw and other by-products such as peanut pods. Several ratios of carbonaceous material and animal waste are recommended in the literature. The Ausvetplan (2007) plan recommends a ratio of about 3:1 (w/w). According to NABC (2004), a 50:50 (w/w) mix can be used as a base for composting. A general rule is to define the ratio according to that of the carbon to nitrogen ratio (C:N). A ratio of carbon source materials to animal waste of 1:1 has been proposed for high C:N materials such as sawdust, 2:1 for medium C:N materials such as litter, and 4:1 for low C:N materials such as straw (NABC 2004). Table 12.3 summarises the recommended conditions for an active composting.

Bulking agents are also used during the composting process as they provide nutrients for the system and maintain adequate air space (25–35% porosity) within the compost pile by preventing the packing of the materials. The proposed ratio of bulking agent to carcases should result in a bulk density not exceeding 600 kg/m$^3$.

While the criteria guiding site selection vary depending upon local legal requirements, some characteristics should always be taken into account during the selection process. A compost site should be located in a well-drained area at least 90 cm above the water-table level and at least 90 m from water resources. It should also have an adequate slope (1–3%) that allows proper drainage. Runoff from the composting facility should be collected and directed away from production facilities (NABC 2004).

#### 12.6.3.1 Windrow and Bin Composting

These two composting techniques share common guidelines even though different management principles may be required.

Windrow composting (Fig. 12.1) should be placed at the highest point on the identified site. A plastic liner covering the base of the windrow is needed as a moisture barrier. The liner should then be covered completely with co-composting material (such as sawdust or straw) to a thickness of about 30 cm for small carcases. A layer of bulking material (litter) is then placed on top to absorb moisture from the carcases and to maintain adequate porosity. The thickness of the bulking material should be 0.5 ft (15 cm) for small carcases (NABC 2004). A layer of carcases should be placed on top of the bulking material layer. In the case of small carcases, the first layer of animals can be covered with co-composting material and then a second layer of carcases placed over it. After the layering process, the entire windrow should be covered with a thick layer of biofilter material (carbon sources/bulking agents). With this construction method the approximate dimensions of the completed windrow for small carcases are: bottom width 3.6 m, top width 1.5 m, height 1.8 m.

Bin composting is well-suited to the disposal of small carcases. The required bin capacity will depend on the type of co-composting material used. Approximately 10 m$^3$ of bin capacity is required for 1,000 kg of carcases. Bins can be built with any material, such as wood or concrete. A simple and economical way to construct a bin is to use large round bales placed end to end to form a three-sided structure (also called bale composters). Bins may or may not be covered with a roof although it may be efficacious in rainfall areas, thereby reducing the potential for leaching from the pile. If bin walls are made of concrete, the recommended thickness is 15 cm. The height should be 1.5–1.8 m and the width should not exceed 2.4 m. The front of the bin is designed to

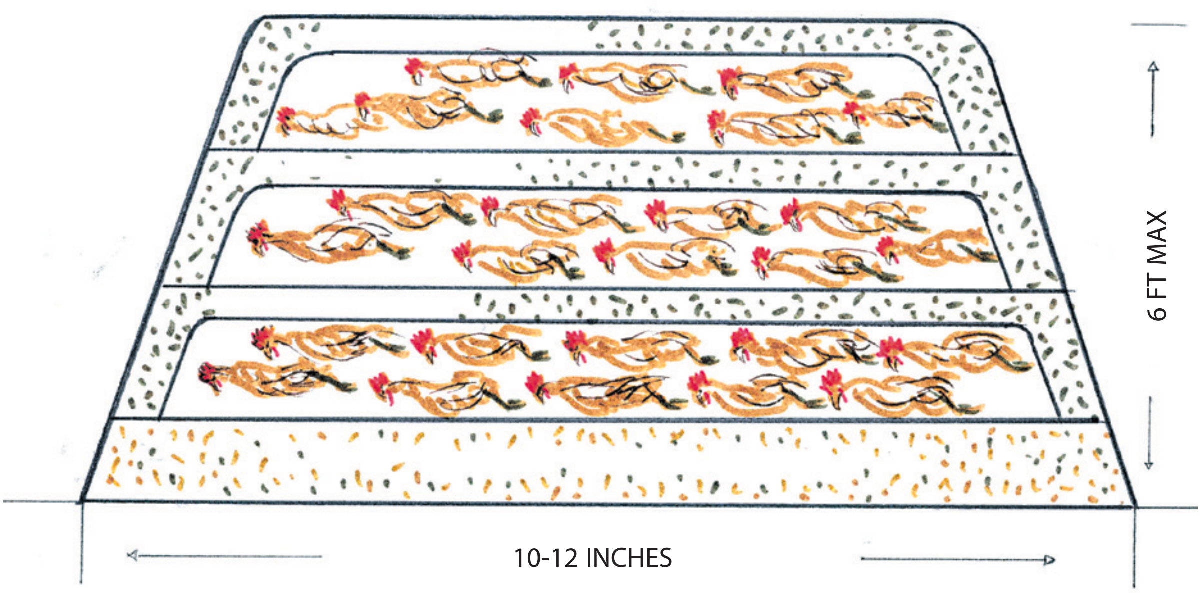


**Fig. 12.1** Cross-section of carcass composting in a windrow (Carr et al. 1998). If straw is used, place 3-4 inches on top of sawdust or litter. Amount of sawdust can be reduced to 4-6 inches. (Courtesy of Amelio Meini)

**Table 12.3** Poultry mortality rates and design weights (adapted from OSUE, 2000)[a]

| Poultry Species and stage average | Weight in kg (lb)[a] | Poultry loss rate (%)[c] | Flock life (days) | Design weight IN kg (lb)[d] |
|---|---|---|---|---|
| Broiler | 1.8-3.6 (4-8) | 4.5-5 | 42-49 | Up to 3.6 (up to 8) |
| Layers | 2.0 (4.5) | 14 | 440 | 2.0 (4.5) |
| Breeding hens | 1.8-3.6 (4-8) | 10-12 | 440 | 3.6 (8) |
| Turkey, females | 6.8-11.4 (15-25) | 6-8 | 95-120 | 11.4 (25) |
| Turkey, males | 11.4-19.1 (25-42) | 12 | 112-140 | 15.9 (35) |
| Turkey, breeders replace | 6.8; 0-13.6 (15; 0-30) | 5-6 | 210 | 9.1 (20) |
| Turkey, breeding hen | 12.7-13.6 (28-30) | 5-6 | 180 | 13.6 (30) |
| Turkey, breeding tom | 31.8-36.4 (70-80) | 30 | 180 | 34.1 (75) |

[a]From NABC (2004).
[b]Average weight used to calculate pounds of annual mortality.
[c]For mature animals, the percent loss is an annual rate for the average number of head on the farm.
[d]Design weight used to calculate composting cycle periods.

allow easy loading of carcases, thus ensuring that the carcases are not raised over a height of more than approximately 1.5 m.

The bin composting process comprises two phases: the first one is essentially a litter base (40–50 cm) that is placed in the bin 2 days before the carcases to allow pre-heating of the litter. Prior to introduction of the carcases, 15 cm of the pre-heated litter should be removed and the carcases placed on the remaining litter. This will absorb any fluids, preventing leakage. The carcases are then covered completely with of the remaining pre-heated litter. Next, the carcases are layered, placing a thick cover of carbon source material between carcase layers. A final cover (60 cm) of sawdust should be added on top. The second phase of the process involves moving the pile to a secondary bin, which is then covered with a minimum of co-composting material. Moisture is added to the material to allow the pile to reheat, as this is essential for an acceptable end product.

For successful composting, time, porosity, aeration and, especially, temperature are crucial factors. Although high compost temperatures promote rapid decomposition and effective pathogen elimination, excessively high temperatures may inactivate desirable enzymes. The time needed to complete the composting process depends on a variety of factors. Generally, composting time is shorter in warmer climates than in colder ones. The size of the animal also affects the time required. The estimated time at which piles are moved from the primary to the secondary phase for small carcases such as poultry is 7–10 days (NABC 2004). Murphy and Carr (1991) reported that the composting of broiler carcases required two consecutive 7-day periods to reduce carcases to bony residues. Appendix C contains a description of the calculation of the correct design parameters for an effective composting facility for poultry. Murphy and Carr (1991) and Keener and Elwell (2000) developed a model based on a mathematical formula for the calculation of composting volumes. Tables 12.3 and 12.4 describe the design weight used to calculate composting cycle periods for poultry.

**Table 12.4** Recommended conditions for active composting (Rynk 1992)

| | |
|---|---|
| Carbon-to-nitrogen (C:N)ratio[b] | 20:1–40:1 |
| Moisture content | 65% |
| Oxygen concentration[c] | >5% |
| Particle size (diameter in inches) | 0.5–2 |
| Pile porosity | >40%[d] |
| Bulk density | 474–711 kg/m$^3$ (800–1,200 lb/yd$^3$) |
| pH | 5.5–9 |
| Temperature (°F) | 110–150 |

[a]Although these recommendations are for active composting, conditions outside these ranges may also yield successful results.
[b]Weight basis (w:w). C:N ratios > 30 will minimise potential odours.
[c]An increasing likelihood of significant odours occurs at approximately 3% oxygen or less. Maintaining oxic conditions is key to minimising odours.
[d]Depending upon the specific materials, pile size and/or weather conditions.

#### 12.6.3.2 Additional Remarks

Lessons learned from the 2002 AI outbreak in the US suggest that factors important for successful in-house composting are the active involvement of poultry companies in managing the process, the formation of an expert team, the availability of carbon material and litter, identification of sources of carbon and water and the rapid identification of response teams that are trained and equipped to compost flocks within 24 h of virus confirmation (Flory et al. 2006). According to the US experience, in-house composting is preferred to the other disposal methods. The main disadvantages of this method include the need for long-term management and the risk incurred by the need to transport the carbon material off-site, with a potential risk of secondary spread of the infectious agent by transport vehicles. Under certain atmospheric conditions, an unpleasant odour may persist for extended periods of time.

### *12.6.4 Rendering*

The process of cooking and sterilising non-edible waste is referred to as rendering. Specifically, it has been defined as the separation of fat from animal tissues by the application of heat (NABC 2004) with the goals of eliminating water, sterilising the final products, and producing meat and bone meal (MBM) from dead animals or waste materials associated with slaughtering operations (Kamur 1989). The meat meal derived from rendering poultry waste is technically referred to as poultry by-product hydrolysed feather meal (PBHFM), or simply meat meal. Meat meal is 60% protein and 20–22% fat.

Rendering involves the use of high temperatures and pressure to convert animal carcases to safe, nutritional and valuable economic products (UK-DEFRA 2000). Animal carcases are converted into three main end products by rendering: carcase meal, melted fat and water. The main procedures for rendering carcases involve size reduction, cooking and the separation of fat, water and protein materials. Rendering processes may be divided into “edible” or “inedible” (NACB 2004). During edible rendering, the carcase by-products are reduced into small pieces and disintegrated by cooking, resulting in moisture and edible tallow or fat. Inedible rendering converts protein, fat and keratin materials into tallow, carcase meal (used in livestock feed, soap, production of fatty acids) and fertilizer, respectively. Raw materials are dehydrated and cooked, and fat and protein subsequently separated. The two rendering processes differ in their raw materials and end products. Several rendering systems exist, two of which are summarised below.

“Wet rendering” adds moisture to the raw materials during the cooking process. Although this method produces good-quality tallow, it is less frequently used because of its high energy consumption and adverse effect on fat quality (Ockerman and Hansen 2000). It has been reported that the accumulated water in this system needs extra energy to evaporate, with the consequence of material remaining, termed “sticky liquor” (Romans et al. 2001).

The newer method of “dry rendering” uses heat generated by steam condensation and applied to agitator blades to obtain uniform heat distribution. This shortens the time needed to cook the carcases. The indirect heat applied in this system converts the moisture in the carcases to steam. During this process, the yield of meat meal is higher than that obtained by wet rendering.

Both systems, wet and dry, can be converted into a batch system consisting of multiple cooker units (usually two to five). Most rendering options have a continuous cooker such that all rendering steps are carried out simultaneously and consecutively (EPAA 2002). The system needs little or no manual operation and end products are generated at a constant rate using indirect steam.

The time required for a rendering process depends mostly on the temperature and air pressure. Increasing both factors decreases automatically the rendering time. Air pressure mainly impacts the quality of the outgoing products. The advantages and disadvantages of the rendering process were summarised by Flory et al. (2006).

Advantages:

- The poultry industry owns some of the rendering plants, giving it more control over the disposal process.
- Long-term management is not required.
- No environmental impact.
- Produces a usable end product (market uncertain).
- If no market for the product exists, rendered proteins can be transported biosecurely to the landfill.

Disadvantages:

- Rendering plants are often located close to poultry operations; thus, all possible sources of disease transmission must be identified and controlled.
- Plant capacity may not be adequate.

- Due to upgraded biosecurity requirements, a plant may need to be dedicated to rendering AI carcases for the duration of the outbreak. This may not be economically feasible for a limited outbreak.
- Integrators without rendering capability would be at the mercy of a private rendering company.
- Rendering costs are uncertain and can dramatically increase during an outbreak.

The following must be considered in the determination of whether or not rendering is the most suitable method for the disposal of birds infected with the AI virus:

- Discussions with rendering companies and the poultry industry should take place before the occurrence of the outbreak.
- Most rendering facilities are privately owned (i.e. not owned by the poultry industry) and are not allowed to accept material infected with AI or ND virus.

## Appendix A: Practicalities of Decontamination with Formaldehyde Gas

Formaldehyde gas can be used with safety only in certain environments and in the hands of experienced operators. Effective decontamination with gaseous formaldehyde requires a favourable combination of gas concentration, temperature, relative humidity and contact time. Most procedures suggest formaldehyde concentrations of 2–10 g/m$^3$ and a relative humidity of 70–90% at temperatures of 20°C for periods of 15–24 h. Electric fans, where present, should promote homogeneous dispersal of the gas in the enclosed space. Although a high relative humidity is necessary for optimal activity, water cannot be present in liquid form, as it will dissolve the gas and reduce its concentration in the gaseous phase. It is therefore difficult to establish the required relative humidity conditions outside a controlled laboratory situation. An evenly controlled temperature is also essential for effective decontamination. If the temperature of the walls of the vessel or building falls during decontamination, the formaldehyde will polymerise on them to form a powdery precipitate of paraformaldehyde, which reduces the effectiveness of the operation and creates problems of residual toxicity. Such conditions are likely to occur in farm buildings or vehicles during overnight decontaminations.

Fumigation should be adopted at the end of the disinfection procedure to optimise the viricidal effect of the formaldehyde gas. To produce the gas, formalin solution (20 ml/m$^3$ space) can be added to potassium permanganate (16 g/m$^3$); a violent reaction that produces heat and boiling will follow and is potentially dangerous to the inexperienced operator. The enclosure must be prepared in advance so the operator, wearing protective clothing and a full facial respirator, can mix the ingredients and leave the enclosure quickly. Because formaldehyde is a very toxic gas, it must be totally retained within the space to be treated and then effectively neutralised prior to exposure, by reaction with ammonia gas obtained from the heating of ammonium carbonate. Breathing masks and special equipment for monitoring residual formaldehyde are essential.

## Appendix B: Techniques of Humane Destruction of Animals

When selecting a killing method, only those that can guarantee a high-volume killing capacity under all weather circumstances should be used. All birds to be killed for disease control purposes should be handled with the same care and concern for their welfare as those that are killed for food. Killing for disease control purposes and vaccination should be carried out only by properly trained individuals. Training should be provided at times when there is no disease outbreak so that efficient, trained persons are available when an outbreak occurs. Resources should be made available to create a group of trained facilitators for emergency culling of large numbers of birds. It is advisable to involve the local farming community in drawing up plans for each farm or type of farm during non-crisis times, so that in the event of an outbreak of a disease such as AI there will be an optimal killing process with a minimal amount of animal suffering. Birds vary considerably in their size structure and physiology. Since many species require expert handling during euthanasia, it is recommended that careful planning and consultation be carried out first. If there is a risk that the virus will spread to wild or captive birds, the welfare of these birds should be preserved.

Generally, carbon dioxide ($CO_2$) gassing or barbiturate overdose are the methods of choice for euthanasia. For small numbers of birds (e.g. fancy breeds and pigeons), the preferred method may be dislocation of the neck (using forceps or bare hands) or the injection of barbiturate.

Euthanasia of cassowaries, emus, ostriches, brolgas and other unusual/difficult birds requires expert assistance. The preferred options for large birds are lethal injection (for managed birds) and firearms (for free-ranging birds). Developing embryos in fertilised eggs can be killed by cooling them to +4°C for 4 h. For large numbers of birds in commercial poultry units, the preferred method is gassing with $CO_2$. Birds can be caught by teams of 10–15 labourers (experienced catching teams are preferable). Chicks are easily caught under heaters and are transferred in plastic garbage bins to waste skips for $CO_2$ gassing. Broilers on the ground can be driven to the catching area, where they can be caught and then placed directly into skips.

Caged birds are more difficult and progress will be slower. Skips should be filled to a level (between 70 and 90%) such that the remaining $CO_2$ gas layer will effectively kill the last layer of birds and the truck is not overloaded. The skip is then sealed and transported to the disposal site. Care must be taken to ensure that no bird is still alive when dropped into the burial pit.

The following methods of killing poultry for AI control are recommended by the Animal Health and Welfare Panel of the European Food Safety Authority (EFSA 2005).

- The birds are placed in suitable containers, including effectively restricted areas of a building, containing appropriate inert gas mixtures, such as argon, with not more than 2% oxygen.
- The birds are put into a suitable container of pure 4–6% carbon monoxide gas for a duration of at least 6 min; proper safeguards for human operators must be implemented.
- With the exception of ducks and geese, for which $CO_2$ should not be used, birds are exposed to not more than 30% $CO_2$ in an inert gas, such as nitrogen or argon, and not more than 2% oxygen.
- The use of a portable electrical stunner, poultry killer or captive bolt stunner is allowed but only if death can be confirmed in each animal.
- Individual birds can be injected with barbiturates; this method is impractical for large numbers of birds. For poultry during the first week of life, the chicks may be dropped into a macerator, which kills the bird instantaneously.

Other methods, such as putting birds into plastic bags and burning them or gassing them with hydrogen cyanide, impure carbon monoxide, or high concentrations of $CO_2$, are not allowed, neither is the gassing of whole buildings without adequate restriction of the area occupied by the gas or injection with any chemical except barbiturates.

## Appendix C: Design Parameters for an Effective Poultry Composting Facility

The formula presented by Murphy and Carr (1991) is based on the concept that the capacity of bin systems for composting poultry depends on the theoretical farm live weight. The authors described a model in which the peak capacity of dead poultry for the first phase of composting is predicted based on the market age and weight of birds (see example 1 below):

Daily composting capacity = theoretical farm live weight/400

Theoretical farm live weight = farm capacity × market weight

Keener and Elwell (2000) developed models based on the results of experiments for a bin system for poultry (broilers). They assigned a specific volume coefficient of 0.0125 $m^3$/kg mortality/growth cycle (0.20 $ft^3$/lb mortality/growth cycle) for calculating primary, secondary and storage volumes (V1, V2, and V3, respectively). As discussed earlier, the composting times of primary, secondary and storage phases (T1, T2 and T3, respectively) are affected by various factors in the composting pile and are not equal to each other. Based on the above information, the authors suggested the following models for calculating the composting time and volume needed for primary, secondary and storage phases:

T1 = (7.42) (W1) 0.5 ≥ 10, days (5) V1 ≥ (0.0125) (ADL) (T1), $m^3$

T2 = (1/3) (T1) ≥ 10, days (7) V2 ≥ (0.0125) (ADL) (T2), $m^3$

T3 ≥ 30, days (9) V3 ≥ V2 or V3 ≥ (0.0125) (ADL) (T3), $m^3$

where W1 is the average weight of mortality in kg, and ADL is the average daily loss or rate of mortality in kg/day.

### *Example 1: Bin Composting of Poultry Carcasses Calculation*

The following example is based on the method of Murphy and Carr (1991).

### Available Information

- A poultry farm with 100, 000 birds of 4.5 lb (2.02 kg) average market weight where carcases are to be composted using a bin system.
- 0.45 kg (1 lb) of the compost material needs a volume of approximately 0.027 $m^3$ (1 $ft^3$).
- Daily composting capacity = theoretical farm live weight/400.
- Theoretical farm live weight = farm capacity × market weight.

### Daily Composting Capacity

Daily composting capacity =100,000 (birds) × 4.5 (lb/birds)/400 (day) = 1125 lb/day (506.25 kg/day) or about 1125 $ft^3$/day

### Suggested Number of Bins and Their Dimensions

Based on the experimental data of Murphy and Carr (1991), the most appropriate bin dimensions are 7 ft length, 5 ft width and 5 ft height. Therefore:

- N (number of primary treatment bins) = (compost capacity)/(L × W × H of a primary bin).
- N = (1,125 $ft^3$/day)/(7 ft × 5 ft × 5 ft) = 6 primary treatment bins/day.
- The six bins can be arranged in any of several configurations to suit the needs of a particular situation.
- Overall length = (1,125 $ft^3$)/(7 ft × 5 ft) = 32 ft (9.64 m).
- Total area = 7 ft × 32 ft = 214 $ft^2$ (19.26 $m^2$).
- Area for each primary bin= 214 $ft^2$/6 = 35 $ft^2$ (3.21 $m^2$).

### *Example 2: Bin Composting of Poultry Carcase Sample Calculation*

The following example is based on the method of Keener and Elwell (2000).

### Available Information

A poultry farm with an average weight of 1.36 kg (3 lb) per carcase and ADL of 13.6 kg/day (30 lb/day where carcases are to be composted using a bin system.

T1 = (7.42) (W1) 0.5 ≥ 10, days V1 ≥ (0.0125) (≥ ADL) (T1), $m^3$
T2 = (1/3) (T1) ≥ 10, days V2 ≥ 0.0125) (ADL) (T2), $m^3$
T3 ≥ 30, days V3 ≥ V2 V3 ≥ (0.0125) (ADL) (T3), $m^3$

The relation between bin volumes, width, and length with a constant depth or height of 1.50 m (5 ft).

### Composting Time and Volume for Primary, Secondary and Storage Phases

From the above equations, the required information is:
T1 = (7.42) (1.36) 0.5 ≥ 10 days, T2 (1/3) (T1) ≥ 10 days and T3 ≥ 30 days,
V1 ≥ (0.0125) (≥13.6) (10) =1.70 $m^3$, V2 ≥ 0.0125) (13.6) (10) = 1.70 $m^3$ and
V3 ≥ 3 V2 (recommended as a design parameter) = 3 (1.70) = 5.10 $m^3$.

### Number of Required Bins and Their Associated Dimensions

The bin volume closest to a calculated value of 1.70 $m^3$ is 2.26 $m^3$ (80 $ft^3$) or a mini-bin with dimensions of 1.22 m × 1.22 m × 1.52 m (4 ft × 4 ft × 5 ft).

Thus, two primary bins, each with an area of 1.22 m × 1.22 m =1.5 $m^2$ (16$ft^2$) or a total of 3 $m^2$ (32 $ft^2$), and one secondary bin of 1.50 $m^2$ (16 $ft^2$) are needed.

The end-product storage area is 5.10 $m^3$/ 1.5 m = 3.36 $m^2$.

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