



Managing Contaminated Animal and Plant Materials Field Guide on Best Practices



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Introduction

Managing Contaminated Animal and Plant Materials: Field Guide on Best Practices presents the information required for the safe, effective, and economical disposal of contaminated animal and plant materials. Management of these materials on a large scale (300 tons of carcasses or more) presents major challenges for emergency personnel responding to diseases, natural and accidental incidents, or acts of terrorism against enterprises engaged in food production, processing, or distribution.

Large-scale incidents typically involve local and state agencies, which have the authority to make decisions about disposal. If the scale of the incident exceeds the ability of a state or local government to respond, the state usually requests federal resources.

Purpose

This book was designed to be used as a reference for training and operations in preparing and disposing of contaminated animal and plant materials. It was produced by the Technical Support Working Group, in conjunction with the U.S. Department of Agriculture and the Environmental Protection Agency, for landowners, private industry, animal producers, and local, state, federal, and military government agencies.

Responders should apply this information in conjunction with their previous training and experience, site-specific regulatory and environmental factors, and standard procedures and policies already in place. Because every situation has unique challenges, responders must be flexible enough to adjust to the situation at hand using the resources available to them.

Introduction

This field guide is intended to be a source of ideas and information on methods and technologies for the disposal of contaminated animals and plants and is not intended to be all-inclusive. The information given is for educational and guidance purposes only.

This guidance does not substitute for any statute or regulation, nor is it a regulation itself. By its terms, the guidance itself does not impose binding requirements on any Federal agency, States, other regulatory or resource management authorities or any other entity. Statutory provisions and regulations described in this document may contain legally binding requirements that would apply to a particular situation based on the circumstances.

Reference to businesses, commercial products, or trade names is made with the understanding that no discrimination is intended and no endorsement by the Technical Support

Contaminated Animal Disposal

Working Group or any other U.S. Government agency is implied.

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Overview

Seven disposal options are discussed in this guide: thermal, burial, composting, rendering, alkaline hydrolysis, digestion, and emerging technologies. The “General Considerations” chapter pertains to all of these options. The disposal methods are discussed in separate chapters, most of which include six color-coded sections: Summary of the **disposal method** (purple), **Regulatory synopsis** (yellow), **Planning** (blue), **Procedures** (light blue), **Safety** (red), **Biosecurity** (light green), **Environmental Impacts** (brown), and **Cost** (green).

This format was designed to help practitioners and incident commanders compare the various disposal methods for evidence-based and consensus-based decision making. Decision trees to aid in choosing the appropriate disposal method are included for contaminated animals (Fig. 1) and plants (Fig. 2). A table listing methods considerations is also included in most chapters to further advance the decision-making process.

Incident command structure: Before beginning any disposal method, responders must obtain approval from the local, state, or federal authorities providing leadership at the incident command post. The proper procedure for a local/county incident command team to follow when managing animal carcasses will come from the incident commander and will depend on the magnitude of the incident, the type of agent, and the potential economic and environmental impact.

Figure 1. Decision tree for contaminated animal disposal.

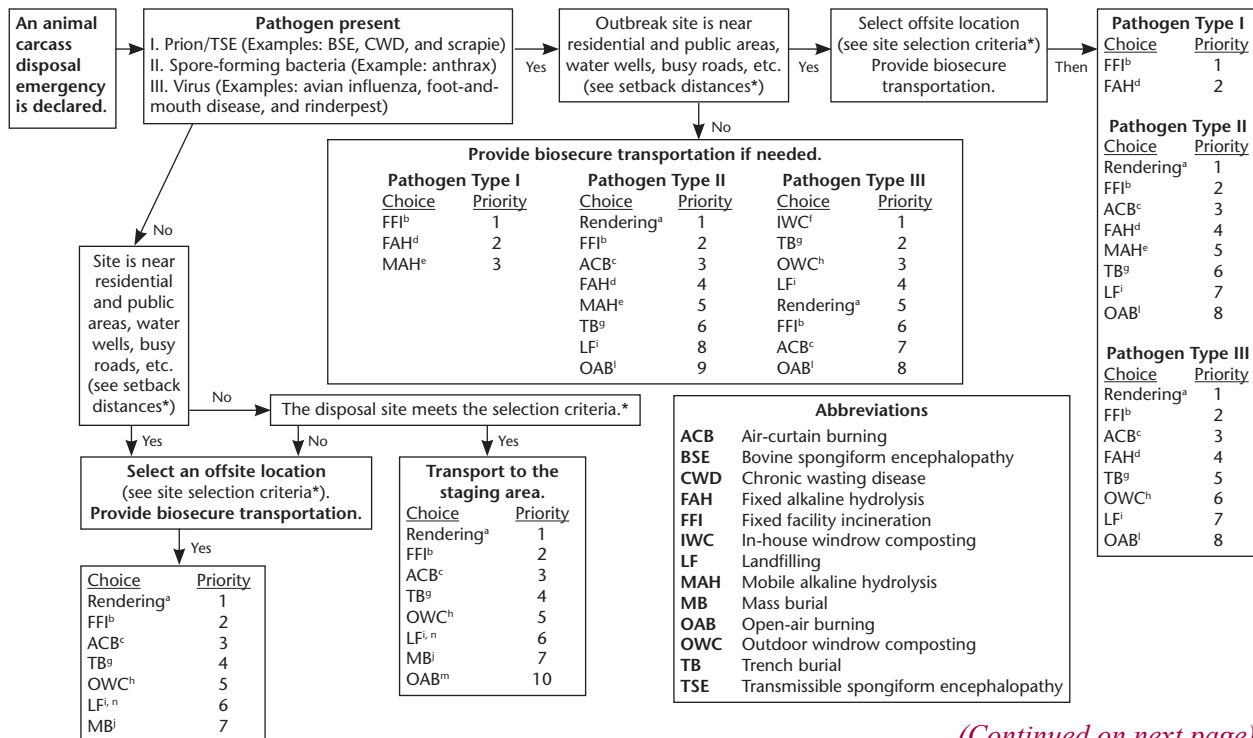


Figure 1. (Continued).

^aNo storage is necessary for carcasses ≤ 200 tons (400 cattle carcasses); otherwise, plan to store the extra carcasses. The throughput of a rendering plant is about 100 tons/24 h.

^bNo storage is necessary for carcasses ≤ 12 tons (24 cattle carcasses) and if the throughput of the fixed facility incinerator is about 6 tons/24 h; otherwise, plan to store the extra carcasses. Fixed facility incineration of carcasses eliminates the consumption of water for the disposal process.

^cNo storage is necessary for carcasses ≤ 200 tons (400 cattle carcasses); otherwise, plan to store the extra carcasses. Throughput of an air-curtain burning system is about 100 tons/24 h.

^dNo storage is necessary for prion-infected carcasses ≤ 15 tons and non-prion-infected carcasses ≤ 30 tons if the throughput of fixed alkaline hydrolysis is about 15 tons/24 h and about 30 tons/24 h, respectively; otherwise, plan to store the extra carcasses. Water consumption is a limiting factor in fixed alkaline hydrolysis and mobile alkaline hydrolysis (0.5–2 lb/1 lb of carcass). To dispose of the effluent of fixed alkaline hydrolysis in municipal waste treatment facilities (MWTF), it is

necessary to acidify and dilute it and obtain permission from authorized personnel in the MWTF.

^eNo storage is necessary for prion-infected carcasses ≤ 6 tons and non-prion-infected carcasses ≤ 12 tons if the throughput of mobile alkaline hydrolysis is about 6 tons/24 h and about 12 tons/24 h, respectively; otherwise, store the extra carcasses. On-site use of mobile alkaline hydrolysis eliminates the biosecure transportation costs but requires skilled drivers/operators.

^fNo transportation is necessary. No storage is necessary for carcasses ≤ 200 tons (about 200,000 chickens); otherwise, plan to store the extra carcasses. The throughput of in-house windrow composting depends on the size of the poultry house and available equipment. For example, 10 skid-steers can make a windrow (12 ft wide and 6 ft tall) composting pile for about 400 tons of carcasses within 2 days of operation.

^gNo storage is necessary for carcasses ≤ 800 tons (1,600 cattle carcasses); otherwise, plan to store the extra carcasses. A trench digger with 1 yd³ bucket capacity will trench and bury about 800 tons of carcasses within 2 days.

(Continued on next page)

Figure 1. *(Continued).*

^bNo storage is necessary for carcasses ≤ 200 tons (400 cattle carcasses); otherwise, plan to store the extra carcasses. The throughput of windrow composting depends on the size of carcasses, preprocessing (carcass grinding), and available equipment. For example, 10 skid-steers can make a windrow (12 ft wide and 6 ft tall) composting pile for about 400 tons of carcasses within 2 days of operation.

ⁱNo storage is necessary for carcasses ≤ 200 tons (400 cattle carcasses); otherwise, plan to store the extra carcasses. The throughput of carcass landfilling depends on the size of the Type I (modern) landfill, transportation vehicles and processing machinery. Most landfills have a capacity of less than 100 tons/day.

^jCarcass mass burial capacity depends on the availability of equipment, personnel, and the required pit dimensions.

^{k,l}The capacities for carcass bin composting and digestion are limited; these methods are not appropriate for disposal of a large quantity of dead animals.

^mCarcass open-air burning is the last choice for disposal of carcasses, and its capacity depends on the trench length.

ⁿLandfilling costs:

1. The charge can range from \$10 to \$50 per ton, not including costs for transporting the carcasses to the landfill. Source: Nebraska Department of Environmental Quality, 2004.
2. The actual price of using a landfill in California was \$42.55/ton for dead stock. (Source: Personal communications with Matthew Hickman, Riverside County Waste Management Department, Moreno Valley, CA, August 21, 2006).

^{*}Carcass disposal site specifications and regulations for thermal destruction, burial, and composting methods:

- Perform thermal destruction of large numbers of animal carcasses (usually more than 1,000 cattle carcasses) at a distance of at least 2 miles (3 km) from residential buildings, roads, and utilities (wires/lines) and from any public, religious, historical, and archaeological areas for the air-curtain burning and open-air burning systems. If possible, consider leaving the same distance from crop fields and wildlife. This will protect the public from smoke inhalation

(Continued on next page)

Figure 1. *(Continued)*.

and excessive heat and can prevent fire damage to property, plants, and wildlife.

- Consult the USDA Natural Resources Conservation Service and evaluate the site for water table and proper soil conditions.
- Use refractory boxes for air-curtain burning systems where the site has a high water table (< 2 ft from the bottom of a planned trench) or rocky soil and where the construction of trenches is difficult and costly.
- When choosing an appropriate site for carcass burial, consider sites that are a minimum of 150 ft

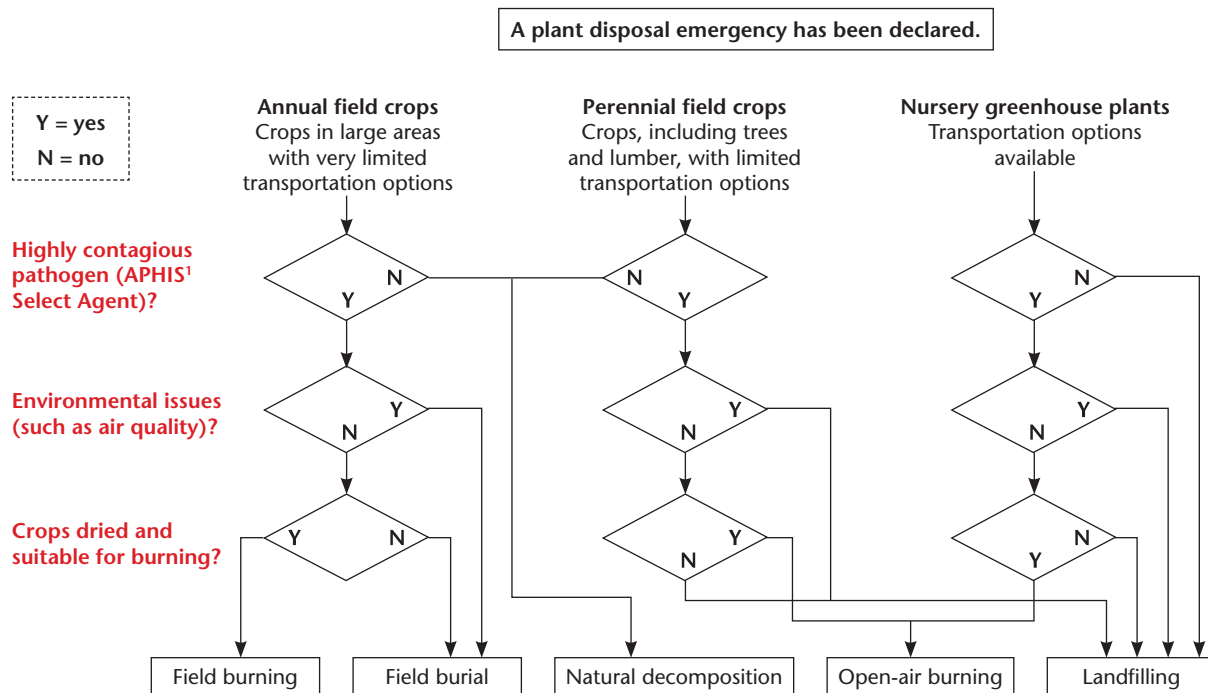
from private wells, springs, watercourses, sink-holes, streams, springs (or any source of water used for domestic purposes), and public areas; 200 ft from residences or property lines; 500 ft from public wells; 1,000 ft for the burial of disease-infected carcasses from public and private water-supply wells; and 1,325 ft from public roads, highways, and parks.

- The composting site should be at least 3 ft above the high water table level and 300 ft from sensitive water resources (such as streams, ponds and wells, etc.). It should have 1–3% slope to provide proper drainage and prevent ponding of water.

Introduction

Contaminated Plant Disposal

 **Figure 2.** Decision tree for contaminated plant disposal.



¹USDA Animal and Plant Health Inspection Service, <http://www.aphis.usda.gov>

General Considerations

Many management practices are available for the disposal of contaminated plants and animals. The “best” method depends on the circumstances at hand. Factors that affect the choice of disposal method include:

- The nature of the incident or outbreak (such as species of animal and type of pathogen)
- Site characteristics
- Amount of contaminated materials to be handled
- Local, State, and Federal regulatory constraints
- Facilities available

When planning a response to an incident or outbreak, practitioners and incident command teams also must consider:

- Worker health and safety
- Security
- Transportation
- Equipment
- Environmental impacts
- Public perception
- Direct and indirect costs

Information about these factors can guide decision makers in selecting the most appropriate disposal method for a specific contaminated material, pathogen, and location.

General Considerations

Disposal of contaminated plant materials

To protect the U.S. agricultural industry, it is vital that plant pathogens (disease-causing organisms) and contaminated plants be destroyed or disposed of effectively.

A key difference between infectious pathogens of plants and those of animals is that plant pathogens rarely infect humans. A few isolated cases of human infections have been found in immuno-compromised patients. If the appropriate protective gear and common sense are used, human infection by plant pathogens is unlikely.

The most practical and economically feasible techniques for disposing of contaminated plants are described in detail in the specific methods sections in this guide:

- Thermal destruction methods (field burning, open-air burning)
- Burial methods (field burial, landfilling)

- Evolving and alternative methods (no-tillage cropping system, crop rotation)

To select the best disposal methods, users need to have a baseline understanding of:

- The classifications of plant materials
- Plant diseases and epidemiology
- The general considerations for handling contaminated plant materials

This manual provides information on the best practices and disposal methods for contaminated plant materials. It is not intended to be a guide for general crop-disease management.

In the United States, diverse groups of plants are cultivated, imported, and processed. Table 1 categorizes these plants into three major groups: annual field crops, perennial field crops, and nursery greenhouse plants. The groups are organized according to the disposal methodologies outlined in this guide.

Table 1. Characteristics, disease-control considerations and disposal issues of plant groups cultivated, processed, and/or imported in the United States.

Consideration	Annual field crops	Perennial field crops	Nursery greenhouse plants
Examples	Cotton, corn, soybeans, tomatoes, tobacco, wheat, and potatoes	Grapes, citrus, pome fruits (apples, pears), stone fruits (almonds, peaches, plums), and lumber	Geraniums, pansies, and other seasonal plants in single- and multi-season greenhouses
General characteristics	<ul style="list-style-type: none"> Planted in large areas across the U.S. Generally produced in the U.S. and a significant portion exported Not cost-effective to harvest and transport for disposal purposes 	<ul style="list-style-type: none"> Can be planted in large areas but not at the scale of annual field crops Typically woody plants and relatively of larger size Because of the plant size, transportation can be an issue 	<ul style="list-style-type: none"> High-value plants Restricted production/ distribution locations Shipping-friendly Significant portion imported from foreign countries
Disease control	<ul style="list-style-type: none"> Most pathogens that can contaminate these crops have already been introduced to the U.S. Key disease control strategies include the use of resistant hybrids and proper cultural practices 	<ul style="list-style-type: none"> Prone to insect and virus damage New pathogens from other continents can be introduced Because of the crops' high economic value, pesticides and fungicides are used to control diseases 	<ul style="list-style-type: none"> Vulnerable to new, introduced pathogens (particularly imported plants) Strict quarantine measures enforced
Key disposal issues	<ul style="list-style-type: none"> Large area of production Difficulty of harvesting and transporting infected crops High epidemic potential 	<ul style="list-style-type: none"> Larger crop size Transportation difficulty Disposal location (if burning or burial is planned) 	<ul style="list-style-type: none"> New pathogen introduction Rapid diagnosis necessary Disposal location

General Considerations

Disposal of contaminated animal materials

Before disposal or treatment, animal carcasses must be preprocessed and then moved from the disaster area to the disposal site.

Carcass preprocessing involves the bio-secure handling and disinfection of contaminated animal carcasses. This step includes not only collecting the dead animals, but also sometimes preparing them, such as grinding, packing, and sterilizing the carcasses and storing them in enclosed containers.

Carcass transportation is the movement of those dead bodies from a disaster area to the disposal site.

The objectives of preprocessing and transportation are to properly prepare and transport infected animal carcasses to prevent:

- The transmission of diseases to other animals or humans
- The production of excessive odors

- The contamination of soil, water, air, and plants

The carcasses must be collected and handled hygienically and without physically damaging them during transportation.

To control the spread of infectious diseases, it is important that dying and deceased animals be collected and removed from livestock and poultry operations quickly. Delaying the removal of carcasses to fixed-facility sites (such as rendering, incineration, alkaline hydrolysis, and digestion plants) may cause the disease agents to be spread to the environment or other animals.

Components needed

During a catastrophic animal event, carcass preprocessing and transportation require several main components:

- Approved disinfecting materials
- Trained workers
- Appropriate equipment for preprocessing
- Vehicles for transportation
- Fuel
- Electricity

Packing and handling equipment that is designed to manage a specific type of animal carcasses, such as cattle, may or may not be appropriate for dealing with a mass die-off of other species, such as poultry.

The loading and transportation requirements will be affected by the physical condition of the diseased animals or carcasses and the location of the selected disposal sites. Deteriorated or decomposed carcasses and some types of disease infections may call for certain portable disposal equipment, such as a portable gasifier and mobile alkaline hydrolysis apparatus, or they may require on-site disposal methods, such as trench burial and

outside windrow composting.

Normally, dead animals are transported over long distances for disposal only if they are fresh carcasses with no signs of deterioration. Smaller infected carcasses are collected and transferred quickly to the assigned disposal sites in containers able to hold 25,000 pounds. However, larger carcasses (cattle) must be reduced in size and stored in temperature-controlled vehicles on site until they can be transported to a central processing or disposal facility.

Carcasses with disease-causing organisms require special vehicular containers that are sealed and equipped with liquid collection and/or absorption systems. To reduce the spread of pathogenic microorganisms, the vehicles transporting animal carcasses may require air-filtration systems.

Cold storage of carcasses reduces odors, reduces chemical and microbial activities, extends the amount of time needed for disposal,

General Considerations

prevents scavenging, and keeps the carcasses out of sight.

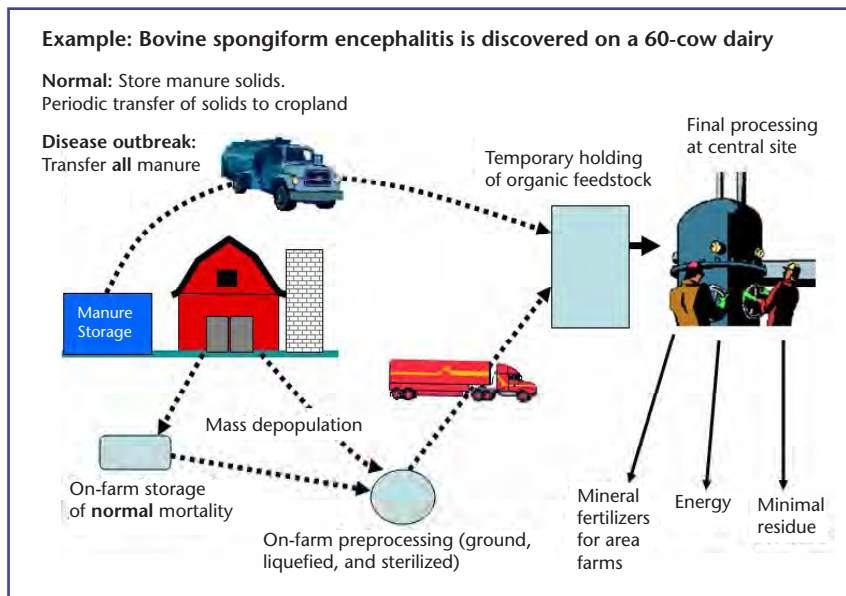
Some large poultry and swine producers freeze farm-animal carcasses in portable cold-storage units. Once filled, the units can be hauled away to central disposal sites. However, this process has high installation and utility costs and requires defrosting if the subsequent processing includes size reduction.

Carcass preprocessing provides raw materials for rendering, lactic acid fermentation, and biogas generation. It also minimizes the

risk of transmitting disease during transport through populated or animal production areas. Figure 1 is a schematic of how the preprocessing model might work for infected animal carcasses.

Although the decontamination procedures described reduce the threat of disease transmission, keep in mind that animal catastrophic emergencies are rare, and workers without proper training and education may hesitate to disinfect the carcasses.

Figure 1. A schematic flow of farm-animal carcasses in storage, preprocessing, and transportation. When dealing with a communicable disease such as bovine spongiform encephalitis, it may be necessary to process all the stored manure on the farm (*Pullen, 2004, in National Agricultural Biosecurity Consortium for Carcass Disposal Working Group report, National Agricultural Biosecurity Center, Kansas State University*).



Planning considerations

Managing the disposal of a large number of contaminated animal carcasses requires a proper plan to match the selected disposal method. Take these steps to ensure the safety and biosecurity of the workers, the general public, and the environment during the collection, storage, handling, and transportation stages:

- Consult with Federal, State, county, and city officials to find the most appropriate routes for transporting the dead animals from the farm-animal operations to the carcass disposal sites.
- Consult with your State's regulatory agencies for the minimum setback distances required to locate the temporary storage and pickup areas of infected farm animals. They must be placed far from the public, homes, healthy animals, and routinely traveled roads.
- Set up the entire system of carcass processing and transport under veterinary supervision. This will help prevent and/or control the spread of infectious diseases.
- Follow this section's biosecurity guidelines for cleaning and disinfecting all containers and vehicles before they leave the affected premises and again after the materials have been unloaded at the disposal site.
- Provide ample temporary storage for the carcasses if they are located in a warm climate, if equipment is inaccessible for handling and transportation, if controlling wild animals (such as coyotes or feral pigs) is impossible, if disease vectors (organisms that transmit pathogens away from their source) exist, or if more preparation time is required for the disposal process.

- To achieve suitable conditions for moving the carcasses to a processing facility, consider picking up the carcasses daily and bringing short-term freezing units to the farm. Remember that neither of these options eliminates pathogenic microorganisms.
- Keep records of skilled personnel (such as contractors, operators, and drivers) who can provide mechanical handling, storage, and conveyance of infected animal carcasses.
- Brief and train the supervisors, equipment operators, and drivers about all pertinent environmental, transportation, and public health regulations.
- Train the personnel on how to use personal protective equipment and to collect and handle diseased animals and carcasses in the various stages of pre-processing and transportation.
- Train the workers across the multiple city, county, and State jurisdictions. Also educate them about the regulations on public health, the displacement of carcasses, and the protection of the environment in those jurisdictions.
- Prevent work hazards by using Occupational Safety and Health Administration (OSHA) standards for the people working in carcass preprocessing and transportation.
- Keep and update a transportation route guide for moving large numbers of carcasses in an emergency.
- Provide equipment and vehicles, including cranes, heavy trucks, tractors, bulldozers, front-end loaders, shovels, and containers (such as roll-off or drop-off), to lift, move, load, and transport the carcasses. Table 2 lists some of the contractors that collect, handle, decontaminate, and transport carcasses. Also, some poultry production

units, rendering plants, and landfilling companies have transportation systems that can be used for hauling dead animals to disposal sites. In Nebraska, contractors can transport up to 1.2 million pounds of carcasses a day from disaster areas to rendering plants.

- Plan to use large off-road haulers in emergency situations if the travel route

allows them. The greater capacity of these haulers reduces the number of loads and trips.

- Maintain and update a list of commercial dead-animal haulers. Agencies such as the California Department of Food and Agriculture provide this information on their Web sites.

Table 2. Examples of contractors that collect, handle, decontaminate, and/or transport carcasses.

Company	Nature and throughput of the work	Contact information
Subcontractors of Tetra Tech EM, Inc.*	Collection, handling, and transportation of up to 2,400 tons/day	8030 Flint Street Lenexa, KS 66214 Phone: 913-894-2600
Sanitec® Microwave Healthcare Waste Disinfection System	Decontamination of more than 14 tons of carcasses/day	1250 24th St., NW Suite 350 Washington, DC 20007 Phone: 202-263-3630 www.sanitecindustries.com
Contractors of Riverside County Waste Management (landfilling company)	Carcass transportation and disposal of up to 80 tons/day	14290 Frederick St. Moreno Valley, CA 92553 Phone: 909-468-3308 http://www.rivcowm.org
Phillips and Jordan, Inc.	Transportation of up to 1,200 tons/day	P.O. Drawer 604, 191 P&J Rd. Robbinsville, NC 28771 Phone: 800-511-6027 www.pandj.com

These are examples only and not an exhaustive list. Endorsement of companies, individuals, or their services mentioned is not intended, nor is criticism implied of similar companies, individuals, or services that are not mentioned.

***Source:** Telephone conversations with Edward Hubert and David A. Zimmermann, (Dave.Zimmermann@ttemi.com) of Tetra Tech, Sept. 18, 2006.

Procedures for collection and storage

Follow these procedures for collecting and storing contaminated carcasses and other materials:

- Secure the carcasses and other items awaiting preprocessing, transportation, and disposal to prevent unauthorized access by people, access by scavengers, and potential disease spread to susceptible species.
- Use a closed building or cold-storage facility as a first priority for collecting and storing farm carcasses. Also control the wastewater runoff from the cold-storage facilities.
- Because of the biosecurity aspects (see the “Safety and Biosecurity” section of this chapter) of storing the weights of infected carcasses, keep records on the carcasses entering and exiting the cold storage facilities.
- When possible, wrap the carcasses securely in plastic and pack them in large containers, such as lined wooden crates, in a designated storage area.
- If a catastrophic event occurs or if adequate disposal facilities are unavailable, store the carcasses in a barn, shed, or other covered space to protect them from snow or rain. When the storage temperatures are between 46 and 68 °F (8 and 20 °C), store the carcasses for no more than 72 hours. The University of Minnesota Extension Service recommends that they be stored for no more than 7 days at storage temperatures of less than 45 °F (7 °C). The Government

of Ontario, Canada, recommends storing carcasses up to 240 days after the animals' death if they are stored in a frozen (about 0 °F or -18 °C) state.

- To minimize the amount of energy required for refrigeration, transport the frozen carcasses in sealed, insulated trucks.
- Use stationary air-conditioned units whenever the mobile units are not equipped with refrigeration systems and it takes more than 1 or 2 days to load the dead livestock into truck containers.
- Before loading and after unloading, thoroughly clean the storage facilities inside and out to prevent contamination within the facilities and in the surrounding areas. After cleaning, treat hard, nonporous surfaces of the facility with an EPA-registered disinfectant; be sure to follow all label precautions and directions. The choice of disinfectant depends on the material being decontaminated.
- Select a dry, cool area downwind from other agricultural and nonagricultural operations to set up the temporary storage facility. Do not locate this facility near property lines or roads.
- To store carcasses temporarily, use storage systems such as preconstructed roll-off containers, dumpsters, and/or possibly silage trenches. Figures 2 and 3 show the general views of these storage systems.
- Use earth-moving equipment to store the carcasses in piles on or above the ground surface.
- Use impervious materials such as polyethylene or compacted clay to prevent seepage from piled carcasses from entering the soil. Control water penetration into and runoff from outdoor piles by building temporary dikes (Fig. 4).
- Cover the carcass pile with soil to prevent scavenging and disease transmission during temporary storage.

Figure 2. A dumpster (Left, courtesy of Teena Middleton, Ag ProVision Company, Kenansville, NC) that can be used for storage and a roll-off container (Courtesy of Kent Munden, USDA Animal and Plant Health Inspection Service (APHIS), Clifton, TX) that can be used for transportation of carcasses.

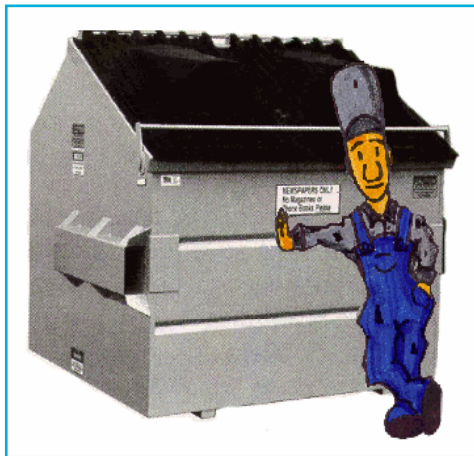


Figure 3. Trench silage storage used to store carcasses temporarily
(Courtesy of Teena Middleton, Ag ProVision Company, Kenansville, NC).

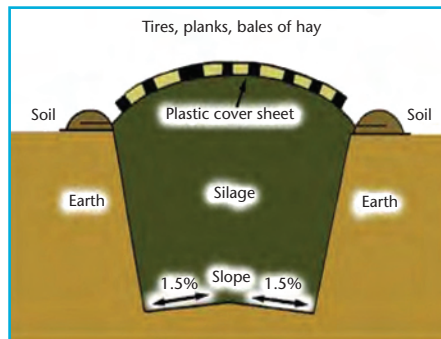
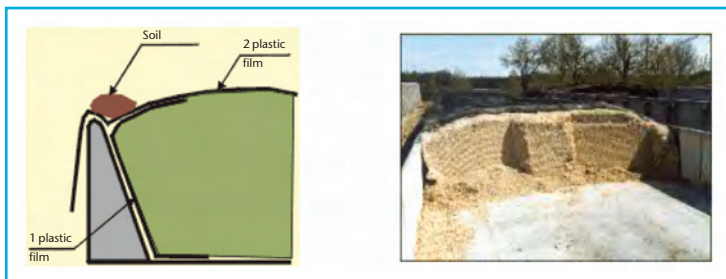


Figure 4. Temporary storage (for 1 to 2 days) of poultry carcasses with a berm to control water runoff and run-on (*Courtesy of Kent Munden, USDA-APHIS, Clifton, TX*).



Handling

When handling carcasses of diseased animals, use equipment such as trucks, bins, backhoes, tractors, and front-end loaders with different bucket sizes (1 to 4 cubic yards) to lift, move, and load the carcasses and related materials.

Use a tractor with a front-end loader to place the livestock bodies in containers (Fig. 5). For ease in loading, keep 7 feet of clearance on all sides of each container.

Consider the physical conditions of the diseased carcasses, and use the appropriate equipment so that they can be handled and displaced carefully without destroying them.

Use the handling equipment to carry only the carcasses and related co-disposal materials (such as soil in burial systems, trash in land-filling systems, and carbon sources in thermal destruction and composting systems) to the disposal site or when unloading the finished waste materials. Do not use the handling equipment to move any materials not related to or designated for the selected carcass-disposal methods.

Thoroughly clean and disinfect the parts of equipment that have contacted disposal materials. Use an EPA-registered disinfectant and follow all label directions.

Figure 5. Two views of loading poultry carcasses into plastic-lined containers for transportation to a disposal site. (Courtesy of Kent Munden, USDA-APHIS, Clifton, TX).



Transportation

To transport carcasses from an affected area to the disposal site, use planned travel routes to limit human exposure and disease transmission and minimize negative public perception.

Obtain any required permissions for personnel hauling dead animals commercially. States such as Georgia require that such permits be obtained from the State Department of Agriculture.

Use cleanable containers, such as drop-off containers or front-dump container trucks, for loading the carcasses and transporting them to the disposal site (Fig. 6). Bring the empty containers back to the loading area.

Resources available to help with planning transportation routes in response to large-scale events include the U.S. Department of Energy's Transportation Routing Analysis Geographic Information System (<https://tragis.ornl.gov>).

Provide a separate exit for moving the infected carcasses out of an animal feeding operation. Pick up any nondiseased carcasses within 72 hours of the animals' demise.

Infected bird carcasses such as those infected with avian influenza should be transferred from the affected premises to off-site locations if on-site disposal is deemed not feasible or desirable. Use leak-proof containers. After loading the carcasses into containers lined with materials such as polyethylene plastic sheets, cover the containers to prevent odor problems, disease transmission, and negative public perception (Figs. 7 and 8).

Protect the drivers and operators from contamination by disinfecting the cabins, lockers, clothing, and footwear. Use an EPA-registered disinfectant to decontaminate the trucks as they leave the event site to travel to the disposal site.

Figure 6. Views of a completely sealed mobile container (A), a mechanical loading system (B), a drop-off container (C), and a front-dump truck (D) used to temporarily store and transport biomass materials (*Courtesy of Kent Munden, USDA-APHIS, Clifton, TX*).



Supervise the departure of the transport vehicles from the farm, their travel routes, and their arrival at the disposal plant or site. Provide an escort vehicle carrying first-aid equipment, additional plastic covers, and emergency equipment to assist carcass transportation vehicles during travel emergencies. Ask for a designated government representative to accompany the transport vehicles for biosecurity reasons.

Guard the carcass load against possible thefts by terrorists seeking to cause harm, spread disease, or spread contamination.

To limit vehicle refueling and minimize the number of stops needed, select a disposal site near the disease site.

Carcasses should be removed quickly and properly. Always consider that the spread of pathogenic microorganisms during routine pickup and transportation of dead animals to a disposal site presents a substantial threat.

If the average temperature of the container rises above 70 °F, do not transport the dead animals for rendering to sites more than 150 miles away.

Figure 7. Two views of plastic-lined trailers before and after they were filled with poultry carcasses. Note the plastic sheets to cover the carcasses (after the trailer was filled) for biosecurity during hauling and transportation. (Courtesy of Kent Munden, USDA-APHIS, Clifton, TX).



Figure 8. A view of the decontamination and covering process of a transporting truck containing infected poultry carcasses (*Courtesy of Kent Munden, USDA-APHIS, Clifton, TX*).



Safety and Biosecurity

Safety programs

The major focus of a safety program is to prevent deaths and to minimize the incidence and severity of injuries to workers engaged in waste-disposal operations, including the disposal of contaminated plant and animal materials. Safety programs involve the use of administrative controls, engineering controls, and personal protective equipment.

When administrative and engineering controls—either alone or in combination—do not achieve the required level of personnel safety, use personal protective equipment to minimize the workers' exposure to contaminants or disease agents. This equipment limits

the disease agents' contact with body surface areas, reducing the likelihood of injury or illness and the spread of the disease agents.

Use administrative and engineering controls as much as possible to manage safety; personal protective equipment should be used only as a last resort. The use of personal protective equipment, particularly for respiratory protection, carries a significant administrative burden in that the workers wearing respirators should be medically qualified, be fit-tested using the masks they intend to wear on site, and undergo ongoing medical monitoring, both on- and off-site.

Administrative controls

Establish a perimeter around the disposal site. Regardless of the perimeter's design, carefully plan a lane through which the personnel can decontaminate themselves and their vehicles and equipment to reduce the spread of the pathogens.

The perimeter should have only one entrance and one exit. The entrance and exit sites may be in the same location, or they may be separated so that the contaminated material is brought in on a “dirty” side, and ash or sanitized waste is removed from a “clean” side.

Use access rosters to limit the number of personnel working on site to the minimum necessary to complete a given task.

When developing an access roster, consider:

- The medical, physical, and professional qualifications required
- Any need for personal protective equipment
- The scope and size of the disposal task
- The number of qualified personnel available

Early in the planning and initial phases of the operation, you must establish, clarify, and enforce the rules for who may enter and exit, and how, when, and where the entry and exit may take place. Stress these rules continually throughout the operation. Controlling the visitors and workers assigned to the site is of paramount importance, both to ensure personnel safety and to avoid spreading diseases.

Safety and Biosecurity

Health and safety plan

The U.S. Occupational Safety and Health Administration (OSHA), through the Hazardous Waste Operations Program (HAZWOPER), has set requirements and recommendations for people engaged in hazardous waste operations involving disease-causing organisms. (Code of Federal Regulations, Part 21, Chapter 1910, <http://www.osha.gov/SLTC/hazardouswaste/index.html>).

When developing a health and safety plan, refer to the OSHA standard, but also consult with experienced and qualified personnel before any incident response occurs. Personnel such as those possessing current OSHA

HAZWOPER certifications of at least the technician level are qualified to develop health and safety plans for large, elaborate disposal operations using many personnel. A common source of such people is the local fire department. Information on this credential is available at or through the Academy of Certified Hazardous Materials Managers (<http://www.achmm.org>).

The health and safety plan is an important document for worker protection and must be given careful thought. It should be developed as part of the pre-incident planning phase and refined as the situation is further assessed.

Engineering controls

Decontamination lanes and protocols

You can greatly reduce the likelihood of disease spread by decontaminating workers and equipment before they exit the disposal site. Although decontamination protocols vary, all should consider at least three aspects:

Decontamination procedures, processes and technologies: First, include the decontamination procedures, processes, and technologies that have been determined to be effective or are recommended by an appropriate Federal and/or State regulatory agency.

For example, use disinfectants registered by the U.S. Environmental Protection Agency (EPA) to clean and disinfect hard, nonporous surfaces of equipment, vehicles, farm premises, and personal protective equipment. If a foreign animal disease is involved, EPA-registered disinfectants may be available for use; if not, the U.S. Department of Agriculture

(USDA) Animal and Plant Health Inspection Service has exemptions in place allowing certain common chemicals to be used for a wide range of foreign animal diseases.

Use the decontamination agents that have been licensed under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for use on the specific organism of concern. The licensing process includes application methods to ensure that the decontamination is effective. If not enough of the decontamination agent is available for that particular pathogen, you will need to use a decontaminant for which the EPA has issued either an exemption or a registration

The choice of decontamination agent should be based on the organism or pathogen of concern, the availability of decontamination solutions, the logistics of acquiring and disposing of either raw or diluted waste

Safety and Biosecurity

generated from the decontamination process, and the contact time (the amount of time required for the decontamination solution to remain in place on the equipment or personnel for maximum effectiveness). Table 3 provides guidance on choosing decontamination agents based on these factors.

Support requirements for the decontamination process: Often, especially in larger operations, the personnel performing the actual disposal operations must focus on

those tasks exclusively, with little time to conduct decontamination operations as well.

In disposal operations requiring higher levels of personal protective equipment (such as OSHA Level B, in which air-supplying respirators are used), the amount of time that workers may spend on site is restricted by the rate at which they use pressurized breathing air. This period is generally less than 45 minutes.

Table 3. EPA-approved pesticides (disinfectants) for use against highly pathogenic diseases.

Disease	Product
African horse sickness	
	None registered ¹
African swine fever	
	Low Ph Phenolic 256
	Pheno Cen Germicidal Detergent
	Klor-Kleen
	Virkon S
Akabane	
	None registered
Avian influenza	
	Odo-Ban Ready-to-Use
	Odo-Ban
	Johnson's Forward Cleaner
	Johnson's Blue Chip Germicidal Cleaner for Hospitals
	BTC 2125 M 10% Solution
	NP 4.5 (D&F) Detergent/Disinfectant
	Scented 10% BTC 2125M Disinfectant
	BTC 2125 M 20% Solution
	Quat 44
	Quat Rinse
	Spray Nine

Disease	Product
<i>(continued)</i>	Maquat 256
	Maquat 128
	Maquat 64
	Maquat 10
	Maquat 20-M
	Maquat 50DS
	Maquat 10 FQPA
	Maquat 256 EBC
	Maquat 128 EBC
	Maquat 64 EBC
	Maquat MQ2525M-14
	Maquat 10-B
	Maquat FP
	Maquat 256 PD
	D-125
	Public Places
	Public Places Towelette
	CCX-151
	D-128
	PJW-622

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Safety and Biosecurity

Table 3. *(Continued).*

Disease	Product
<i>(continued)</i>	Opticide-3
	Opticide-3 Wipes
	Disinfectant DC 100
	Sterilex Ultra Disinfectant Cleaner
	HI-Tor Plus Germicidal Detergent
	Marquat 256-NHQ
	Maquat 2420 Citrus
	Formulation HS-652Q
	Formulation HS-821Q
	HS-867Q
	HS-867Q Germicidal Cleaner and Deodorant
	Formulation HH-652 Q
	Virex II/128
	Virex II Ready to Use
	Virex II 64
	Virex 11/256
	Virocide
	Ucarcide 14 Antimicrobial
	Ucarcide 42 Antimicrobial
	Ucarsan 442 Sanitizer

Disease	Product
<i>(continued)</i>	Ucarsan 414 Sanitizer
	Synergize
	Maxima 128
	Maxima 256
	Broadspec 256
	Maxima RTU
	Q5.5-5.5NPB-2.5HW
	Sanox II
	7.5% BTC 885 Disinfectant/Sanitizer
	Quik Control
	Bardac 205M-7.5B
	Lonza Formulation Y-59
	Lonza Formulation S-21
	Lonza Formulation S-18
	Lonza Formulation R-82
	Lonza Formulation S-18F
	Lonza Formulation R-82F
	Lonza Formulation S-21F
	Lonza Formulation DC-103

(Continued on next page)

Table 3. *(Continued).*

Disease	Product
<i>(continued)</i>	Bardac 205M-50
	Bardac 205M-10
	Bardac 205M-1.30
	Bardac (R) 205M-14.08
	Bardac 205M-2.6
	Bardac 205M-5.2
	Microban QGC
	Microban Professional
	Maquat MQ651-AS
	Maquat 615-HD
	Maquat 5.5-M
	Maquat 7.5-M
	Maquat 86-M
	Maquat 750-M
	Maquat 710-M
	Maquat A
	DC & R Disinfectant
	Biosol
	Husky 806 H/D/N
	Pheno Cen Germicidal Detergent
	Pheno-Cen Spray Disinfectant/Deodorant

Disease	Product
<i>(continued)</i>	Low Ph Phenolic 256
	Phenocide 256
	Phenocide 128
	Phenolic Disinfectant HG
	Tek-Trol Disinfectant Cleaner Concentrate
	Advantage 256 Cleaner Disinfectant Deodorant
	LPH Master Product
	Sporicidin Brand Disinfectant Solution
	Ucarsan Sanitizer 420
	Ucarsan Sanitizer 4128
	Accel TB
	Virkon
	Oxonia Active
	OxySept LDI
	Peridox
	Vortexx
	DisinFx
	Dyne-O-Might
	Virkon S

(Continued on next page)

Safety and Biosecurity

Table 3. *(Continued).*

Disease	Product
<i>(continued)</i>	Klor-Kleen
	Clorox
	Dispatch Hospital Cleaner with Bleach
	Dispatch Hospital Cleaner Disinfectant Towels with Bleach
	CPPC Ultra Bleach 2
	CPPC Storm
	Aseptrol S10-Tabs
Bovine babesiosis	
	None registered
Bluetongue	
	None registered
Borna disease	
	None registered
Bovine ephemeral fever	
	None registered
Bovine parafilaria	
	None registered
Bovine spongiform encephalopathy	
	None registered

Disease	Product
Classical swine fever ("hog cholera")	
	Pheno Cen Germicidal Detergent
	Pheno-Cen Spray Disinfectant/Deodorant
	Tri-Cen
	Q5.5-5.5NPB-2.5HW
	Low Ph Phenolic 256
	Ucarsan Sanitizer 420
	Ucarsan Sanitizer 4128
	1-Stroke Environ
	Fort Dodge Nolvasan Solution
	Fort Dodge Nolvasan S
	Virkon S
	Klor-Kleen
Contagious agalactia of sheep and goat	
	None registered
Contagious bovine pleuropneumonia	
	None registered
Contagious caprine pleuropneumonia	
	None registered

(Continued on next page)

Table 3. *(Continued).*

Disease	Product
Contagious equine metritis	
	None registered
Dourine	
	None registered
Duck virus hepatitis	
	None registered
Epizootic lymphangitis	
	None registered
Equine encephalosis	
	None registered
Foot-and-mouth disease ³	
	Low PH Phenolic 256
	Oxonia Active
	Oxysept LDI
	Lonza DC 101
	Aseptrol S10-TAB
	Aseptrol FC-Tab
	Virkon S
Getah virus disease	
	None registered
Glanders	
	None registered

Disease	Product
Heartwater	
	None registered
Hendra Virus Disease	
	None registered
Hemorrhagic Septicemia	
	None registered
Infectious salmon anemia	
	Virkon S ⁴
Japanese encephalitis	
	None registered
Jembrana disease	
	None registered
Louping III	
	None registered
Lumpy skin disease	
	None registered
Malignant catarrhal fever	
	None registered
Nairobi sheep disease	
	None registered

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Safety and Biosecurity

Table 3. *(Continued).*

Disease	Product
Newcastle disease	
	Vesphene II SE
	LPH Master Product
	Vesta-Syde Interim Instrument Decontamination Solution
	Process Vesphene II ST
	Amerse II
	Beaucoup Germicidal Detergent
	Matar II
	1-Stroke Environ
	Tek-Trol Disinfectant Cleaner Concentrate
	Bio-Phene Liquid Disinfectant
	Phenocide 256
	Phenocide 128
	Phenolic Disinfectant HG
	Mikro-Quat
	Odo-Ban Ready-to-Use
	Odo-Ban
	Johnson Blue Chip Germicidal Cleaner for Hospitals

Disease	Product
<i>(continued)</i>	Grenadier
	BTC 2125M 20% Solution
	Maquat 10
	Maquat 20-M
	Maquat 50DS
	Maquat 10-PD
	Maquat 256 EBC
	Maquat 128 EBC
	Maquat 64 EBC
	Maquat MQ2525M-CPV
	Maquat MQ2525M-14
	Maquat 10-B
	Maquat FP
	Maquat 256 PD
	D-125
	Public Places
	Public Places Towelette
	CCX-151

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Table 3. *(Continued).*

Disease	Product
<i>(continued)</i>	Bioguard 453
	Gemstone
	Hospital Disinfectant Cleaner
	Maquat 2420-Citrus
	Formulation HS-652Q
	Formulation HS-821Q
	FMB 1210-5 Quat
	HL-867 Q
	HS-267Q Germicidal Cleaner and Disinfectant
	FMB 1210-8 Quat Concentrated Germicide
	Formulation HS-1210 Disinfectant/Sanitizer (3.85%)
	Formulation HS-1210 Disinfectant/Sanitizer (50%)
	Formulation HS-1210 Disinfectant/Sanitizer (14.08%)
	Virex II/128
	Virex II Ready to Use
	Virex II 64
	Virex II/256
	Biosentry 904
	Process NPD

Disease	Product
<i>(continued)</i>	Bardac 205M-7.5B
	Lonza Formulation S-21
	Lonza Formulation S-18
	Lonza Formulation R-82
	Lonza Formulation S-18F
	Lonza Formulation R-82F
	Lonza Formulation S-21F
	Lonza Formulation DC-103
	Bardac 205M-50
	Bardac 205M-10
	Bardac 205M-1.30
	Bardac (R) 205M-14.08
	Bardac 205M RTU
	Bardac 205M-2.6
	Bardac 205M-5.2
	Bardac 205M-23
	Maquat MQ615-AS
	Maquat 615-HD
	Maquat 5.5-M
	Maquat 7.5-M

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Safety and Biosecurity

Table 3. *(Continued).*

Disease	Product
<i>(continued)</i>	Maquat 86-M
	Maquat 750-M
	Maquat 710-M
	Maquat A
	KP 3510
	Quick Control
	Microban QGC
	Microban Professional Strength Multi-Purpose Antibacterial Cleaner
	DC & R Disinfectant
	Fort Dodge Nolvasan Solution
	Nolvasan S
	Ucarsan Sanitizer 420
	Ucarsan Sanitizer 4128
	Mikroklene
	Mikroklene DF
	Oxonia Active
	Oxysept LDI
	Virkon S
	Klor-Kleen

Disease	Product
New world screwworm ("screwworm")	
	Champion Insecticide Spray
	Black Jack Multipurpose 0.5% Insecticide
	Sunbugger Flea & Mite Spray
	CT Residual Spray
	Permethrin Insecticide Spray
	Permanone Multi-Use Insecticide Spray
	Co-Ral Coumaphos Flowable Insecticide
	Co-Ral Fly and Tick Spray
Nipah virus disease	
	None registered
Peste des petits ruminants	
	None registered
Rabbit calicivirus disease	
	None registered
Rift Valley fever	
	None registered
Rinderpest	
	None registered

(Continued on next page)

Table 3. (Continued).

Disease	Product
Sheep and goat pox	
	None registered
Spring viremia of carp	
	None registered
Swine vesicular disease	
	None registered
Trypanosomosis	
	None registered
Theileriosis	
	None registered
Venezuelan equine encephalomyelitis	
	None registered

Disease	Product
Vesicular exanthema of swine	
	Alcide Brand LD 10:1.1 Base
	Virkon S
	Klor-Kleen
Vesicular stomatitis	
	Alcide Exspor 4:1:1 - BASE
	Alcide Brand LD 10:1.1 BASE
	D-125
	Virkon S
	Bio-Phene Liquid Disinfectant
	Biosentry 904
Wesselsbron disease	
	None registered

¹“Registered” refers to a FIFRA Section 3 registration.

²Products listed for use against avian influenza were not generated from the National Pesticide Information Retrieval System (NPIRS) database. This list originated with the EPA’s “Registered Antimicrobial Products with Label Claims for Avian (Bird) Flu Disinfectants” list dated July 13, 2007, located at: http://www.epa.gov/pesticides/factsheets/avian_flu_products.htm.

³Products listed for use against foot-and-mouth disease (FMD) were not generated from the NPIRS database. This list originated from EPA’s 8/8/07 FMD table provided via e-mail to APHIS.

⁴Product is not listed in NPIRS as approved for use against this virus, but the use does appear on the federally approved label.

Source: Information provided by the U.S. Department of Agriculture, Animal and Health Inspection Service, 9-25-07.

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Disposal of the hazardous waste generated from the decontamination process:

All disposable protective clothing must be discarded before the workers exit the site. After the clothing has been collected, it must be incinerated or autoclaved to prevent the spread of disease.

Decontamination protocols should be developed or selected by appropriately trained personnel (HAZWOPER-certified or equivalent).

Work zones

At least five types of worksites should be established (Fig. 9):

Site perimeter and work zones: The establishment and maintenance of the work zone described in this guide are intended to meet the requirements of the OSHA HAZ-

WOPER standard. As discussed in the Administrative controls section, a work zone is established to:

- Reduce the accidental spread of hazardous substances by workers or equipment
- Confine work activities to the appropriate areas
- Facilitate the location and evacuation of personnel in case of emergency

Exclusion zone: The area where contamination is present. In this guide, it is the area where contaminated animal and plant materials are placed for disposal.

Contamination reduction zone: The transition zone between the contaminated area and the clean area.

Support zone: The uncontaminated area where workers should not be exposed to contaminated materials or conditions. This area is

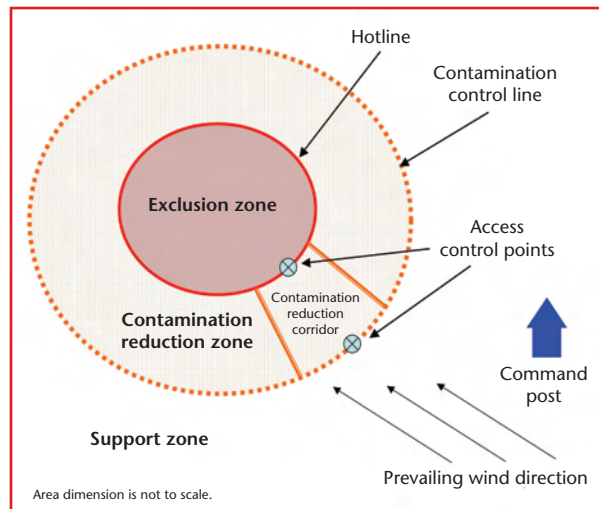
an appropriate location for the command post.

Contamination reduction corridor: An area with at least two lines of decontamination stations, one for personnel and one for equipment (see the Decontamination section).

Access control points are physical or virtual “gates” that control the flow of workers and equipment in and out of the exclusion zone (Fig. 9).

Establish the command post and contamination reduction corridor upwind of the exclusion zone. Given that some disposal operations may continue for days and that the wind direction may change, you may use historical wind data (available from an area meteorologist) for planning purposes to obtain the most probable wind direction for a particular season in a specific geographical region.

Figure 9. A schematic of decontamination area containing appropriate work sites.



For information, refer to EPA publication 9285.2-15FS, contact your EPA Regional Office, or consult with a HAZWOPER-certified technician, often found in larger municipal fire departments.

Safety and Biosecurity

Security

The physical construction of a boundary or perimeter is an engineering control. The level of physical security required for a particular operation depends largely on:

- The scope of the disposal process
- The length of time the disposal operation will be at a particular location
- The likelihood of scavengers or curious people venturing onto the site
- The availability of appropriate fencing material

For example, thermal destruction of a large number of cattle using a low-throughput technique may necessitate the piling of carcasses on site until they can be destroyed appropriately.

The importance of protecting the diseased carcasses from scavenging mammals and birds cannot be overstated, especially for cases in which the diseases are caused by pathogens highly resistant to environmental degradation, such as in the case of foot-and-mouth disease.

Contamination reduction corridor

Decontaminating workers and equipment before they exit the disposal site greatly reduces the likelihood of disease spread to unaffected animals at other sites. In the case of zoonotic diseases, it can also prevent the spread of disease to humans.

Although decontamination protocols vary, all should consider the decontamination procedures, processes, and technologies; the disposal of the hazardous waste generated from those processes; and personnel.

As discussed in the Engineering controls section, it is important that you use decontamination procedures, processes, and technologies that have been determined to be effective or are recommended by an appropriate federal and/or state regulatory agency. Use FIFRA-licensed decontamination agents for use

on the specific organism of concern. If not enough of the decontamination agent is available for that particular pathogen, a crisis exemption will be needed from the EPA to use another decontaminant.

The decontamination process requires supplies and equipment. During the event planning phase, stockpile supplies and decontamination solutions. See Table 4 for potential requirements. The importance of logistics planning well before an event to obtain decontamination supplies and equipment cannot be overstated.

The disposal of hazardous waste generated from the decontamination process entails thoroughly decontaminating the nondisposable items or equipment before removing them from the worksite. Before exiting the con-

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tamination reduction corridor, workers should discard or store in appropriate containers (such as lidded rubber trash cans lined with 8-mil garbage bags) all disposable equipment and protective clothing.

As discussed in the Engineering controls section, incinerate or autoclave all disposable clothing and equipment to prevent the spread of disease.

Note: The runoff from the contamination reduction zone is contaminated and should be collected and disposed of according to local, State, and Federal environmental regulations in coordination with local, State, and Federal officials and guidelines.

Personnel

The personnel required for 24-hour continuous operations should include at least two teams of 10 people each, working in either two 12-hour shifts or four 6-hour shifts. Guidelines for the use of personnel in decontamination operations are highlighted in Table 5.

The decontamination of personnel—especially when higher levels of protection and personal protective equipment are used—is a major consideration and requires additional personnel beyond those used for actual disposal operations. Likewise, medical monitoring by an emergency medical technician or paramedic is advised and, in some operations, required by law.

Table 4. Team equipment planning (modified from the National Animal Health Emergency Management System’s “Operational Guidelines for Cleaning and Disinfection,” Draft, November 2005).

Equipment	Nondisposable items (per team)	Disposable items (per team-day ¹)
Decontamination equipment		
Power spray unit and tank	2	
Spray nozzles	4	
Safety can (5 gal with gas)	2	
Hose (¾ in x 50 ft)	5	
Garbage bags (8 mil; 50 gal)		20
Pressurized garden sprayers	4	
Safety equipment		
Pressure eyewash station (alkaline hydrolysis)	1	
Disposable eyewash bottles		1
Bottled water (2 gal/person/day)		20
First aid kit		0.5
Stretcher/litter		0.5
Miscellaneous equipment		
Multi-tool with knife blade	10	

This team equipment planning table assumes two teams of 10 people each in a 24-hour period, each working a 12-hour shift.

¹Team-day is the number of units one team will use in a 12-hour day, based on the assumptions above.

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Table 5. Guidelines for the use of personnel in decontamination operations.

Function	# People required	Estimated time required
Dry removal of straw and other materials from the equipment; physical removal of mud, blood, and other materials	4	10 min
High-pressure rinse	4	10 min
Detergent application and soak time	4	20 min
Final rinse	4	10 min
Drip-dry	0	10 min
Application of decontaminant/disinfectant	4	10 min
Emergency medical monitoring (people not conducting decontamination functions)	2	n/a
Backup (people suited up and ready to enter the contamination reduction zone to serve as rescue personnel; they should remain at rest unless needed)	2	n/a
Total	12	70 min

Text in blue indicates the functions that can be conducted simultaneously so that the workers conducting the high-pressure rinse can immediately follow those performing dry removal as it is completed on a particular area or component of machinery.

Decontamination guidelines

Decontamination protocols should be developed or selected by qualified personnel (HAZWOPER-certified or equivalent). The major considerations in decontaminating equipment and personnel follow.

Vehicles

To keep the transport as clean as possible, thoroughly spray the animal carcasses with water or water mixed with detergent to remove as much gross filth as possible before loading them into the vehicles.

Line each vehicle with a tarp, such as an 8-mil disposable polyethylene plastic sheet, and seal the truck at the top. The plastic sheet(s) must be large enough to cover the carcasses and to be secured to the sides and ends of the box or dumpster.

Place a layer of an absorbent material, such as wood shavings or sawdust, on top of the plastic liner to prevent punctures, such as by the

horns or hooves.

After transport, disinfect all the trucks, trailers, and other equipment used to transport the diseased carcasses or materials. If a vehicle must enter the exclusion zone, it must be completely decontaminated through the contamination reduction zone before leaving the site. The minimum equipment necessary for adequate decontamination includes:

- Long-handled, stiff bristle brushes
- 5-gallon buckets half-filled with an appropriate disinfectant
- Appropriate personal protective equipment (see the planning guidelines for personal protective equipment)
- Containers for mixing the disinfectants and/or decontaminants
- High-pressure, heated-water sprayers (at 200 psi) for physically removing mud, blood, soil, and other contaminants

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Disinfect vehicles in this order:

Step 1. Completely remove any straw, feed, wood chips, manure, or other dry matter, using shovels, forks, or similar tools, before applying any liquid solution to the vehicle.

Step 2. Use stiff brushes to dislodge any mud, blood, or animal parts from the wheels, tires, or other parts of the vehicle. Rinse them with water at 100 to 115 °F (38 to 46 °C).

Note: A visibly clean surface is absolutely necessary before disinfection and decontamination can be effective.

Step 3. Allow the vehicle to drip-dry for about 10 minutes.

Step 4. Spray down the entire vehicle with an appropriate disinfecting agent, allowing for appropriate soak times.

Step 5. Rinse the vehicle again with water at an increased temperature of 120 to 170 °F (49 to 77 °C).

If the driver or any passengers exit the vehicle at either the disposal site or the carcass/plant material pickup site and do not decontaminate themselves before reentering the truck cab, disinfect the rubber floor mats, dashboard, steering wheel, gear stick, and seats. Spray an approved pesticide inside the cab of the vehicle to kill any insects that could become vectors/vehicles for the disease.

Before reentering the cab, all personnel should remove any contaminated clothing and wash with antiseptic soap and water before leaving the site.

If possible, maintain the biosecurity of the interior of the vehicle by providing enough ground personnel (such as those to open tailgates) so that the driver need not exit the vehicle at any time in the exclusion and contamination reduction zones.

Other equipment

Disinfect all small equipment items used in the work zone before removing them from the work zone. Do not use shovels, axes, hammers, stiff brushes, or other tools that have wooden handles. Fiberglass or plastic components are much easier to decontaminate.

Personnel decontamination

All personnel who enter the work zone must exit through the contamination reduction corridor and be adequately decontaminated to avoid spreading disease agents off-site and, in the case of zoonotic disease agents, to avoid either becoming a vector for a contagious disease or contracting the disease of concern.

Figure 10 presents a layout for a multipurpose decontamination line and guidelines for setting it up. However, multiple site-specific factors should also be considered.

The same decontamination protocol must be used for small equipment as for workers: All soil, mud, blood, and other contaminants must be physically removed with brushes and initially rinsed from the equipment. An appropriate disinfection solution must be applied at the proper volume, allowed adequate stay time and rinsed thoroughly with clean water.

The green line represents the path taken by workers exiting the work zone through the contamination reduction zone. The red line represents the path taken if a casualty occurs in the work zone.

Workers should follow this procedure for routine (nonemergency) personnel decontamination:

Step 1. If the outer gloves are made of a synthetic material and not of leather, rinse and disinfect them. If they are made of leather

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or other liquid-permeable material, drop the gloves in a bucket for disposal or autoclaving.

Step 2. Drop the equipment into the equipment drop basin, and clean and disinfect the equipment.

Step 3. Step into the boot decontamination (decon) basin and remove any gross contamination using a stiff-bristled, long-handled brush. **Note:** Use a “hand hold,” fashioned from T-posts, wood or other sturdy material at the boot decon station. This will help prevent falls when workers are entering, standing in, and exiting the basin. Upon completion of gross removal of contaminants, step out of the basin, moving toward the area of least contamination (to the “clean” side of the contamination reduction zone).

Step 4. If the outer protective suit is not disposable or is liquid permeable, step into the decontamination shower area. If ample per-

sonnel are available, one person (dressed in a level of protection one level down from the workers being decontaminated—for example, if the workers are in Level B, the decontamination personnel may be in Level C) may disinfect the other workers by using a simple pressurized garden sprayer filled with an appropriate disinfectant. This person should thoroughly cover the other workers’ outer protective ensembles with the disinfectant and allow the recommended soak/stay time. Make every effort to avoid getting disinfectant spray on the respirator. Note: Steps 4 and 5 are unnecessary if the workers are wearing disposable outer protective suits.

Step 5. Step into the rinse shower, where all disinfectant is removed with clean water.

Step 6. Disinfect and rinse the outer gloves, then step into the boot disinfection basin. The workers should step to the tank ex-

change area if they are wearing OSHA Level A or B gear and are planning to reenter the work zone without undergoing full decontamination. Step out of the basin moving toward the area of least contamination (to the clean side of the contamination reduction zone).

Step 7. Remove the outer protective garment and discard it into an approved container. Remove this outer garment from the inside out to avoid contaminating the skin or the inner set of clothing items. Providing another

worker to assist in this process in the decon line will not only help prevent contamination but will also assist the workers who may already be physically and mentally exhausted.

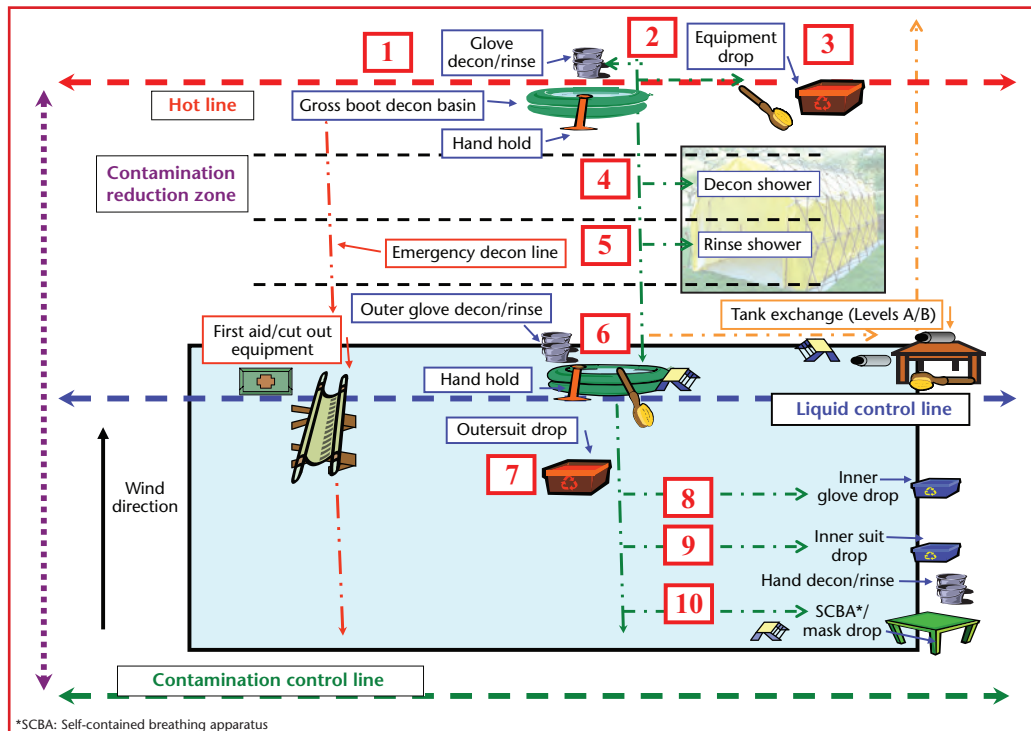
Step 8. Remove the inner gloves.

Step 9. Remove the inner suit (if one is worn).

Step 10. Remove the respirator (if one is used) and place it in an approved container for disposal or reuse. Step across the contamination control line.

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Figure 10. Schematic of a multipurpose decontamination line.



Personal protective equipment

Several factors affect the process of selecting an appropriate protective ensemble: the tasks being performed; the physical, chemical, and biological hazards to which the workers are exposed; and the logistical support that must accompany a specific protective level.

For example, workers in thermal destruction operations may require protection from physical hazards such as high heat and heavy equipment, from chemical hazards such as decontamination solutions, and from biological agents such as aerosolized anthrax spores. One choice for an appropriate protective ensemble might be OSHA Level C, which could include the following:

- A half- or full-facepiece air-purifying respirator with a filter that can remove anthrax spores. The respirator must be approved by National Institute for Oc-

cupational Safety and Health (NIOSH).

Note: See 29 CFR 1910.134c for guidelines on establishing and maintaining a respiratory protection program.

- Eye protection if a full facepiece respirator is not used
- Hooded, chemical-resistant coveralls
- Outer and inner gloves that are chemical resistant
- Outer boots with chemical-resistant steel toes and shanks
- Outer boot covers that are disposable and chemical resistant
- Hard hat

However, for workers who might be required to enter confined spaces or areas of low oxygen concentration or high concentrations of toxic gases, the ensemble should include a positive-pressure, full-facepiece, self-contained breathing apparatus (SCBA), or a posi-

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tive-pressure-supplied air respirator (air line) with an escape SCBA (OSHA Level B). As a final option, consider selecting a supplied-air respirator because the logistics burden of maintaining an adequate and safe air supply

and the added physical burdens of carrying air tanks are great.

Specific recommendations for personal protective equipment are highlighted under each disposal method.

Equipment planning factors

Tables 4, 6, and 7 list the recommended equipment to ensure health and safety in disposal operations. Note that if a catastrophic outbreak of plant or animal disease occurs, certain pieces of personal protective equipment may be difficult to obtain. If space and resources are available, acquire and store a 5- to 7-day supply of basic items such as gloves and boots.

The data in these tables assume 24-hour

operations and 12-hour shifts each day. These estimates account for the occasional equipment failure (such as torn gloves or boots), excessively contaminated or damaged personal protective equipment that must be destroyed instead of reused, and the inevitable unknown incident that occurs during any hazardous waste disposal operation. These tables are meant to serve as guidelines and are not comprehensive for most operations.

Figure 11. Four levels of personal protective equipment.

Level A

Level A affords the greatest level of skin, respiratory, and eye protection:

- A positive-pressure, full-facepiece, self-contained breathing apparatus or a positive-pressure-supplied air respirator with an escape self-contained breathing apparatus, approved by NIOSH
- A totally encapsulating chemical-protective suit
- Coveralls¹
- Long underwear¹
- Outer chemical-resistant gloves
- Inner chemical-resistant gloves
- Chemical-resistant boots with steel toes and shanks
- Hard hat (under the suit).¹
- Disposable protective suit, gloves, and boots (depending on the suit construction, it may be worn over a totally encapsulating suit)

¹Optional, as applicable



Level B

Level B offers the highest level of respiratory protection but a lesser level of skin protection:

- A positive-pressure, full-facepiece, self-contained breathing apparatus or a positive-pressure-supplied air respirator with an escape self-contained breathing apparatus (NIOSH-approved)
- Hooded chemical-resistant clothing (overalls, a long-sleeved jacket, coveralls, a one- or two-piece chemical-splash suit, and disposable, chemical-resistant overalls)
- Coveralls¹
- Outer chemical-resistant gloves
- Inner chemical-resistant gloves
- Chemical-resistant boots with steel toes and shanks
- Disposable, chemical-resistant outer boot covers
- Hard hat
- Face shield

¹Optional, as applicable



(Continued on next page)

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Figure 11. *(Continued).*

Level C

Level C is used when the concentration(s) and type(s) of airborne substance(s) are known and the criteria for using air-purifying respirators are met:

- Full-face or half-mask air-purifying respirators (NIOSH approved)
- Hooded, chemical-resistant clothing (overall, a long-sleeved jacket, coveralls, a one- or two-piece chemical-splash suit, and disposable chemical-resistant overalls)
- Coveralls¹
- Outer chemical-resistant gloves
- Inner chemical-resistant gloves
- Outer, chemical-resistant boots with steel toes and shanks
- Outer disposable, chemical-resistant boot covers¹
- Hard hat¹
- Escape mask¹
- Face shield¹

¹Optional, as applicable



Level D

Level D is a work uniform affording minimal protection; it is used for nuisance contamination only:

- Coveralls¹
- Gloves¹
- Outer, chemical-resistant boots/shoes with steel toes and shanks
- Outer, chemical-resistant boots
- Safety glasses or chemical splash goggles
- Hard hat¹
- Escape mask¹
- Face shield¹

¹Optional, as applicable



Table 6. Personal protective equipment planning.

Equipment	Nondisposable items (per team)	Disposable items (per person-day ¹)
Hand protection		
Leather gloves (specific to work)		4 pairs
Gloves (heavy butyl rubber)		1–2 pairs
Gloves (nitrile; worn under leather)		10–12 pairs
Foot protection		
Steel toe/steel shank leather work boots	2 pairs	
Steel toe/steel shank butyl rubber boots	2 pairs	
Head protection		
Hard hat	1	
Waterproof hat	1	
Respiratory protection		
SCBA positive-pressure respirator	1	
Supplied-air positive-pressure respirator	1	
Air-purifying respirator	1	
Powered air-purifying respirator	1	
Filter cartridges for respirators		0.25
Disposable N95/N100 respirators		4–6

(Continued on next page)

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Table 6. *(Continued).*

Equipment	Nondisposable items (per team)	Disposable items (per person-day ¹)
Chemical protective overgarment		
Butyl rubber apron	2	
Protective eyewear		
Indirectly vented chemical goggles	2 pairs	
Safety glasses (with side shields)	2 pairs	
Polystyrene face shield (caustic solutions)	1	
Hearing protection		
Disposable earplugs		4–6 pairs
Earmuffs	2 pairs	
Protective suit (Tyvek, cloth or other material)		
Disposable (Level C or D)		3
Decontaminable (Level A or B)	2	
Spare clothing		
Surgical scrubs or disposable protective suits		2 sets
Spare pair of shoes (supplied by workers)	1 pair	
Miscellaneous equipment		
Multi-tool with knife blade	1	

¹Person-day is the number of units one person will use in a day, based on the assumptions above.

Table 7. Recommended tools for a crew of 10 people (Modified from the National Animal Health Emergency Management System’s “Operational Guidelines for Cleaning and Disinfection,” Draft, November 2005).

Equipment	Nondisposable items (per team)
Claw hammer	2
Pliers	2
Screwdriver (2 flathead; 2 Phillips)	4
Adjustable end wrench	2
Crowbar/wrecking bar	2
Hatchet	2
Axe	2
Wire brush (with scraper nose)	24
Fiber brush (long-handled)	5
Plastic bucket (5-gal)	6

Equipment	Nondisposable items (per team)
Sponge	24
Tent	2
Shovel (flat-billed)	4
Broom (heavy)	3
Shop vacuum	1
Electrical cord (12-ga, 100 ft)	1
Post hole digger	2
Garden rake	2
Fork (manure)	2
Scraper (long-handled)	2

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Heat-stress monitoring and measurement

Portable heat-stress meters or monitors are used to measure heat conditions. These instruments can calculate both the indoor and outdoor wet-bulb globe temperature (WBGT) indexes, which consider the combined effects of radiant heating from the sun, relative humidity, and air temperature.

With this measurement and information on the type of work being performed, heat stress meters can help in determining the length of time a person can safely work or remain in a particular hot environment. The resultant data can provide guidance on work/rest cycles.

In Table 8, examples of light work might include the assembly of tools or clerical work done in the operations center. Moderate work might include the operation of heavy equip-

ment such as trucks and loaders. Heavy work would include the physical manipulation of contaminated materials or the performance of decontamination operations on the ground.

As an example, consider a worker wearing Tyvek and performing moderate work. A theoretical heat-stress meter provides a value of 87 °F. Because the worker is wearing Tyvek, subtract 10.8 °F (Table 9) from the WBGT value of 87 °F, resulting in 76.2 °F.

To stay within the permissible heat exposure threshold limit value of 76.2 °F for workers performing moderate work, according to Table 8 this person would need to be on a cycle of 25 percent work, 75 percent rest for each hour worked (15 minutes of work, 45 minutes of rest).

Table 8. Heat-stress monitoring during worker performance.

Permissible heat exposure threshold limit values	Work load		
	Light	Moderate	Heavy
Continuous work	86 °F (30.0 °C)	80 °F (26.7 °C)	77 °F (25.0 °C)
75% work, 25% rest, each hour	87 °F (30.6 °C)	82 °F (28.0 °C)	78 °F (25.9 °C)
50% work, 50% rest, each hour	89 °F (31.4 °C)	85 °F (29.4 °C)	82 °F (27.9 °C)
25% work, 75% rest, each hour	90 °F (32.2 °C)	88 °F (31.1 °C)	86 °F (30.0 °C)
These values apply to physically fit and acclimatized individuals wearing light summer clothing. As contaminated material disposal operations will undoubtedly require heavier clothing that impedes sweat or has a higher insulation value, the permissible heat exposure values above must be reduced by the corrections shown in Table 9.			

Source: OSHA Technical Manual, Section III, Chapter 4 (TED 01–00–015)

Table 9. Wet-bulb globe temperature index correction factors for worker performance while wearing heavier protective clothing.

Clothing type	WBGT ¹ index correction (°F)
Summer lightweight working clothing (such as operations center personnel)	0
Cotton coveralls (such as truck drivers)	–3.6
Winter work clothing (such as for operations in winter)	–7.2
Water barrier, permeable (such as workers wearing Tyvek or similar protective ensemble)	–10.8
Fully encapsulating suit, gloves, boots, and hood (such as OSHA Level A or B)	–18.0

¹ WBGT: Wet bulb globe temperature

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Heat index: An alternative measure to assess conditions causing heat stress

The heat index shows the relationship between the relative effects of temperature and humidity. The index can be used as a second-choice approach if no heat stress meter or wet-bulb globe temperature thermometer is available. Use Table 10 only when a wet-bulb globe temperature thermometer or heat-stress meter and qualified operators are unavailable.

As the heat index does not take into account the heat resulting from radiant energy from the sun, add a conservative estimate of 15 °F to the environmental temperature value taken from this chart when workers are in direct sunlight. After a value is identified in Table 10, use Tables 8 and 9 to obtain an estimate of the work/rest cycle.

Sample calculation: The environmental conditions at a disposal site are 80 °F and 20

percent relative humidity, with the workers in direct sunlight. The heat index value (obtained from Table 10 and adding 10 °F to the environmental temperature to account for the direct sunlight exposure) is 87 °F.

According to Table 8, a worker dressed in a Tyvek suit with boots, gloves, and a hard hat (WBGT correction factor of -10.8 °F) performing moderate work would need a work-rest cycle of 25 percent work/75 percent rest for each hour worked. Because of the personal protective equipment correction factor of 10.8 °F (Table 9), this worker can continue with this work/rest cycle as long as the heat index or wet-bulb globe temperature does not exceed 76.2 °F. For more information, visit <http://www.OSHA.gov>.

Table 10. Heat index used as an alternative measure to assess conditions causing heat stress.

				Heat index							
				Environmental temperature °F (°C)							
	70° (21)	75° (24)	80° (27)	85° (29)	90° (32)	95° (35)	100° (38)	105° (41)	110° (43)	115° (46)	120° (49)
Relative humidity	Apparent temperature °F (C)										
0%	64 (18)	69 (20)	73 (23)	78 (26)	83 (28)	87 (31)	91 (33)	95 (35)	99 (37)	103 (39)	107 (42)
10%	65 (18)	70 (21)	75 (24)	80 (27)	85 (29)	90 (33)	95 (35)	100 (38)	105 (41)	111 (44)	116 (47)
20%	66 (19)	72 (22)	77 (25)	82 (28)	87 (30)	93 (33)	99 (37)	105 (41)	112 (44)	120 (49)	
30%	67 (19)	73 (23)	78 (26)	84 (29)	90 (33)	96 (36)	104 (40)	113 (45)	123 (51)		
40%	68 (20)	74 (23)	79 (26)	86 (30)	93 (34)	101 (38)	110 (43)	123 (56)			
50%	69 (20)	75 (24)	81 (27)	88 (31)	96 (36)	107 (42)	120 (49)				
60%	70 (21)	76 (24)	82 (28)	90 (33)	100 (38)	114 (46)					
70%	70 (21)	77 (25)	85 (29)	93 (34)	106 (41)	124 (51)					
80%	71 (22)	78 (26)	86 (30)	97 (36)	113 (45)						
90%	71 (22)	79 (26)	88								
Apparent temperature				Heat-stress risk with physical activity and/or prolonged exposure							
90–104 °F (32–40 °C)				Heat cramps or heat exhaustion possible							
105–130 °F (31–54 °C)				Heat cramps or heat exhaustion likely; heat stroke possible							
Above 130 °F (54 °C)				Heat stroke very likely							

Economic factors

The relevant economic and cost factors to evaluate can be separated into direct and indirect costs (Tables 11 and 12).

Direct costs involve direct disposal-

related operations, transportation, facilities, energy, storage, and security.

Indirect costs are related to increased disease incidence, environmental impacts, public perception, and indirect income loss.

Table 11. Direct costs incurred from installation and operating disposal activities.

Category	Expense
Operation costs	<ul style="list-style-type: none"> • Energy • Labor • Chemicals • Personal protective equipment • Decontamination equipment/chemicals • Cost of livestock or crops destroyed by disease, or to prevent spread of disease • Disposal of treatment residue (such as ash or finished compost)
Facilities, permitting and other capital equipment	<ul style="list-style-type: none"> • Permit fees and legal costs for obtaining disposal sites • Hauling in facilities • Any portable disposal facilities adopted • Installing new disposal facilities
Security	<ul style="list-style-type: none"> • Labor • Fencing • Site entry/exit procedures/decontamination
Transportation	<ul style="list-style-type: none"> • Transporting animal carcasses or plants that must be moved • Loading/unloading • Leasing/ownership • Fuel • Labor • Educating truck operators/drivers/supervisors • Preventive activities, including livestock relocations, along the transport route to reduce the possibility of disease spread • Security associated with transport
Storage	<ul style="list-style-type: none"> • Maintaining the carcasses or plants awaiting disposal • Security to keep out wildlife • Odor control • Landscape appearance maintenance

Table 12. Indirect costs associated with disposal activities.

Category	Expense
Disease-related	Added costs of infections spread by: <ul style="list-style-type: none"> • Leakage during transport of carcasses and contaminated plants • Incomplete decontamination • Wildlife incursion into the disposal operation • Disease management activities (such as vaccinations) to reduce the disposal-related costs to the environment and/or because of public perception • Security costs along the transportation routes if the carcasses are to be moved
Environmental	<ul style="list-style-type: none"> • Air pollution • Water pollution • Soil contamination • Loss of future returns to land employed for disposal • Harm to wildlife and/or fisheries
Public perception	<ul style="list-style-type: none"> • Increased legal fees resulting from public opposition • Changes in income because of shifting public opinions resulting from disposal activities, including reduced: <ul style="list-style-type: none"> – Tourism – Regional economic activity – Domestic meat sales – International meat export sales
Income	Loss of business in areas where disposal activities are undertaken or transport routes pass through

Note: Certain disposal methods may have unique indirect costs. For example, alkaline hydrolysis disposal incurs costs resulting from increased commission of support equipment because of alkaline exposure. Some methods may also incur additional indirect costs because of soil disturbances and erosion caused by the operation of heavy machinery and trucks.

Definition and objectives

The thermal method of managing contaminated materials is the destruction of plant or animal materials using high-temperature combustion ignited and burned by auxiliary fuel such as wood or propane.

The objectives of thermal destruction are to convert dead animals or plants into inert gases and sterile ash and to deactivate pathogens. Some thermal methods can deactivate transmissible spongiform encephalopathy viruses, which require exposure to very high temperatures (a minimum of 1,560 °F, or 850 °C; preferred temperature: 1,830 °F, or 1,000 °C) for at least 15 minutes (Brown et al., “Infectivity Studies of Both Ash and Air Emissions from Simulated Incineration of Scrapie-Contaminated Tissues,” *Environmental Science & Technology*, 2004).

Four methods of thermal destruction are used to dispose of infected plants and/or animals:

- **Fixed-facility incineration**, in which materials are burned completely and reduced to ash at an established facility. Usually fueled by diesel, natural gas, or propane, the incineration is wholly contained and usually highly controlled.
- **Air-curtain burning**, in which a fan forces air through a manifold into a metal refractory box or burn pit, where the contaminated materials are burned with wood and diesel fuel. The process increases the temperature and speeds the incineration of the materials.
- **Open-air burning**, in which contaminated materials are burned in open fields

on piles of organic materials without the assistance of incineration equipment. The piles are made of materials such as wood or hay bales.

- **Field burning**, in which contaminated plant materials, such as field crops, are burned over large areas. Because of regulatory statutes, field burning should be considered only under emergency situations and with appropriate regulatory approvals.

To select a feasible method, consider logistics and the type of biomaterials involved (Table 1). The least desirable thermal method for carcasses is open-air burning; it should be avoided, primarily because its combustion is inefficient.

Compared to the fixed-facility incineration and air-curtain burning methods, open-air burning poses greater environmental and safety hazards.

Table 1. Methods considerations for thermal destruction.

Consideration	Fixed-facility incineration	Air-curtain burning	Open-air burning	Field burning
Application	Animals	Animals	Animals/plants	Plants
Transportation concerns	Yes	Yes	Yes	No
Agents inactivated	All	Not suitable for TSE ⁴	Not suitable for TSE ⁴	All field crop diseases
Disposal capacity ¹	Small	Large	Small	Small to large (acreage)
Potential for environmental impact	Low	Medium	High	High
Regulatory restrictions ¹	Low	Medium	High	High
Cost ²	High ³	Medium	Low	Low
Availability of resources	Low	Medium	High	High
Procedure speed	Medium	High	Low	High

¹ Animal carcasses (tons): Small = < 100 tons; Medium = 100–299 tons; High = 300+ tons

² Cost estimate (per ton): Low = < \$200; Medium = \$200–800; High = \$800+ (Cut-off points may vary, depending on factors such as carcass load, affected animals, transportation, disposal facility, and security level.)

³ Fixed-facility incineration could be a low-cost option, given the low disposal load.

⁴ TSE = transmissible spongiform encephalopathy

Fixed-facility incinerator: Description

In fixed-facility incineration, materials are burned completely and reduced to ash at an established facility. The aim of fixed-facility incineration is to completely burn and volatilize carcasses and plants and convert them into inert ash.

A fixed-facility incinerator is equipped with an afterburner that burns the remaining volatile materials exiting the combustion chamber (Fig. 1). It produces ash that is less than 5 percent of the carcass weight (Table 2).

Fixed-facility incineration is the preferred and approved option for destroying carcasses infected with transmissible spongiform encephalopathy. It maintains a combustion temperature of a minimum of 1,560 °F (850 °C) or a preferred temperature of 1,830 °F (1,000 °C) for more than 15 minutes. The resulting

ash is free of pathogens.

Typically fueled by diesel, natural gas, or propane, a controlled fixed-facility incinerator has a more evenly distributed combustion temperature and burns carcasses more effectively and completely than does air-curtain burning.

Many fixed-facility incineration units in the United States have a limited throughput capacity (Table 2) and generally hold small or medium-size carcasses such as poultry carcasses with lower moisture content and swine carcasses with higher fat content. They generally do not hold cattle carcasses with high moisture content (about 70 percent).

Grain commodities that are contaminated with high levels of mycotoxin, such as aflatoxins or fumonisins, may be destroyed by fixed-facility incineration, but cost (for facili-

Figure 1. A fixed-facility incinerator (left) and ash from carcass combustion in a fixed-facility incinerator (right). *(Courtesy of FC Industries, Inc. Kansas City, MO)*



ties, transportation, and labor) is a limiting factor. Landfilling is considered the best prac-

tice for disposing of mycotoxin-contaminated grain.

Air-curtain burning: Description

Air-curtain burning introduces a high volume of airflow through a manifold to accelerate the combustion of carcasses at a higher temperature and in less time than does open-air burning.

An air-curtain burner with a centrifugal fan generates airflows, providing an air curtain across the upper portion of a trench or a refractory box that can withstand high temperatures (Fig. 2).

Air-curtain burning has a higher throughput capacity than does fixed-facility incineration, and it generates less ash than does open-air burning because of its higher combustion temperatures. Thus, this option may be more

suitable for disposing of massive amounts of animal carcasses than is fixed-facility incineration or open-air burning.

A carefully operated air-curtain burner is hotter, cleaner, faster (up to six times), and more efficient (in fuel and labor) than is open-air burning.

An air-curtain burning using a refractory box burns cleaner and produces less carbon monoxide and emissions than does air-curtain burning with trenches.

The carcass-burning capacity of an air-curtain burner will decrease if the trench/pit becomes narrower or wider than the dimensions specified in Table 2.

Table 2. The dimensions, burning throughput capacities, and field requirements of fixed-facility incineration and air-curtain burning systems.

Option	Size	Through-put capacity	Solid fuel/1,000 lb carcass weight ^d	Liquid fuel/1,000 lb carcass weight ^d	CO ^g lb/hr	NMH ^g lb/hr	TSP ^g lb/hr	Nitrogen oxides ^g as NO ₂ lb/hr	SO ₂ ^g lb/hr
Fixed-facility incinerator	Top load opening ^a : 6 x 9 ft	110–500 lb/h ^c	—	60 gal ^e	0.5	0.05	1.8	2.73	2.82
Air-curtain burning	Trench burning ^b : Depth = 8 ft Width = 10–15 ft	4-6 T/h	1,000–2,000 lb	2 gal ^f	N/A ^h	N/A ^h	N/A ^h	N/A ^h	N/A ^h

^a Approximate dimensions of large animal incinerators with a single batch load capacity of more than 5,000 lb (such as the Therm-Tec Model made by FC Industries)

^b Trench length depends on the size needed and the number of animal carcasses to be incinerated.

^c Available capacities in the United States (FC Industries, 2006)

^d Assuming a carcass density of 62.4 lb/ft³, the volume of a 1,000-lb carcass is 16 ft³.

^e Use only virgin fuel (such as propane).

^f Use only for initial ignition of carcasses.

^g CO = carbon monoxide; NMH = non-methane hydrocarbons; TSP = total suspended particulates; and SO₂ = sulfur dioxide. (Obtained from New Jersey Department of Environmental Quality.) The particulate matter emissions from fixed-facility incineration must not exceed 1 lb/h; otherwise, permits from air-quality regulatory agencies are required. To check particulate matter emissions, government-authorized contractors use sensors to measure the stack emission of carcass incineration after the first operation of a newly installed fixed-facility incineration system. These contractors will retest if there are any complaints from neighbors about the emissions of incineration facilities.

^h Not available

Figure 2. An air-curtain burner with a refractory fire box (left) and a trench (right).
(Courtesy of Air-burners, LLC, Palm City, FL)



Open-air burning: Description

In the open-air burning method, carcasses are burned in open fields and on combustible heaps (pyres) of materials without the assistance of incineration equipment. Open-air burning of carcasses occurs on fire beds built with organic materials such as hay bales and wood, which allow for sufficient air to enter underneath the bed (Fig. 3).

This thermal destruction method is the option of last resort, as it has significant regulatory limits, high environmental impacts, and very low public acceptance. It is also inappropriate for massive carcass disposal and should be performed only in emergencies when there

are no other options.

Open-air burning is subject to State and local regulatory approvals.

When winds are calm, most of the carcasses will burn within 48 hours. Compared to fixed-facility incineration or air-curtain burning operations, open-air burning yields more airborne ash emissions. Open-air burning requires much more fuel than does air-curtain burning and therefore will yield more ash from the burned coals, timber, and straw.

Because of fire and safety hazards, do not conduct open-air burning of carcasses during windy conditions.

Figure 3. Open-air burning of carcasses placed on a pit/trench
(Courtesy of Scudamore et al., 2002)



Field burning: Description

Field burning can be used to destroy contaminated plant materials that are covering large areas, such as annual field crops.

Because of regulatory statutes such as the Clean Air Act and state burn bans, field burning should be considered only under emergency situations and with appropriate regulatory approvals.

Also, consider the possibility of spread-

ing airborne pathogens during a field-burning (flaming) procedure. For instance, fungal pathogens, which can be easily dispersed by air currents or winds, may actually spread farther during the burning process.

In emergency situations, thermal destruction methods can be used on site for plants contaminated with bacterial and viral diseases if the regulatory issues have been resolved.

Coordination and jurisdictional considerations

The decision on the location of the burning activity should be made jointly by the members of the incident command structure established by local and State authorities.

Local authorities should have an inter-county memorandum of understanding in place so that carcass overflow may be easily

transported to nearby counties for burning.

Conduct burning only with explicit approval by the institutions and agencies competent to make decisions about protecting the integrity of the environment.

Open-air burning is subject to local and State regulatory approvals.

Pollution and other property damage considerations

Although governmental entities are accorded wide discretion in making decisions about burning carcasses to protect public health, they are subject to nuisance actions if the proper precautions are not taken.

The smoke and chemicals that result from open-pit burning could trigger nuisance or other kinds of lawsuits. Sovereign immunity—the doc-

trine that the government is immune from civil or criminal lawsuits—may not be a defense.

As lawsuits could be prompted by injury to people or damage to property because of environmental pollution, the decision on the disposal of ash waste must be made jointly by the appropriate technical group within incident command structure.

Planning considerations

For all thermal options, consult with the appropriate state regulatory agencies for air-quality and solid-waste disposal on potential sites before temporary carcass storage or ash disposal.

Inform the local authorities, including firefighting officials, about the planned thermal destruction. Secure ample fire retardant, equipment, personnel, and gear. Provide the appropriate cleaning, disinfection, and personal protective gear.

Coordinate with the local utility company to provide electricity (for example, drop service from power lines for different electrical equipment), and secure batteries and generators for remote sites.

Participate in real-life thermal destruction exercises of carcass disposal. For example,

contact the fixed-facility incineration operating units and air-curtain burning manufacturers or contractors to prepare for an animal catastrophic event (Table 3).

Enough trained personnel must be provided for continual operation and maintenance (24 hours a day), as well as ample drinking water, housing, and meals for workers. Training should include logistical expertise, leadership, and managerial skills, and health and safety precautions needed for thermal destruction of carcass and plant residues.

Equipment and spare parts must be available for:

- The excavation of trenches/pits in air-curtain burning and open-air burning systems
- Carcass loading and unloading

- Ash disposal
- Firefighting
- Cleaning and disinfection
- Emergency communication systems

To enhance the safety of workers in and around the equipment, consider providing mechanical loading platforms, conveyors, and other equipment. Also consider the predominant wind directions when choosing sites for control rooms and worker rest areas.

Table 3 lists information on some of the manufacturers, operators, and contractors of fixed-facility incineration and air-curtain burning systems.

Make a spill response plan, and provide for equipment and secondary containment for on-site fuel storage.

Flashers or signs attached to fences and barriers will be needed to alert approaching travelers of the impending traffic-control points.

Consider important issues related to handling, storage, and conveyance of carcasses to the incineration or burning site as described in the “General Considerations” chapter of this guide.

For large numbers of animal carcasses (those with a cumulative weight of more than 1 million pounds), conduct the thermal destruction operations at a distance of 2 miles (3 kilometers) from residential buildings, roads, and utilities (wires/lines). Air-curtain burning and open-air burning operations should also be conducted 2 miles from public, religious, historical, and archaeological areas.

If possible, consider establishing the same distance from crop fields and wildlife. This will protect the public from smoke inhalation and excessive heat and prevent fire damage to property, plants, and wildlife.

Table 3. Contractors and operating companies for fixed-facility incineration and air-curtain burning systems.

Company	Nature and capacity of work	Contact information
FC Industries	Manufacturer of fixed-facility incinerators, up to 500 lb/hr per unit	13508 Oak Street Kansas City, MO 64145 <i>fcindustries@cysource.com</i>
Shenandoah Manufacturing Co., Inc.	Manufacturer of fixed-facility incinerators, less than 100 lb/hr per unit	919 Cottontail Trail Crawford, VA 22841 <i>www.firelakemfg.com</i>
Air Burners LLC	Manufacturer of air-curtain burners, up to 4 t/hr per unit	4390 Cargo Way Palm City, FL 34990
McPherson Systems	Manufacturer of air-curtain burners, less than 4 t/hr	100 Springhill Church Road Tifton, GA 31794 <i>www.mcphersys.com</i>
Crowder Excavating, Inc.	Contractor of air-curtain burners, up to 10 t/hr	901 Geddie Road Tallahassee, FL 32304
Phillips and Jordan, Inc.	Contractor of air-curtain burners, up to 10 t/hr	P.O. Drawer 604, 191 P&J Road Robbinsville, NC 28771 <i>www.pandj.com</i>

This is not an exhaustive list. No endorsement of companies or individuals or their services mentioned is intended, nor is criticism of similar companies implied.

Do not:

- Burn carcasses with explosive materials, especially gasoline in fixed-facility incineration, air-curtain burning, and open-air burning operations. The recommended accelerants include propane, waste oil, furnace oil, and diesel fuel.
- Burn carcasses with tires, rubber, plastics, or similar materials because the resulting emissions contain significant amounts of pollutants of concern that could affect human health and the environment.
- Allow personnel to approach the carcass-burning site from downwind without proper personal protective equipment.

Make arrangements for the disposal of ash obtained from permitted fixed-facility

incineration plants for thermal destruction of TSE-infected carcasses in licensed landfills (approved by the U.S. Environmental Protection Agency, 2004).

The ash of non-infected carcasses (obtained from fixed-facility incineration, air-curtain burning, and open-air burning options) can be applied to agricultural lands.

If ash is land-applied, allow an area of $\frac{1}{2}$ acre per:

- 60,000 broilers
- 30,000 layers
- 100 adult hogs (average weight of 375 pounds)
- 75 large or heavy cattle (average weight of 500 pounds)

Plan to restore the thermal destruction site to its original condition.

Planning for fixed-facility incineration

Obtain the required licenses from the state government or regulatory agencies to build and operate a fixed-facility incineration system. For example, in New Jersey, the Department of Environmental Protection issues permits for preconstruction and the certificate of operation for fixed-facility incineration systems. In Texas, regulations that control particulate emissions and air quality of incinerators used on poultry farms must meet the

specifications of the Texas Commission on Environmental Quality.

Animal carcasses must be fed through a door into the refractory bottom of the main incineration chamber. If the fixed-facility incineration's average capacity becomes overburdened, the carcasses must be stored in a refrigerated room, transport vehicle, or freezer.

Planning for air-curtain burning

Assess the availability, location, and costs related to air-curtain burning. Although air-curtain burning units are mobile, the location of a disaster may limit availability or access.

Plan to provide an electrical generator (including diesel fuel) and lighting equipment to illuminate the thermal destruction site and identify “authorized personnel only” work areas.

Planning for open-air burning

A fire bed will need to be built perpendicular to the prevailing wind to minimize the amount of sparks, soot, and objectionable odors blowing toward buildings or across public roads.

Plan to use mechanical chains and lifting equipment (such as front-end loaders) to accomplish all the loading, spreading, and handling of solid fuels and carcasses.

Considering one adult bovine carcass to be equal to five finishing pigs or five adult sheep, the amount of solid and liquid fuels needed for each bovine carcass (average weight of 1,000 pounds) is:

- Three bales of straw or hay
- Three pieces of untreated heavy lum-

ber (about 8 feet long by 1 square foot in cross section). Railroad ties, bridge lumber, and smaller wood such as fence or cordwood are useful too.

- 50 pounds of kindling wood. Sources include wrecking companies, farm woodpiles, and sawmill slab piles.
- 100 pounds of coal pieces, with 6 to 8 inches in diameter
- 1 gallon of liquid fuel such as waste oil, furnace oil, or diesel fuel. Do not use gasoline as a fuel for carcass burning. Be careful when using flammable and hazardous liquid fuel.

Plan to restore the open-burning site to its original condition.

Planning for field burning

Field burning is considered an economical method for disposing of contaminated plant materials unless fuel costs rise too high.

Perennial field crops such as fruit trees and lumber may be destroyed on-site if the proper open-air burning procedures are followed. Address site-safety and air-quality issues before beginning destruction procedures.

One caution with these burning methods is to avoid lumbars that are treated with chemicals such as chromated copper arsenate. These lumbars are typically treated as special waste and must be disposed in accordance with local

and State regulations. In general, the lumbars can be buried at approved landfills but cannot be incinerated as are other plant materials.

Nursery greenhouse plant materials may be burned at designated burning locations. However, if a fixed facility is used, the cost of harvesting and transporting the crop materials should be considered.

For some crop pathogens, field burning may have undesirable effects and increase the severity of the disease. Consult with a plant disease specialist before conducting a field-burning operation.

Procedure for fixed-facility incineration

Feed the animal carcasses through a manually or hydraulically activated door into the refractory bottom of the main incineration chamber. If the fixed-facility incinerator's average capacity becomes overburdened, store the carcasses in a refrigerated room, transport vehicle, or freezer.

Preset the burning time and temperature manually or automatically (using programmable digital controls).

Adjust the pressure of the air blowers to create turbulence and to distribute the combustion air to the afterburner (secondary chamber) to reach and maintain temperatures at a minimum of 1,560 °F (or 850 °C), or a preferred temperature above 1,830 °F (about

1,000 °C). Monitor the temperature using a digital temperature sensor.

The amount of combustion time required depends on the carcass load for each batch and the capacity of the fixed-facility incineration system. For example, it may take 10 hours to incinerate 5,000 pounds of carcasses in a fixed-facility incineration unit with a throughput of 500 pounds per hour.

Reload the system with carcasses after combustion of the first batch is completed.

After all the carcasses have been incinerated, shut off the combustion system and allow it to cool down for 10 hours to enable the ash to be removed and handled safely.

Procedure for air-curtain burning

Locate the air-curtain burning unit in an area that is easily accessible to heavy vehicles hauling carcasses, and equipment.

Consult with the USDA Natural Resources Conservation Service and evaluate the site for the depth to the water table and proper soil conditions.

Build the trenches according to the dimensions in Table 2. This approach accommodates more carcasses than does burning in refractory boxes because the ash can be buried in the trenches after the carcass combustion is completed.

Refractory boxes should be used on sites with a high water table (less than 2 feet from the bottom of a planned trench) or on rocky soil and where trenches would be difficult or costly to build.

Monitor the wind direction before and during the burning operations, and keep the workers out of the path of the flame.

Use solid fuels such as straw, hay, coal, kindling wood, and untreated lumber.

For proper combustion, provide an appropriate solid fuel-to-carcass weight ratio ranging from 1:1 to 2:1. The fuel-to-carcass ratio is determined by the moisture in the wood or other organic sources (such as hay, grain stalks, and straw) and the fat and moisture content of the carcasses. For example, the finished hogs have more fat and less water than do steer carcasses.

To reduce air pollution, handle the ash in the refractory boxes carefully and dispose of it at a burial or land application site that has been approved by the appropriate regulatory agency.

Procedure for open-air burning

Stake out and fence the selected burning site for the fire-bed construction.

Allow a fire-bed length of 3 feet for each adult cattle carcass, five swine carcasses, or five sheep carcasses.

Lay three rectangular rows of straw or hay bales lengthwise along the line of the fire bed (Fig. 4). These rows should be 12 inches apart; each bale should be separated by a 12-inch gap within the row.

Fill the spaces between the rows and bales with loose straw to provide natural air flow.

Place large pieces of lumber lengthwise on top of each row. Distribute the large and medium-sized pieces of lumber across the fire bed, leaving 6 to 12 inches of space between them. Place small kindling wood on the fire bed, and cover it with loose straw.

Spread 6- to 8-inch-diameter coal evenly at the rate of 500 pounds per square yard, or other liquid fuel such as diesel or furnace oil, over the wood mixture to make a level bed.

Lay the carcasses on the fire bed, positioned on their backs with their feet in the air and alternately head to tail. Place the carcasses of goats, sheep, or swine on top of the bovine carcasses and burn them without additional fuel at the rate of two animals per bovine carcass. Place loose straw over the carcasses and fill all the spaces between the carcasses.

Spray the liquid fuel over the fire bed with a pump, or use sprinkling cans or buckets. Soak rags or similar materials in kerosene oil or waste oil, and place them every 30 feet along the fire bed for a better and more harmonized ignition.

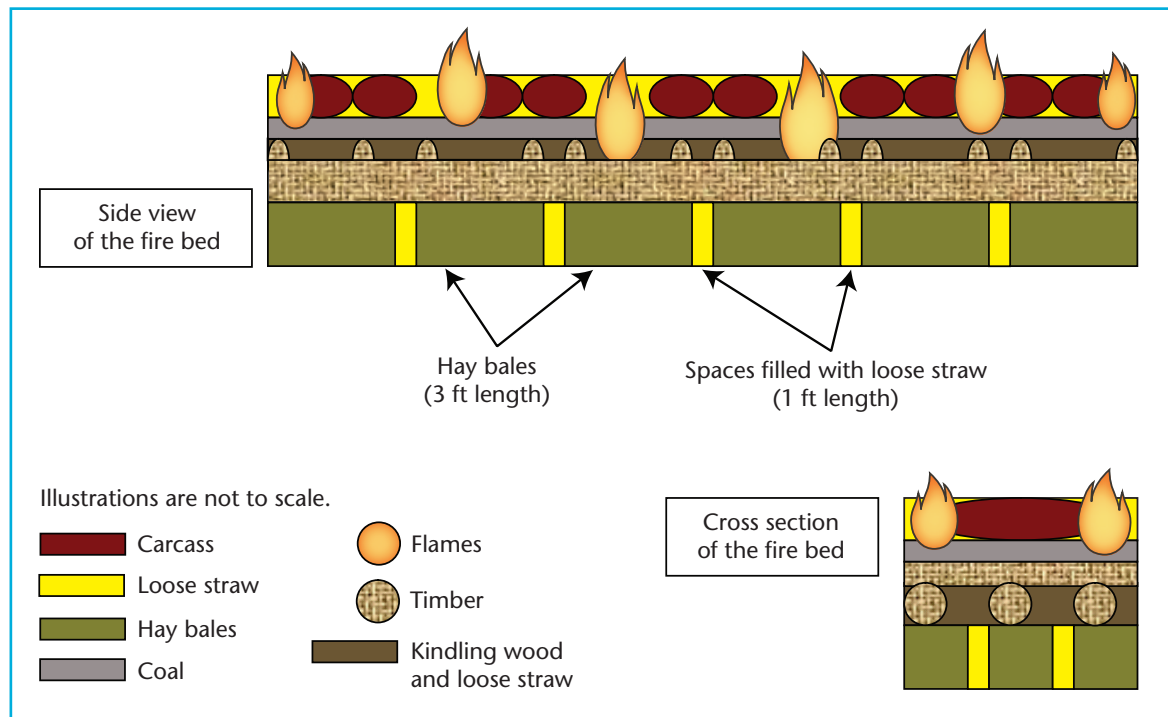
Before igniting the fire bed, make sure that all people, equipment, and supplies are at least 25 feet from the burning pile. Have fire-fighting equipment ready in case the equipment, buildings, or grass ignites.

Use front-end loaders to stir the burning pile occasionally. Quickly replace any carcass

pieces that drop off the pile, and add more fuel if needed. Be careful! Do not douse open flames with flammable liquids.

Bury the ash after all the carcasses have been burned completely and the fire has been extinguished thoroughly.

Figure 4. Side view and cross section of carcass open-air burning setup.



Procedure for field burning

Check with the local authorities on the health, safety, and environmental restrictions for field burning. Field burning is recommended only for emergencies.

Before igniting the fire, verify that the crops (or crop residues) are dry. Annual field crop residues may need 3 to 10 days of drying time. For drying perennial field crops, 3 weeks (for small branches) to 6 weeks (for large branches and stumps) is recommended.

Consult with local authorities on safety measures and specific burn hours (if any). Ensure that the burning activities are supervised and that the burning area has been fire-guarded adequately.

Propane- or oil-fueled flamers, which do not produce black smoke, can be used to

ignite and destroy contaminated plant materials. Plant materials are a solid fuel containing varying amounts of minerals and moisture.

Light a test fire. Observe whether the dried plant materials burn, and note the direction of the smoke. Terminate the operation if the plant materials are too damp or if the smoke is blowing toward populated areas.

If possible for the full-scale fire, light the fire on the downwind side of the field—it will burn more slowly but more thoroughly.

For tree branches and stumps, stack the starter pile tightly, but make sure there is enough air circulation. Ignite the fire with a propane torch or other commercial lighting device. When the starter pile is fully engulfed, continue adding dried plant materials.

Table 4. Personal protective equipment guidelines for thermal destruction operations.

Nature of work	Mask/respirator ^{a, b, c}		Protective clothing ^a	Eye/hearing protection ^{a, c}	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Fixed-facility incineration workers directly handling contaminated material	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Liquid-impermeable suit or overgarment (such as an apron)	Same as for open-air burning	Same as for open-air burning	Same as for open-air burning
Air-curtain burning workers directly handling contaminated material	Same as for fixed-facility incineration	Same as for fixed-facility incineration	Liquid-impermeable suit or overgarment (such as an apron)	Same as for open-air burning	Same as for open-air burning	Same as for open-air burning

(Continued on next page)

Table 4. (Continued)

Nature of work	Mask/respirator ^{a, b, c}		Protective clothing ^a	Eye/hearing protection ^{a, c}	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Open-air burning	Disposable particulate respirator (N95, N99, or N100); half or full facepiece (for description, see Safety section of this guide)	None recommended unless nuisance dusts/ash impede work	Impermeable to liquids; consider fire-retardant overgarment for those working around open flame; select based on heat situation	Eyes: Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles Hearing: Consider disposable earplugs if necessary	Gloves: Heavy-duty (15–18 mil) chemical resistant gloves that can be disinfected or disposed of; consider 10–12 mil nitrile gloves worn under leather gloves, depending on task	Feet: For workers handling carcasses, steel toe/steel shank waterproof boots; for others, steel-toed work shoes or boots Head: Hard hat

^a See www.safetyequipment.org for a list of vendors from OSHA

^b For information on a full respiratory protection program, see www.osha.gov/SLTC/respiratoryprotection/index

^c Regulations governing use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the Safety section of this guide.

Diseases of concern

Viruses and non-spore-forming bacteria: Viruses and non-spore-forming bacteria are temperature susceptible. However, some viruses such as foot-and-mouth disease (FMD) are easily spread by piggybacking in the respiratory tract of humans. Take precautions to prevent inhalation of these airborne pathogens. Use appropriate personal protective equipment.

Although open-air burning and air-curtain burning are suitable for destroying viruses and non-spore-forming bacteria, the best method for controlling the spread of disease is fixed-facility incineration.

The diseases for which thermal methods are appropriate include African swine fever, highly pathogenic avian influenza, contagious bovine pleuropneumonia, brucellosis

(*B. melitensis*, *B. abortus*, and *B. suis*), FMD, glanders, Japanese encephalitis, Q fever, Rift Valley fever, rinderpest, classical swine fever, tularemia, and vesicular stomatitis.

Spore-forming bacteria: Although spore-forming bacteria are temperature susceptible, they must be incinerated thoroughly. If not destroyed, they will persist in the environment for long periods.

If it is not possible to incinerate the carcasses immediately, the carcasses must remain intact to prevent the spread of spores into the environment.

Fixed-facility incineration is the best method for destroying carcasses contaminated with a spore-forming bacteria.

Diseases of concern include anthrax.

Prions: Because prions are temperature

resistant, destroying them requires that they be exposed to extremely high temperatures (minimum of 1,560 °F, or 850 °C, or a preferred temperature of about 1,830 °F, or 1,000 °C) for at least 15 minutes. Lower temperatures will generate ash, but the prions will persist in the ash until the process exceeds 800 °C. If not inactivated by heat, the prions may persist in ash or soil for a considerable period.

The best thermal method for destruction of prion-infected animal carcasses is fixed-facility burning. Open-air burning and air-cur-

tain burning may not provide the temperatures required to destroy these diseases.

Although the ash from burning carcasses, particularly those infected with conventional microorganisms, may be suitable for later uses such as land application, its use may be precluded by public opposition to the use of ash from carcasses infected with some pathogens, particularly transmissible spongiform encephalopathy.

Diseases include bovine spongiform encephalopathy, chronic wasting disease, and scrapie.

Site safety

Heat stress is a major consideration during hazardous waste disposal operations and an even greater consideration when using thermal destruction methods. See the heat exposure guidelines in the “General Considerations” chapter of this guide.

Set the work schedule according to worker needs. A worker with a core temperature of 100.4 °F is considered at a heat stress level. To prevent dehydration, allow the workers to drink water at liberty.

The U.S. Occupational Safety and Health

Administration suggests establishing:

- A training program informing employees about heat stress
- A screening program to identify worker health conditions before beginning any burning
- Procedural programs guiding the workers in case of a heat-related emergency

Because all of these thermal methods pose significant fire hazards, workers must wear appropriate personal protective equipment while inside the perimeter (Table 4).

Avoid inhaling the toxic smoke constituents from petroleum and coal as much as possible, and do not allow it to contact the skin.

Monitor the wind direction and speed, and

be prepared to move unprotected personnel.

For protection while moving and burning carcasses during fixed-facility incineration, air-curtain burning, and open-air burning operations, workers should wear half- or full-facepiece air-purifying respirators with appropriate filter cartridges. Chemical protective clothing is especially important during movement of carcasses.

During the actual burning process, workers should wear clothes suitable for high-heat situations, including flame-retardant coats, pants, steel-toe rubber boots, gloves, and helmets with facepieces. Although it is more controlled than is open-air burning, fixed-facility incineration does pose a fire hazard.

Best practices and guidelines for biosecurity are found in the Safety and Biosecurity section of the “General Considerations” chapter of this guide.

Decontaminating heat-resistant clothing is difficult. As such, firefighter “turnout” gear should not be used by personnel directly handling contaminated material unless such

clothing is expendable (that is, it can be destroyed and will not be reused) or can be used multiple times onsite before final destruction.

In many jurisdictions, the ash could be considered contaminated material and be subject to various regulations. Consult with State agriculture and environmental regulatory agencies before disposing of ash by burial.

Groundwater and soil pollution

After the thermal destruction of diseased carcasses, most of the waste produced will be in the form of ash. If the destruction methods are conducted thoroughly and as described in this guide, the resultant ash would be considered safe for burial or further use.

Carcasses affected by transmissible spongiform encephalopathy that are not burned for at least 15 minutes at about a minimum of 1,560 °F (850 °C) or a preferred temperature of 1,830 °F (1,000 °C) may continue to pose a potential health risk to people, animals, and the environment. Even if the carcasses are burned thoroughly, public concern may be great enough that the ash should be disposed of as contaminated waste and not

composted or buried at unregulated sites.

Toxicants such as dioxins, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs) are often generated as byproducts of burning pyres and fuel. These toxicants can threaten the soil and groundwater. Even relatively low concentrations of these materials left in the soil may result in some States requiring further cleanup of the burn site.

These risks are heightened mainly by open-air burning techniques in pits. In the past, measures were taken to ensure that as little contamination as possible seeped into the soil. These precautions have kept the soil and groundwater chemical levels at a minimum.

Air pollution

Fixed-facility incineration should be the first choice during an outbreak and at the end when the small number of carcasses makes the other methods uneconomical or otherwise unsuitable. Fixed-facility incineration significantly reduces the amount of air pollution in a small area. Most hydrocarbons and other airborne toxicants are reduced by this method.

Like fixed-facility incineration, air-curtain burning produces smaller plumes of smoke than do the other thermal methods. Compared to open-air burning, air-curtain burning has

higher combustion efficiencies and produces less carbon monoxide.

Of the thermal methods in this guide, the one generating the most air pollution is open-air burning. Volatile chemicals and particulate matter in the form of smoke are released into the air when burning fuel, wood, coal, and animal and plant materials. In quantities generated by open-air burning, these chemicals may present a health hazard to personnel not wearing appropriate respirators (Table 4) near the open pit.

Additional information: Waste produced

All of these burning methods produce significant amounts of benign ash waste. This ash may be used as fertilizer because it does not usually attract pests if it is burned thoroughly. As noted, carcass materials containing

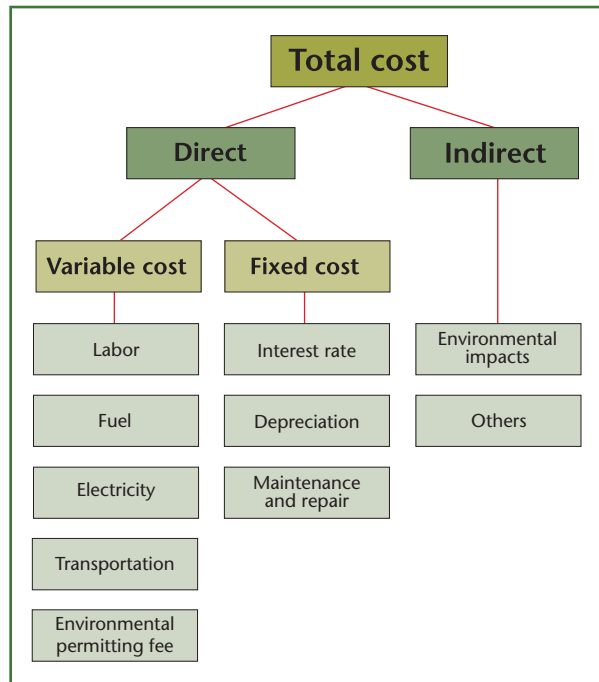
residues potentially contaminated with transmissible spongiform encephalopathy should be disposed of as contaminated waste according to State regulations.

Thermal destruction costs

The cost components relating to thermal destruction follow the general specifications in the overall direct/indirect economic cost section. Figure 5 demonstrates the main cost components.

For specific indirect cost items, see the “General Considerations” chapter of this guide.

Figure 5. Components of direct and indirect costs of thermal destruction methods.



Direct costs

The direct fixed cost depends on facility type (with or without afterburner) and capacity. Table 5 shows the initial investment and the corresponding direct annual fixed cost estimates of thermal destruction with an annual capacity of 40,000 pounds.

Tables 6 and 7 list the direct variable costs per carcass and per ton for various animals. Table 8 shows the cost of an air-burning proj-

ect for 91,600 pounds of swine.

The fixed-facility incineration, air-curtain burning and open-air burning methods are not cost efficient for disposal of contaminated plants, mainly because of transportation costs.

Costs for field burning of plants are for a small amount of fuel to start the fire and for labor to start and control the fire.

Table 5. Initial investments for incineration with and without an afterburner of an annual capacity of 40,000 pounds.

With afterburner	Investment (\$)	Depreciation^a (\$)	Maintenance and repair (3%)	Interest (6%)	Annual cost (\$)
Incineration (500 lb/cycle)	3,000.00	300.00	90.00	180.00	570.00
Shed and base slab	642.00	64.20	19.26	38.52	121.98
Afterburner	1,000.00	100.00	30.00	60.00	190.00
Total	4,642.00	464.20	139.26	278.52	881.98

Without afterburner	Investment (\$)	Depreciation (\$)	Maintenance and repair (3.0%)	Interest (6%)	Annual Cost (\$)
Incineration (500 lb/cycle)	3,000.00	300.00	90.00	180.00	570.00
Shed and base slab	642.00	64.20	19.26	38.52	121.98
Total	3,642.00	364.20	109.26	218.52	691.98

^a The life expectancy of the investment is assumed to be 10 years.

Table 6. Estimates of direct variable costs per carcass of thermal destruction.

Consideration	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
Labor (\$10/hr)	\$11.36	\$4.03	\$2.02	\$0.09	\$1.17
Fuel ^a (\$2.40/gal)	\$31.15	\$11.05	\$5.52	\$0.25	\$3.20
Electricity (\$0.0024/lb)	\$1.80	\$0.64	\$0.32	\$0.01	\$0.18
Environmental permitting fee	n/a	n/a	n/a	n/a	n/a
Transportation	n/a	n/a	n/a	n/a	n/a
Average cost per carcass	\$44.31	\$15.72	\$7.86	\$0.35	\$4.55

Source: <http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=193>

^a Both propane and diesel can be used as fuel. Diesel (propane) needs 1.35 gal (1 gal) per hour and each gallon will burn 78 lb (31 lb) of carcasses.

Table 7. Estimates of direct variable costs per ton of thermal destruction for cattle, calves, weaned hogs, preweaned hogs, and others (sheep, lambs, and goats) when the manager has thermal disposal facilities.

Consideration	Cost
Labor (\$10/hr)	\$30.30
Fuel ^a (\$2.40/gal)	\$83.08
Electricity (\$0.0024/lb)	\$4.80
Environmental permitting fee	N/A ^b
Transportation	N/A ^b
Average cost per ton	\$118.18

Source: <http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=193>

^aBoth propane and diesel can be used as fuel. Diesel (propane) needs 1.35 gal (1 gal) per hour and each gallon will burn 78 lb (31 lb) of carcasses.

^bN/A = not applicable

Table 8. Costs of an air-curtain burning project based on 91,600 pounds of swine carcasses if the thermal disposal facility is rented. (*Courtesy of the National Agricultural Biosecurity Center Consortium for Carcass Disposal Working Group*)

Consideration	Cost
Site and equipment preparation	\$1,700
Site rental (by contract)	650
Air-curtain incinerator	7,500
Diesel fuel ¹	300
Protective clothing	2,400
Lumber and plywood	135
Firewood and delivery	3,960
Truck rental	250
Animal transportation	4,640
Modification of chute/knock box	1,285
Miscellaneous supplies	225
Total costs	\$23,045
Cost per ton	\$503

¹The fuel prices dramatically increase and, thus, this cost component needs to be considered.

Figure 6. Formulas to estimate the direct variable cost relating to thermal destruction.

If the hourly labor, fuel price and electricity prices are \$10/hr, \$2.4/gallon, and \$0.0024/lb of animal carcasses, the formulas to estimate the **direct variable cost (DVC)** are

- **By carcass:**

$$DVC = 44.31Q_{\text{cattle}} + 15.72Q_{\text{calves}} + 7.86Q_{\text{weaned hogs}} + 0.35Q_{\text{preweaned hogs}} + 4.55Q_{\text{others}}$$

Where Q_i is the total mortality of animal category i .

- **By weight:**

$$DVC = 118.18 (W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

(Figure continued on next page)

Figure 6. (Continued)

If the hourly labor cost, fuel price and electricity price, are C_L , C_F and C_E rather than \$10/hr, \$2.4 gallon and \$0.0024/lb, formulas to estimate the **direct variable cost (DVC)** are

- **By carcass:**

$$DVC = (1.1C_L + 13.0C_F + 750.0C_E)Q_{\text{cattle}} + (0.4C_L + 4.6C_F + 266.0C_E)Q_{\text{calves}} + (0.2C_L + 2.3C_F + 133.0C_E)Q_{\text{weaned hogs}} + (0.01C_L + 0.1C_F + 6.0C_E)Q_{\text{preweaned hogs}} + (0.1C_L + 1.3C_F + 77.0C_E)Q_{\text{others}}$$

Where Q_i is the total mortality of animal category i .

- **By weight:**

$$TVC = (3.0C_L + 34.6C_F + 200.0C_E)(W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

Besides labor, fuel, and electricity costs, direct variable disposal costs include trans-

portation cost, which depends mainly on the distance that the carcasses are moved.

Definition and objectives

Burial methods are disposal practices in which plants and dead animals (contaminated biomaterials) are placed in earth-filled trenches or pits. These contaminated biomaterials are disposed of in a properly selected, enclosed environment and may be mixed with soil and solid waste in landfills.

In handling contaminated animals and plants, the objectives of burial methods are to:

- Provide the conditions that impede the growth and spread of pathogens from the contaminated materials and limit access to them by vermin
- Convert the contaminated materials into inert compounds (mainly minerals)

- Control nuisance odors
- Dispose of and degrade the materials so that they neither pose a health hazard nor pollute the air, water, leachate, or soil

Burial and landfilling can be used only where allowed by permits and the depths of the soil and water table.

Large amounts of contaminated materials can be disposed of by trench burial (animals), landfilling (animals and plants), mass burial (animals), and field burial (plants). To select a feasible method, consider the classification of the contaminated materials and the logistics—cost, location, facilities, and environmental impact—for handling them (Table 1).

Table 1. Methods considerations for the burial of contaminated plants and animals.

Consideration	Trench burial	Landfilling	Mass burial	Field burial
Application	Animals	Animal/plants	Animals	Plants
Transportation concerns	No	Yes	Yes	No
Pathogens inactivated	Viruses and non-spore-forming bacteria	Viruses and non-spore-forming bacteria	Viruses and non-spore-forming bacteria	All field crop diseases
Disposal capacity ¹	Small to large	Small to medium	Small to medium	Small to large (acreage)
Potential for environmental impact	High	Medium	Medium	Low
Regulatory restrictions ²	Medium	High	High	Low
Cost ³	Low	Medium	High	Low
Availability of resources	High	Medium	Low	High
Procedure speed	High	Medium	Low	High

¹ Animal mortality (tons): Low = < 100 t; Medium = 100–300 t; High = > 300 t

² The stringency of restrictions imposed by federal, state and local agencies

³ Cost estimate (per ton): Low = < \$200; Medium = \$200–800; High = > \$800

(Cutoff points may vary, depending on such factors as transportation, carcass load, animals affected, disposal facility, and level of security.)

Trench burial

In the trench burial method, animal carcasses are placed in unlined trenches or pits that are then backfilled with excavated soil. The soil absorbs the leachate and microorganisms and minimizes feeding by scavengers.

Trench burial provides a confined soil environment for absorbing carcass fluids and preventing heat loss, thus speeding up the anaerobic degradation process at low moisture content.

This method offers several advantages:

- It is logistically simple and relatively easier than are the other burial options.
- The equipment needed for this disposal method is widely available at farms and feed yards.
- Burying the animals on site eliminates the need for transporting potentially

infectious materials to landfills or mass burial sites.

However, this method encourages vermin and increases the potential for groundwater contamination. Also, routine poultry carcasses are usually not permitted to be buried on site. Some States, such as Texas, permit the on-site burial of poultry carcasses in emergencies when the mortality rate exceeds 0.3 percent of the total on-farm inventory per day.

Although the trench burial method needs much less area than does mass burial, a limiting factor is the availability of sites with the appropriate soil and hydrologic properties.

From an environmental perspective, trench burial is the least preferred burial option for carcass disposal because the trench walls and bottom are not lined with an imper-

meable barrier, as is required for mass burial and landfilling.

The decomposition time for buried carcasses depends on the species, carcass size, and soil properties (texture, temperature, moisture and chemical composition).

Another disadvantage of trench burial is that although the carcass body fluid will drain within about 2 months, it can take a long time to release much of the pollutant load from the carcass material. Buried carcasses may continue

to produce both leachate and gas for as long as 20 years; they may harbor spore-forming bacteria such as *Bacillus anthracis* for 200 years, as has been seen from old, infected graves.

Despite the heat generated from the buried carcasses, many bacteria may survive, especially when they are buried in cold climates or during cold seasons. Summer is a more suitable time in which to bury dead animals because they decompose faster then and the soil is easier to excavate.

Landfilling: Description

Landfilling is an excellent option for disposing of carcasses if the farm operation or organizations supporting the incident response have access to vehicles large enough and suitable for transporting the carcasses quickly and biosecurely.

The aim of landfilling is to deposit the

dead animals in an engineered, sealed containment area between layers of compacted solid waste and impermeable lining materials. The carcasses are taken to a Type I landfill, a modern facility permitted to accept municipal solid waste, contaminated soil, and dead animals.

The leachate from the contaminated carcasses is collected and sprayed and recirculated on the surface of the landfill area.

Of the landfill area designated for carcass disposal, only 30 percent is used for the actual burial of carcasses. The remaining acreage is required for runoff and leachate collection, drop-off stations, a buffer area, and sites from which cover soil can be obtained or “borrowed.”

The base and walls of modern landfills are built with 2 to 3 feet (0.6 to 0.9 meter) of compacted impermeable soil. The soil’s hydraulic conductivity must be less than 0.00034 inch per day. The landfill base and walls are lined with a thick, flexible membrane that is at least 30 mils (0.76 millimeter) thick. Lining made of high-density polyethylene must be 60 mils (1.52 millimeters) thick.

Although adding this lining increases the cost of disposal, it reduces the risk of expo-

sure to the environment and reduces future liabilities.

For modern landfilling sites, the amount of setup time for carcass disposal is minimal if the disposal arrangements are made in advance. However, the carcasses may take longer to degrade at a landfill than in a trench burial site because the co-fill materials in landfills are less homogenous than the soil in trenches, and they absorb moisture inconsistently.

In addition to the inconsistent moisture contents, landfills have widely varying temperatures, which can also slow the biochemical reactions in the carcasses. These reactions may generate landfill gases, including methane and carbon dioxide as well as trace amounts of hydrogen, hydrogen sulfide, and carbon monoxide. If the landfill operations are conducted improperly, these noxious gases

may be released to the air, and leachate and gases may migrate to the soil and water.

Another drawback is that the temperatures in landfills do not reach high enough to inactivate heat-resistant organisms and spore-forming bacteria. Also, modern landfills are not available in every state.

Some landfill sites are owned by municipalities; others are privately owned. Those owned by municipalities may not have enough capacity for additional waste such as carcasses. All owners may face political consequences of accepting the carcasses. Some

landfills may not accept carcass materials because of local opposition or fear of disease transmission.

Long-term requirements and costs for this method include the maintenance of the landfill's lined surface (cap) to control pollution and prevent settling.

The standard operating procedure for landfilling animals can be used for disposing of plant materials. Because of the nature of plant pathogens, those planning plant disposal operations should focus more on costs and logistics issues than on biosafety.

Mass burial

Mass burial is used when large numbers of animal carcasses are collected from multiple disaster locations and buried at remote designated sites that have pre-engineered and constructed pits.

Mass burial is appropriate if no licensed landfill in the disaster area accepts carcasses. Generally, the inputs and resources needed for mass burial sites are in many ways similar to those of landfilling.

Mass burial is an engineered technology that requires lead time for proper design and construction as well as prior regulatory approvals. The pits for mass burial are built with sophisticated liners and proper drainage to collect the carcass leachate and to minimize the risk of contaminating the groundwater. Although this lined design may make the option more costly, it greatly minimizes the risk of future liabilities and harm to the environment.

Mass burial may be necessary at the height of a large outbreak such as during the United Kingdom's incidence of foot-and-mouth disease, when the number of diseased, at-risk, or humanely slaughtered animals overwhelmed other disposal methods.

In emergency situations, the mass burial of carcasses is done in shallow (about 3 feet [0.9 meter] deep) trenches. Therefore, mass burial requires more land area than does trench burial. Preconstructed mass burial sites can reach to 10 feet (about 3 meters) deep.

Because the lined walls and bottoms of mass burial pits are sealed, the carcass leachate is not absorbed. Therefore, the leachate collection system must be engineered properly, with the leachate being conveyed to a treatment facility.

Mass burial pits should be located on ground that is level or gently sloping (less than 5 percent).

Field burial

Field burial is suitable for disposing of contaminated plant materials, particularly annual field crops. Generally termed *tillage* or *cultivation* in field crop production, field burial is used to remove established vegetation and to prepare the soil for planting a new crop.

The goal of this method of disposal is to bury contaminated plant materials under the soil surface, thus sequestering the pathogens and beginning the decomposition of the overturned plant materials. Field burial is probably the most economical and practical method for disposing of contaminated plant

materials in the field.

Several types of plows are available for use in field burial, including disk, moldboard, ripper, and chisel plows.

In conventional tillage, a moldboard plow turns up the soil to a depth of 8 to 12 inches. This operation buries the contaminated plant materials and pathogens (disease-causing organisms) beneath the soil surface and can help control a plant disease epidemic.

Shallow plowing (about 6 inches deep) may be enough to bury the pathogen spores and control new infections.

Coordination and jurisdictional considerations

Burial should be undertaken only with the explicit approval of the local and state institutions and agencies competent in making determinations about protecting the environment. States have established orders of priority for carcass disposal, and the incident command structure must exhaust higher disposal priorities before undertaking burial activities.

The location of the burial activity should be chosen by the members of the incident command structure established by local or

state authorities. Local authorities should establish an intercounty memorandum of understanding so that the carcass overflow can be easily transported to nearby counties for burial.

If the carcasses are to be transported to nearby counties, the incident command structure must consider the added problem of transportation safety and contamination of other property.

Pollution and other property damage considerations

The exercise of police power gives governmental entities and agencies wide discretion in making decisions about burying carcasses to protect public health. However, this power does not shield the entities against nuisance actions if the proper precautions are not taken.

Burying carcasses near wells, residences, water bodies, public areas, or property lines could trigger nuisance or other types of lawsuits. Sovereign immunity may not be a defense to such action.

If the carcasses are buried in an area not

included in the list of “suitable areas” as defined by the local Natural Resource Conservation Service, the burial could constitute a violation of the incident command structure rules and serve as a basis for due process, equal protection, nuisance, or other challenges.

Because injury to people or property could trigger suits claiming violation of site selection procedures, the burial decision must be made jointly by the members of the appropriate technical group within the incident command structure.

Planning considerations

Consult with state solid-waste-management officials and regional, county, or municipal authorities to obtain the required permits and information about the restrictions on burial methods and the permissible volume of animal carcasses. States and counties may assist by providing draft permits as part of their emergency management plans.

When planning for emergency carcass disposal by burial, obtain input from private contractors (heavy machinery operators), animal producers, first responders, and personnel from fire departments, law enforcement, county roads and public works departments, departments of transportation, parks and recreation departments, regulatory agencies, the USDA Natural Resources Conservation

Service (NRCS), and the Extension service. Maintain a current list of telephone, fax, and e-mail information for key representatives of the collaborating agencies.

Consult the NRCS offices to obtain soil maps, drainage information, records of seasonally high water table depth, and other relevant data on environmental impacts. County NRCS offices may maintain a listing of suitability for “Animal Mortality Burial (Catastrophic)” by soil map unit.

When choosing a burial site, consider its proximity to wells, residences, roadways, municipalities, public areas, religious sites, archaeological zones, property lines, and bodies of water (Table 2).

Table 2. Capacity and setback distances of carcass burial options for various soil types.

Burial option	A	B	C	D	E	F (Capacity)
Trench burial	150 ft	200 ft	500 ft	1,000 ft	1,325 ft	Variable
Landfill	—	—	—	—	—	40 tons/400 ft ² 4,300 tons/acre
Mass burial	150 ft	200 ft	500 ft	1,000 ft	1,325 ft	Variable

A. Minimum distance from private wells, springs, watercourses, sinkholes, streams, springs (or any source of water used for domestic purposes), and public areas.

B. Minimum distance from residences or property lines.

C. Minimum distance from public wells.

D. Minimum set-back distance for the burial of disease-infected carcasses near private or public wells for supplying water for drinking and other uses.

E. Minimum distance from public roads, highways, and parks.

F. Sometimes the carcass depth in LF may reach to 6 ft., and thus the capacity will be 80 tons of carcass in 400 ft.²

Also when locating a burial site, consider various soil properties, including slope, texture, permeability, surface fragments (cobbles or stones), the depth to bedrock, and the presence of fractured or cavernous bedrock.

Do not locate a burial site in highly permeable soils such as sands, loamy sands, or old gravel quarries. Locate it in an area with appropriate soil (loam or finer), or provide a mixture of clay and low-porosity sand (fine texture) to cover the carcasses. This coverage prevents seepage into the groundwater and maximizes the natural decomposition of carcasses.

Work with university Extension and NRCS personnel to conduct sampling as part of a geotechnical investigation of the proposed burial sites to determine the appropriate areas for excavation of trenches and pits. Plan to take soil samples to a depth of 2 feet (0.6

meter) below the lowest planned excavation point.

Before excavation, consider the landfilling, trench burial, and mass burial dimensions to estimate the burial area (Table 3). Multiple pits should be spaced at least 20 feet (about 6 meters) apart.

Also before excavation, contact the local utility company or other State-approved notification center to check for underground utilities in the general work area.

Do not bury animal carcasses where the water table is within 10 feet (about 3 meters) of the bottom of the burial site. High concentrations of ammonia and dissolved solids have been reported in groundwater near burial sites and around the poultry carcass disposal pits.

Fence and stake the burial site to keep out unauthorized personnel, pets, wildlife, and farm animals.

Under no circumstance should you bury in trenches, pits, or landfills any carcasses infected with transmissible spongiform encephalopathy (TSE), such as bovine spongiform encephalopathy. TSEs are not inactivated by any burial process and can seriously threaten the health of people and animals. For burial of animals with chronic wasting disease,

check your local and state rules.

Plan to collect and dispose of the carcasses as quickly as possible to avoid negative public reaction resulting from the prospect of odors and the fear of disease transmission. Rapid burial prevents scavengers and vermin from feeding on the carcasses and possibly spreading diseases.

Table 3. Trench/pit/landfill dimensions for burial of animal carcasses.

Burial option	Volume ratio ^a	Width	Depth	Length ^d
Trench burial	2–4	4–10 ft	3–12 ft ^c	—
Landfill	—	14 ft	10–20 ft	30 ft
Mass burial	2–4	4–6 ft ^b	3–12 ft ^c	—

^aRatio of the volume of excavated trenches to the volume of carcasses

^bHistorical data show a width of up to 20 ft, but most new references recommend a width of up to 6 ft.

^cDepth excludes 2 ft and 4 ft of mound to shed rain water and divert runoff for trench burial and mass burial, respectively.

^dAs needed to bury a given number of carcasses in trench burial and mass burial. Each bovine carcass is equivalent to five adult sheep or five mature hogs and requires 5 ft of trench length. Additionally, a 10–14 ft²-area is required at the bottom of trench/pit for one mature cattle carcass.

Train the members of the disposal crew on how to use safety equipment while excavating the trenches or pits, especially for the deeper trenches. Also educate them about safety, biosecurity, and operational procedures, such as how to receive and properly stage the carcasses.

Plan well in advance to protect the excavated soil from erosion until it is used as backfill.

Provide equipment for digging pits and burying carcasses. Each cubic yard of the bucket size can excavate about 100 cubic yards (about 76.5 cubic meters) of trench per hour.

Also provide machinery and equipment for handling, loading, unloading, cleaning, and disinfecting, as well as for lighting and

safety, as described in the “Thermal” chapter. The capacity of the equipment depends on the amount of carcasses and the time required (usually 24 to 48 hours, but up to 72 hours in cold climates) for a proper burial process.

Provide a backhoe, scraper, bulldozer, or other equipment that can excavate a trench and/or burial pit, and use tools suited to working in rocky soils. For information on some of the equipment suppliers, operators, and contractors of the trench burial, landfilling, and mass burial options, see Table 4.

Plan to decontaminate the equipment used for handling, packing, storing, and conveying the carcasses as described in the Transportation section of the “General Considerations” chapter.

Table 4. Contractors and operating companies for trench burial, landfilling and mass burial systems.

Company	Nature and capacity of work	Contact information
Phillips and Jordan, Inc.	Contractor of trench burial up to 50 tons/hr	Robbinsville, NC 28771 800-511-6027, 909-337-0083 or 919-605-4571 www.pandj.com
Riverside County Waste Management	Carcass landfilling 40–80 tons/day	14290 Frederick Street Moreno Valley, CA 92553 909-468-3308 www.rivocowm.org
Crowder Excavating, Inc.	Contractor, up to 10 tons/hr	901 Geddie Road Tallahassee, FL 32304 850-576-7176; 800-992-6207 or 251-653-6590 www.environmentalexpert.com
Tetra Tech EM, Inc.	Consultant and contractor for landfilling and burial up to 50 tons/day	8030 Flint Street Lenexa, KS 66214 913-894-2600 www.tetrattech.com

This is not an exhaustive list. No endorsement of companies or individuals or their services mentioned is intended, nor is criticism of similar companies implied.

Planning for trench burial

When considering trench burial, plan for an alternative burial method in case no area with suitable soils is available for trench burial of large amounts of animal carcasses.

Where the soil type is not necessarily suitable for trench burial, you may need a source of clay to supplement the base (bottom layer) of the trench. This clay will minimize the potential for environmental contamination.

Do not consider sites that have no cutoffs, drainage, or other special design features if

water (apparent, perched, or seasonal) is likely to emerge just above the level of the trench bottom or if it flows down into the trench or away from the site.

Do not allow vehicular traffic to come within 4 feet (1.3 meters) of the trench/pit edges. Vehicles may damage the topsoil near the trenches/pits and may create cracks or fractures in the subsoil, making it permeable to leachate.

Planning for landfilling

Lessons learned from the outbreak of foot-and-mouth disease in the United Kingdom and from outbreaks of poultry diseases in the United States suggest that state and county carcass disposal plans should include prior approvals to use landfills. Prepare contingency contracts in advance to avoid delays and high costs once an outbreak occurs.

When planning for disposal of carcasses in Type I landfills, involve landfilling and state solid waste management officials.

Identify the Type I landfills available for disposal of carcasses. Because they are

equipped to collect leachate and gas, modern or Type I landfills are permitted to accept carcasses except those contaminated with prions such as mad cow disease, scrapie, or chronic wasting disease.

Modern landfills must meet the requirements of the Resource Conservation and Recovery Act, Subtitle D, and many other federal, state, and local regulations. Subtitle D stands for sanitary landfills that keep wastes “dry” and minimize the production of leachate and gases, the major byproducts of waste degradation.

Planning for mass burial

The base of an excavated pit for mass burial should be built at least 10 feet (about 3 meters) above the historical high groundwater level.

Use unlined, excavated pits for mass burial only when the carcasses will be stored

temporarily and disposed of promptly.

Be prepared to provide adequate containment and collection systems for the leachate generated in mass burial.

Planning for field burial

If the plants are confirmed to be contaminated with pathogens on the Select Agent and Toxin List published by the USDA Animal and Plant Health Inspection Service (APHIS), the plants may need to be buried at a designated, approved site. The list is located at http://www.aphis.usda.gov/programs/ag_select_agent/ag_bioterr_toxinslist.html.

A practical option for disposing of annual field crops is on-site field plowing. This method does not require that the plant materials be transported from the farm, and air quality issues are not a concern.

Landfill burial is a practical choice for perennial field crops and nursery greenhouse plants. However, a limiting factor can be the

proximity of the farm to the landfill. Consider landfill burial also for trees and lumber if thermal destruction is unfeasible and if they can be transported in a timely, cost-effective manner.

Because plant pathogens are not known to cause human diseases, the biosecurity and environmental safety efforts should focus on preventing the spread of pathogens to crops in other regions.

Procedure for trench burial

When considering trench burial of contaminated plants or animals—except those contaminated with prions—first verify that they need to be disposed of immediately. Determine whether they are contaminated with aggressive pathogens with a great potential to cause an epidemic. If they are not considered to be an immediate threat, consider using a natural decomposition or crop rotation method.

Select a cross-sectional geometry (trapezoidal or rectangular) for the carcass burial site.

Determine the length of the trench from the cross-sectional area of the trench geometry. The ratio of trench volume to carcass volume should be:

- 4:1 for burying one to two layers of large carcasses (1,000 pounds [about 450 kilograms] or more)

- 2:1 for burial of two to three layers of medium-sized or small carcasses.

To determine the length of the trench, see the calculations in Figure 1.

Dig the trenches/pits with relatively level bottoms according to the dimensions in Table 3. Some states, such as Iowa, permit the construction of burial trenches with vertical walls if the wall height is less than 5 feet (about 1.5 meters). See Figure 2 for details.

In general, there must be at least 2 feet (about 0.6 meter) of impermeable soil between the bottom of the trench and the water table. The carcasses should be covered with at least 2 feet of soil.

Adjust the width, depth, and side slopes of the trench to match the needs of the equipment without compromising the safety of the

crew. Prevent trench cave-in hazards by using Occupational Safety and Health Administration (OSHA) standards for the people building or working in or around trenches/pits during excavation and material emplacement.

Where space is limited, use more than one trench/pit and separate them by a minimum of 3 feet (about 0.9 meter) of undisturbed or compacted soil.

To inhibit bloating, which can displace and shift the soil or even raise the carcasses to the trench/pit surface, vent the carcasses before burial, especially those of large animals. This venting will minimize the accumulation and entrapment of gases.

For small animals such as poultry or nursery pigs, place a layer of carcasses at the trench/pit bottom and cover it with at least 1

foot (about 0.3 meter) of soil. For large animals such as hogs or cattle, place the layer of carcasses at the trench bottom and cover it with at least 2 feet (about 0.6 meter) of soil. Repeat this process for up to three layers of carcasses in deep trenches/pits (Fig. 2).

To reduce potential predator problems in and around the trenches/pits during the burial process, cover the carcasses daily, particularly if the burial process takes more than 24 hours.

Mound the trenches with at least 2 feet of soil, preferably impermeable soil (Fig. 2). Do not try to compact the earth-filled trenches/pits because compaction is difficult to achieve; it also may impede the natural decaying process.

Refill the caved-in mounds to prevent access by vermin (or vectors), and the collection of surface water.

Figure 1. Length calculation for burial of 100 cattle in deep or shallow trenches.

Assumptions

- 1 - Average weight of carcass = 1,000 lb
- 2 - Bulk density of carcass = about 62.4 lb/ft³
- 3 - Volume ratio for a two-layer or one-layer burial trench = 4 ft³ of trench/ft³ of carcass
- 4 - Trench depths for one layer and two layers = 4 ft (shallow trench) and 8 ft (deep trench), respectively
- 5 - Trench width for both cases = 6 ft; two carcasses lie side by side
- 6 - Length of each cattle carcass = about 5 ft

Solutions

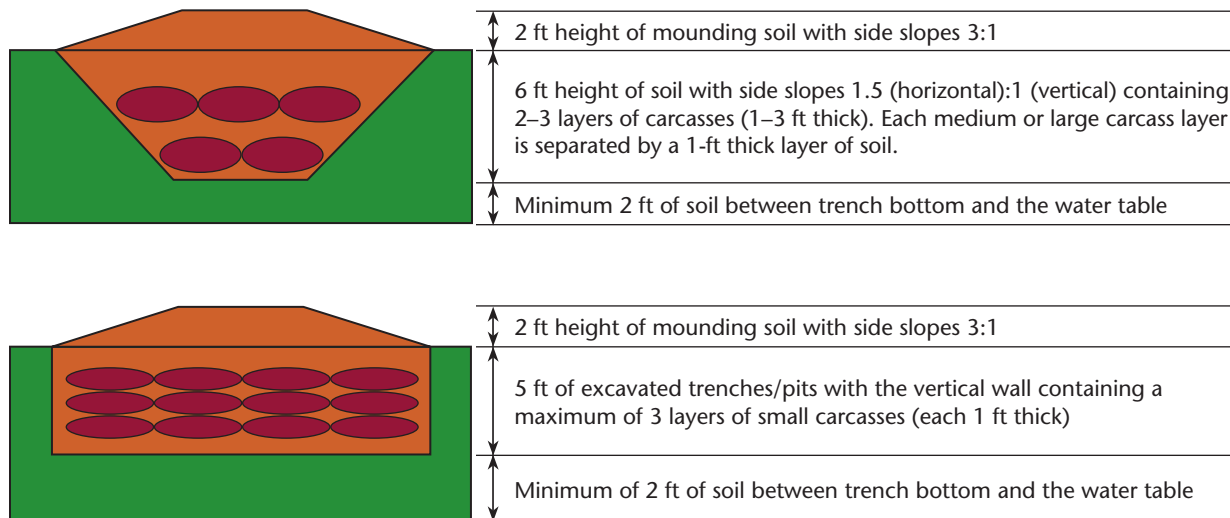
A. Deep trench

- 1 - Trench length in a deep trench = $\{(100 \text{ cattle}) \times (1,000 \text{ lb/cattle}) (4 \text{ volume ratio})\} \div \{(62.4 \text{ lb/ft}^3) (8 \text{ ft deep}) (6 \text{ ft wide})\}$ about 130 ft
- 2 - Number of buried cattle in two layers and two rows = $\{(130 \text{ ft.}) \times (2 \text{ layers}) \times (2 \text{ rows})\} \div (5 \text{ ft length/carcass}) = 104$ carcasses

B. Shallow trench

- 1 - Trench length in shallow trench = $\{(100 \text{ cattle}) \times (1,000 \text{ lb/cattle}) (4 \text{ volume ratio})\} \div (62.4 \text{ lb/ft}^3)(4 \text{ ft deep}) (6 \text{ ft wide})\}$ ~ 260 ft
- 2 - Number of buried cattle in one layer and two rows = $\{(260 \text{ ft}) \times (2 \text{ rows})\} \div (5 \text{ ft long/carcass}) = 104$ carcasses

Figure 2. Cross sections (not to scale) of a trapezoidal trench (top) and a vertical trench used for burying carcasses. For massive carcass burial, trenches of up to 12 feet deep with no more than two 3-foot layers of dead animals are recommended. The bottom soil should be highly impermeable, without fractured or cavernous rock.



Procedure for landfilling

All landfills used must agree to the delivery of carcasses. Most landfills, even those closed to the public, accept carcasses. Confirm with the operator that the landfill is properly designed and is designated to accept carcasses, and either collect and treat the leachate on site or transport it to a waste treatment plant.

For the carcass disposal process, use the conventional equipment that is available in Type I landfills. At the landfill site, load the carcasses evenly at deepest part of the pit to a height of 3 to 6 feet. Cover this layer of animal carcasses with a 3-foot (about 0.9-meter) layer of solid waste (household trash) and compact it to reduce its porosity.

Repeat adding 3-foot layers of solid waste only, and compact each layer until a

total height of 10 feet is reached (Fig. 3). The deepest part of landfill is not necessarily in the preconstructed and lined bottom. The landfill may have a depth of 20 feet (about 6 meters) of compacted trash.

At the end of each day, cover the left-over solid waste (co-filling materials) with a thin layer of soil (less than 1 foot [0.3 meter] thick) to keep the landfill in a sanitary condition and to minimize nuisance problems such as odors, vectors, and predators.

Mound the top (final) compacted layer of solid waste with at least 2 feet (0.6 meter) of impermeable soil.

Continue to monitor the mound for settling and caving-in. Fill and recompact the mound to shed water and to prevent the release of odors and noxious gases.

Figure 3. Two views of carcass disposal in the Badlands Landfill, in Moreno Valley, California (*Photos courtesy of Riverside County, Waste Management Department, CA*).



Procedure for mass burial

For mass burial, select a cross-sectional geometry (rectangular or trapezoidal) according to Figure 4.

When excavating to more than 5 feet (about 1.5 meters) deep, prepare the side slopes with a minimum ratio of 1.5 (horizontal) to 1 (vertical).

Prepare gravel drainage channels to convey the seepage to the leachate collection sumps. To prevent or minimize seepage, line the inside (walls and bottom) of the trenches/pits with clay or an impermeable membrane.

Divert the upstream runoff by building

berms or a cutoff ditch along the up-gradient side of the pit.

In the burial process, place one or two layers of carcasses in shallow or deep pits. The carcass layers can be a maximum of 2 feet [0.6 meter] or one large animal thick. The depth of a shallow pit is 3 feet (0.9 meter); that of a deep pit is 10 feet (3 meters).

Cover each carcass layer with up to 3 feet of soil (Fig. 4). Fill the pits with excavated soil and mound them with 4 feet (about 1.2 meters) of impermeable soil above the ground level (Fig. 5).

Figure 4. Cross sections of vertical pits (top) for temporary mass burial and of a trapezoidal trench/pit for mass burial of carcasses at preconstructed sites. The walls and bottom of the trenches/pits are built with 2 to 3 feet of impermeable soil such as compacted clay, especially in the deep pits used for mass burial. The bottom soil should not be highly permeable.

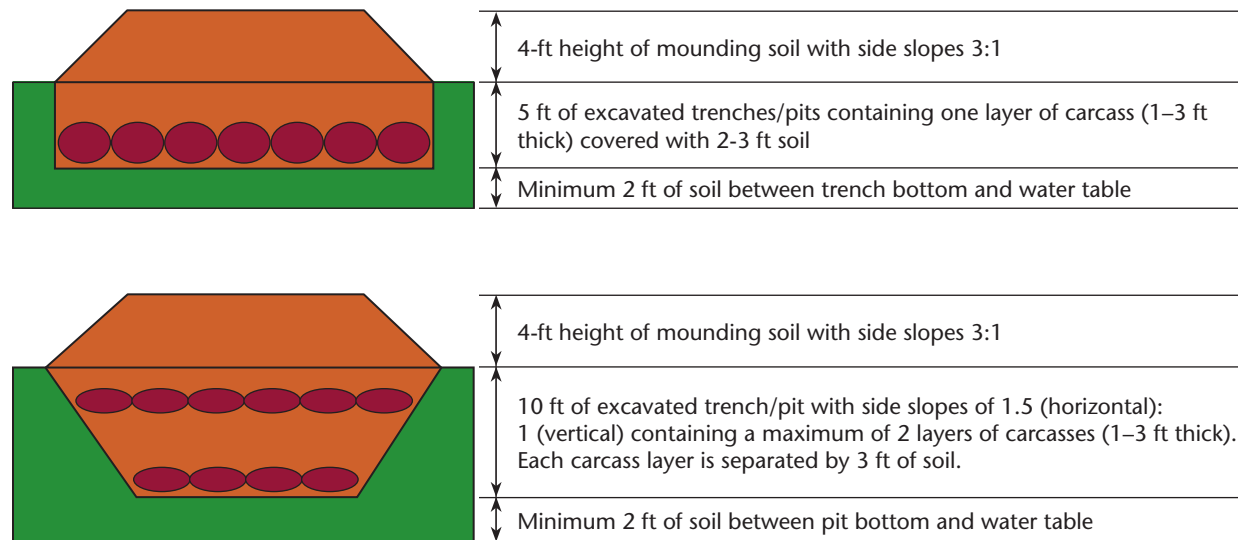


Figure 5. Great Orton, United Kingdom, in 2005 after mass burial in 2001. (*Photo courtesy of Scudamore et al., 2002*). <http://www.visitcumbria.com/footandmouth.htm>, accessed Nov. 6. 2006.



Procedure for field burial

When considering field burial of contaminated plants, first verify whether they need to be disposed of immediately. Determine whether the plants are contaminated with aggressive pathogens with a great potential to cause an epidemic. If they are not deemed to be an immediate threat, consider using a natural decomposition/crop rotation method.

Prepare the equipment (tractors and appropriate plows) and personnel for the operation. Before field plowing, remove the established vegetation (such as trees and shrubs) by mechanical or chemical means.

Generally, plowing 6 inches deep can ef-

fectively dispose of the pathogens and crop residues, which will ultimately reduce the pathogen population significantly. In severely diseased areas, consider plowing 12 inches deep.

Turn but do not compact the soil because plant residues generally decompose quickly when they are mixed with soil aerobically; they decompose slowly when they are buried deeply (anaerobically) as compact layers.

A time frame of 1 hour per acre is estimated for field plowing. Do not plow the area again because this may simply return the active pathogens to the soil surface.

Table 5. Guidelines for the use of personal protective equipment.

Nature of work	Mask/respirator ^{a,b,c}		Protective clothing ^a	Eye/hearing protection ^a	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Direct handling of contaminated materials	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Impermeable to liquids; depending upon heat situation	Eyes: Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles Hearing: Consider disposable earplugs if necessary	Gloves: Heavy duty (15–18-mil) chemical resistant gloves that can be disinfected or disposed; if desired, 10–12-mil nitrile gloves worn under leather gloves	Feet: For workers handling carcasses, steel-toe/steel shank waterproof boots; for others, steel-toe work shoes or boots Head: Hard hat
No direct handling of contaminated materials	None recommended	None recommended	No special clothing required; work clothing appropriate for season	Eyes: Safety eyewear Hearing: Consider disposable earplugs, if necessary	Work gloves if necessary	Feet: Steel-toe work shoes or boots Head: Hard hat

^aFor a list of vendors recommended by OSHA, visit www.safetyequipment.org.

^bFor information about a full respiratory protection program, visit www.osha.gov/SLTC/respiratoryprotection/index.

^cRegulations governing the use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the Safety section of the “General Considerations” chapter of this manual.

Diseases of concern

For burial methods, the diseases of concern include those caused by viruses, bacteria, and prions.

Viruses and non-spore-forming bacteria: Burial is an effective method for controlling the spread of viral and non-spore-forming bacteria.

For viruses such as those that cause foot-and-mouth disease (FMD) and classical swine fever (CSF), some of the viruses will persist after burial. Reports estimate that these viruses may survive for up to 40 days before they begin to deteriorate. Although some viruses persist in the soil longer than do non-spore-forming bacteria, burial is still an acceptable disposal method for them.

Precautions must be taken to prevent inhalation of airborne pathogens. Personal protective equipment is essential for worker safety while the carcasses are being transported and handled on site.

The diseases for which burial is an acceptable method include African swine fever, brucellosis, CSF, contagious bovine pleuropneumonia, FMD, glanders, highly pathogenic avian influenza, Japanese encephalitis, Q fever, Rift Valley fever, rinder pest, tularemia, and vesicular stomatitis.

Spore-forming bacteria: Burial is not recommended for materials infected with spore-forming bacteria because the spores may persist indefinitely in the soil. Spore-forming bacteria must be incinerated thoroughly. If it is not possible to incinerate the carcasses immediately, they must remain intact to prevent the spores from spreading into the external environment.

Diseases of concern include anthrax.

Prions: Extremely high temperatures are necessary to destroy carcasses infected with prions. Prions are resistant to thermal and

environmental degradation. The best method of destruction is fixed-facility burning. **Do not bury prion-infected carcasses.**

Notes on safety

During extreme heat, rest periods must be instated to prevent heat stress and dehydration. OSHA recommends establishing a work/rest schedule that decreases heat exposure. Develop this schedule according to worker needs.

A worker with a core temperature of 100.4 °F is considered to be at a heat stress level. To prevent dehydration, allow the workers to drink water at liberty.

Heavy equipment operations are inherently dangerous. Use a safety observer with the training and authority to minimize the risk of dangerous situations.

Prion-based diseases include bovine spongiform encephalopathy.

Other suggestions from OSHA:

- Implement a training program for managers and employees on how to recognize and treat heat stress.
- Before beginning burial activities, screen the workers to identify existing health conditions.
- Institute procedural programs guiding the workers on what to do if a heat-related emergency arises.

For more information on heat stress and work/rest cycles, see the Safety and Biosecurity section of the “General Considerations” chapter of this guide.

Control of scavenging animals is of paramount importance in controlling the spread of disease from the burial site. Insects, birds, and animals that come into contact with the diseased carcasses can become vectors, spreading the disease outside the site or containment area.

To prevent easy access by vermin to the contaminated material, follow the engineering guidelines for burial sites carefully. The carcasses must be covered with soil by the end of the work day to prevent scavenging by wildlife. Institute controls for birds, vermin, and other scavengers.

Place and compact the backfill material so as to prevent or minimize contact of the excavator or compactor with the carcasses. Compactors should not touch the carcass material

until the backfill material is in place.

The site where animal carcasses are being deposited should be closed to all nonessential vehicles and personnel. Keep all other vehicles clear of the area accepting animal carcasses.

Equipment and truck drivers must remain in their vehicles while on the burial site to avoid contamination of footwear and clothing. Provide another set of personnel on the ground to open tailgates and offload carcasses.

Personnel and vehicles must be decontaminated before they leave the disposal site. See additional information in the Safety section of the “General Considerations” chapter of this guide.

Groundwater pollution

Because each state sets its own regulations for burial of hazardous waste, it is critical to identify the appropriate authorities before selecting a landfill for carcass disposal.

It is absolutely essential that you work closely with State agriculture and environmental regulatory agencies before burying large volumes of contaminated plant and animal materials. The appropriate state and local agencies are best able to handle considerations such as soil type, groundwater depth, nearby surface water flows, proximity to drinking water wells, and assessment of ground water monitoring approaches.

Landfill operators must provide the required information on this topic and will have the authority to deny burial of hazardous carcass waste at their sites if they believe the environmental risk to be greater than acceptable.

The most relevant human hazards are the waterborne protozoa, pathogenic bacteria, and transmissible spongiform encephalopathies that may be transported by groundwater and can contaminate water supplies. Controlled conditions and groundwater monitoring will minimize the risk of contamination; they are instrumental in preventing a public health hazard.

Air pollution

There should be no notable emissions if the burial methods are followed carefully according to the guidelines presented in this handbook.

Concerns are limited to on-site workers who will need personal protection equipment to minimize their exposure to airborne or aerosolized biological agents.

Operating landfills

All owners/operators of municipal solid waste landfills must comply with the requirements for proper landfill management:

- **Receipt of regulated hazardous waste:**

The owner/operator must set up a program to detect and prevent the disposal of regulated quantities of hazardous waste. The program must include procedures for random inspections, record keeping, training of personnel to recognize hazardous wastes, and notification of the appropriate authorities if such

waste is discovered at the facility.

- **Cover material:** The owner/operator must cover the solid waste with at least 6 inches of earthen material at the end of each operating day to control fires, odors, vectors, scavengers, and blowing litter. An approved state or tribe may allow an owner/operator to use an alternative cover material or depth and/or grant a temporary waiver of the cover requirement.
- **Vectors:** The owner/operator is responsible for controlling populations of vec-

tors, which include rodents, flies, mosquitoes, and other animals and insects that can transmit diseases to humans. Application of cover at the end of each operating day generally controls vectors.

- **Explosive gases:** The owner/operator must set up a program to check for methane gas emissions at least every 3 months. If the limits specified in the regulations are exceeded, the owner/operator must immediately notify the state director (that is, the official in the state or area responsible for implementing the landfill criteria) and take immediate steps to protect human health and the environment.
- **Access:** The owner/operator must control public access to prevent illegal dumping, unauthorized vehicular traffic, and public exposure. Artificial and/or natural barriers

may be used to control access.

- **Storm water run-on/runoff:** The owner/operator must build and maintain a control system designed to prevent storm waters from running onto the active part of the landfill. Runoff waters must be managed according to the requirements of the Clean Water Act, particularly the restrictions on the discharge of pollutants into water bodies and wetlands.
- **Surface water protection:** All landfills must be operated in a way that ensures they do not release pollutants that violate the Clean Water Act.

For details in planning, see <http://www.epa.gov/epaoswer/non-hw/muncpl/criteria/landbig.txt>.

The costs of burial (Fig. 6) follow the category definitions from the “General Considerations” chapter of this guide. The cost of burial depends critically on labor, equipment, and outlays for off-site burial and related transportation.

Table 6 lists estimates of direct costs for on-site burial of cattle, calves, hogs, sheep, lambs, and goats. For formulas to estimate direct costs of burial, see Figure 7.

For indirect cost items, see the Cost section of the “General Considerations” chapter of this guide.

Figure 6. Components of direct and indirect costs for burial operations.

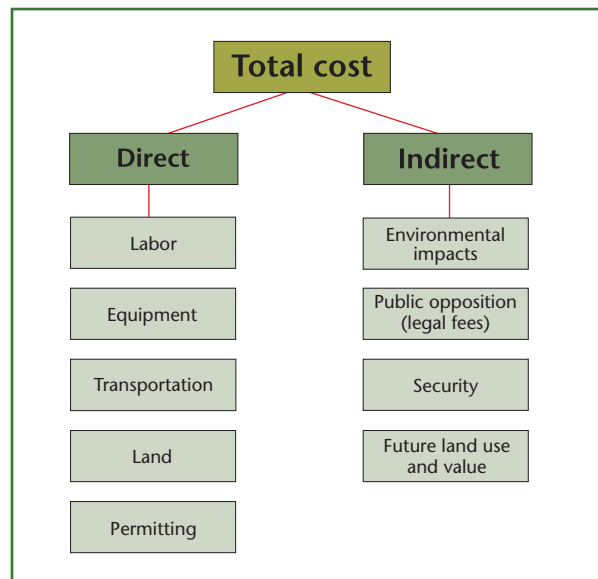


Table 6. Estimates of direct cost items for on-site carcass burial.

	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
Estimated average cost per carcass (\$ per carcass)					
Labor cost	\$3.33	\$1.67	\$1.67	\$0.17	\$1.67
Equipment cost	\$11.67	\$5.83	\$5.83	\$0.58	\$5.83
Permitting fee	n/a	n/a	n/a	n/a	n/a
Transportation cost	n/a	n/a	n/a	n/a	n/a
Land cost	n/a	n/a	n/a	n/a	n/a
Average cost per carcass	\$15.00	\$7.50	\$7.50	\$0.75	\$7.50
Estimated average cost per ton (\$ per ton)					
Labor cost	\$8.89	\$12.53	\$25.06	\$55.56	\$43.29
Equipment cost	\$31.11	\$43.86	\$87.72	\$194.99	\$151.52
Permitting fee	n/a	n/a	n/a	n/a	n/a
Transportation cost	n/a	n/a	n/a	n/a	n/a
Land cost	n/a	n/a	n/a	n/a	n/a
Average cost per ton	\$40.00	\$56.39	\$112.78	\$250.55	\$194.81

Source: Livestock mortalities and burial costs in 2002 by Sparks Companies, cited by a report by the National Agricultural Biosecurity Center Consortium for Carcass Disposal.

Figure 7. Formulas to estimate direct variable cost relating to burial.

If the hourly labor and equipment costs are \$10 and \$35 respectively, the **direct variable cost (DVC)** of on-site burial can be estimated using the following formulas:

- **By number of carcasses:**

$$DVC = 15.00Q_{\text{cattle}} + 7.50Q_{\text{calves}} + 7.50Q_{\text{weaned hogs}} + 0.75Q_{\text{preweaned hogs}} + 7.50Q_{\text{others}}$$

Where Q_i is the total number of carcasses in animal category i .

- **By weight:**

$$DVC = 40.00W_{\text{cattle}} + 56.39W_{\text{calves}} + 112.78W_{\text{weaned hogs}} + 250.00W_{\text{preweaned hogs}} + 194.81W_{\text{others}}$$

Where W_i is the total weight in tons of animal category i .

If the hourly labor cost and equipment cost are C_L and C_E rather than \$10 and \$35, the total direct variable cost (DVC) of on-site burial can be estimated using the following formulas:

- **By number of carcasses:**

$$DVC = (C_L + C_E)[0.33Q_{\text{cattle}} + 0.17Q_{\text{calves}} + 0.17Q_{\text{weaned hogs}} + 0.02Q_{\text{preweaned hogs}} + 0.17Q_{\text{others}}]$$

- **By weight:**

$$DVC = (C_L + C_E)[0.89W_{\text{cattle}} + 1.25W_{\text{calves}} + 2.51W_{\text{weaned hogs}} + 5.56W_{\text{preweaned hogs}} + 4.33W_{\text{others}}]$$

Estimating the costs of field burial for plant materials

The **fixed cost** is the daily rental cost of a tractor equipped with a plow. Below is a case example using a 60-horsepower tractor with a three-bottom, 16-inch moldboard plow. However, the field manager must be aware that the fuel consumed and the fixed cost will depend on the size of the tractor and the moldboard plow.

Hourly operation cost = Equipment rental cost per hour + Hourly labor + Hourly fuel cost

The **variable cost** is the sum of the labor cost plus the fuel cost during the operation.

Using the formula above, if the labor cost is \$10 per hour, the fuel price is \$3 per gallon for diesel, and **1 hour of operation** is estimated to plow **1 acre of field**, the **hourly operation cost** is estimated to be:

Hourly operation cost = Equipment rental cost per hour + \$10 + \$16.98

Hourly operation cost = Equipment rental cost per hour + \$26.98

Definition and objectives

Carcass composting is a disposal process that conceals animal carcasses under a blanket of organic material to promote decomposition at elevated temperatures.

Initially in this process, mesophilic microorganisms (those that grow in moderate temperatures, from 77 to 104 °F, or 25 to 40 °C) heat the pile to about 104 °F (40 °C). At this stage, naturally occurring thermophilic microorganisms (those adapted to living at high temperatures) convert the organic nitrogen and carbon compounds into a stable and relatively homogenous mixture of bacterial biomass and humic acid. In the compost pile, the organic nitrogen is mainly from animal sources and the carbon compounds are mainly from plant sources.

The objectives of carcass composting are to:

- Provide the proper conditions for carcass biodegradation
- Inactivate some of the pathogens that can spread diseases in soil, plants, animals, and humans
- Prevent livestock carcasses from generating environmental pollutants, such as the leaching of nitrogen and sulfur compounds to groundwater and the odors that can reduce the quality of life and decrease property values
- Convert the carcasses into useful end products for agricultural lands

Several factors should be considered when choosing the type of carcass composting system. These include costs, system capacity, procedure speed, transportation concerns, environmental risks, and the availability of resources (Table 1).

Table 1. Methods considerations for carcass composting.

Consideration	Outdoor windrow composting	In-house windrow composting	Carcass bin composting
Transportation concerns ¹	Yes	No	Yes
Pathogens inactivated	Viruses and bacteria	Viruses and bacteria	Viruses and bacteria
Capacity for carcass disposal ²	Large	Large	Small
Environmental risk	Medium	Low	Medium
Regulatory restrictions	Medium	Low	Low
Cost ³	Medium	Low	High
Availability of resources	Medium	High	Low
Procedure speed	Low	High	Medium

¹ If the disaster area meets the disposal site requirements for carcass composting, there is no need for off-site transportation.

² Animal carcasses (tons): Small = < 100 tons; Medium = 100–299 tons; Large = 300 or more tons

³ Cost estimate (per ton): Low = < \$50; Medium = \$50–100; High = \$100 and more (The cutoff points may vary, depending on factors such as carcass load and types, transportation, and available disposal facilities.)

Composting phases and systems

Carcass composting has two principal phases: the **active phase** and the **curing phase**. The composting method can occur in three major conventional systems: **outside windrow composting**, **in-house windrow composting**, and **carcass bin composting**.

The first phase of carcass composting is characterized by aerobic (in the presence of oxygen) reactions, high temperatures, and large reductions in biodegradable solids. This phase has the potential to produce significant odors.

A properly constructed carcass composting pile should have:

- An oxygen concentration of more than 5 percent
- Particle sizes of the co-composting materials ranging from 0.5 to 2 inches
- A pile porosity of less than 40 percent

- Bulk densities ranging from 800 to 1,200 pounds per cubic yard
- An average pH of 5.5 to 9.0

The first phase of a carcass composting operation should raise the core temperature of the pile to about 135 to 140 °F within 15 days and maintain it for several days for poultry or ground carcasses, to weeks for larger intact carcasses. Under these conditions, *Mycobacterium tuberculosis*, and *Salmonella* will be destroyed. If the core temperature is maintained at 149 °F for 1 to 2 days, the pathogenic bacterial activity and weed seed germination will be reduced considerably.

During the composting process, the mesophilic and thermophilic species of bacteria and fungi are active. These microorganisms produce a variety of antibiotics that destroy some pathogens such as *Salmonella* and *Shigella*.

In the first phase of composting, the volume and weight of the pile may decrease by as much as 50 percent. The porosity of the pile also will decrease. As the lack of air spaces makes less oxygen available to the microbes, the compost pile becomes anaerobic, which increases the potential for odors. During Phase I, it is vital that the compost has adequate aeration to maintain a uniform temperature and moisture content throughout the pile.

The first or active phase of carcass composting takes 3 to 12 weeks, depending on the type and weight of carcasses. Most of the biomass components stabilize during this period.

In the second or curing phase, aeration is not a critical factor. During this period, a series of slow-rate reactions such as the breakdown of lignin occur at temperatures below 105 °F.

At the end of Phase II, the internal temperature of the compost pile ranges from 77 to 86 °F (25 to 30 °C), the bulk density is reduced by 25 percent, and the finished product appears dark brown to black and is free of unpleasant odors when turned.

Figure 1 shows the temperature changes of the carcasses during the two phases of outside windrow composting. Figure 2 shows the average temperatures of carcasses during in-house windrow composting.

The time required for Phase II of composting differs according to the carcass size:

- Small carcasses (poultry): 10 days
- Medium-sized carcasses (sheep and swine): 90 and 180 days
- Heavy carcasses (cattle and horses): 240 days

Figure 1. Example of internal carcass temperatures during the first 63 days after the carcasses are placed in a windrow compost pile. (Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)

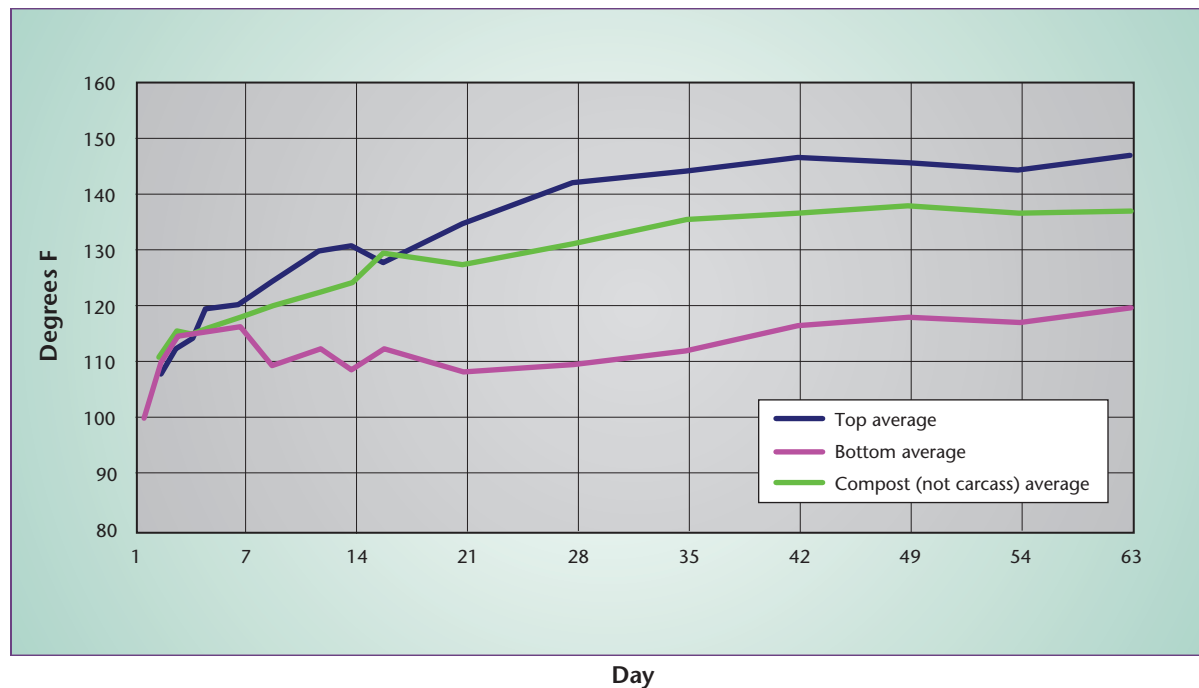
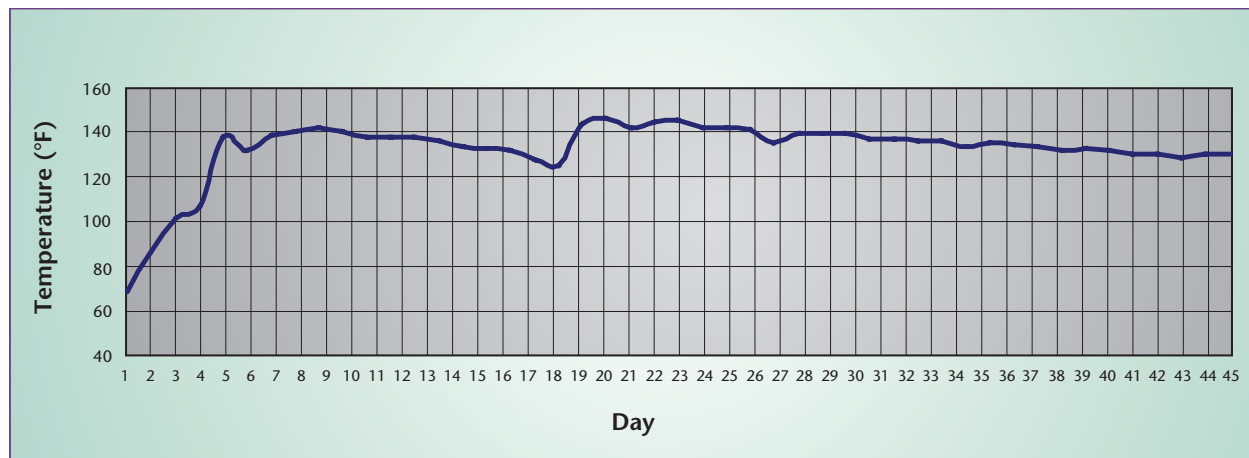


Figure 2. An example of a daily log of internal poultry carcass temperatures during 45 days of in-house windrow composting. (Courtesy of Dr. Nathaniel Talbante of the University of Maryland College Park and Rob Malone of the University of Delaware)



Speeding decomposition

You can speed the decomposition of the carcasses considerably—by up to 50 percent—by grinding them before composting. Grinding provides uniform porosity and suitable conditions for aeration. It also eliminates the need to mechanically turn the carcasses three times during the two phases, a common requirement when intact carcasses are composted.

Organic co-composting materials such as peanut shells, wood chips, and tree trimmings are less absorbent than straw for intact carcasses. Grinding these materials with the carcasses makes them readily available for the composting process. These organic materials are smaller (less than 2 inches) than straw.

Carcass grinding also reduces the maximum weight ratio of the bulking agent to carcass from:

- 4:1 to 1:4 for carcass bin composting

- 3:1 to 1:3 for in-house windrow composting
- 3:1 to 1:3 for outside windrow composting

Use of biofilters

A biofilter is a layer of organic materials (mainly from plants) placed over the compost pile to:

- Deodorize the gases released from the active pile
- Maintain the proper moisture, pH, nutrients and temperature in the pile
- Enhance the microbial activities in the pile

For the first 3 days, a compost pile covered with a biofilter layer has very pronounced odor and gaseous emissions. Later, the odor level is reduced by more than 80 percent.

End product

The end product of carcass composting is a homogenous, dark brown, soil-like material called “humus.” This material contains mostly mesophilic bacteria and is suitable for use as a soil amendment.

Some carcass parts, such as pieces of skull, hooves, teeth, and large bones, may remain intact in windrows (outside and in-

house) and in carcass bin compost piles but are not identifiable in ground carcass composting. However, these materials are relatively small and brittle or rubbery and degrade when exposed to nature.

Overall, the decomposition rate of intact carcasses in a properly managed compost pile during the two phases (mainly the first phase) is about 2.2 pounds (1 kilogram) per day.

Outdoor windrow composting: Description

The goal of outside windrow composting is the natural decomposition of dead animals. Carcasses are buried above ground in a static pile (trapezoidal shape) with no walls or roofs. They are buried beneath a mound of organic materials and in the presence of oxygen.

The carcass windrow piles are mounded to shed rainfall; to better control moisture, temperature, gases, and odors; and to maintain an adequate biofilter cover. The recommended height for a pile is 5 to 7 feet (1.5 to 2.1 meters).

An advantage of outdoor windrow composting is that it can be adapted for a large number of dead animals after a catastrophic event. This method is feasible for any size of animal, and the length of a windrow can be

increased to accommodate additional carcasses. This method also enables the workers to load, unload, and turn the pile from all sides.

However, because outdoor windrow compost piles are built in open spaces unprotected from weather, rain, or wind, they are exposed to more adverse weather conditions than are the components of other methods. These conditions can affect the degradation process of outdoor windrow compost piles.

Windrow composting of ground carcasses also requires more care and protection against health hazards during material preparation and pile formation. Figures 3 through 9 show the different stages of intact and ground carcass composting.

Composting

Summary

Figure 3. Carcasses on top of a windrow base before being covered. (Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)



Figure 4. Carcasses partially covered in a windrow pile with carbon amendments. (Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)



Figure 5. Contents of a cattle carcass windrow without initial grinding after 2 months of active composting. Note the steam rising from the exposed windrow. (Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)



Composting

Summary

Figure 6. Loading of a carcass into a large-scale carcass grinder and windrows of composted ground carcasses. (Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)



Figure 7. Ground carcass mixed with amendments ready for composting.
(Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN)



Composting

Summary

Figure 8. A 200-foot-long windrow of 65 ground carcasses. (*Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN*)



Figure 9. A view of composting windrows of ground carcasses. (*Courtesy of Dr. John Kube of Elanco Animal Health, Greenfield, IN*)



In-house windrow composting: Description

An in-house windrow composting pile is built inside a livestock barn or house to reduce labor, minimize the workers' exposure to pathogens, reduce biosecurity risks, and minimize exposure to the elements.

Carcass in-house composting occurs in a poultry house after birds infected with contagious diseases such as avian influenza are euthanized. One method of euthanizing is the foaming technique (Figs. 10 and 11). Chemicals in the foam, such as mixtures of hydrocarbon surfactants, alcohols, propylene glycol, solvents, and stabilizers, produce foam bubbles that fill the breathing passageways of birds (called hypoxia), causing death.

In-house windrow composting limits

the transmission of diseases from the farm, reduces the risks of groundwater and air pollution, allays public concerns over disease exposure, and protects the composting piles from extreme weather conditions.

This composting method is relatively low cost and uses readily available farm equipment. This system of composting protects the pile from scavengers and, to some extent, from outside disease vectors.

This method degrades carcasses efficiently, quickly, and in a controlled manner, containing the disease inside the barn and inactivating the pathogens in the carcasses and litter for poultry. It also probably provides enhanced composting because environmental

parameters such as moisture and temperature can be controlled more easily in an in-house windrow composting system than in outdoor windrow composting systems. In addition, there is no need to transport contaminated carcasses.

Figure 11 shows two views of a windrow composting pile inside a poultry house.

Microbial activity (mesophilic and thermophilic) within a well-constructed in-house windrow composting pile can generate and maintain temperatures in the range of 130 to 150 °F (54 to 66 °C) for several weeks, which is sufficient to inactivate the avian influenza virus.

Figure 10. In-house foaming of a poultry house. (Courtesy of G.W. Benson, University of Delaware, Newark, DE)



Figure 11. The euthanizing of diseased turkeys. (*Courtesy of Eric S. Bendfeldt, Virginia Cooperative Extension, Blacksburg, VA*)



Composting

Summary

Figure 12. Two views of preparing windrow piles for in-house composting. (Courtesy of Eric S. Bendfeldt, Virginia Cooperative Extension, Blacksburg, VA)



Carcass bin composting: Description

The goal of carcass bin composting is the natural decomposition of dead animals buried in a contained system. The carcasses are buried in a mound of organic material and in the presence of oxygen. The system may be built of any material that is structurally adequate to confine the compost pile material.

The system consists of a:

- Primary bin to actively compost the carcasses (Phase I)
- Secondary bin to cure the carcass compost (Phase II)
- Storage bin to store the mature compost (Phase III)

In bin composting, the contained structure may or may not be covered by a roof. Unroofed bins are simple and inexpensive

and can be constructed of large round bales placed end to end to form three-sided enclosures (bale composters). Although the pile is protected from predators, pests, and runoff, it is susceptible to precipitation and weather variations.

Roofed bins have the advantages of reduced weather effects, less unwanted moisture, potentially less leaching from the pile, and better working conditions for the operator during inclement weather.

Although carcass bin composting is a more environmentally controlled process than is outside windrow composting, it is not feasible for handling large amounts of farm carcasses.

Coordination and jurisdictional considerations

The decision on whether to use composting for carcass disposal should be made jointly by the members of an incident command structure that has been established by State or local authorities.

Local authorities should have an inter-county memorandum of understanding in place so that the carcasses can be easily transported to the county where the nearest facility for composting is located. If the carcasses are to be transported to nearby counties for composting, the incident command structure must

consider the added problems of transportation safety and contamination of other properties.

Composting should be undertaken only with the explicit approval by the institutions and agencies that are competent in making determinations about protecting the integrity of the environment.

States have established orders of priority for carcass disposal, and the incident command structure must exhaust the higher disposal priorities before undertaking composting activities.

Pollution and other property damage considerations

The exercise of police power gives wide discretion to governmental entities and agencies in making decisions about carcass disposal to protect public health. However, this police power does not shield the governmental entities from nuisance actions if the proper precautions are not taken.

The main challenge in the composting process is to make sure that the materials used to build the system are impervious to water and rot resistant. If constructed properly, composting systems usually pose no problems

of odors or flies. However, the failure to build the compost facility properly could trigger nuisance or other types of lawsuits. Sovereign immunity may not be a defense to such an action.

Because injury to people or property could also trigger suits similar to those based on nuisance, the decision to use composting must be made jointly by the members of the appropriate technical group within the incident command structure.

Planning considerations

When planning to dispose of carcasses by composting, include in the discussions people from many fields of expertise: private contractors, heavy machinery operators, animal producers, and personnel from regulatory agencies, fire departments, transportation departments, the Extension service, parks and recreation departments, the USDA-Natural Resources Conservation Service, county roads and public works departments, and other first responders.

To minimize the neighbors' exposure to odors or dust, plan to locate the composting facility far from water resources and downwind of homes and other dwellings (Table 2). The facility should have all-weather access and clearance from underground and overhead utilities. The site also should not interfere with other operations or traffic.

Worker training should include:

- Educating the composting crew about operational procedures, such as those on working safely, receiving and staging dead animals properly, and maintaining biosecurity around carcasses
- Training the personnel involved with the on-site carcass composting on proper composting procedures
- Educating the operators of composting companies on how to produce a good organic soil amendment while protecting the environment through proper disposal of composted animal carcasses

Plan also to use personal protective equipment, including working suits, disposable overboots, disposable gloves, and respirators according to Occupational Safety and Health Administration (OSHA) standards for train-

ing, equipment maintenance and composting in confined spaces.

Consider the issues related to sanitizing the equipment such as shredders or grinders and handling, packing, storing, and conveying the carcasses to the composting site, as described in the Transportation section of the “General Considerations” chapter in this guide.

Plan to provide ample co-composting materials in the piles. A ratio of carbon to nitrogen (C:N) ranging from 25:1 to 40:1 must be maintained. This will provide the energy needed for the organic materials to decompose as well as minimize the production of odors during the active composting process. The weight ratio of some organic materials to carcasses is specified in Table 2.

Co-composting materials include organic materials such as sawdust (C:N~100), oats (C:N~60), barley straw (C:N~40 to 60), corn silage (C:N~40), poultry litter (C:N~10

to 30), ground corncobs (C:N~100), baled cornstalks (C:N~65), wheat straw (C:N~125), semi-dried screened cattle manure (C:N~20), hay (C:N~15 to 30), leaves (C:N~55), paper pulp or paper mill sludge (C:N~60 to 80), rice hulls (C:N~120), cotton gin trash (C:N~20 to 40), shrub trimmings (C:N~15), and bulking agents such as tree trimmings (C:N~70).

Plan to grind the carcasses and organic materials to speed the composting process and to increase the composting capacity.

The finished composted product of poultry, sheep, swine, and cattle carcasses can be applied on coarse-textured soils that are low in organic matter. The product will increase those soils’ organic matter and water-holding capacity. Determine the compost application rates according to crop needs, and perform a compost analysis that includes measuring the nitrogen, phosphorus, and potassium levels in the end product.

Table 2. Carcass composting specifications.

Consideration	Specification
Carbon sources to mortality ratio	1:1 (w/w) ^a 2:1 (w/w) ^b 4:1 (w/w) ^c
Compost site	Height: 3 ft ^d Distance: 300 ft ^e Slope: 1–3% ^f
Bin volume (ft ³ /1,000 lb)	Phase I: 150 Phase II: 450 Storage: 450
Lumber for bin walls (pressure treated)	Width: 2 ft Length: 6–8 ft Thickness: 1 in studs, 2 x 6 in
End product	Organic matter: 35–70% pH: 5.5–8.0 Bulk density: 40 lb/ft ³ Moisture content: 35–40%

^a For high C:N materials such as sawdust

^b For medium C:N materials such as litter

^c For low C:N materials such as straw

^d Height of composting site above the high water-table level

^e Setback distance from sensitive water resources (such as streams, ponds and wells)

^f To provide proper drainage and prevent ponding of water

Planning for outdoor windrow composting

When planning an outdoor windrow composting operation, identify a crowned location (highest point) on which to build the concrete pad or base on the compost site.

To control water infiltration, use low-permeability soil as the initial layer for the composting pile on a concrete pad or on a base.

Provide plastic liners that are 0.24 inch thick and:

- 12 feet wide and the length of the windrow for the composting base of small carcasses (poultry)
- 13 feet wide and the length of the windrow for the composting base of medium carcasses (sheep and swine)
- 15 feet wide and the length of the windrow for the composting base of large carcasses (hogs, sows, cattle, and horses)

Planning for in-house windrow composting

For an in-house windrow composting system, plan to establish and train rapid-response teams (with team leaders) within each poultry complex to oversee the sanitation, depopulation, and in-house composting processes.

Make sure that the poultry house ceiling is high enough for a loader to build a compost pile to about 4 to 6 feet tall. If it is not high enough, compost the carcasses infected with contagious diseases in an outdoor windrow system.

Plan to ventilate the in-house area because the composting piles will release large volumes of gases such as ammonia (NH_3) that are toxic.

If there is not enough litter in the poultry house, use other supplemental organic materials such as sawdust and woodchips. To calculate the amount of litter required for in-house windrow composting, use the formula in Figure 13.

To ensure proper in-house windrow com-

posting, use skilled compost laborer(s) and operators of skid-steer loaders, and consult with representatives of state and federal agencies, poultry producers, and composting experts. Table 3 shows the required number of skid-steer loaders and workers for each broiler house of euthanized poultry.

Plan to provide pressure washers, a tiller attachment, a hay fork, scoops, and midsize skid-steer loaders (1.25-1.5 cubic yard bucket), which are more suitable for in-house handling and conveying of materials.

Plan to keep the poultry house depopulated for 2 to 4 weeks after the in-house windrow composting ends to allow for testing to ensure that the composting windrow (if kept in the house) is free of pathogens and for sanitization of the poultry house.

Figure 13. Calculation of the minimum amount of litter or other organic material required for the carcass in-house windrow composting. (*Tablante and Malone, 2005*)

Given:

- Floor area of poultry house: 20,000 square feet (40 feet x 500 feet)
- Number of broilers in the poultry house: 25,000
- Amount of litter required per pound of carcass weight: 0.8 cubic foot
- Average weight of each broiler: 4 pounds
- Thickness of litter base: about 3 inches

Solution:

- Total carcass weight: 100,000 pounds (4 pounds x 25,000 broilers)
- Ratio of carcass weight to floor area: 5 pounds of carcass weight per square foot (100,000 pounds ÷ 20,000 square feet)
- Required depth of litter: 4 cubic inches of litter required per carcass (5 pounds of carcass weight per square foot x 0.8 cubic foot of litter per pound of carcass weight)
- Additional litter required for each additional inch of litter base: about 1,670 cubic feet (20,000 square feet ÷ 1 inch/12 inches /foot = 1,667 cubic feet)

Table 3. Minimum loader and worker requirements to compost chicken from broiler houses. (*Tablante and Malone, 2005*)

Number of poultry houses	Number of skid-steer loaders	Number of workers
2	2	4
4	3	6
6	4	8
8	5	10

Planning for carcass bin composting

When creating a carcass bin composting operation, plan to locate an appropriate composting site as described in Table 2. Use new facilities such as poured concrete, pole construction, and hoop houses.

For low-cost options, use existing facilities such as machine sheds, corn cribs, or cattle sheds if their ceilings are high enough to allow the front-end or skid loader to lift and turn the compost in the composting site.

Use modular bins by building compartments in the bins, which will increase the capacity and efficiency of the bin composting.

Enclose the bins on three sides, leaving an opening wide enough to accommodate a front-end loader.

Plan for the primary (Phase I), secondary (Phase II), and storage (Phase III) bin volumes as prescribed in Table 2.

Outside windrow composting: Procedures for Phase I

For outside windrow composting, the composting site must be fenced to prevent access by livestock and scavenging animals.

Create a moisture barrier by spreading appropriate plastic liners on selected crushed and compacted rock, particularly if the water table is high or the site drains poorly.

For the composting process, use the appropriate grinding or milling equipment, including tub grinders, tub mills, hammer mills, continuous mix pug mills (machines in which materials are mixed, blended, or kneaded into a desired consistency), and vertical grinders. Similarly, use a bale processor to grind baled cornstalks, hay, straw, and grass.

Grind the co-composting materials for 15 to 45 minutes to provide enough air space between the compost materials. If a large crusher (able to handle more than 8,000 pounds per

day) is available, grind the carcasses to 1 to 2 inches along with the organic materials to provide uniform raw materials for the composting process.

Do not mix the organic materials for more than 5 minutes. Prolonged mixing decreases the particle size because of breakage, reducing the air spaces in the compost pile.

To produce homogenous materials for the composting operations, use suitable batch mixers (either truck- or wagon-mounted), including mixers with augers, rotating paddles, rotating drum mixers, or slats on a continuous chain.

Reduce the amount of fresh organic materials needed by mixing in separated solids from liquid manure or the finished composted carcasses from a previous composting batch (up to 50 percent by volume of the co-com-

posting materials). These can be used to recycle the heat and bacteria in a new windrow. The handling volume of the finished compost is reduced if it is partially recycled as a co-composting material for a new windrow.

Use skid-steer or front-end loaders to:

- Build and maintain the composting piles for forming windrows
- Lift and place the carcasses on the compost piles
- Mix the co-composting materials properly
- Cover the carcasses
- Move the compost as needed for aeration
- Feed a compost screener or shredder with the finished product (Figs. 6 and 7)

Use organic materials and bulking agents to build the windrow pile for small, medium,

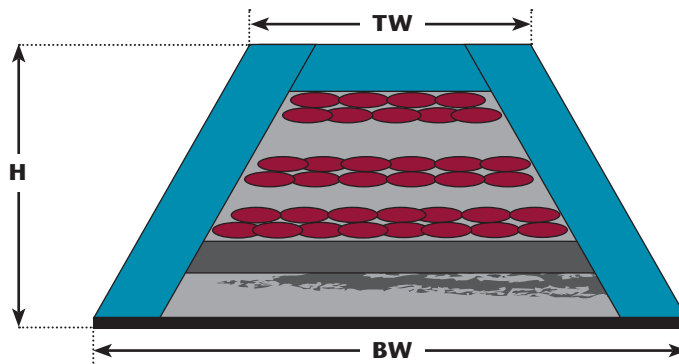
large, or very large carcasses as shown in Figures 14, 15, and 16.

Do not stack medium-sized, large, or very large carcasses on top of one another. Do not stack small carcasses more than the thickness specified in Figure 14 without an appropriate layer of co-composting materials between two carcasses.

Cover the compost pile with a biofilter layer during Phase I (active) and Phase II (curing) of composting to reduce odors, preserve moisture, and prevent access by insects and birds (as the most important carriers of disease microorganisms). This layer will prevent the transmission of many microorganisms from the carcasses to livestock or humans.

A minimum biofilter depth of 0.5 foot is recommended.

Figure 14. Cross-sectional dimensions (not to scale) of a trapezoidal windrow for small carcasses (such as poultry). (Source: A. Kalbasi and S. Mukhtar (2006), *Biological and Agricultural Engineering Department, Texas A&M University*)








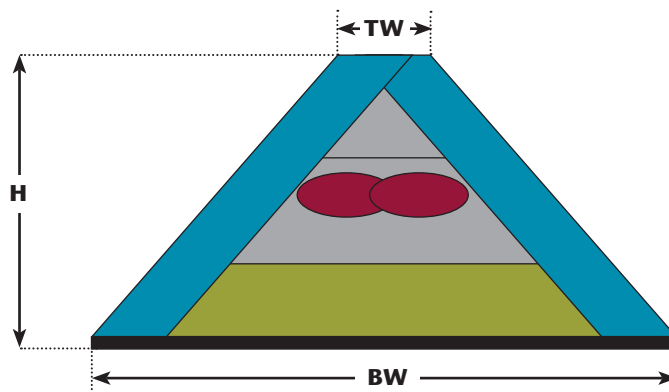





-  Plastic liner, 0.24 in thick, used as an impermeable layer under the composting materials
 -  Three layers of mixed organic materials containing plant and animal sources (such as litter) to enrich bacterial activities; they are used as a base layer and between carcass layers, each up to 1 ft thick
 -  Layer of bulking agent, such as wood chips, 0.5 ft thick
 -  Layers of poultry carcasses, each layer up 1 ft thick containing more than one row
 -  Biofilter layer containing mainly plant organic materials on top and two sides of the windrow, up to 1 ft thick
- Bottom width (BW) = 15 ft (3.6 m); top width (TW) = 5 ft (1.5 m); height (H) depends on the thickness of carcasses

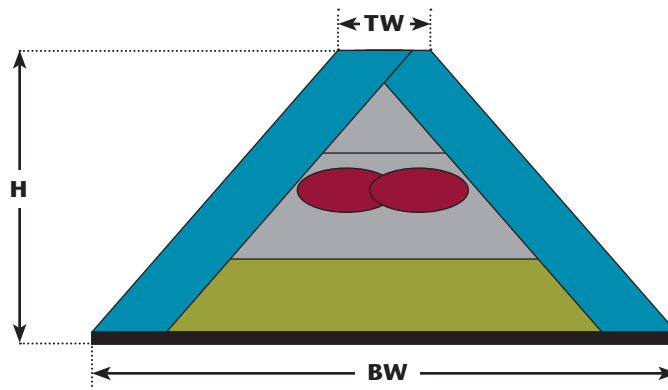
Figure 15. Cross-sectional dimensions (not to scale) of a trapezoidal windrow for medium carcasses (such as sheep and swine). (Source: A. Kalbasi and S. Mukhtar (2006), *Biological and Agricultural Engineering Department, Texas A&M University*)








-  Plastic liner with thickness of 0.24 in used as an impermeable layer under the composting materials
-  Two layers of mixed organic materials containing plant and animal sources (such as litter) to enrich bacterial activities; they are used as a base layer and top of carcasses, 1.5 and 1 ft thick
-  Layer of moistened bulking agent, 1 to 1.5 ft thick
-  Layer of medium-sized carcasses
-  Biofilter layer containing mainly plant organic materials on top and two sides of the windrow, 1 ft thick

Bottom width (BW) = 13 ft (3.9 m); top width (TW) = 1 ft (3 m); height (H) depends on the carcass thickness

Figure 16. Cross-sectional dimensions (not to scale) of a trapezoidal windrow for large (hogs and sows) and heavy (cattle and horses) carcasses. (Source: A. Kalbasi and S. Mukhtar (2006), *Biological and Agricultural Engineering Department, Texas A&M University*)



-  Plastic liner, 0.24 in thick, used as an impermeable layer underneath composting materials
-  Two layers of mixed organic materials containing plant and animal sources (such as litter), 2 and 1 ft thick, respectively, used to enrich bacterial activities are used as a base layer and top of carcasses
-  Layer of moistened bulking agent, 1.5–2 ft thick
-  Layer of large or heavy carcasses
-  Biofilter layer containing mainly plant organic materials on top and two sides of the windrow, 1 ft thick

Bottom width (BW) = 15 ft (4.5 m); top width (TW) = 1 ft (3 m); height (H) = depends on the carcass thickness

Use self-propelled or towed windrow turners to adequately mix the ground carcasses and organic materials during Phase II of the intact outdoor windrow composting processes. Windrow turner capacities range from 800 to 3,000 tons per hour.

To haul water or other effluent and spray it on the windrows, use pump trucks, honey wagons with pumps, or tanker trucks with side-delivery flail-type spreaders.

Maintain the moisture content in the carcass compost pile in a range of 40 to 60 percent (wet basis). Use analytical equipment or the hand-squeeze method to test the windrow moisture content.

If the compost moisture content in Phase I is low (less than 40 percent) and the pile temperature is very high (150 °F), rake back the compost pile biofilter cover (up to 1 foot) and add enough water (see the hand-squeeze method) to bring the compost moisture level to nearly 50 percent.

The hand-squeeze method

Squeeze a handful of compost material firmly several times to form a ball. If the ball crumbles or breaks into fragments, the moisture content is much less than 50 percent. If it remains intact after being gently bounced three or four times, the moisture content is nearly 50 percent. If the ball texture is slimy with a musty, soil-like odor and liquid squeezes out, the moisture content is more than 50 percent.

If the carcasses are infected with diseases that can be transmitted to humans, personal protective equipment must be worn.

If liquid begins to leach out of the pile, spread an absorbent organic material such as sawdust around the pile.

If the compost temperature does not rise to expected levels within the first 2 weeks of composting, evaluate the initial pile formulation for proper C:N ratio (30:1) and the mixture of co-composting materials and carcasses.

Control water run-on to and runoff from the composting site. Divert all runoff from nearby animal production facilities and treat it through a vegetative filter strip or infiltration area.

For non-zoonotic agents, use disposable gloves to handle and test the temperature, moisture, and odor of the pile.

To monitor and record the physical and chemical properties of the composting system, provide the necessary instruments and supplies, including long-stemmed thermometers, pH meters, bulk-density testing devices, odor-testing materials (resealable plastic bags), and log books to record the composting activities and status along with test results.

Insert a temperature probe carefully and straight down into each quadrant of the pile to

allow daily and weekly monitoring of internal temperatures at depths of 10, 20, 30, and 40 inches after stabilization during Phases I and II of composting. Use the average to represent the compost pile temperature.

Maintain the air spaces in the windrow piles by turning (or lifting and dropping) the compost materials rather than pushing them to a new space.

Use windrow turners or bucket loaders and rotating-tiller turners (rototillers) to turn the windrow composting piles. If a bucket loader is used, the bucket contents should be discharged in a cascading manner rather than dropped as a single mass, for greater pile aeration.

After the carcass compost has matured, recycle or store the finished product to begin another pile afterward or, where appropriate, land-apply the finished product as a soil amendment or as a fertilizer.

Odor evaluation for compost

To evaluate the odor of the compost pile during the Phase I, place two handfuls of material in a resealable plastic bag. Close the bag and let it sit for an hour, or place it in sunlight for 5 to 10 minutes.

If immediately after the bag is opened, the compost has a musty soil odor (dirt cellar odor), it is ready for Phase II.

If the compost has a sweetish odor (such as like that of slightly burnt cookies), the decomposition process needs a couple more weeks to mature.

If the compost odor is like that of rotting meat or flesh, if it is overpowering, reminiscent of manure, or if it has a strong ammonia smell but less of a manure odor, the compost process is not complete (mainly because the internal temperature is less than 130 °F and the pile is anaerobic) and requires more organic materials and aeration for temperatures to rise to acceptable levels.

In-house windrow composting: Procedures for Phase I

Begin the procedures for in-house windrow composting by making a list of the available supplies, equipment, and materials. Collect site-specific data such as the age of the birds, the depth of the litter in each part of the house, the moisture and condition of the litter, the location of the carcasses, the access to the end doors for delivery of the co-composting material and compost removal, the ability to turn the piles, the poultry house dimensions, the ceiling height, and the number and average weight of the carcasses.

Unless specified otherwise in this procedure, follow the processing steps regarding organic material preparation, mixing, pile formation, and turning as described in the section on outside windrow composting.

Before euthanizing the birds, let them consume all the feed, then turn off the fans, close the curtains, and raise the feeders and waterers in the barn. Preparations must be made in a

manner that does not create an animal welfare issue.

Provide a minimum of 1.5 pounds of litter (at a density of 30 pounds per cubic foot) per pound of bird: Place 1 pound of litter per pound of bird in the layer, and use the remaining 0.5 pound for the cap and cover.

Create a windrow base of litter about 1 foot thick with a 10- to 12-foot-wide base. Scoop the dead birds with a loader and lay them on top of the base. Spread the carcasses evenly with a rake or pitchfork.

Repeat the layering procedure of litter and poultry carcasses as described in Figure 14. If the poultry house is not tall enough for a 6-foot-high windrow, make only two layers to keep the pile less than 4 feet tall.

To construct windrows in free-span houses, till the caked litter in the house to form a good base 4 to 6 inches deep for the windrow. Avoid

compacting the windrow base with equipment traffic. Use any remaining litter to cap the windrow.

Use a tiller attached to a skid-steer loader or tractor-driven power take-off (PTO) vehicle to shred the carcasses. To ensure adequate shredding, make at least two passes of the tiller with sharp tines at a high rotational speed. An alternative to shredding is to crush the carcasses under the rubber tires of a skid-steer loader.

Every day during composting, monitor and record the temperatures of the compost pile. Measure the temperature at the outside edges and from inside the center of the pile every 20 feet along the length of the windrow. Turn the windrow pile when its temperature drops below about 125 °F (52 °C) or 10 to 14 days after the composting process begins. After turning the windrow, the temperature should equal or exceed that in an unturned windrow.

If the windrow temperature peaks and drops

below 105 °F within the first 2 weeks, aerate the compost by slowly lifting it with a hay fork along the length of the pile. This method does not disturb the cap but allows oxygen into the pile. If no fork is available or space is limited, the pile can be completely turned and recapped.

About 3 to 4 weeks after the windrow is built, inspect the material in the pile to evaluate the decomposition of the carcasses. At this stage, the carcasses should be reduced to bones and feathers, with little flesh remaining.

Inspect the decomposition of all fleshy materials and sample and test the pile to verify that the targeted virus has been eliminated. After complete pathogen inactivation has been confirmed, move the pile from inside the poultry house to an outdoor location (after 6 weeks of composting) and store it for 2 to 3 weeks in a litter storage shed or another appropriate roofed site with an impervious base (plastic sheet) for additional curing.

Two new fact sheets provide details on in-house poultry composting have been published:

- *Guidelines for In-House Composting Poultry Mortality as a Rapid Response to Avian Influenza*, by the Virginia Department of Environmental Quality and Virginia Cooperative Extension
- *In-House Composting of Poultry Mortality due to Catastrophic Disease*, by the University of Maryland–College Park and the University of Delaware

Procedures for Phase I: Carcass bin composting

When building composting bins, determine their volume based on the amount of storage required and the specifications in Table 2 for Phases I and II. Build bin composters of any material (such as concrete, wood, and hay bales) that is structurally adequate to confine the compost pile material and resist lateral loads.

Simple, economical structures can be made by placing large, round bales end to end

to form three-sided enclosures or bins. These are sometimes called bale composters.

Locate the structure in a free space with (preferred) or without a roof and situate the structure so as to protect the pile from predators, pests, and precipitation runoff.

Build a 5-inch-thick impervious compacted or concrete floor with a weight-bearing foundation to accommodate the heavy machinery, to allow for all-weather use, and to

prevent the contamination of the soil and surrounding areas.

To improve accessibility during wet weather, build and pave the access ways (10 to 28 feet wide) to the primary, secondary, and storage bins with concrete, fly ash, or compacted crushed rock.

Build a concrete bin by using a concrete floor along with a poured bin wall 6 inches thick. The bin entrance should be at least 2 feet wider than the loading bucket.

The bins should be between 5 and 6 feet tall. Determine the width of the bins by the width of carcass-handling equipment. However, to ease pile handling and to minimize the bin construction costs, do not make the bins wider than 8 feet.

Design the bin front so that the carcasses need not be lifted above the door. Accomplish

this with removable drop boards that slide into a vertical channel at each end of the bin or with doors that split horizontally, whichever is more practical.

Design hinged doors to swing back flat against the adjoining bins and allow the doors to swing open by using removable hinge pins at both ends. Allow the top of the door to fold down for easier loading of the lower portion of the bin.

Before adding carcasses to a fresh bin, build a 1.5- to 2-foot-thick base (substrate) of co-composting material such as sawdust or a litter-shavings mixture, including up to 50 percent composted manure and straw.

Rake back 6 inches of the co-composting material and place the first layer of carcasses inside the bin. Leave a minimum base depth of 1 foot to absorb the carcass fluids and leachate

(runoff fluid). Surround and cover the first layer of carcasses with the co-composting material.

To ensure that the carcasses are subjected to peak temperatures, place them at least 8 to 12 inches from the sides, front, and rear of the compost bin. Spread the organic material so that it can be placed completely around each carcass and between the carcass layers.

Provide a 1-foot-thick layer of inactive materials (organic material with very low moisture and very low compaction) between the layers of carcasses to insulate and maintain the compost temperature.

Immediately after placement, cover the carcasses with a 1-foot-thick layer of biofilter

materials. Check the carcasses daily to ensure that they are surrounded by the cover material. Continue to cover any exposed parts to control leachate or odors that attract flies, vermin, or predators.

In a farrowing operation, place the fetal and nursery pigs in bins separate from the sows; these pigs require less composting time.

Alternatively, if a sow has been in a bin for a few weeks, finish by filling it with baby pigs that may require only a couple of months before the turning process.

In a log book, record the bin number, date, time, and ambient and compost temperatures every day.

Procedures for Phase II: Outdoor windrow composting, in-house windrow composting and carcass bin composting

In Phase II of the carcass composting process, add moisture to the partially composted materials to reheat and reactivate the compost pile and to obtain an acceptable end product.

After moving the pile to the secondary storage area, add moisture if necessary and cover the compost pile with a minimum of 4 inches of co-composting materials. This will insulate the pile, reduce the potential for odors, discourage predators, and ensure the decomposition of the remaining carcass parts.

The composted finished product can be identified by a brown color (similar to humus) and a faint or lack of unpleasant odor upon pile turning.

Commercial stability tests for odor concentrations, carbon dioxide production, oxygen consumption rate, NH_3 concentration, color, and seed germination are available to confirm that the compost is suitable for land application.

Table 4. Personal protective equipment guidelines for composting.

Nature of work	Mask/respirator ^{a, b, c}		Protective clothing ^a	Eye/hearing protection ^{a, c}	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Direct handling of contaminated material	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Impermeable to liquids; consider based on heat situation	Eyes: Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles Hearing: Consider disposable earplugs if necessary	Gloves: Heavy duty (15–18 mil) chemical resistant gloves that can be disinfected or disposed	Feet: For workers handling carcasses, steel toe/steel shank waterproof boots; for others, steel-toed work shoes or boots Head: Hard hat
No direct handling of contaminated material	None recommended	None recommended	Protective coveralls	Eyes: Safety eyewear, if needed Hearing: Earplugs or muffs if working around noise hazards	Work gloves if necessary	Feet: Steel-toed work shoes or boots Head: Hard hat

^a See www.safetysupplyequipment.org for a list of vendors from OSHA.

^b For information on a full respiratory protection program, see www.osha.gov/SLTC/respiratoryprotection/index.

^c Regulations governing use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the Safety section of this guide.

Diseases of concern

In composting, the diseases of concern include those caused by viruses, bacteria, and prions.

Viruses and non-spore-forming bacteria: Composting is an effective method of eliminating viral and non-spore-forming bacteria. Precautions must be taken to prevent inhalation of airborne pathogens.

While the carcasses are being transported and handled on site, the use of personal protective equipment is essential for worker safety. Under proper conditions, these types of diseases can be inactivated by the composting method.

Diseases include Q fever, foot-and-mouth disease, vesicular stomatitis, Rift Valley fever, brucellosis (*B. melitensis*, *B. abortus*, and *B. suis*), rinderpest, contagious bovine pleuro-

pneumonia, glanders, Japanese encephalitis, African swine fever, classical swine fever, highly pathogenic avian influenza, and tularemia.

Spore-forming bacteria: Any bacteria that will form endospores should not be composted because the temperatures will not be high enough to inactivate this type of bacteria.

Diseases include anthrax.

Prions: Extremely high temperatures are necessary to destroy prion-infected carcasses. Carcasses suspected of contamination with prion diseases should not be composted because the temperatures reached will not be high enough to inactivate these agents.

Diseases include bovine spongiform encephalopathy, chronic wasting disease, and scrapie.

Notes on safety

Heat stress: See the guidelines on heat stress in the Safety and Biosecurity section in the General considerations chapter of this guide.

First aid: First aid should be available to the employees at all times.

Safety observers: Movement of heavy equipment is dangerous; use caution and a

safety observer.

Specialized equipment: Grinders and crushers are sometimes used in composting operations. Use care when near this dangerous equipment.

Watch for loose or dangling clothing, equipment, or hair when working around this equipment; use a safety observer.

Of paramount importance in preventing diseases from spreading from the compost site is the control of scavenging animals. Insects, birds, and other animals may come into contact with diseased animals and can become vectors, spreading the disease outside the site or containment area.

Carefully follow the engineering guidelines for compost sites to prevent easy access by vermin to contaminated material.

The area on site where animal carcasses are being deposited should be closed to all nonessential vehicles and personnel. All other

vehicles should be kept clear of the area accepting animal carcasses.

Equipment and truck drivers should remain in their vehicles while on the composting site; provide another set of personnel on the ground to open tailgates and unload carcasses.

Decontamination of vehicles and any contaminated personnel must occur before the vehicles leave the disposal site. For more information on these procedures, see the Safety and Biosecurity section of the “General Considerations” chapter in this guide.

Groundwater pollution

Before beginning any composting work, it is essential that you coordinate closely with State and local health and public works authorities.

State, county, and local regulations differ on the distances that composting sites can be located away from bodies of water, the groundwater table, and other natural features.

Soil pollution

No soil pollution concerns are associated with composting of contaminated animals unless the composting sites are uncontrolled or inadequately engineered.

Some tissue may remain after the composting process. This tissue can be ground

Your State and local health and public works authorities can provide guidance on these regulations.

Nearby landfill operators may be able to provide information on the depth to groundwater tables and on the appropriate points of contact in the State and local agencies having jurisdiction over any burial or composting activity.

and disposed of in landfills as solid waste in accordance with State and local solid waste regulations.

All waste will be monitored and tested before shipment of potentially dangerous materials.

Air pollution

There are no notable emissions for the composting methods described if the guidelines in this manual are followed carefully.

The air-pollution concerns associated with

composting are limited to the on-site workers, who will need personal protective equipment to minimize their exposure to airborne or aerosolized agents.

Composting costs

The cost breakdown relating to composting destruction follows the category definitions in the “General Considerations” chapter of this guide. Figure 17 shows the components of direct and indirect costs.

For specific indirect cost items, see the “General Considerations” chapter of this guide.

Direct costs

The direct fixed cost of composting carcasses depends on the facility’s capacity. The initial investments for two major carcass facilities—windrow composting and bin composting—differ dramatically. Table 5 shows the initial investment and direct fixed cost estimates for windrow composting with an annual capacity of 10,000 tons per acre. Table 6 shows the direct-variable cost estimates of on-site composting.

Figure 17. Components of direct and indirect costs for composting operations.

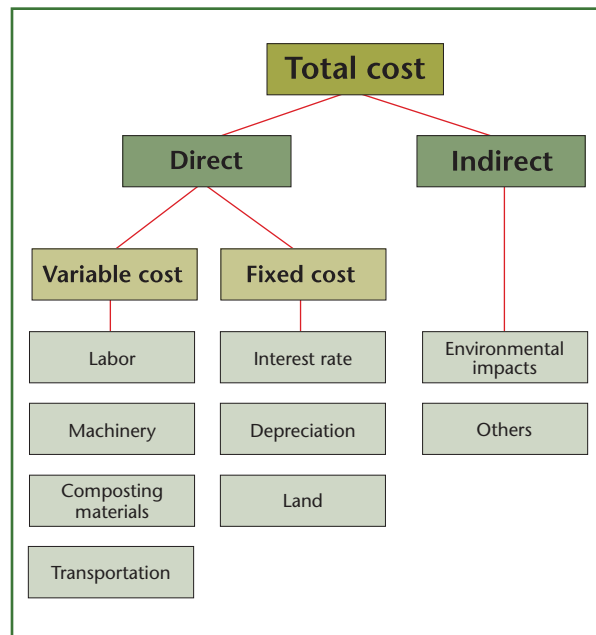


Table 5. Initial investment and annual direct fixed cost estimates of windrow composting with an annual capacity of 10,000 tons per acre.

Investment item	Price adjustment (2002, \$)	Life expectancy (years)	Annual fixed cost (2002, \$)
Land			
Land ^a	1,618		97
Sediment ^b	705	20	78
Fencing (\$6.75/ft) ^c	7,353	20	809
Subtotal	9,676		984
Surfacing			
Grading compaction	6,589	20	725
2 in. asphalt	82,096	10	13,135
4 in. asphalt	94,727	10	15,156
6 in. asphalt	189,453	15	23,997
Subtotal	372,865		53,013
Equipment and machinery^c			
Water pump	587	10	94
Thermometer	261	10	42
Scale	19,572	20	2,153
Front-end loader	146,135	10	23,382
Compost turner	168,316	10	26,931
Screening system	87,616	10	14,018
Shredding system	118,669	10	18,987
Subtotal	541,156		85,607
Total investment cost	923,697		139,604

Source: "A cost analysis of municipal yard waste composting," by Mitch Renkow, Charles Safley and Jeff Chaffin, North Carolina State University. 1993. <http://www.p2pays.org/ref/12/11875/>

^aDollars per acre ^bDollars per linear foot ^cDollars per unit

Note: The annual interest rate is assumed to be 6 percent.

Table 6. Estimates of direct variable cost items of on-site composting of animal carcasses.

	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
Estimated average variable cost per carcass					
Labor	\$18.88	\$6.74	\$3.17	\$0.14	\$1.83
Equipment	\$23.57	\$8.42	\$4.20	\$0.19	\$2.51
Composting material (sawdust)	\$6.10	\$2.17	\$1.09	\$0.05	\$0.63
Permitting	n/a	n/a	n/a	n/a	n/a
Transportation	n/a	n/a	n/a	n/a	n/a
Average variable cost per carcass	\$48.55	\$17.33	\$8.46	\$0.38	\$4.97

Estimated average cost per ton					
Labor	\$50.34	\$50.71	\$47.65	\$47.50	\$47.49
Equipment	\$62.84	\$63.29	\$63.20	\$63.00	\$65.23
Composting material (sawdust)	\$16.28	\$16.28	\$16.33	\$16.28	\$16.28
Permitting	n/a	n/a	n/a	n/a	n/a
Transportation	n/a	n/a	n/a	n/a	n/a
Average variable cost per ton	\$129.46	\$130.28	\$127.18	\$126.78	\$129.00

Source: Livestock mortality and burial cost in 2002 by Sparks Companies, cited in the National Agricultural Biosecurity Center Consortium for Carcass Disposal (NABCCD) Working Group report

Figure 18. Formulas for estimating the direct variable costs of carcass composting.

If the hourly labor cost and equipment cost are \$10 and \$35, respectively, the formulas to estimate the **direct variable costs (DVC)** are

- **By number of carcasses:**

$$DVC = 48.55Q_{\text{cattle}} + 17.33Q_{\text{calves}} + 8.46Q_{\text{weaned hogs}} + 0.38Q_{\text{preweaned hogs}} + 4.97Q_{\text{others}}$$

Where Q_i is the total number of carcasses in animal category i .

- **By weight:**

$$DVC = 142.71W_{\text{cattle}} + 143.61W_{\text{calves}} + 140.19W_{\text{weaned hogs}} + 139.75W_{\text{preweaned hogs}} + 142.20W_{\text{others}}$$

Where W_i is the total weight in tons of animal category i .

(Figure continued on next page)

Figure 18. (Continued)

If the hourly labor cost and equipment cost are C_L and C_E , rather than \$10 and \$35, respectively, the formulas to estimate the **direct variable cost (DVC)** are

- **By number of carcasses:**

$$DVC = (1.89C_L + 0.67C_E + 6.10)Q_{\text{cattle}} + (0.67C_L + 0.24C_E + 2.17)Q_{\text{calves}} + (0.32C_L + 0.12C_E + 1.09)Q_{\text{weaned hogs}} + (0.01C_L + 0.01C_E + 0.05)Q_{\text{preweaned hogs}} + (0.18C_L + 0.07C_E + 0.63)Q_{\text{others}}$$

Where Q_i is the total mortality of animal category i .

- **By weight:**

$$DVC = (5.03C_L + 1.8C_E + 16.3)W_{\text{cattle}} + (5.07C_L + 1.8C_E + 16.3)W_{\text{calves}} + (4.76C_L + 1.8C_E + 16.3)W_{\text{weaned hogs}} + (4.75C_L + 1.86C_E + 16.3)W_{\text{preweaned hogs}} + (4.75C_L + 1.86C_E + 16.3)W_{\text{others}}$$

Where W_i is the total weight in tons of animal category i .

Besides labor, equipment, and composting material costs, disposal costs include the trans-

portation cost, which depends mainly on the distance that the animal carcasses are moved.

Definition and objectives

In a carcass rendering procedure, animal carcasses are broken down thermally and sterilized in a sealed and controllable container using pressurized steam; the process converts the carcasses into safe, nutritional, and valuable products.

The objective of rendering is to convert farm carcasses, except those infected with transmissible spongiform encephalopathy (TSE), into pathogen-free feed protein and other valuable end products while reducing the negative effects of the carcasses on people and the environment.

Carcass rendering separates the fat, protein, and water from a variety of dead animals and sterilizes the final products and byproducts, which include tallow, meat, bone meal, and wastewater.

Rendering should not be used for carcasses infected with TSE. These materials should be disposed of by incineration or alkaline hydrolysis.

Although carcass rendering occurs as dry or wet rendering, either in a batch or continuous flow mode, only dry rendering is discussed here. The processing steps for rendering are illustrated in Figure 1.

A rendering plant should process at least 60 to 70 tons of carcasses per day, assuming 20 working hours per day to justify the processing costs. Independent rendering facilities may not be able to process large numbers of animal carcasses. Storing the livestock carcasses on site could extend a facility's capacity.

The raw materials used by independent rendering plants include the relatively fresh

carcasses of cattle, pigs, goats, sheep, poultry, and other animals that perish during transport or natural disasters or because of animal diseases.

Improper carcass rendering can produce over- and under-heating. Although overheated products have lower feed values, they do not pose hazards to human health. Under-processing conditions will reduce the efficiency of the fat extraction and may generate contaminated products and byproducts that can spread diseases to soil, plants, animals, and people. The resulting health hazards or aesthetic concerns, such as odors, can reduce the quality of life and decrease property values near a rendering plant.

Proper rendering inactivates most biological contaminants except prions and hardy organisms. It also produces meat and bone meal at a volume of 20 percent of that of the raw carcasses.

Although the risk of spreading prions has been very low, feeding proteins of mammalian origin to cattle and other ruminant animals (such as sheep and goats) is prohibited. This feed rule has prevented emerging problems related to this issue.

The carcasses used for rendering are primarily ground to particle sizes ranging from 0.4 to 1.2 inches (10 to 30 millimeters). Larger particles would require much more time for their cores to reach the desired temperature.

The ground carcasses are fed at ambient temperatures into a horizontal and cylindrical cooking vessel equipped with a heating system (such as a steam-jacketed shell along with an agitator, a rotating steam-heated shaft and bundles, and rotating steam-heated disks). The carcasses are then rapidly heated to 212 °F (100 °C) at a steam jacket shell internal pressure of 40 pounds per square inch (2.8 bar).

The agitating and heating system converts the fat into a hot slurry that optimizes the heat transfer to the raw material. After most of the free moisture has evaporated, the temperature of the cooked material quickly rises to 245 to 285 °F (depending on the equipment design), which is maintained for at least 30 or 10 minutes, respectively. When the moisture content of the mixed materials falls below 10 percent, the resulting meal is deep-fried in hot fat.

Continuous dry rendering units are equipped with automatic controls for chop-

ping large particles and grinding and uniformly mixing the raw material. Revolving beater shafts facilitate the further breakdown of fatty tissues and maintain the amount of time and the temperature required for the cooking process.

The heating, cooking, and separation processes occur simultaneously, with no need for manual operation. Figure 2 illustrates two general views of the equipment used in a rendering plant.

Description of a continuous dry-rendering system

As shown in Figure 1, animal carcasses are received in temporary storage or raw material bins (1), conveyed by a raw material conveyor (2), and discharged across a magnet (3) to remove any ferrous metal contaminations.

A raw material grinder (4) reduces the raw material to a uniform particle size for handling and improved heat transfer in the cooking step. The ground raw material is fed at a controlled rate from a metering bin (5) into a continuous cooker (6).

The discharge is transported to a drainer conveyor (7). The drainer conveyor separates the liquid fat from the solids, which are then conveyed from the drainer conveyor by a discharge conveyor (8).

In the discharge conveyor, the solids from the drainer conveyor are combined with the solids discharged from the settling tank (10)

and from the decanter-type centrifuge (11).

The solids from the discharge conveyor go to the screw presses (9), which reduce the fat content of the solids to 10 to 12 percent. The solids that bypass the screw presses in the form of pressed cake go to the pressed cake conveyor for further processing into meal.

The fat removed in the screw presses goes to the pressed fat conveyor (12), which separates the large particles from the liquid fat and returns them to the discharge conveyor. The fat from the pressed fat conveyor is pumped to the settling tank (10). Fat discharged from the drainer conveyor (7) goes into the settling tank (10).

In the settling tank, the heavier bone and protein particles settle to the bottom, where they are discharged by the screw conveyor (not shown) into the discharge conveyor (8). Liquid fat from the settling tank is pumped

into the centrifuge (11), which removes the residual solid impurities from the fat. The solids from the centrifuge go to the discharge conveyor (8). The clarified fat is transported for further processing or for storage as finished fat.

Water vapor exits the continuous cooker (6) through a vapor duct system that generally includes an entrainment trap to separate and return the entrained particles to the continuous cooker. The vapor duct system transports the vapor stream to an air-cooled condenser

(13), which condenses the water vapor. Other forms of condensers, such as direct contact or indirect shell and tube units, may be used.

Noncondensable gases are removed from the condenser by a noncondensable fan. Odorous gases generated at various points in the process are collected by a ductwork system and are transported along with the noncondensable gases from the condenser to an odor-control system (not shown) to neutralize odors.

Figure 1. A schematic diagram of machinery, equipment, and material flow in a continuous dry rendering process. (Adapted from a diagram courtesy of Dr. David Meeker of National Renderers Association, Alexandria, VA)

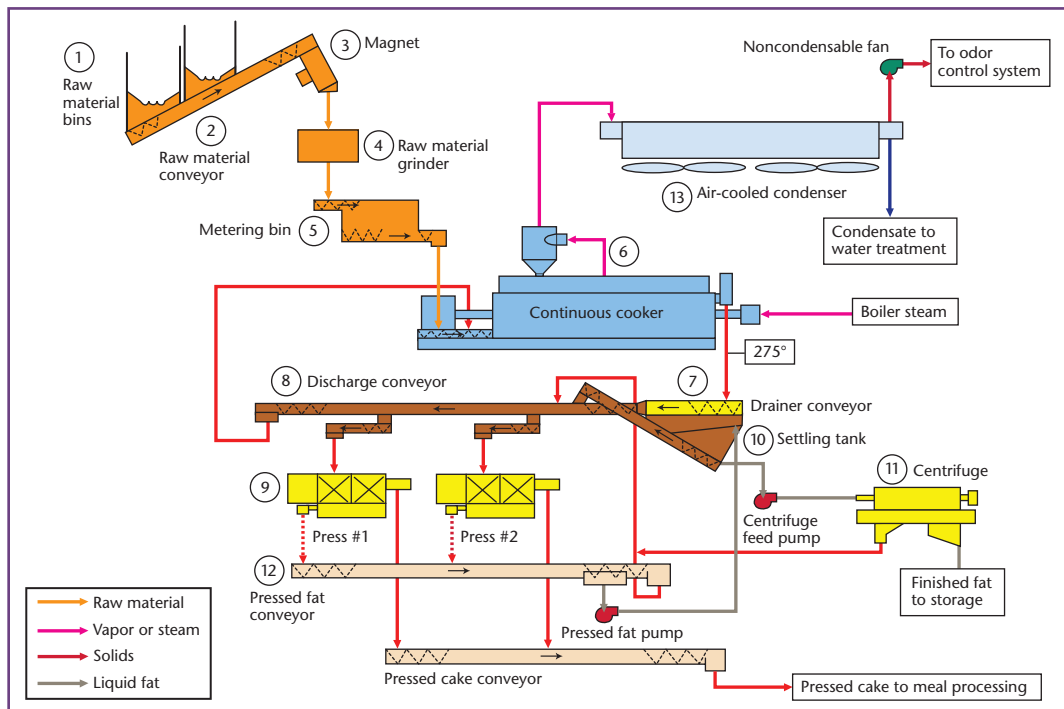


Figure 2. Two views of the equipment used for rendering processes. *(Courtesy of Dr. David Meeker of National Renderers Association, Alexandria, VA)*



Coordination and jurisdictional considerations

The decision to use rendering as a carcass-disposal option should be made jointly by the members of the appropriate technical group within the incident command structure established by the State or local authorities.

Local authorities should have an inter-county memorandum of understanding in place so that the carcasses can be easily transported through nearby counties to the nearest rendering facility.

If carcasses are to be transported out of the county for rendering, the incident command structure must consider the added problems of transportation safety and the possible contamination of other property.

Rendering should be undertaken only with the explicit approval by the institutions and

agencies that are competent to make determinations about protecting the integrity of the environment.

States have established orders of priority for carcass disposal, and the incident command structure must exhaust the higher disposal priorities before undertaking a rendering activity.

Converting a rendering plant into a “disposal rendering” plant may result in situations in which the incident command structure may be responsible for its decontamination or other forms of restitution before returning the facility. In addition, the incident command structure may have “bought” the plant by using it in such a manner.

Pollution and other property damage considerations

The exercise of police power gives governmental entities and agencies wide discretion in making decisions about carcass disposal to protect public health. However, the exercise of police power does not shield governmental entities against nuisance actions if the proper precautions are not taken. In the case of rendering, private firms engaged in rendering could also face legal challenges.

The two main problems posed by rendering are pathogen residue in the rendered product and disease spread when the carcasses are transported. If these problems occur, they could trigger a nuisance claim or lawsuit. Sovereign immunity may not be a defense to such an action. Private firms that trigger the spread of disease may be subject to both civil and criminal actions.

Planning considerations

Plan to coordinate with the managers of the rendering plants and make all the necessary arrangements such as the transportation and delivery of carcasses to the plant. The managers of the facilities under consideration must be willing to stop all other operations to render the “infected” carcasses. Table 1 lists the Web sites and contact information for seven rendering plants in the United States.

Consider the issues related to handling, packing, storing, and conveying the carcasses to the rendering plant as described in the Transportation section of the “General Considerations” chapter of this guide.

Although most rendering companies will charge a fee for pickup, plan to use their services for transporting large amounts of animal carcasses. Consider that a mass mortality event may require multiple trips between the

farm and the rendering facility. If the rendering company does not offer pickup service, or the farm is out of the range of the pickup service, alternatives must be considered.

Determine in advance whether the local rendering plants will accept infected or noninfected carcasses and, if so, the volume accepted per day.

Before any incident occurs, train the rendering plant personnel on carcass rendering, biosecurity, work safety issues, and the use of personal protective equipment based on the Code of Practice approved October 18, 2004, by North American Rendering Industry (<http://www.animalprotein.org>).

The fallen infected carcasses must be rendered under close veterinary supervision and surveillance.

Plan to minimize the risk of contamina-

Table 1. Some of the U.S. rendering plants that may accept contaminated carcasses.*

Company	Contact information
Baker Commodities Los Angeles, CA	James Andreoli 323-268-2801 jandreoli@bakercommodities.com
Darling International Irving, TX	Ross Hamilton 972-281-4461 rhilton@darlingii.com
Griffin Industries Cold Spring, KY	Robert Griffin 859-781-2010 Rgriffin@griffinind.com
Pascal Enterprises Dallas, TX	Mel Roshanraven 214-871-0300 melr@pascalenterprises.com
Sacramento Rendering Sacramento, CA	Michael Koewler 916-363-4821 michaelkoewler@aol.com
Anamax Corp. Green Bay, WI	Bob Pfeil 920-494-5233 bpfeil@anamax.com
Valley Proteins Winchester, VA	J.J. Smith 540-877-2590 jjsmith@valleyproteins.com

***Source:** David Meeker, Vice President, Scientific Services, National Renderers Association, 801 N. Fairfax St., Suite 205, Alexandria, VA 22314. Office: 703-683-2633, Fax: 703-683-2626. For information, visit http://www.renderers.org/Member_Directory/index.htm.

tion from carcass materials entering and of finished products exiting the processing plant by careful and precise inspection, an on-site chemical control program, proper housekeeping and sanitation of the facility/equipment, and inspection and decontamination of the load-out and transport trucks, cars, vessels, and containers.

Each carcass rendering plant should participate in the Animal Protein Producers Industry (APPI) program to test for *Salmonella* (pathogenic bacteria) in the meat and bone meal and have at least one person on site who has received training by the APPI or a certified trainer from an equivalent program.

All of the equipment of rendering plants that comes into contact with carcasses and their derivatives should be easily cleanable and washable.

Plan to control the harmful compounds, such as nitrogen and sulfur compounds, that may leach from wastewater of the rendering plant to groundwater.

Rendering 1 ton of carcass materials produces 1.5 to 2 tons of wastewater. Additional wastewater results from the washing and cleaning of rendering equipment. To decrease organic loads, mechanically aerate and oxidize the wastewater. Rendering plants have on-site wastewater treatment systems.

Add appropriate chemical flocculants, such as aluminum sulfate, to the wastewater to reduce the available phosphorus to permissible levels so the wastewater can be directly discharged or land-applied. This process converts the soluble phosphorus to insoluble phosphorus that can be removed by a settling process.

Keep unauthorized personnel and uninfected carcasses out of the plant area used for processing infected carcasses.

Perform rendering processes within 24 to 48 hours of an animal's death unless it is stored at a proper temperature (at least 40 °F, or 4.4 °C). It is easier to remove hides, hair, and paunch from fresher carcasses than from those that are highly decomposed and have reduced quality of fat and protein.

To ensure that the carcass materials are not processed too quickly, control and record the input rate relative to the size of the rendering vessel and control the temperatures in different locations in the vessel.

Properly maintain the carcass-receiving and finished-product sections as “dirty” and “clean” areas of the rendering plant, and keep them separated from each other. Prevent workers from moving from the receiving area

to the finished-product area unless they have taken cleaning and disinfection measures. Restrict equipment movement to keep contamination from the receiving area from moving to the finished-product area.

To produce rendered products with low levels of microorganisms, routinely sanitize the equipment and maintain the tools used on the processing lines and in the facilities. “Dirty” areas and all processing equipment should be sanitized with steam or suitable chemicals (see the EPA list of approved disinfectants in the “General Considerations” chapter) that produce sterilized animal meal and fat.

Prevent the drainage of liquids from dirty to clean areas to avoid contaminating the finished products and their transportation system. Direct the airflow within the plant from the finished-product area to the receiving area.

Ensure that the rendering plant has a deodorization system (including a condenser, chemical scrubber, gas burner, and biofilter) and implements procedures to monitor odors and investigate and resolve odor-related complaints.

Perform all of the prescribed rendering guidelines for cooking time and carcass temperature to produce high-quality tallow, meat, and bone meal that is free of pathogens. Monitor the cooking process periodically. A

good indication of cooking is a slight grittiness in and fibrous nature of the cooked carcasses (cracklings). Slippery cracklings indicate under-cooking; a lack of fiber indicates overcooking.

Ensure that the rendered products are tested for disease agents, and document that the rendering process has produced a safe product. If a disease agent has been identified in a finished product, dispose of it using an appropriate carcass disposal method.

Table 2. Personal protective equipment guidelines for rendering.

Nature of work	Mask/Respirator ^{a,b}		Protective clothing ^a	Eye/hearing protection ^a	Gloves ^a	Head/foot protection
	Zoonotic Agent	Non-zoonotic Agent				
Direct handling of contaminated material	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Impermeable to liquids; consider based on heat situation	Eyes: Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles Hearing: Consider disposable ear plugs if necessary	Gloves: Heavy duty (15–18 mil) chemical resistant gloves that can be disinfected or disposed	Feet: For workers handling carcasses, steel-toe/steel shank waterproof boots; for others, steel-toe work shoes or boots Head: Hard hat
No direct handling of contaminated material	As directed by the facility safety officer	As directed by the facility safety officer	As directed by the facility safety officer	As directed by the facility safety officer	As directed by the facility safety officer	As directed by the facility safety officer

^aSee www.safetysupply.com for a list of vendors from OSHA

^bFor information on a full respiratory protection program, see www.osha.gov/SLTC/respiratoryprotection/index.

^cRegulations governing use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the “General Considerations” chapter of this guide.

Diseases of concern

Viruses and non-spore-forming bacteria: Viruses and non-spore-forming bacteria are temperature susceptible. For viruses such as foot-and-mouth disease (FMD), precautions must be taken to prevent transmission of airborne pathogens. Non-spore-forming bacteria will be inactivated at continuous rendering temperatures.

Diseases for which rendering is an appropriate disposal option include African swine fever, highly pathogenic avian influenza, contagious bovine pleuropneumonia, brucellosis (*B. melitensis*, *B. abortus*, and *B. suis*), FMD, glanders, Japanese encephalitis, Q fever, Rift Valley fever, rinderpest, classical swine fever, tularemia, and vesicular stomatitis.

Spore-forming bacteria: Spore-forming bacteria are temperature susceptible. Those that are not destroyed can persist in the environment for long periods.

If it is not possible to render these carcasses immediately, they must remain intact to keep the spores from spreading to the external environment. The spore-forming bacteria will be inactivated and controlled if the uncut carcasses are properly rendered using the continuous method.

Diseases of concern include anthrax.

Prions: Prions (TSEs) are temperature resistant. Extremely high temperatures (more than 1,830 °F or 1,000 °C) for at least 15 minutes are needed to destroy prion-infected carcasses. The best method for destroying prion-infected animal carcasses is fixed-facility burning or alkaline hydrolysis. **Rendering is not an appropriate method of deactivation for prion-infected animal carcasses.**

Diseases include bovine spongiform encephalopathy, chronic wasting disease, and scrapie.

Once the safety of the rendered material has been established, the material may then be

buried, incinerated, composted, or applied as fertilizer.

Notes on safety

Heat stress: See the guidelines on heat stress in the Safety section of the “General Considerations” chapter of this guide.

First aid: First aid should be available to employees at all times.

Safety observers: Moving heavy equipment is dangerous. Use a safety observer with the authority to stop and correct unsafe conditions or operations.

Physical hazards: Grinders, crushers,

and cookers are used in rendering operations. Use care when near this dangerous equipment. Watch for loose or dangling clothing, equipment, or hair when working around this equipment; use a safety observer.

Ventilation: Although rendering equipment uses enclosed pressure vessels, the area surrounding the vessel should be adequately ventilated.

The facility or facilities accepting contaminated materials may be fixed-site facilities located on heavily trafficked public or private property; they will probably be on secondary streets next to major highways. The movement of animal materials contaminated with non-zoonotic organisms (those that do not transmit diseases from animals to people) onto these sites should be planned very carefully.

Although moving carcasses contaminated with non-zoonotic materials does not present a health hazard to the public, a significant effort must go into public awareness and public relations activities well before any carcasses are moved to the site.

A rendering plant should process 60 to 70 tons of carcasses per day, assuming 20 working hours per day to justify the processing costs. Do not use such facilities to dispose of

large volumes of carcasses contaminated with zoonotic agents; do not use them at all for destroying TSE-contaminated carcasses.

When handling infected animal materials, the rendering facility must discontinue all other operations in order to treat only the carcasses infected with hazardous agents. Continuous rendering rather than batch rendering should be used for the entire shipment of animal carcasses. This will prevent the vapors and materials generated during the rendering process from becoming airborne and spreading to the environment.

The rendering facility should have security measures in place to monitor and exclude animals and unauthorized personnel.

Allow no one to move between the two areas without thorough cleaning and disinfection. Do not allow equipment to move between the sides.

The air flowing through the plant must be directed from the finished side through to the receiving side.

Trucks being used to haul away the finished product may not come into contact with

the receiving side or any vehicles containing hazardous materials. Vehicles and personnel must be decontaminated before the vehicles leave the disposal site.

Groundwater pollution

Although discharge of effluent into a public sewer system and not into groundwater is anticipated, close coordination with State and local health and public works authorities is essential before any effluent can be released into a public sewer system.

Soil pollution

Continuously operating rendering facilities are nearly always fixed on site and will have coordinated with local health and public works authorities concerning releases. Before any discharge, confirm with the facility officials that all of the necessary permits are in place.

Soil pollution is not a concern unless the carcasses are allowed to accumulate on the surrounding grounds faster than the facility's processing rate. Unprotected decomposing car-

Some products of the rendering process may not be acceptable for further use. Such material can likely be disposed of in landfills as solid waste according to State and local solid waste regulations.

casses are a source of disease for people and animals and can pollute soil and surface water.

Do not allow the carcasses to accumulate at a rate faster than that which the facility can process. Piled carcasses outside the facility create a public awareness issue and can create human and animal health problems from disease vectors drawn to the carcasses. Decomposing carcasses also create an air quality issue.

Some onsite workers may need personal protective equipment to minimize their exposure to airborne or aerosolized agents. For more information, see the Safety section of this chapter.

Air pollution

Air emissions containing chemicals with unpleasant odors should be controlled at levels well below the odor threshold for chemicals of concern. Rendering facilities should have air emissions programs in place

Depending on the pathogen involved, there may be a stigma attached to the rendered products that makes them unacceptable for further use.

that comply with all Federal, State, and local regulations. Therefore, air emissions from the rendering process should be of minimal concern to outside personnel managing recovery operations from a catastrophic event.

The costs of rendering follow the general specifications in the Cost section of the “General Considerations” chapter. Figure 3 shows the components of the direct and indirect costs of rendering.

Table 3 lists direct variable costs for rendering carcasses. For indirect cost items, see the “General Considerations” chapter of this guide.

Figure 3. Components of direct and indirect costs for rendering operations.

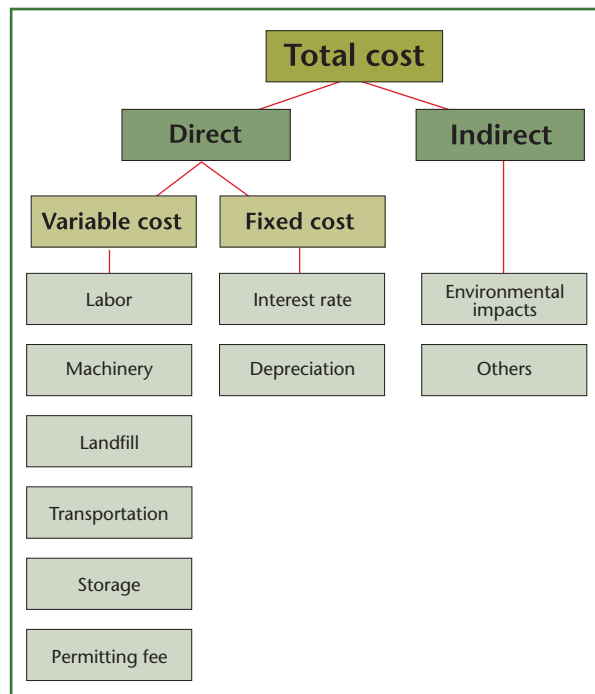


Table 3. Estimates of direct variable cost items for rendering animal carcasses.

	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
Estimated average variable cost per carcass					
Labor	\$11.38	\$4.04	\$2.02	\$0.09	\$1.17
Equipment	\$27.28	\$9.68	\$9.49	\$0.61	\$8.44
Landfill cost of disposing of residual	\$2.69	\$0.95	\$0.48	\$0.02	\$0.28
Permitting	n/a	n/a	n/a	n/a	n/a
Transportation	n/a	n/a	n/a	n/a	n/a
Average variable cost per mortality	\$41.35	\$14.67	\$11.99	\$0.72	\$9.89

Estimated average cost per ton					
Labor	\$30.35	\$30.35	\$30.35	\$30.35	\$30.35
Equipment	\$72.75	\$72.75	\$142.32	\$204.15	\$219.33
Landfill cost of disposing of residual	\$7.16	\$7.16	\$7.16	\$7.16	\$7.16
Permitting	n/a	n/a	n/a	n/a	n/a
Transportation	n/a	n/a	n/a	n/a	n/a
Average variable cost per ton	\$110.26	\$110.26	\$179.83	\$241.66	\$256.84

Source: Livestock mortality and burial cost in 2002 by Sparks Companies, cited in the National Agricultural Biosecurity Center Consortium for Carcass Disposal (NABCCD) Working Group report

Figure 4. Formulas to estimate the direct variable cost relating to rendering.

If the hourly labor and equipment costs are \$10 and \$25, respectively, use these formulas to estimate the **direct variable cost (DVC)**:

- **By number of carcasses:**

$$DVC = 41.35Q_{\text{cattle}} + 14.67Q_{\text{calves}} + 11.99Q_{\text{weaned hogs}} + 0.72Q_{\text{preweaned hogs}} + 9.89Q_{\text{others}}$$

Where Q_i is the total number of carcasses in animal category i .

- **By weight:**

$$DVC = 110.26W_{\text{cattle}} + 110.26W_{\text{calves}} + 179.83W_{\text{weaned hogs}} + 241.66W_{\text{preweaned hogs}} + 256.84W_{\text{others}}$$

Where W_i is the total weight in tons of animal category i .

(Figure continued on next page)

Figure 4. (Continued)

If the hourly labor and equipment costs are C_L and C_E , rather than \$10 and \$35 respectively, use these formulas to estimate the **direct variable cost (DVC)**:

- **By number of carcasses:**

$$DVC = (1.14C_L + 0.78C_E + 2.69)Q_{\text{cattle}} + (0.40C_L + 0.28C_E + 0.95)Q_{\text{calves}} + (0.20C_L + 0.27C_E + 0.48)Q_{\text{weaned hogs}} + (0.01C_L + 0.02C_E + 0.02)Q_{\text{preweaned hogs}} + (0.12C_L + 0.24C_E + 0.28)Q_{\text{others}}$$

Where Q_i is the total number of carcasses in animal category i .

- **By weight:**

$$DVC = (3.04C_L + 2.08C_E + 7.16)W_{\text{cattle}} + (3.04C_L + 2.08C_E + 7.16)W_{\text{calves}} + (3.04C_L + 4.07C_E + 7.16)W_{\text{weaned hogs}} + (3.04C_L + 5.83C_E + 7.16)W_{\text{preweaned hogs}} + (3.04C_L + 6.27C_E + 7.16)W_{\text{others}}$$

Where W_i is the total weight in tons of animal category i .

Besides the labor, equipment, and land-fill costs of disposing residuals, the variable

disposal cost includes transportation costs and permitting fees.

Definition and objectives

Alkaline hydrolysis of carcasses is a process by which heat and pressure dissolve and sterilize animal carcasses in a strong solution of sodium or potassium hydroxide. An alkaline hydrolysis system can completely decontaminate infected tissue.

The objectives of alkaline hydrolysis are to:

- Inactivate pathogens and prions such as transmissible spongiform encephalopathy (TSE)
- Convert dead animals into a sterile solution or dried material that has less potential for environmental pollution than before treatment

The ultimate goal of the alkaline hydroly-

sis process is to convert animal carcasses into environmentally safe materials while avoiding negative public perception.

This system costs less to operate than do other carcass disposal methods such as incineration. The mechanical components of this process are highly durable.

Alkaline hydrolysis can occur in fixed or mobile facilities. When choosing between these two types of facility for disposing of animal carcasses, several factors should be considered, including cost, transportation, agent suitability, environmental risk, disposal capacity, procedure speed, and the availability of resources (Table 1).

Table 1. Considerations for choosing an alkaline hydrolysis system.

Consideration	Fixed alkaline hydrolysis	Mobile alkaline hydrolysis
Application	Animal	Animal
Transportation concerns	Yes	No
Agents inactivated	Viruses, bacteria and TSE ³	Viruses, bacteria and TSE ³
Disposal capacity ¹	Low	Low
Environmental risk	Low	Medium
Regulatory restrictions	Low	Medium
Cost ²	Lower rent but higher operation cost	Higher rent but lower operation cost
Availability of resources	Low	Low
Procedure speed	High	High

¹ Animal mortality (tons): Low < 100 tons < Medium < 300 tons < High

² The initial investment of mobile alkaline hydrolysis is higher than that of fixed alkaline hydrolysis because of the higher rent cost of mobile facilities. However, the transportation cost of mobile alkaline hydrolysis is lower, thereby reducing the operation cost.

³ TSE = transmissible spongiform encephalopathy

Unless specified, the descriptions on the next few pages apply to both fixed and mobile facilities (Figs. 1, 2, and 3).

Figure 1. A tissue digester in a fixed alkaline hydrolysis facility. *(Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)*



Alkaline hydrolysis

Summary

Figure 2. A carcass digester in a fixed alkaline hydrolysis facility. *(Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)*



Figure 3. The crushable bone and teeth remaining from a carcass digester in a fixed alkaline hydrolysis facility. *(Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)*



General description

The method of the alkaline hydrolysis process to treat carcasses depends on the kind of contamination:

- To inactivate **microbial pathogens**, the carcasses must be heated to 212 °F and pressurized at 15 pounds per square inch for 3 hours.
- To destroy **TSE, including bovine spongiform encephalopathy**, the carcasses must be heated to 300 °F and pressurized at 70 pounds per square inch for 6 to 8 hours.

Alkaline hydrolysis processes occur in hot oil or in steam-jacketed, insulated, stainless-steel pressure vessels with automatic or manual control systems. The process breaks large molecules of organic matter into smaller molecules (amino acids, sugars, and fatty

acids). Destroyed during this process are all pathogens, including the protein coats of the viruses, the peptide bonds of the prions, and vegetative and sporulated bacteria.

The pH level of the treated material drops from 14 at the beginning of the process to about 11 at the end. The pH level at the end of the alkaline hydrolysis process highly depends on the total amount of operation time, the amount of fat in the carcass (a higher fat content can result in a lower pH), and other factors such as the buffering of the alkaline solution by the carcass.

The vessels used in the process may be equipped with devices to measure the weights of the carcasses, water and alkali powder, and to measure and control the temperature, pH, pressure, and the amount of time needed for steril-

ization. The mixed materials are agitated and heated consistently either by mechanical mixers or by steam and alkaline circulation systems.

Containers are provided for the bone pieces and indigestible materials such as cellulose, latex, and metal, which are separated from the final effluent. The wetted parts of the digester are stainless steel or a fluoropolymer such as Teflon, which can tolerate high temperatures and strong acidic or alkaline solutions.

Some materials are resistant to alkaline hydrolysis digestion, including bulk cellulose (such as paper, strings, undigested plant fiber, and wood shavings) and the inorganic content of the fecal matter associated with the carcasses. However, the process completely sterilizes these indigestible materials.

The carcass digestion process occurs in a completely sealed environment; very little gas is emitted into the air. Odors are released for a short period during carcass loading and unloading.

The biochemical oxygen demand (BOD) of the final effluent is very high because of the high concentrations of organic matter. The BOD may reach 0.58 to 0.83 pounds per gallon (70,000 to 100,000 milligrams per liter). It can be diluted by adding water or a low-BOD solution. It may be disposed of into the sewer system after local wastewater treatment authorities have been consulted.

The pH of the final liquid effluent should be reduced to about 9 by adding carbon dioxide or industrial acid (such as acetic acid) before land application.

Because the mobile alkaline hydrolysis units do not require that the carcasses be transported, the disposal process is considerably faster than for fixed facilities. However, it may not be possible to deploy these units into the field quickly for massive amounts of animal carcasses.

Coordination and jurisdictional considerations

The decision to use alkaline hydrolysis as a carcass disposal option should be made jointly by the members of the incident command structure established by local or state authorities.

Alkaline hydrolysis should be undertaken only with explicit approval by the institutions and agencies that are competent in making determinations about protecting the environment.

States have ranked preferred methods for carcass disposal, and the incident command

structure must use the preferred options before undertaking alkaline hydrolysis activities.

If the carcasses are to be transported to nearby counties for alkaline hydrolysis, the incident command structure must consider the added problems of transportation safety and contamination of other property. Local authorities should have an inter-county memorandum of understanding in place so that the carcasses can be easily transported to the nearest facility for alkaline hydrolysis.

Pollution and other property damage considerations

The exercise of police power gives governmental entities and agencies wide discretion in making decisions about carcass disposal to protect public health. However, the exercise of this power does not shield governmental entities against nuisance actions if the proper precautions are not taken.

The two main problems with alkaline hydrolysis are waste and odor, both of which

could trigger nuisance or other kinds of lawsuits. Sovereign immunity may not be a defense to such an action.

The decision to use alkaline hydrolysis must be made by the appropriate technical group within the incident command structure because injury to people or property could prompt suits similar to those based on nuisance.

Planning considerations

To operate successfully, alkaline hydrolysis units require more skill and expertise than do some of the other disposal methods, such as burial. At least two technicians per shift for each alkaline hydrolysis system must be trained and equipped for operation, safety, and biosecurity.

The personnel must be trained in safe handling of the animal carcasses, prevention of cross contamination, processing procedures, and decontamination of the equipment and the site during and after processing.

Issues that must be considered include those related to handling, packing, and storing the carcasses as well as conveying them to the alkaline hydrolysis (mainly fixed alkaline hydrolysis) site. For more information, see the Transportation section of the “General Con-

siderations” chapter of this guide.

Provide the appropriate amounts of sodium or potassium alkaline materials at about 10 percent of the carcass weight if it is in dried form or 20 percent of the carcass weight if it is in liquid form. If potassium hydroxide is used, the fertilizer value of the effluent will increase for land use.

Make sure that the vessels in the alkaline hydrolysis units can tolerate pressures of up to 100 pounds per square inch as recommended by the American Society of Mechanical Engineers. TSE-infected carcasses need a vessel pressure of no more than 70 pounds per square inch. Failure to comply with this rule may result in serious injury or death.

Provide diesel fuel for electricity generation and propane for steam production. Gener-

ally, 1 pound of steam is needed to sterilize 1 pound of carcass.

Sufficient water must be provided for the alkaline hydrolysis process, for steam generation, and for the washing and rinsing processes. Additional clean water must be supplied for safety as well as a contingency for spills of the caustic solutions.

Although soft water is needed to generate steam from the boiler, clean water from lakes, ponds, and rivers may be used for washing, rinsing, and using carcass hydrolysis. Any surface water may be used to dilute the final effluent. Table 2 shows the water consumption and final effluent production for alkaline hydrolysis of 1,000 pounds of carcasses.

Additional energy will be required if you plan to dehydrate the final effluent, which may contain up to 90 percent moisture. To mini-

mize the foaming problem during the dehydration process, reduce the pH of the effluent to about 6 by adding acid or carbon dioxide before drying it.

The dried weight (inorganic and mineral content) of the final effluent is about 2 percent of the total carcass weight and can be used for land application. Coordinate in advance and plan for the land disposal of the final effluent and solids with county and State regulatory agencies, USDA Natural Resources Conservation Service, and university Extension agronomists.

Plan to use the effluent directly as a substrate in an anaerobic digester and the solids (mainly bone and teeth, which can easily be crushed into a fine powder) as nitrogen and mineral sources in compost, or dispose of the effluent at a public landfill.

Table 2. Capacities and dimensions for fixed alkaline hydrolysis and mobile alkaline hydrolysis systems.

Alkaline hydrolysis options	Carcass digestion capacity ^a	Minimum installation area	Water consumption for 1,000 lb of carcasses ^b	Effluent production for 1,000-lb carcasses
Fixed alkaline hydrolysis	2,000–10,000 lb/8 ha	1,000 ft ²	60–240 gal ^b	120–300 gal
Mobile alkaline hydrolysis	4,000 lbs/8 ha	300 ft ²	60–240 gal ^b	120–300 gal

^aFor higher carcass capacities, it is better to use fixed and mobile alkaline hydrolysis units in a modular pattern rather than using units with higher capacities. This is because they can be operated sequentially; they use less energy and labor; and they are easier to manage than are larger units.

^bWater consumption will be minimized if the alkaline hydrolysis systems use more alkali and have a longer period of time for hydrolysis, and if the carcasses are shredded instead of intact and contain a highly agitated mixture of materials. More water is required for inactivating carcasses infected with TSE than for those infected with bacteria.

Fixed alkaline hydrolysis procedures

Follow the operator's manual for fixed alkaline hydrolysis systems. Assign two trained operators per shift, one to control and manage the carcass feeding, processing, and off-loading; the other to manage the boiler, generators, and the alkaline and water storage systems.

Operate the entire system for at least 1 hour without feeding in any carcass materials to ensure the proper and smooth operation of the processing equipment, including the steam generator, digester, mixer or circulation pump, and controlling devices.

For proper operation of a fixed alkaline hydrolysis system, make sure that the following processes occur in this order:

1. The carcasses are loaded into the hopper of the fixed alkaline hydrolysis system and their weights are measured by the built-in load cells.

2. The carcasses are fed into the vessel.
3. The feeders of the different materials add the required amount of alkaline solution and water to the vessel.
4. The vessels are properly sealed, and the heating process occurs in a completely enclosed environment.
5. The final effluent is tested for temperature, pH, and suspended solids before disposal.

Follow local and Federal guidelines, and adjust the pH, temperature, and biological oxygen demand of the solution.

Fixed alkaline hydrolysis units operate at high pressure. The equipment must be designed, maintained, and used in strict accordance with industrial and State guidelines. Failure to do so may result in an explosion, causing serious injury or death.

Mobile alkaline hydrolysis procedures

Assign skilled drivers with the appropriate driving permits to maneuver the mobile alkaline hydrolysis units. These drivers are in addition to the technicians required to manage the mobile alkaline hydrolysis process.

Plan to provide up to two truck trailers and an adjunct truck/feeder for mobile alkaline hydrolysis. The first trailer is for mounting the grinder and cooker/conveyor; the second is for an oil heater or steam generators along with a feed conveyor system. The truck/feeder carries an alkaline supply system. Truck containers will also be needed to collect

and transport the final effluent to a disposal site.

Propane and water tanks will be needed for a 400-horsepower on-site steam generator. Equip the mobile alkaline hydrolysis with an electric generator of sufficient horsepower to provide electricity for various functions of the unit and for illumination.

Store the final effluent in a container equipped with a heating system to prevent freezing during winter. To dispose of the end product, follow the procedures outlined in the fixed alkaline hydrolysis section of this guide.

Figure 4. Schematic of a mobile alkaline hydrolysis system with two auxiliary trucks.
(Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)

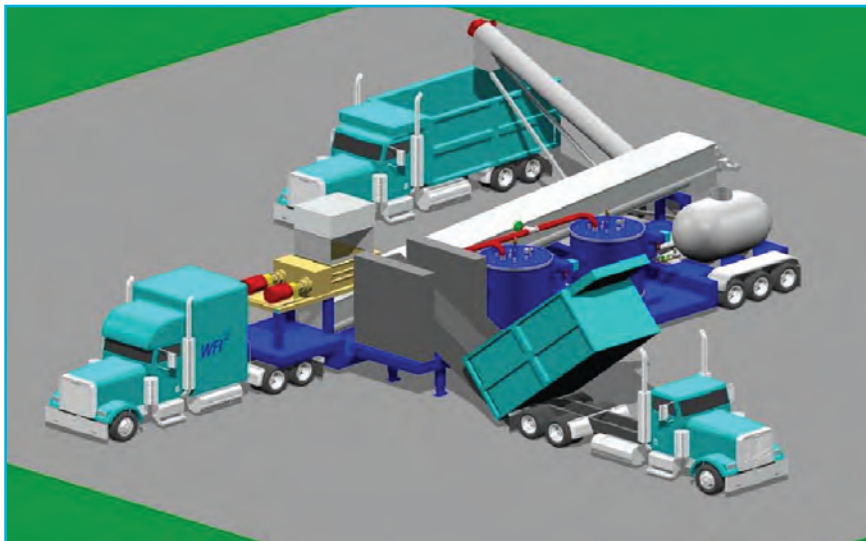


Figure 5. Schematic of a mobile alkaline hydrolysis system with the main components of high capacity of 0.5×10^6 pounds per 8 hours. (Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)

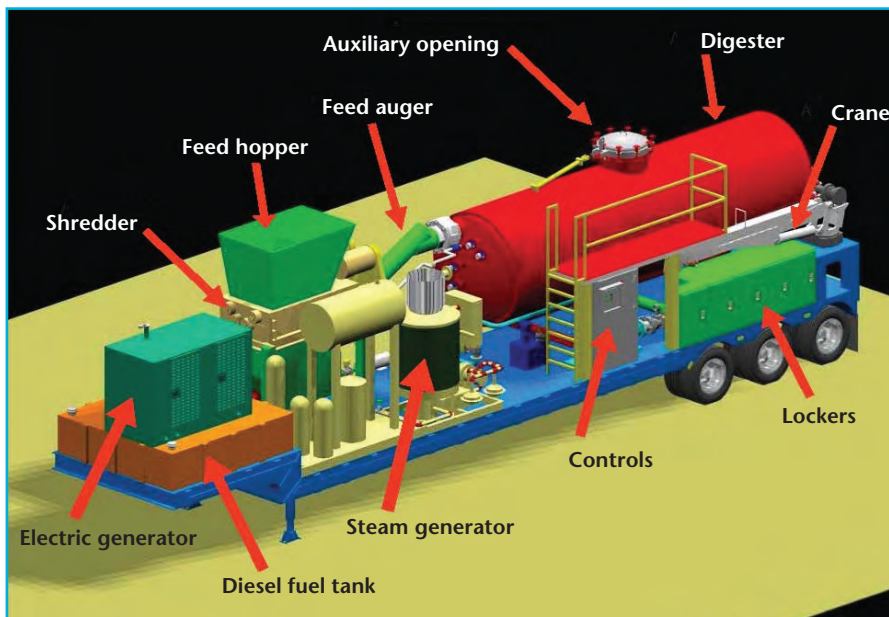


Figure 6. A mobile alkaline hydrolysis unit. *(Photo courtesy of Waste Reduction by Waste Reduction, Inc., Indianapolis, IN)*



Table 3. Personal protective equipment guidelines for alkaline hydrolysis.

Nature of work	Mask/Respirator ^{a,b, c}		Protective clothing ^a	Eye/hearing protection ^a	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Direct handling of contaminated material	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Impermeable to caustic liquids (such as Dupont Tychem® QC); consider based on heat situation	Eyes: Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles; face shield unless wearing a full facepiece respirator	Gloves: Heavy duty (15–18 mil) chemical resistant gloves that can be disinfected or disposed	Feet: For workers handling carcasses, steel-toe/steel shank waterproof boots; for others, steel-toe work shoes or boots Head: Hard hat
No direct handling of contaminated material, but potentially in contact with caustic chemicals	None recommended	None recommended	Overgarment impermeable to caustic liquids (such as Dupont Tychem® QC)	Eyes: Splash-proof, indirectly vented goggles; face shield	Same as above	Feet: Steel-toe work shoes or boots Head: Hard hat

^a See www.safetyequipment.org for a list of vendors from OSHA

^b For information on a full respiratory protection program, see www.osha.gov/SLTC/respiratoryprotection/index.

^c Regulations governing use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the “General Considerations” chapter of this guide.

Diseases of concern

Viruses and non-spore-forming bacteria: Alkaline hydrolysis is an effective method for eliminating viral and non-spore-forming bacteria.

Precautions must be taken to prevent inhalation of airborne pathogens. Personal protective equipment is essential for worker safety while the carcasses are being transported and handled on site.

Diseases for which alkaline hydrolysis processes are appropriate include highly pathogenic avian influenza, contagious bovine pleuropneumonia, brucellosis, foot-and-mouth disease, glanders, Japanese encephalitis, Q fever, Rift Valley fever, rinderpest, African

swine fever, classical swine fever, tularemia, and vesicular stomatitis.

Spore-forming bacteria: Alkaline hydrolysis is an effective method of disposal to control the spread of spore-forming bacteria.

Diseases of concern include anthrax.

Prions (TSEs): Alkaline hydrolysis is an effective method of disposal; however, material suspected of being contaminated with TSEs should be digested for no less than 6 hours.

Diseases include bovine spongiform encephalopathy, chronic wasting disease, and scrapie.

Notes on safety

Heat stress: See guidelines on heat stress in the Safety section of the “General Considerations” chapter of this guide.

First aid: First aid should be available to employees at all times.

Safety observers: It is dangerous to move contaminated plant and animal materials around large volumes of heated sodium hydroxide; **use a safety observer.**

Chemical hazards: Provide safety showers and emergency eyewash stations within 20 feet of each alkaline hydrolysis unit; caustic chemical burns are exceptionally hazardous and can cause irreparable damage to the eyes within seconds if not removed using copious

amounts of water **for at least 15 minutes.** Workers exposed to **any** amount of sodium hydroxide in their eyes should use the eyewash station and report to an emergency room.

Ventilation: Although alkaline hydrolysis reactors use enclosed pressure vessels, the area surrounding the vessel should be adequately ventilated.

Pressure vessels: Alkaline hydrolysis pressure vessels operate under high pressure and temperature. The risk of injury resulting from failure of a vessel is significant; follow all manufacturer directions carefully.

Groundwater pollution

Facilities accepting contaminated material may be fixed sites on heavily trafficked public or private property (such as a university campus). Moving non-zoonotic-contaminated plant or animal materials onto these sites should be planned carefully.

Although the movement of carcasses contaminated with non-zoonotic materials does not present a human health hazard, a significant effort must go into public awareness and public relations activities well before moving any carcasses to the site. Such facilities should not be used for disposal of large amounts of carcasses contaminated with

zoonotic agents or TSEs.

Vehicles and personnel must be decontaminated before the vehicles leave the disposal site. See additional material in the Safety and Biosecurity section of the “General Considerations” chapter of this guide.

If performed according to this guide, releasing effluent poses no threat to public health; however, a public relations plan should be in place before disposing of any effluent in a public sewer system. Disposal should be performed fully in conjunction with state and local health department authorities.

Environmental Impacts *Alkaline hydrolysis*

Control of effluent discharge

Close coordination with state and local health and public works authorities is essential before any effluent is released into a public sewer system.

Effluent should be tested and monitored before release into a sewage system. A pH

range of 10.0 to 11.5 is generally acceptable throughout the United States but may vary by jurisdiction. Effluent must be released at or above 374 °F (190 °C) to ensure that the effluent will not solidify.

Soil pollution

Alkaline hydrolysis poses no soil pollution concerns unless the effluent disposal is not controlled.

Some tissue, such as bone and teeth, will remain after the alkaline hydrolysis process is complete. This material can be ground

and disposed of in landfills as solid waste in accordance with State and local solid waste regulations.

All waste will be monitored and tested before shipment of potentially dangerous materials.

Air pollution

There are no notable emissions associated with alkaline hydrolysis. Gas release is not significant either as a health hazard to the public or as a nuisance gas.

Air pollution concerns are limited to the on-site workers, who will need personal protective equipment to minimize their exposure to the airborne or aerosolized agents.

Costs and issues

The cost breakdown relating to alkaline hydrolysis follows the general specifications from the “General Considerations” chapter of this guide.

The direct cost consists of fixed cost, including depreciation and financing costs, and variable costs for the use of labor, alkali, steam, sewer disposal, electricity, landfill materials, transport, maintenance, and repair.

The direct fixed cost and the variable costs depend on the facility’s capacity (Tables 4–6). For specific indirect cost items, see the “General Considerations” chapter of this guide.

Table 4. Initial investment and direct fixed cost estimates for a tissue digester with 2,000-pound capacity per cycle.

Initial investment ^a	Investment (2,000-lb digester capacity: 0.25 ton/hr)
Digester unit	\$400,000
Installation cost	\$200,000
Remodel sampling rooms and redirect pipes	\$225,000
Dehydration and odor control system	\$300,000
Total	\$1,125,000

Fixed annual cost	
Depreciation (20 years)	\$56,250
Interest (6%)	\$67,500
Total	\$123,750

^a **Source:** <http://www.co.larimer.co.us/boards/minutes/Aug03Min.htm>. There is no initial investment breakdown for a 10,000-pound digester.

Table 5. Estimates of direct variable costs by weight and mortality for a 2,000-pound digester.

<i>2,000-lb equipment</i>						
	Cost per ton	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
<i>Average weight per mortality (lb)</i>		750	266	133	6	77
Alkali	\$49.50	18.56	6.58	3.29	0.15	1.91
Electricity	\$1.00	0.38	0.13	0.07	0.00	0.04
Water	\$1.84	0.69	0.24	0.12	0.01	0.07
Steam	\$20.40	7.65	2.71	1.36	0.06	0.79
Sewer	\$1.65	0.62	0.22	0.11	0.00	0.06
Landfill	\$1.09	0.41	0.14	0.07	0.00	0.04
Repairs and maintenance	\$40.00	15.00	5.32	2.66	0.12	1.54
Labor	\$22.00	8.25	2.93	1.46	0.07	0.85
Transportation	n/a	n/a	n/a	n/a	n/a	n/a
Variable cost per ton	\$137.48					
Variable cost per carcass		\$51.56	\$18.27	\$9.14	\$0.41	\$5.30

Source: http://www.wr2.net/sales/cost_calculator.html

Table 6. Estimates of direct variable costs by weight and carcass for a 10,000-pound digester.

<i>10,000-lb equipment</i>						
	Cost per ton	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
<i>Average weight per carcass (lb)</i>		750	266	133	6	77
Alkali	\$49.50	18.56	6.58	2.99	0.15	1.91
Electricity	\$1.00	0.38	0.13	0.07	0.00	0.04
Water	\$1.84	0.69	0.24	0.12	0.01	0.07
Steam	\$20.40	7.65	2.71	1.36	0.06	0.79
Sewer	\$1.65	0.62	0.22	0.11	0.00	0.06
Landfill	\$1.09	0.41	0.14	0.07	0.00	0.04
Repairs and maintenance	\$40.00	15.00	5.32	2.66	0.12	1.54
Labor	\$0.92	0.34	0.12	0.06	0.00	0.04
Transportation	n/a	n/a	n/a	n/a	n/a	n/a
Variable cost per ton	\$116.40					
Variable cost per carcass		\$43.65	\$15.46	\$7.44	\$0.34	\$4.49

Source: http://www.wr2.net/sales/cost_calculator.html

Figure 7. Formulas to estimate the direct variable cost relating to alkaline hydrolysis.

The **direct variable cost (DVC)** using a tissue digester with a 2,000-pound capacity:

- **By number of carcasses:**

$$DVC = 51.56Q_{\text{cattle}} + 18.27Q_{\text{calves}} + 9.14Q_{\text{weaned hogs}} + 0.41Q_{\text{preweaned hogs}} + 5.30Q_{\text{others}}$$

Where Q_i is the total mortality of animal category i .

- **By weight:**

$$DVC = 137.48(W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

(Figure continued on next page)

Figure 7. (Continued)

The **direct variable cost (DVC)** using a tissue digester with a 2,000-pound capacity:

- **By number of carcasses:**

$$DVC = 43.65Q_{\text{cattle}} + 15.46Q_{\text{calves}} + 7.44Q_{\text{weaned hogs}} + 0.34Q_{\text{preweaned hogs}} + 4.49Q_{\text{others}}$$

Where Q_i is the total mortality of animal category i .

- **By weight:**

$$DVC = 116.40(W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

Definition and objectives

Digestion is a process that effectively preserves carcass materials under acidic conditions (using lactic or phosphoric acid) or uses fermentative bacteria to convert the materials to a mixture of primarily methane, carbon dioxide and water.

The objectives of digestion methods are to:

- Provide long-term storage for animal carcasses using acid preservation
- Prevent the growth of disease-causing microorganisms
- Anaerobically digest animal carcasses

and produce methane for energy generation

The ultimate goal of carcass digestion processes is either to preserve carcass materials under acidic conditions or to convert them to valuable products without creating health hazards or negative environmental impacts.

Three processes are used widely to digest carcasses: lactic acid fermentation, phosphoric acid preservation, and carcass biogas production. Some organic acids, such as acetic, formic, and propionic acids, are used to simply preserve the carcasses.

Table 1. Methods considerations for the digestion of contaminated animals.

Consideration	Lactic acid fermentation	Phosphoric acid preservation	Carcass biogas production
Transportation concerns	No	Yes	Yes
Agents inactivated	Viruses and bacteria (except TSE ⁴)	Viruses and bacteria (except TSE ⁴)	Viruses and bacteria (Except TSE ⁴)
Disposal capacity ¹	Low	Low	Low
Potential for environmental impact	Low	Low	Medium
Regulatory restrictions ²	Low	Low	Medium
Cost ³	Medium	Low	High
Availability of resources	Low	Low	Low
Procedure speed	Medium	High	Low

¹ Animal carcasses (tons): Low = < 100 t; Medium = 100–300 t; High = > 300 t

² The stringency of restrictions imposed by federal, state, and local agencies

³ Cost estimate (per ton): Low = < \$200; Medium = \$200–800; High = > \$800

⁴ TSE = transmissible spongiform encephalopathy

(Cutoff points may vary, depending on such factors as transportation, carcass load, animals affected, disposal facility, and level of security.)

The carcasses of several kinds of animals—cattle, swine, poultry, sheep, goats, fish, and wild birds—can be treated in the lactic acid fermentation, phosphoric acid preservation, and carcass biogas production systems. However, none of these options can inactivate abnormal proteins (prions).

In the lactic acid fermentation process, lactic acid bacteria are added to ground carcasses mixed with fermentable carbohydrates to produce lactic acid under anaerobic conditions. These bacteria may produce volatile acids, hydrogen peroxide, and antibiotic-like compounds that inhibit many bacteria.

In the phosphoric acid preservation process, phosphoric acid is added directly to ground or small pieces of carcasses. The phosphoric acid disrupts the membrane functions of the microorganisms, reducing their disease-causing activity.

Lactic acid fermentation and phosphoric acid preservation are called minor digestion or

stabilization processes. They cause little noticeable change in protein structure, whereas carcass biogas production changes the protein materials considerably.

Lactic acid fermentation and phosphoric acid preservation not only destroy or inactivate most disease-causing microorganisms, but also create an acidic pH that pickles the carcass materials, enabling them to be preserved safely for up to 4 months if they remain immersed at the proper chemical concentrations.

Carcass pickling is used for decontamination and long-term storage of dead poultry. Most rendering companies accept carcasses pickled in acid because they are ready for cooking and meal production.

Compared to cold storage, lactic acid fermentation costs less to preserve ground and homogenized poultry carcasses and transport them to rendering facilities. However, in lactic acid fermentation, the costs of the additives

cannot be recovered with any feed ingredient produced. Inoculants may include a fermentable carbohydrate such as sucrose, molasses, whey, or ground corn added to the ground carcasses.

In contrast, the cost of the added phosphoric acid in the phosphoric acid preservation process can be recovered as a nutritional phosphorus source in the feed ingredients produced from the materials preserved.

Lactic acid fermentation and phosphoric acid preservation eliminate the need for renderers to pick up the carcasses every day; they reduce the biosecurity risks and costs by reducing the number of farm visits. Transporting acid-preserved carcass materials has less potential to transmit disease than does transporting “fresh” carcasses.

After 30 days at 80 °F, lactic acid digestion of poultry carcasses produces about 4 to 5

percent lactic acid, 0.2 percent acetic acid, 0.2 percent ethanol, and 0.2 to 0.3 percent ammonia-nitrogen. The treated materials maintain a composition of 63 to 67 percent water, 11 to 14 percent protein, 13 to 14 percent fat, and 2 to 3 percent ash, which is similar to the composition of the original materials.

At concentrations of more than 3 percent lactic acid or 6 percent phosphoric acid, many pathogens such as *Salmonella* spp., *Campylobacter jejuni*, fecal coliforms, and streptococci are destroyed in poultry offal and carcasses. Lactic acid also reduces the amount of fungi in broiler carcasses and offal.

Some factors make it difficult and expensive to control the biological process in lactic acid fermentation and carcass biogas production. For example, carcasses have higher nitrogen content than do most wastes, which results in high ammonia concentrations that can

inhibit the anaerobic digestion of the carcass wastes. Under controlled conditions, fermentation failures occur 10 percent of the time.

For carcass biogas production, the operational cost of using mesophilic organisms (those that are active at 95 to 100 °F) is less than that for thermophilic organisms (those active at 131 °F). Mesophilic organisms require 15 to 30 days of retention time for pathogen inactivation; thermophilic organisms require 12 to 14 days.

The thermophilic fermentors used in carcass biogas production are better than the mesophilic fermentors at reducing to acceptable levels the coliform bacteria, insect eggs, and internal parasites in the carcass material. However, they may not destroy some pathogens or temperature-resistant bacteria such as *Bacillus cereus* associated with carcasses. This is why additional heat treatment is required to fully inactivate the pathogenic agents that can survive carcass biogas production.

Carcass biogas production considerably reduces the chemical and biological oxygen demand, total solids, and volatile solids of the materials. The remaining materials, generally amino and fatty acids, can be used for composting.

When treated by an anaerobic digester, the sludge or semisolid biowaste such as ground carcasses mixed with manure can yield 8 to 11 cubic feet of methane per pound (0.5 to 0.67 cubic meter per kilogram) of volatile solids removed by the process.

Carcass biogas production is a multi-step process (Fig. 1):

1. **Hydrolysis:** The biopolymers (carbohydrates, fats and proteins) of the animal matter are broken down into smaller, soluble molecules.
2. **Fermentation:** The products of Step 1 are converted into organic acids (mainly acetic), volatile fatty acids, carbon dioxide, and hydrogen.

3. **Acetogenesis:** The volatile fatty acids are converted to acetic acid, carbon dioxide, and hydrogen.
4. **Methanogenesis:** The acetate and ethanol compounds are converted to methane and carbon dioxide.

Several groups of bacteria perform each of these steps in carcass biogas production. Some of these microorganisms (such as intestinal anaerobic lactic-acid-forming bacteria) are naturally available in manure and in the intestines of poultry and cattle. This is why adding manure to the carcasses speeds the fermentation process and enriches the ratio of carbon to nitrogen to more than 20:1.

The pH of the digester should range from 6.8 to 7.5. Because the byproducts of the fat degradation inhibit the methanogenic activity (because the pH is lowered), calcium carbonate and calcium hydroxide may need to be

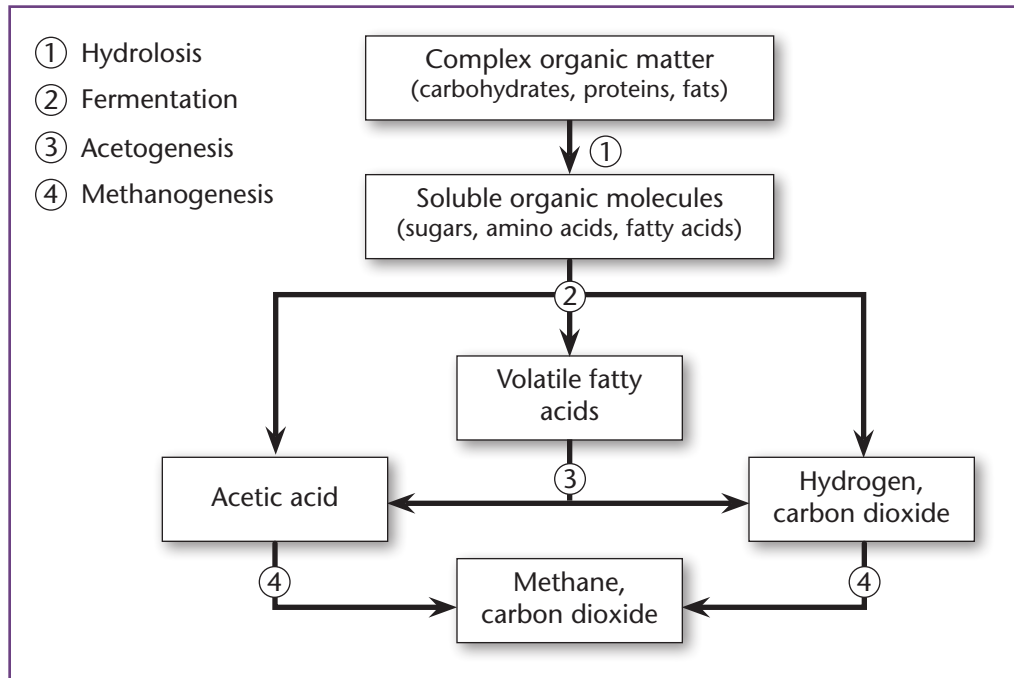
added to maintain a near neutral pH and to precipitate long-chain fatty acids (which are toxic to methanogenic bacteria) in the biodigester.

Because domestic livestock and poultry carcasses are composed of more than 50 percent water, it is easier to use wet digestion, which has a higher efficiency than does dry digestion.

Carcass biogas production systems are available in batch or continuous digesters. Three types of batch systems—single-stage, sequential-batch, and hybrid-batch—are used for biogas production.

In the single-stage system, a pump recirculates and mixes its contents from the bottom to the top of the digester, and fermentation is allowed to continue until production of the gas stops. Once the digestion is completed (no more gas is produced), the effluent is removed and a new process is started.

Figure 1. Anaerobic digestion pathway (*Erickson et al., 2004*).



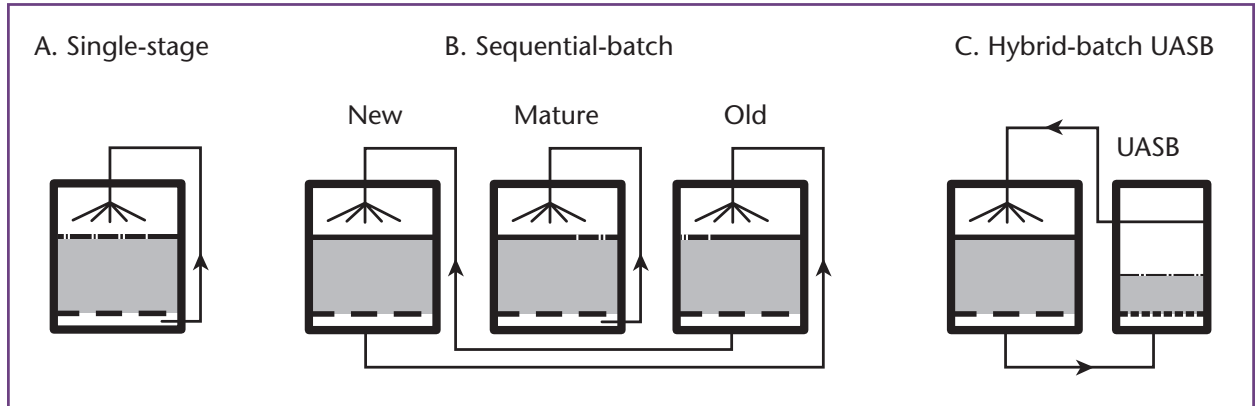
A sequential-batch system uses two or more reactors. The sludge from the first reactor contains high levels of organic acids and is injected into the second reactor. The leachate from the second reactor—after the pH is adjusted with lime or calcium carbonate—is injected into the first digester. Methane production occurs efficiently in the second reactor because its sludge contains little or no acid.

The third process is a hybrid-batch or up-flow anaerobic sludge blanket (UASB). It is similar to the multistage system with two reactors. The system comprises a simple batch

reactor coupled with a UASB reactor. In this reactor, methanogenesis takes place and treats the liquid effluents with high levels of organic acids at high loading rates (Fig. 2).

In a continuous digester, the organic material is constantly or regularly fed and moved through the digester. It produces biogas without the interruptions of loading the material and unloading the effluent. A continuous system may be better suited for large-scale operations; however, the input of carcass materials should be continuous and have a consistent composition.

Figure 2. The schematic view and flow of materials in three types of batch reactors, including single-stage, sequential-batch, and hybrid-batch (up-flow anaerobic sludge blanket digester, or UASB). (Courtesy of Erickson *et al.*, 2004)



Coordination and jurisdictional considerations

The decision on whether to use digestion as a carcass disposal option should be made jointly by the members of the incident command structure established by the authorities in the State or local area.

Local authorities should have an inter-county memorandum of understanding in place so that the carcasses can easily be transported to another county that has a digestion facility.

If the carcasses are to be transported outside the county for digestion, the incident

command structure must consider the added problem of transportation safety and contamination of property.

Digestion should be undertaken only with explicit approval by institutions and agencies that are competent in making determinations about protecting the environment.

States have ranked preferred methods for carcass disposal, and the incident command structure must exhaust the preferred options before undertaking digestion activities.

Potential pollution and other property-damage considerations

The exercise of police power gives governmental entities and agencies wide discretion in making decisions about carcass disposal to protect the public health. However, the exercise of this power does not shield the governmental entities against nuisance actions if the proper precautions are not taken. In the case of digestion, private firms engaged in digestion could face legal challenges.

Critical problems associated with digestion include:

- Spread of pathogens
- Transportation
- Waste treatment and disposal to prevent spread of pathogens
- Water contamination because of runoff from land application. One product from the digestion process is sludge, or

“digestate,” that is disposed off on land. The sludge may contain pollutants that could contaminate water resources from runoff.

- Odor
- Microbiological and risk of toxic gases

If these problems occur because of governmental action, they could trigger nuisance or other kinds of lawsuits. Sovereign immunity may not be a defense to such an action.

If a private firm triggers pathogen spread, the firm may be subject to both civil and criminal actions. Water contamination and odors may be a basis for a nuisance action.

Digester size constraints may require the use of inter-jurisdictional (among counties) agreements to transport large quantities of animals to other sites.

Regulatory Synopsis

Digestion

The decision to use digestion must be made jointly by the members of the appropriate technical group within the incident

command structure because injury to people or property could trigger lawsuits similar to those based on biosecurity breach.

Planning considerations

Evaluate in advance the advantages and disadvantages of batch versus continuous digesters. Although a batch digester is easier and less expensive to build than is a continuous digester, a batch digester produces less gas, has a lower loading rate, and carries more risk of explosion while the reactor is being emptied.

A potential disadvantage of continuous systems is that the bacterial flora may become acclimated to inhibitors such as ammonia and retard the production of biogas.

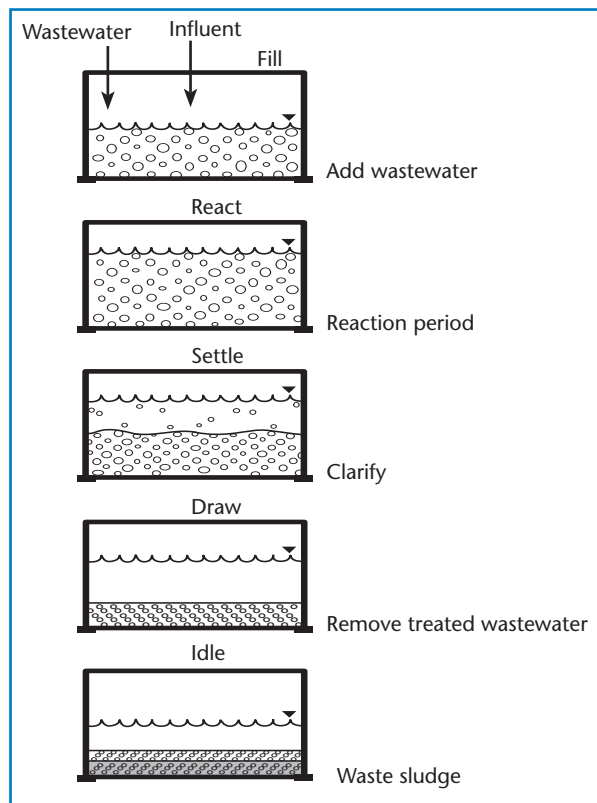
To increase the fermentation capacity, plan to use several batch digesters, and alternate the loading and emptying processes. In such a system, the organic material is loaded into the fermentation tank and digested for the designated retention period. Then the effluent is removed and the process is restarted (Fig. 3).

The volume of carcasses in lactic acid fermentation can increase by 33 percent, mainly because of fermentation and carbon dioxide production.

Plan to store the products of lactic acid fermentation and phosphoric acid preservation in sealed, vented containers. The odor of the final product is similar to that of fermented meats.

Although the phosphoric acid preservation and carcass biogas production of farm carcasses are essentially odor-free processes and are publicly acceptable, the lactic acid fermentation of farm carcasses produces volatile and odorous compounds (such as carbon dioxide, ammonia, and organic compounds) and should be vented to prevent unpleasant consequences.

Figure 3. Operation of the anaerobic sequencing batch reactor. (Courtesy of Erickson et al., 2004)



Plan to use a mobile or portable unit containing pre-breaking, grinding, and pumping equipment at the carcass disposal site to reduce the size of the ground materials and to easily transfer them to the fermentation and storage tanks.

A mobile power generator will be needed during emergency situations because natural disasters such as floods, tornados, thunderstorms, and heat stress may interrupt power in needed areas.

For carcass biogas production, plan to use a vertical, cylindrical tank with a conical bottom to improve mixing and sludge removal. Use a properly sized conveying (piping) system to prevent clogging and special solid handling pumps to transfer thick sludge.

Plan to use sludge from another biogas installation to start up a new carcass biogas production system. Microorganisms in municipal wastewater sludge can biodegrade a

wider range of organic wastes and perform better than those from other sources, such as the biodigesters of milk processing plants.

For long-term carcass biogas production (more than 5 years), consider using a non-corrosive and acid-resistant fermentation tank, such as a stainless steel tank.

Consult with construction and design engineers and obtain the required standards, including the technical dimensions, to use concrete tanks for short-term carcass biogas production. Although concrete tanks are often built partially below ground for better support, they should be strong enough to bear the weight and pressures (vertical and lateral) of mixed semi-liquid materials.

For efficient digestion and biogas production, plan to maintain the digester at the proper thermophilic temperatures (130 to 140 °F) with properly designed heat exchange, insulation, mixing, and sludge removal systems.

To prevent explosions, provide gas collection and pressure regulation equipment, including safety devices.

Provide electricity (for grinding, mixing, pumping, and separation) and water for the biodigester. Conserve water by reusing it. Propane may be needed as a fuel to start up and supply heat to the digester before enough biogas is produced.

Plan to feed the carcasses to the active digester before its temperature drops to below 130 °F. This will prevent any delays associated with the digestion start-up process.

Determine the volume of the digester by using 1 pound of carcass per 4.4 cubic feet per day (3.6 kilograms per cubic meter per day), assuming that the carcasses have 0.23 pound of volatile solids per pound of carcass material.

For example, the volume of the digester needed for anaerobic fermentation of 1,000

cow carcasses (1,540 pounds per cow), or 1.54 million pounds, is 7 million cubic feet, with a loading rate of 0.05 pounds per cubic foot per day of volatile solids.

Plan to prevent high ammonium concentrations in the digester by increasing the ratio of carbon to nitrogen to between 20 and 40. Ammonium inhibits the biodegradation of carbon sources at concentrations above 0.187 pound per cubic foot (3 grams per liter) of the digesting materials.

The crew will need to be protected from microbiological contamination and toxic gases such as hydrogen sulfide produced by carcass biogas production.

Consider also the issues related to handling, packing, storing, and conveying the carcasses to the digestion facility as described in the “General Considerations” chapter of this guide.

Lactic acid fermentation or phosphoric acid preservation

Secure the area for carcass preparation and processing from predators and vermin.

Use appropriate containers, such as high-density polyethylene (Fig. 4) for the lactic acid fermentation and phosphoric acid preservation tanks. After grinding the carcasses, add them to the fermentation (lactic acid fermentation) or preservation (phosphoric acid preservation) tank.

For lactic acid fermentation, mix the ground carcasses with an organic compound that includes:

- A fermentable carbohydrate such as glucose, sucrose, or lactose at a ratio of 10 percent by weight
- Whey, at 17 percent by weight
- Molasses or condensed brewer's solubles, at 20 percent by weight
- And/or finely ground corn, at 20 to 24 percent by weight

Figure 4. Free-standing polyethylene horizontal bulk storage tank used to store lactic or phosphoric acid. *(Courtesy of United States Plastic Corporation, Lima, OH)*



Grind the fresh carcasses alone or with one of the previously mentioned materials to particle sizes of less than 1 inch for phosphoric acid preservation or lactic acid fermentation. Grind-

ing the mixed materials not only promotes the homogenization of the phosphoric acid and the ground carcass material, but it also helps speed the fermentation process and disperse and mix the intestinal anaerobic lactic-acid-forming bacteria (Fig. 5). Do not add decomposed carcasses to a lactic acid fermentation or phosphoric acid preservation process. A proper pH may not be achieved for the mixed materials, resulting in further spoilage.

Use starter cultures such as *Lactobacillus* species to speed up the fermentation process and provide a margin of safety under less than ideal conditions. Such conditions may include poor mixing conditions, low fermentation temperatures (less than 70 °F), and/or larger particle sizes of the mixed materials.

The temperature in the lactic acid fermentation tank should be maintained at 70 to 80 °F to allow the sugars (fermentable carbohy-

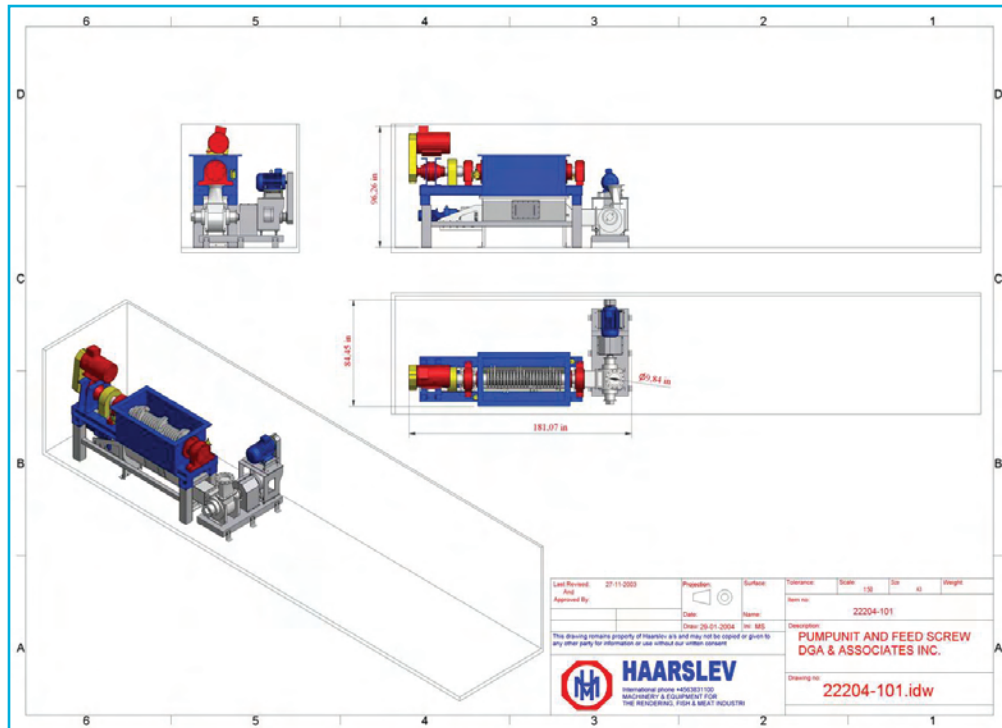
drates) to be converted into lactic acid.

Check the pH of the lactic acid fermentation tank 24 hours after start-up. Under proper working conditions, the pH of the mixed material should change from about 6 to less than 5. Within 7 to 10 days of fermentation, the pH of the ground carcasses mixed with lactic acid bacteria decreases to below 4.5. At this pH level, the lactic acid bacteria quickly grow to concentrations that result in the preservation of the carcass material.

Pump the products of the lactic acid fermentation from the fermentation tank into a storage vessel.

Add an amount of feed-grade phosphoric acid to make the final mixture contain 6 percent of this acid. For pickling, ground carcasses may be dipped in either acetic acid or propionic acid at a concentration of 10 or 3.8 percent concentration, respectively.

Figure 5. Views of a mobile grinder used to reduce the size of carcasses.
(Courtesy of Haarslev, Bogensevej 85, DK-5471 Søndersø, Denmark)



Carcass biogas production

Secure the area for carcass preparation and processing from predators and insects.

To speed the heat transfer rate and provide more surface area for fermentation, grind the carcasses to an average particle size of less than 2 inches. Large pieces of bone can damage the circulation and sludge-removal pumps.

For wet digestion, mix the ground carcasses with water and sludge from another biogas installation or from a municipal wastewater facility to achieve a concentration of total solid contents ranging from 10 to 15 percent.

Use a fermentation tank with a floating lid to accommodate gas expansion with pressure control. This type of system is more expensive and difficult to manage than is a conventional tank with a non-floatable cover or lid.

Use a mixer or circulation pump to uniformly distribute the heat and bacteria by displacing or recirculating the gases collected at the top of the fermentation tank. A recirculation pump is more expensive but more efficient than is a mixer (Fig. 6).

In addition to fresh carcasses, the products of rendering (if not dried) and alkaline hydrolysis can be used as input materials for biogas production.

Incorporate manure or municipal wastewater sludge into the ground carcasses to achieve a ratio of carbon to nitrogen ranging from 20 to 40 and a biodegradable volatile solids content of 60 percent of total solids. This mixture will have a culture of beneficial bacteria and the capability to biodegrade a wider range of compounds and wastes. To in-

oculate the new system, feed the reactor with sludge from another installation.

Once digestion is complete, the effluent

is removed and the process is restarted. Make sure to dry the sludge and store it before disposal as a fertilizer.

Figure 6. The flow diagram of a wet system. (*Erickson et al., 2004*)

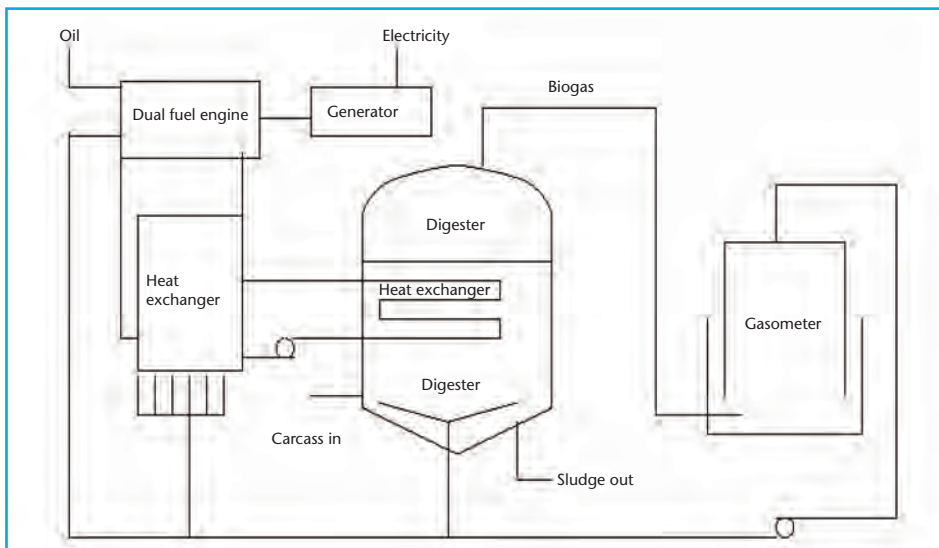


Table 2. Guidelines for the use of personal protective equipment for digestion operations.

Nature of work	Mask/respirator ^{a,b}		Protective clothing ^a	Eye protection ^a	Gloves ^a	Head/foot protection
	Zoonotic agent	Non-zoonotic agent				
Direct handling of contaminated material	Disposable particulate respirator (N95, N99, or N100); half or full facepiece	None recommended unless for foot-and-mouth disease	Impermeable to liquids; may vary, depending upon the heat situation	Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles; face shield unless wearing a full facepiece respirator	Gloves: Heavy duty (15–18 mil) chemical resistant gloves that can be disinfected or disposed of	Feet: For workers handling carcasses, steel-toe/steel shank waterproof boots; for others, steel-toe work shoes or boots Head: Hard hat
No direct handling of contaminated material	As directed by the facility safety officer	As directed by the facility safety officer	As directed by the facility safety officer	Safety eyewear	As directed by the facility safety officer	As directed by the facility safety officer

^a For a list of vendors recommended by OSHA, visit www.safetysupply.com.

^b For information about a full respiratory protection program, visit www.osha.gov/SLTC/respiratoryprotection/index.

^c Regulations governing the use of personal protective equipment in hazardous waste operations can be found at 29 CFR 1910.134 and 29 CFR 1910.156 and are summarized in the Safety section of the “General Considerations” chapter of this manual.

Diseases of concern

For digestion methods, the diseases of concern include those caused by viruses, bacteria and prions.

Viruses and non-spore-forming bacteria: As with other methods, the periods of greatest risk will be during transport and disposal of the contaminated material. Non-spore-forming bacteria and viral diseases are generally destroyed by anaerobic digestion at 131 °F (55 °C); however, all pathogens vary in the amount of time it takes to be deactivated effectively. For these reasons, digest all non-spore-forming bacteria and viruses for 8 days to ensure complete inactivation.

Diseases for which digestion methods are appropriate include African swine fever, highly pathogenic avian influenza, brucellosis (*melitensis*, *abortus*, *suis* and *canis*), classical swine fever, contagious bovine pleuropneu-

monia, foot-and-mouth disease, glanders, Japanese encephalitis, Q fever, Rift Valley fever, rinderpest, tularemia, and vesicular stomatitis.

Spore-forming bacteria: Spore-forming bacteria are temperature susceptible. If not destroyed, they will persist in the environment for long periods. If immediate incineration of these carcasses is not possible, the carcasses must remain intact to prevent the spread of spores into the external environment.

It is recommended that anthrax-infected carcasses be incinerated or inactivated by alkaline hydrolysis. Anaerobic digestion is not recommended for spore-forming bacteria unless a high-heat treatment will be conducted after the digestion process.

Diseases of concern include anthrax.

Prions: Prions are temperature resistant.

Exposure to extremely high temperatures (more than 1,830 °F, or 1,000 °C) for at least 15 minutes is necessary to destroy prion-infected carcasses. If they are not heat inactivated, the prions will persist in ash or soil for a considerable period.

Site safety

Heat stress: See the guidelines on heat stress in the Safety section of the “General Considerations” chapter of this guide.

First aid: Make first aid available to employees at all times.

Safety observers: Use a safety observer who has the authority to stop and correct unsafe conditions or operations.

Chemical hazards: Provide safety showers and emergency eyewash stations within 20 feet of each digestion tank. Caustic chemi-

Anaerobic digestion is not an effective means for destroying TSE-infected carcasses, and therefore should not be performed on them. TSE diseases include bovine spongiform encephalopathy, chronic wasting disease, and scrapie.

cal burns are exceptionally hazardous and can cause irreparable damage to the eyes within seconds if not removed using copious amounts of water for **at least 15 minutes**. Workers exposed to **any** amount of sodium hydroxide in their eyes should use an eyewash station and report to the nearest emergency room.

Ventilation: Although digestion tanks use enclosed pressure vessels, the area surrounding the vessel should be ventilated adequately.

Facilities that accept contaminated materials may be fixed-site facilities located on heavily trafficked public or private property, such as university campuses. Movement of non-zoonotic-contaminated plant or animal material onto these sites should be very carefully planned.

Although transporting carcasses contaminated with non-zoonotic material does not present a health hazard to the public, a significant effort must go into public awareness and public relations activities well before any carcasses are moved to the site. Do not use such facilities to dispose of carcasses contaminated with zoonotic agents or transmissible spongiform encephalopathies (TSEs).

Decontamination of vehicles and any contaminated personnel must occur before the

vehicles leave the disposal site. See additional material in the Safety section of the “General Considerations” chapter of this guide.

Release of the digested material must be coordinated with local and state public health, environmental quality and land-use authorities. A public relations plan should already be in place before disposing of any digested material in a public sewer system or on land, and it must be performed fully in conjunction with state and local authorities.

To ensure the inactivation of all pathogens, have this material tested before disposal or reuse.

Direct contact may be possible by worker exposure to dust or biosolids that have been applied to crops in the field.

Groundwater pollution

Close coordination with state and local health and public works authorities is essential before the release of any digested materials.

No notable groundwater pollution should be present if all procedures are followed correctly. If necessary, groundwater may be checked using a groundwater monitoring program.

Digested materials should be tested for disease-causing organisms before they are released onto land or into bodies of water.

Although direct release of digested sludge into surface waters is not recommended and may be illegal in some jurisdictions, runoff from land-applied digested material does have the potential to be released or migrate to surface water bodies, particularly if the land on which the sludge is being applied is immediately next to such water bodies. This situation is analogous to the movement of constituents of land-applied manure migrating to surface waters.

Soil pollution

No soil pollution concerns are associated with digestion processes unless through uncontrolled disposal.

Landfill disposal: Some tissue, such as bone and teeth, may remain after the digestion

process. This can be ground and disposed of in landfills as solid waste according to state and local solid waste regulations.

All waste must be tested before movement or transfer to landfills or other disposal sites.

Air pollution

No notable emissions are associated with digestion methods of disposal. The biogas generated from the digestion of carcasses and manure will be composed of mainly carbon dioxide (about 40 percent) and methane (about 60 percent) and trace amounts of hydrogen sulfide, nitrogen, oxygen, hydrogen, and other compounds such as methyl mercaptans.

Concerns are limited to the on-site workers, who will need personal protective equipment to minimize their exposure to airborne or aerosolized agents. Hydrogen sulfide may pose an immediate exposure risk to on-site personnel; it does not pose a risk to the public or the environment.

The cost breakdown for anaerobic digestion destruction follows the general specifications in the Cost section of the “General Considerations” chapter of this manual.

The direct fixed cost depends on facility’s capacity (Table 3). The direct cost estimates vary greatly, depending on the ability to reduce energy expenditures by harvesting electricity and generating heat during the anaerobic digestion process (Table 4).

For indirect cost items, see the Cost section of the “General Considerations” chapter of this guide.

Figure 7. Components of direct and indirect costs for digestion methods.

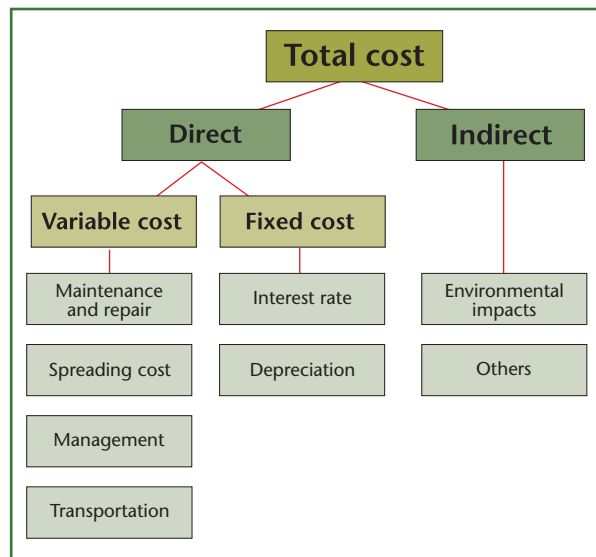


Table 3. Initial investment and annual direct fixed cost estimates of anaerobic digestion with an annual capacity of 637,000 pounds, or 850 cows per year.

Item	Investment	Depreciation	Interest rate (6%)	Annual cost
Digester	\$350,000	\$17,500	\$21,000	\$38,500
Electrical and heating system	\$235,000	\$11,750	\$14,100	\$25,850
Solids and liquids separation	\$89,000	\$4,450	\$5,340	\$9,790
Liquid storage	\$315,000	\$15,750	\$18,900	\$34,650
Others	\$43,800	\$2,190	\$2,628	\$4,818
Total	\$1,032,800	\$51,640	\$61,968	\$113,608

Source: Wright, P., and S. Inglis (2003). An Economic Comparison of Two Anaerobic Digestion Systems on Dairy Farms. ASAE Annual International Meeting, Las Vegas, NV, July 27–30, 2003.

Note: The life expectancy of the investment is assumed to be 20 years.

Table 4. Estimates per carcass of direct variable cost items of anaerobic digestion.

	Cattle	Calves	Weaned hogs	Preweaned hogs	Others (sheep, lambs, goats)
Estimated average direct variable cost per carcass					
Maintenance ¹ , repairs, insurance	\$34.85	\$12.36	\$6.18	\$0.28	\$3.58
Spreading	\$68.24	\$24.20	\$12.10	\$0.55	\$7.01
Management	\$7.49	\$2.66	\$1.33	\$0.06	\$0.77
Benefit from electricity savings	-\$49.88	-\$17.69	-\$8.85	-\$0.40	-\$5.12
Benefit from heat savings on farm	-\$7.06	-\$2.50	-\$1.25	-\$0.06	-\$0.72
Average direct variable cost per carcass					
Excluding benefits from energy savings	\$110.58	\$39.22	\$19.61	\$0.89	\$11.36
Including benefits from energy savings	\$53.64	\$19.03	\$9.51	\$0.43	\$5.52

^a The maintenance cost per herd is calculated at \$29,619/850 lb.

Source: Wright, P., and S. Inglis (2003). An Economic Comparison of Two Anaerobic Digestion Systems on Dairy Farms. ASAE Annual International Meeting, Las Vegas, NV, July 27–30, 2003.

Table 5. Estimates per ton of direct variable cost items of anaerobic digestion for cattle, calves, weaned hogs, preweaned hogs, and others (sheep, lambs and goats).

Consideration	Cost
Maintenance ^a , repairs, insurance	\$92.93
Spreading	\$181.97
Management	\$19.97
Benefit from electricity savings	-\$133.01
Benefit from heat savings on farm	-\$18.83

Average direct variable cost per ton	
Excluding benefits from energy savings	\$294.87
Including benefits from energy savings	\$143.03

^a The maintenance cost per herd is calculated by \$29,619/850 lb.

Source: Wright, P., and S. Inglis (2003). An Economic Comparison of Two Anaerobic Digestion Systems on Dairy Farms. ASAE Annual International Meeting, Las Vegas, NV, July 27–30, 2003.

Besides equipment, management and spreading costs, the disposal cost includes a transportation cost, which depends on the distance that the carcasses are moved.

Figure 8. Formulas to estimate the direct variable cost relating to anaerobic digestion deconstruction.

Direct variable cost (DVC), excluding benefits from energy savings:

- **By number of carcasses:**

$$DVC = 110.58Q_{\text{cattle}} + 39.22Q_{\text{calves}} + 19.61Q_{\text{weaned hogs}} + 0.89Q_{\text{preweaned hogs}} + 11.36Q_{\text{others}}$$

Where Q_i is the total number of carcasses of animal category i .

- **By weight:**

$$DVC = 294.87(W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

(Figure continued on next page)

Figure 8. (Continued)

Direct variable cost (DVC), including energy savings and sale:

- **By number of carcasses:**

$$DVC = 53.64Q_{\text{cattle}} + 19.03Q_{\text{calves}} + 9.51Q_{\text{weaned hogs}} + 0.43Q_{\text{preweaned hogs}} + 5.52Q_{\text{others}}$$

Where Q_i is the total number of carcasses of animal category i .

- **By weight:**

$$DVC = 143.03(W_{\text{cattle}} + W_{\text{calves}} + W_{\text{weaned hogs}} + W_{\text{preweaned hogs}} + W_{\text{others}})$$

Where W_i is the total weight in tons of animal category i .

Definition and objectives

Emerging methods for disposal of contaminated biomaterials include new evolving disposal technologies, nontraditional disposal methods, and alternative disposal methods.

Evolving disposal technologies use heat or irradiation processes to inactivate the disease-causing organisms associated with dead animals. In some cases, the carcasses are converted to inert end products. Evolving disposal technologies include gasification, plasma technology, thermal depolymerization, dehydration, and extrusion.

Nontraditional disposal methods include ocean disposal and the feeding of carcasses to exotic animals such as alligators.

 **Alternative disposal methods** can be used to dispose of plants contaminated with pathogens that do not threaten public health.

An example of these methods is crop rotation.

The objectives of these emerging methods may include:

- To quickly and safely dispose of large numbers of animal carcasses before they decay or deteriorate
- To prevent environmental contamination and reduce public health hazards during animal disposal
- To eliminate the extensive amount of land needed by some conventional carcass disposal methods; however, an even larger area of ocean might be needed
- To use the most cost-effective means to eliminate or reduce the populations of plant pathogens in the field

For all of these methods, no specific

research information is available on whether they can destroy transmissible spongiform en-

cephalopathies from carcasses contaminated with them.

Evolving disposal technologies: General description

Evolving disposal technologies include gasification, plasma technology, carcass thermal depolymerization, dehydration, and extrusion. Because of their heat generation or irradiation processes, most evolving disposal technologies can inactivate microbial cells and viral particles, including airborne pathogens.

Most of these technologies offer several potential advantages. Once full developed, they:

- Can be set up as mobile units that can be moved quickly to the disaster area
- Generate no leachate from the carcasses and prevent the contamination of soil, groundwater, and surface water
- Emit fewer noxious gases and odors than do some conventional methods,

such as air-curtain burning, open-air burning, and composting

- Allow for better control of operating parameters such as temperature, moisture content, pH, and particle size, which results in a more uniform product

A disadvantage of most evolving disposal technologies for animal disposal is that they have low throughput and are not economically feasible for disposing of large numbers of animal carcasses. However, these methods can be modified for higher throughput.

For most evolving disposal technologies, the carcasses are fed as shredded or ground material. This preprocessing requires stricter biosecurity measures than for intact carcasses.

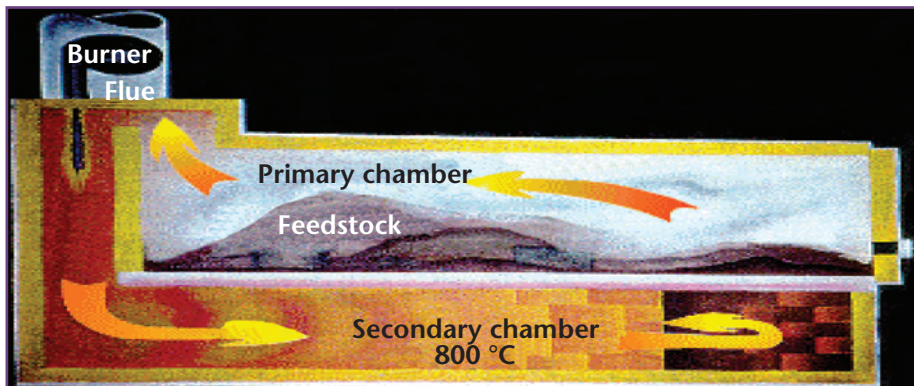
Gasification: Description

In gasification operations, animal carcasses are slowly heated and converted into a producer gas that contains methane, hydrogen, carbon dioxide, and carbon monoxide. Some of the produce gas is burned to supply the heat for the

gasification reactions; the rest is combusted.

If practical, waste heat boilers or electrical generating equipment such as a Sterling engine can be used to generate heat, steam, or electricity produced by the operation (Fig. 1).

Figure 1. Schematic of a batch-size carcass gasifier. *(Courtesy of Brookes, BGP Inc., Raleigh, NC)*



Carcass gasification occurs at a low oxygen content to prevent burning and at temperatures of 1,110 to 1,900 °F (600 to 1,000 °C).

Shredded carcasses can be mixed with other biowaste sources, such as manure, that contain a high ratio of carbon to nitrogen to improve the gasification efficiency.

The first stage of gasification requires an auxiliary fuel such as propane. The amount of fuel consumed depends on the processing technique and the fat and moisture content of the carcass.

If a new batch of carcasses follows the previous batch at a temperature higher than 1,500 °F (800 °C) or lower than 740 °F (400 °C), it is called a hot start or warm start, respectively (Table 1).

Batch systems have limited throughput for carcass gasification; continuous gasifying systems can accept higher throughput (Fig. 2). Continuous carcass gasifiers use less fuel and

have a better fuel efficiency than do batch systems. No continuous gasifiers yet exist at practical scale as of the writing of this handbook.

The carcass gasification throughput is more than 10 tons per day in Scotland (Fig. 3); in the United States, the throughput for a single biogas plant gasifier under development is about 25 tons per day, which can be scaled up to 200 tons a day if multiple gasifier units are connected to a single high-capacity macerator.

The amount of time required to gasify carcasses depends on the gasification capacity, the technique, and the nature of carcass materials. Converting carcasses to gas may take 4 to 12 hours, with a resulting ash and char of about 5 to 15 percent by volume.

The disposal of ash is similar to the procedures followed after carcass incineration in fixed-facility incinerators.

Table 1. Gasification efficiency factors.

Feed stock type	Set temperature (°C)	DM ^a processed (kg)	Propane, ft ³	Run time (min)	Propane (gal/kg DM ^a)
Feces ^{ws}	800	31.0	144	225	0.126
Feces ^{hs}	800	31.7	65	150	0.058
Chicken litter ^{cs}	750	31.1	294	368	0.261
Chicken litter ^{ws}	870	31.8	114	240	0.099
Pig carcasses ^{ws}	800	21.1	~600	315	0.780
Pig carcasses ^{hs}	800	21.1	~200	130	0.261
Poultry carcasses ^{hs}	870	28.0	125	286	0.124

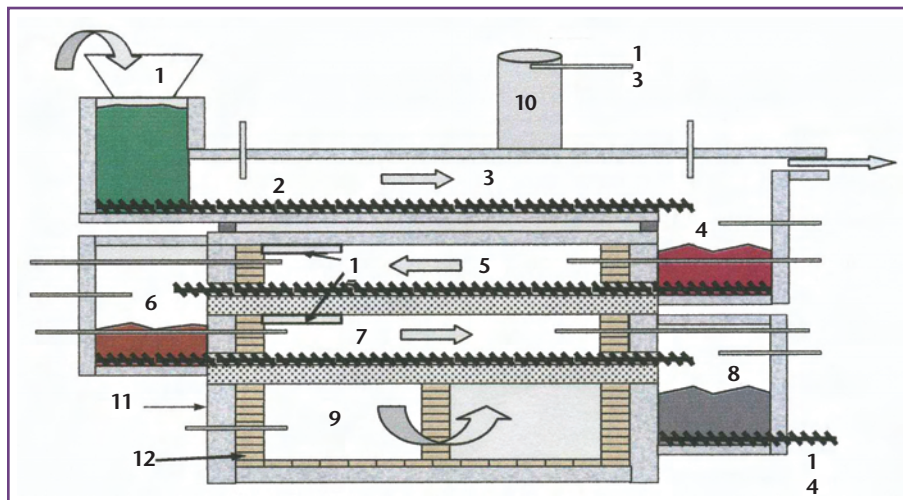
^a = dry matter

^{ws} = warm start

^{cs} = cold start

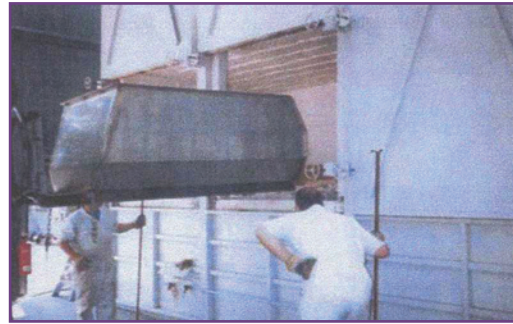
^{hs} = hot start

Figure 2. Schematic of a continuous-carcass, feed-style gasifier.
(Courtesy of Brookes, BGP, Inc., Raleigh, NC)



- | | |
|---|------------------------------------|
| 1 Feeding hopper for sludge-like waste (possibly macerated carcasses) | 8 Unloading zone for remaining ash |
| 2 Continuous-feed auger zone for conveying material in the drying zone | 9 Fuel-heating chamber |
| 3 Drying zone for carcass materials | 10 Exhaust emission channel |
| 4 Feeder zone for conveying the warm and dehydrated carcasses by the second auger to primary chamber for gasification | 11 Insulating materials |
| 5 Primary chamber for gasification | 12 Brick walls |
| 6 Feeder zone for conveying gasification | 13 Air filter |
| 7 Carbon cycle or carbon chamber of carcass gasification | 14 Discharge ash auger |

Figure 3. Views of carcass gasifying system used in Scotland for the bovine spongiform encephalopathy crisis. *(Photos courtesy of Brookes, BGP, Inc., presented in the North Carolina Disposal Roundtable, Farm Bureau Federation of Raleigh, NC, March 30, 2006)*



Plasma technology: Description

Plasma technology fluidizes, or converts into a fluid, the inorganic portion and heat-resistant material of animal carcasses at very high temperatures (up to 7,000 °C) after its organic portion is converted to vapor at 200 to 600 °C (with no added oxygen₂) and converted to gas at 600 to 1,000 °C (with limited oxygen). The resulting molten slag (Fig. 4) is collected in a separate container, where it cools into glasslike material (Fig. 5).

Plasma technology is the application of artificial lightning to gasify organic materials (biogas generation) and melt inorganic materials, including animal carcasses.

The gases emitted in this method can be used to produce methanol. The final rock-like residue is highly resistant to leaching. Also, it

is a good raw material for manufacturing various forms of brick and tiles or the concrete filler used in insulation, roadbed construction, and composition roofing. No special waste disposal is required.

Although no operating systems are available, a mobile system could process 6 to 8 tons of small, intact carcasses (up to 100 pounds) per day. A plasma reactor eliminates the need to shred the carcasses and improves worker safety.

A plasma technology unit has the potential to convert temporarily stored animal carcasses, such as those that have been buried or composted, into inert materials of lower volume than the original mixture of soil/organic matter and carcasses.

Figure 4. An overall view of shredding, feeding, organic gasifying, melting, and solidifying of inorganic materials using carcass plasma technology.
(Courtesy of Dr. Lou Circeo, Georgia Tech Research Institute, Atlanta, GA)

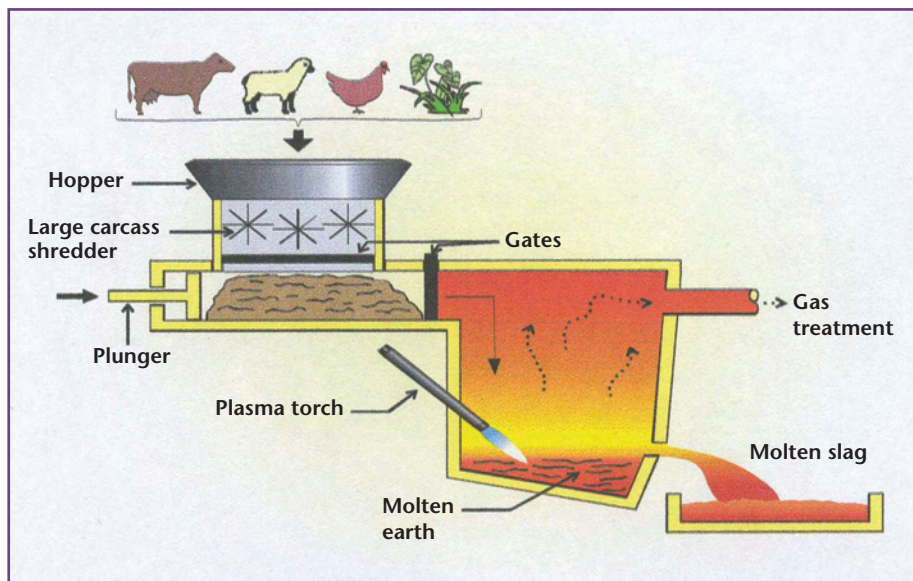
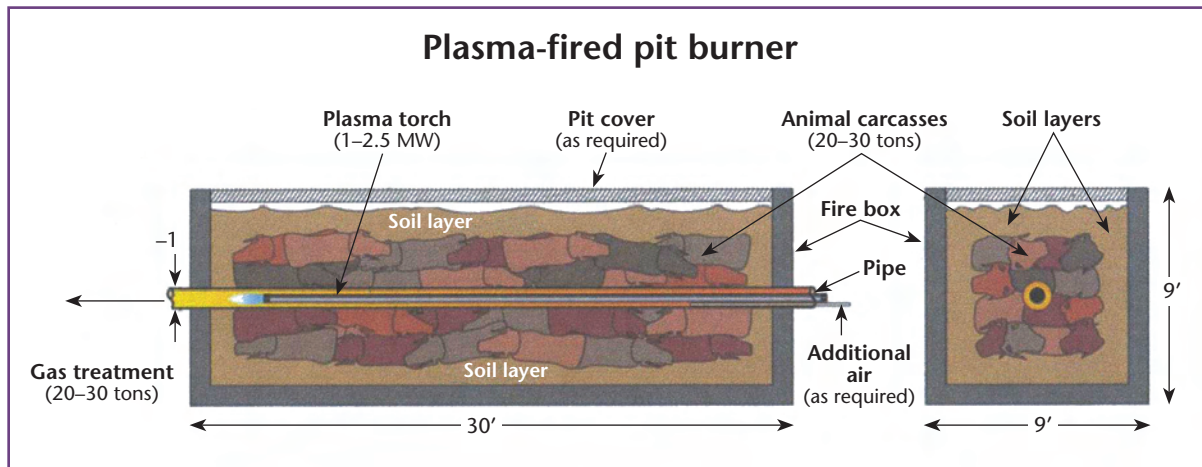


Figure 5. Schematic diagram of plasma technology for disposal of animal carcasses.
(Courtesy of Kent Munden, USDA-APHIS, Clifton, TX)



Thermal depolymerization: Description

Thermal depolymerization technology can treat ground carcasses under high pressure (600 pounds per square inch, or about 40 bars) and high temperatures (steam heating at about 480 °F or about 250 °C) in the presence of carbon monoxide to create useful organic products such as biofuels.

After 15 minutes of carcass depolymerization, the reactor pressure is released rapidly to evaporate most of the water and separate the liquid crude hydrocarbons from the solid minerals.

Although depolymerization of carcasses

is conducted at the molecular level and can effectively destroy pathogens, it does not inactivate abnormal proteins such as prions.

A thermal depolymerization plant has been built in Carthage, MO, to digest 200 tons of turkey processing waste per day.

This technology is expensive and requires highly skilled personnel to operate the system.

The raw materials and residuals are kept in sealed containers before and during processing. The residuals, generally minerals, can be land-applied as fertilizer.

Dehydration and extrusion: Description

In the dehydration and extrusion process, superheated air moves the particles of ground carcasses into a hot channel to evaporate and reduce their moisture. The materials are conveyed to an extruder barrel, where they are blended, cooked, sheared, kneaded, and formed into a plastic-like material that is converted into dried animal feed.

Ground carcasses such as swine are dehydrated in a fluidized bed dryer or a flash dryer (high temperature and short exposure) at 212 °F (100 °C) and mixed with an organic carrier such as finely ground soybean. This process reduces the moisture content of the mixed materials to about 30 percent and facilitates the extrusion process. The amount of each specific carrier depends on the moisture and fat contents of the dead animals.

The mixed materials are conveyed through an extruder channel and subjected to

friction heat, shearing, and pressure. Extruder screws force the material to pass through a series of hot channels where, within 30 seconds, the temperature rises from 240 to 2,800 °F (115 to 1,550 °C) and the pressure rises from 294 to 600 pounds per square inch (20 to 40 bar). The product expands and loses 12 to 15 percent of its moisture content because the high pressure drops suddenly to atmospheric pressure as the product leaves the extruder.

This new technology may emerge as an alternative to the rendering of dead animals, because the final product has more nutritional feed value than does the carcass meal produced in rendering plants.

Dehydration of dead pigs is more efficient than that of poultry or cattle because swine have more fat and less water.

Flash dehydration of ground carcasses causes little damage to protein quality, and the

dried animal feed has superior protein digestibility. If the product must be sterilized, the meal can be dehydrated further to about 10 percent moisture and subjected to extrusion processing.

Because of the high processing temperatures and pressure, the extrusion of ground and dehydrated carcasses readily inactivates

all bacteria, molds, viruses, and spores in the carcasses. However, this process should not be used for disposal of carcasses contaminated with transmissible spongiform encephalopathies.

After dehydration and extrusion of ground carcasses, the feed can be processed further to separate the fat from protein.

Nontraditional disposal methods: Description

Nontraditional disposal methods include dumping carcasses into the ocean and feeding carcasses to exotic animals.

General description

Although intact carcasses can be fed to exotic animals without significant pre-treat-

ment, the carcasses can be disposed of more quickly if they are preprocessed (for example, by grinding them) and if adequate storage is provided.

Ocean disposal: Description

In the ocean disposal method, carcasses are placed deep in the ocean to prevent flotation and allowed to gradually disintegrate. Ocean is defined as the waters lying seaward of the baseline from which the territorial sea is measured.

To transport carcasses for the purpose of ocean dumping, you must obtain a permit from the Environmental Protection Agency, according to the Marine Protection, Research and Sanctuaries Act (MPRSA, 33 USC § 1401 et seq.).

To obtain an ocean-dumping permit:

- The dumping must not unreasonably degrade or endanger human health, welfare, or amenities or the marine environment, ecological systems or economic potentialities.
- The material must be placed in an approved ocean-disposal site.

- The materials must undergo a series of tests and evaluations to determine whether they meet the EPA's ocean-dumping criteria (40 CFR Parts 227 & 228). These criteria include consideration of the effects of disease-causing organisms, hazards to navigation, and dangers to shorelines and beaches as a result of the dumping.

Virtually all materials dumped in the ocean today are dredged materials from navigation channels and berthing areas.

An emergency permit is required and may be issued if the emergency poses an unacceptable risk relating to human health and there is no other feasible solution.

No permits, even emergency permits, may be issued for dumping or biological warfare agents.

Other considerations

When the EPA issues an emergency ocean-dumping permit, the agency determines the location and method of dumping as a condition of the permit.

Avoid dumping animal carcasses near the shore because they may attract scavengers and cause health problems for the people living or recreating near the ocean.

Dumping large quantities of animal carcasses in one location (overdosing) may result in floating debris and “dead zones,” which would not be allowed under an ocean dumping permit.

Roll-off dumpsters may be used to transport the carcasses from the farms if the car-

casses are packed with inert, nontoxic materials to prevent them from floating.

The number of personnel needed for ocean disposal has not been determined, but it may be a major issue in an emergency animal disposal event.

Research has not been conducted on what would happen to the disease microorganisms if animal carcasses were dumped in the ocean. It is not clear whether the pathogens could be re-introduced to farm animals through fish meal in the feed or spread to marine animals and seabirds.

Refeeding: Description

Refeeding methods use whole or shredded farm carcasses as feed for exotic animals and at fur and trout farms.

According to the National Contract Poultry Growers Association, alligator farming operations have become a viable option for disposing of hundreds of thousands of chickens that die before they reach the processing plant.

If a large number of carcasses were caused by a natural disaster, they would need to be preprocessed to inhibit decomposition and then stored in sealed containers or frozen until they were consumed.

In some states, such as Louisiana, raw poultry carcasses cannot be fed to hogs or alligators unless the carcasses are first cooked or rendered.

Rendered-animal carcasses are usually fed at fur farms; however, in some states such as Minnesota, non-rendered animal carcasses can be fed to fur animals if these requirements are met:

- A permit to feed these animal carcasses is obtained.
- The carcasses, facilities, and equipment meet the specifications of the Minnesota Board of Animal Health (MBAH, 2003) for fur-farm consumption, and the farm is in a sanitary condition.
- Animal carcasses may be fed to fur-bearing animals if their products do not reenter the food chain.
- The fur-farm owner accepts the risk of diseases being transmitted from the carcasses to the fur animals.

Alternative disposal methods: General description

Alternative disposal methods focus mainly on crop rotation to naturally dispose of contaminated plant materials. If the plant disease is not considered an immediate threat and if the pathogen does not pose an epidemic concern, the disease spread can be limited by appropriate quarantines and disease monitoring.

Crop rotation is a natural but powerful tool for eliminating non-threatening pathogens in the field. This method is often used to reduce plant pathogen populations in agriculture. At the end of the growing season, the contaminated crops will degrade naturally in the field.

Usually in the next growing season, crops that do not serve as hosts for the pathogens

are planted in the contaminated field. If the crops are rotated properly, many pathogens either die out or their concentrations are reduced sharply. For this reason, it is recommended that you consult with county Extension specialists to select an appropriate crop.

Soil-borne pathogens that typically infect plants of one or a few species can be reduced significantly by planting, for 3 to 4 years, crops that belong to species or families not attacked by the particular pathogen.

Crop rotation can effectively eliminate pathogens that are typically considered soil invaders; these survive only in living plants or in the plant residue that persists in the soil. In the U.S. Midwest, maize and soybean crops are rotated to manage plant pathogens.