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 (about 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.

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

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 about 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 facilities, transportation and labor) is a limiting factor. Landfilling is considered the best practice for disposing of mycotoxin-contaminated grain.
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)
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.

<table>
<thead>
<tr>
<th>Option</th>
<th>Size</th>
<th>Throughput capacity</th>
<th>Solid fuel/1,000 lb carcass weight(^d)</th>
<th>Liquid fuel/1,000 lb carcass weight(^d)</th>
<th>CO(^g) lb/hr</th>
<th>NMH(^g) lb/hr</th>
<th>TSP(^g) lb/hr</th>
<th>Nitrogen oxides(^g) as NO(_2) lb/hr</th>
<th>SO(_2)(^g) lb/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed-facility incinerator</td>
<td>Top load opening(^a): 6 x 9 ft</td>
<td>110–500 lb/h(^c)</td>
<td>—</td>
<td>60 gal(^e)</td>
<td>0.5</td>
<td>0.05</td>
<td>1.8</td>
<td>2.73</td>
<td>2.82</td>
</tr>
<tr>
<td>Air-curtain burning</td>
<td>Trench burning(^b): Depth = 8 ft Width = 10–15 ft</td>
<td>4-6 T/h</td>
<td>1,000–2,000 lb</td>
<td>2 gal(^f)</td>
<td>N/A(^h)</td>
<td>N/A(^h)</td>
<td>N/A(^h)</td>
<td>N/A(^h)</td>
<td>N/A(^h)</td>
</tr>
</tbody>
</table>

\(^a\) 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/ft\(^3\), the volume of a 1,000-lb carcass is 16 ft\(^3\).

\(^e\) 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 SO\(_2\) = 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 after any complaint 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.

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 spreading 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 must 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.

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 doctrine 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

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.

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

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

Do not:
• Burn carcasses with explosive materials, especially gasoline in fixed-facility incineration, air-curtain burning and open-air burning operations.
• Burn carcasses with tires, rubber, plastics or similar materials because the resulting dark smoke harms 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 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 ½ 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 lumber (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 lumbers that are treated with chemicals such as chromated copper arsenate. These lumbers are typically treated as special waste and must be disposed in accordance with local and state regulations. In general, the lumbers 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 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 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 will 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 over the wood or other liquid fuel such as diesel, furnace 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.
Procedures

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

Illustrations are not to scale.

- Carcass
- Loose straw
- Hay bales
- Timber
- Kindling wood and loose straw

Side view of the fire bed

Hay bales (3 ft length)

Spaces filled with loose straw (1 ft length)

Cross section of the fire bed
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.

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

(Continued on next page)
**Table 4. (Continued)**

<table>
<thead>
<tr>
<th>Nature of work</th>
<th>Mask/respirator&lt;sup&gt;a, b, c&lt;/sup&gt;</th>
<th>Protective clothing&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Eye/hearing protection&lt;sup&gt;a, c&lt;/sup&gt;</th>
<th>Gloves&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Head/foot protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zoonotic agent</td>
<td>Non-zoonotic agent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open-air burning</td>
<td>Disposable particulate respirator (N95, N99 or N100); half or full facepiece (for description, see Safety section of this guide)</td>
<td>None recommended unless nuisance dusts/ash impede work</td>
<td>Impermeable to liquids; consider fire-retardant overgarment for those working around open flame; select based on heat situation</td>
<td><strong>Eyes:</strong> Full facepiece respirator or indirectly vented goggles; contact lenses should not be worn under goggles or safety glasses; consider prescription safety goggles <strong>Hearing:</strong> Consider disposable earplugs if necessary</td>
<td><strong>Gloves:</strong> 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</td>
</tr>
</tbody>
</table>

<sup>a</sup>See [www.safetyequipment.org](http://www.safetyequipment.org) for a list of vendors from OSHA

<sup>b</sup>For information on a full respiratory protection program, see [www.osha.gov/SLTC/respiratoryprotection/index](http://www.osha.gov/SLTC/respiratoryprotection/index)

<sup>c</sup>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, B. suis and B. canis*), 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 (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-curtain 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.

Consider any use of ash generated from the thermal destruction as contaminated material. 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 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.
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 project 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.

<table>
<thead>
<tr>
<th>With afterburner</th>
<th>Investment ($)</th>
<th>Depreciation* ($)</th>
<th>Maintenance and repair (3%)</th>
<th>Interest (6%)</th>
<th>Annual cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration (500 lb/cycle)</td>
<td>3,000.00</td>
<td>300.00</td>
<td>90.00</td>
<td>180.00</td>
<td>570.00</td>
</tr>
<tr>
<td>Shed and base slab</td>
<td>642.00</td>
<td>64.20</td>
<td>19.26</td>
<td>38.52</td>
<td>121.98</td>
</tr>
<tr>
<td>Afterburner</td>
<td>1,000.00</td>
<td>100.00</td>
<td>30.00</td>
<td>60.00</td>
<td>190.00</td>
</tr>
<tr>
<td>Total</td>
<td>4,642.00</td>
<td>464.20</td>
<td>139.26</td>
<td>278.52</td>
<td>881.98</td>
</tr>
</tbody>
</table>

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

*The life expectancy of the investment is assumed to be 10 years.
Table 6. Estimates of direct variable costs per carcass of thermal destruction.

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

Source: [http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=193](http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=193)

*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.

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor ($10/hr)</td>
<td>$30.30</td>
</tr>
<tr>
<td>Fuel&lt;sup&gt;a&lt;/sup&gt; ($2.40/gal)</td>
<td>$83.08</td>
</tr>
<tr>
<td>Electricity ($0.0024/lb)</td>
<td>$4.80</td>
</tr>
<tr>
<td>Environmental permitting fee</td>
<td>N/A&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Transportation</td>
<td>N/A&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Average cost per ton</strong></td>
<td><strong>$118.18</strong></td>
</tr>
</tbody>
</table>

Source: [http://www.ianrpubs.unl.edu/epublication/pages/publicationD.jsp?publicationId=193](http://www.ianrpubs.unl.edu/epublication/pages/publicationD.jsp?publicationId=193)

<sup>a</sup>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.

<sup>b</sup>N/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)

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site and equipment preparation</td>
<td>$1,700</td>
</tr>
<tr>
<td>Site rental (by contract)</td>
<td>650</td>
</tr>
<tr>
<td>Air-curtain incinerator</td>
<td>7,500</td>
</tr>
<tr>
<td>Diesel fuel&lt;sup&gt;1&lt;/sup&gt;</td>
<td>300</td>
</tr>
<tr>
<td>Protective clothing</td>
<td>2,400</td>
</tr>
<tr>
<td>Lumber and plywood</td>
<td>135</td>
</tr>
<tr>
<td>Firewood and delivery</td>
<td>3,960</td>
</tr>
<tr>
<td>Truck rental</td>
<td>250</td>
</tr>
<tr>
<td>Animal transportation</td>
<td>4,640</td>
</tr>
<tr>
<td>Modification of chute/knock box</td>
<td>1,285</td>
</tr>
<tr>
<td>Miscellaneous supplies</td>
<td>225</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td><strong>$23,045</strong></td>
</tr>
<tr>
<td><strong>Cost per ton</strong></td>
<td><strong>$503</strong></td>
</tr>
</tbody>
</table>

<sup>1</sup>The fuel prices dramatically increase and, thus, this cost component needs to be considered.
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 \( i \).
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 transportation cost, which depends mainly on the distance that the carcasses are moved.
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 to 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.

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

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

<sup>2</sup> The stringency of restrictions imposed by federal, state and local agencies

<sup>3</sup> 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 carnivorous feeders.

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 hydraulic 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 leachate from the contaminated carcasses is either expelled or transferred to a wastewater treatment plant, where it is sprayed and recirculated on the surface of the landfill area.
Burial

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 exposure 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 landfilled 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 in 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.
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 burial activity should be chosen by the members of the incident command structure established by local or state authorities. Local authorities must 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.

<table>
<thead>
<tr>
<th>Burial option</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F (Capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trench burial</td>
<td>150 ft</td>
<td>200 ft</td>
<td>500 ft</td>
<td>1,000 ft</td>
<td>1,325 ft</td>
<td>Variable</td>
</tr>
<tr>
<td>Landfill</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>40t/400ft²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,300t/acre</td>
</tr>
<tr>
<td>Mass burial</td>
<td>150 ft</td>
<td>200 ft</td>
<td>500 ft</td>
<td>1,000 ft</td>
<td>1,325 ft</td>
<td>Variable</td>
</tr>
</tbody>
</table>

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 from water supply well for the burial of disease-infected carcasses.
E. Minimum distance from pubic 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 ft².
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 cover 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 chronic wasting disease or transmissible spongiform encephalopathy (TSE), such as bovine spongiform encephalopathy, or “mad cow disease.” TSEs are not inactivated by any burial process and can seriously threaten the health of people and animals.

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 carnivorous feeders, scavengers and vermin from feeding on the carcasses and possibly spreading diseases.

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

<table>
<thead>
<tr>
<th>Burial option</th>
<th>Volume ratio</th>
<th>Width</th>
<th>Depth</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trench burial</td>
<td>2–4</td>
<td>4–10 ft</td>
<td>3–12 ft c</td>
<td>—</td>
</tr>
<tr>
<td>Landfill</td>
<td>—</td>
<td>14 ft</td>
<td>10–20 ft</td>
<td>30 ft</td>
</tr>
<tr>
<td>Mass burial</td>
<td>2–4</td>
<td>4–6 ft b</td>
<td>3–12 ft c</td>
<td>—</td>
</tr>
</tbody>
</table>

a Ratio of the volume of excavated trenches to the volume of carcasses
b Historical data show a width of up to 20 ft, but most new references recommend a width of up to 6 ft.
c Depth excludes 2 ft and 4 ft of mound to shed rain water and divert runoff for trench burial and mass burial, respectively.
d As 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.

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

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, Creutzfeldt-Jakob disease 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, which are organisms that transmit pathogens away from their source) and collection of surface water.
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 cattle) * (1,000 lb/cattle) (4 volume ratio)\} ÷ \{(62.4 lb/ft³) (8 ft deep) (6 ft wide)\} about 130 ft
2 - Number of buried cattle in two layers and two rows = \{(130 ft.) * (2 layers) * (2 rows)\} ÷ (5 ft length/carcass) = 104 carcasses

B. Shallow trench
1 - Trench length in shallow trench = \{(100 cattle) * (1,000 lb/cattle) (4 volume ratio)\} ÷ \{(62.4 lb/ft³)(4 ft deep) (6 ft wide)\} ~ 260 ft
2 - Number of buried cattle in one layer and two rows = \{(260 ft) * (2 rows)\} ÷ (5 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.

<table>
<thead>
<tr>
<th>Description</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ft height of mounding soil with side slopes 3:1</td>
<td>![Diagram of 2 ft mounding soil with side slopes 3:1]</td>
</tr>
<tr>
<td>6 ft height of soil with side slopes 1.5 (horizontal):1 (vertical) containing 2–3 layers of carcasses (1–3 ft thick). Each medium or large carcass layer is separated by a 1-ft thick layer of soil.</td>
<td>![Diagram of 6 ft soil with side slopes 1.5 (horizontal):1 (vertical)]</td>
</tr>
<tr>
<td>Minimum 2 ft of soil between trench bottom and the water table</td>
<td>![Minimum 2 ft soil between trench bottom and water table]</td>
</tr>
<tr>
<td>2 ft height of mounding soil with side slopes 3:1</td>
<td>![Diagram of 2 ft mounding soil with side slopes 3:1]</td>
</tr>
<tr>
<td>5 ft of excavated trenches/pits with the vertical wall containing a maximum of 3 layers of small carcasses (each 1 ft thick)</td>
<td>![Diagram of 5 ft excavation with vertical wall and 3 layers of small carcasses]</td>
</tr>
<tr>
<td>Minimum of 2 ft of soil between trench bottom and the water table</td>
<td>![Minimum 2 ft soil between trench bottom and water table]</td>
</tr>
</tbody>
</table>
Procedures

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 leftover 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 recompress 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).
Procedures

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.

- 4-ft height of mounding soil with side slopes 3:1
- 5 ft of excavated trenches/pits containing one layer of carcass (1–3 ft thick) covered with 2-3 ft soil
- Minimum 2 ft of soil between trench bottom and water table.

- 4-ft height of mounding soil with side slopes 3:1
- 10 ft of excavated trench/pit with side slopes of 1.5 (horizontal): 1 (vertical) containing a maximum of 2 layers of carcasses (1–3 ft thick). Each carcass layer is separated by 3 ft of soil.
- Minimum 2 ft of soil between pit bottom and water table.
Procedures

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 effectively 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 compost 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 timeframe 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.

<table>
<thead>
<tr>
<th>Nature of work</th>
<th>Mask/respiratora,b,c</th>
<th>Protective clothinga</th>
<th>Eye/hearing protectiona</th>
<th>Glovesa</th>
<th>Head/foot protection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zoonotic agent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct handling of contaminated materials</td>
<td>Disposable particulate respirator (N95, N99, or N100); half or full facepiece</td>
<td>None recommended unless for foot-and-mouth disease</td>
<td>Impermeable to liquids; depending upon heat situation</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td><strong>Non-zoonotic agent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No direct handling of contaminated materials</td>
<td>None recommended</td>
<td>None recommended</td>
<td>No special clothing required; work clothing appropriate for season</td>
<td>Eyes: Safety eyewear Hearing: Consider disposable earplugs, if necessary</td>
<td>Work gloves if necessary</td>
</tr>
</tbody>
</table>

---

a For a list of vendors recommended by OSHA, visit www.safetyequipment.org.
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 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](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.
Table 6. Estimates of direct cost items for on-site carcass burial.

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th>Calves</th>
<th>Weaned hogs</th>
<th>Preweaned hogs</th>
<th>Others (sheep, lambs, goats)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated average cost per carcass ($ per carcass)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor cost</td>
<td>$3.33</td>
<td>$1.67</td>
<td>$1.67</td>
<td>$0.17</td>
<td>$1.67</td>
</tr>
<tr>
<td>Equipment cost</td>
<td>$11.67</td>
<td>$5.83</td>
<td>$5.83</td>
<td>$0.58</td>
<td>$5.83</td>
</tr>
<tr>
<td>Permitting fee</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Transportation cost</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Land cost</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Average cost per carcass</strong></td>
<td>$15.00</td>
<td>$7.50</td>
<td>$7.50</td>
<td>$0.75</td>
<td>$7.50</td>
</tr>
</tbody>
</table>

|                                |        |        |             |                |                               |
| **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.
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 the 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