Definition and objectives

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

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

- Provide the conditions that impede the growth and spread of pathogens from the contaminated materials and 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.

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

[1] Animal mortality (tons): Low = < 100 t; Medium = 100–300 t; High = > 300 t
[2] The stringency of restrictions imposed by federal, state and local agencies
[3] Cost estimate (per ton): Low = < $200; Medium = $200–800; High = > $800
(Cutoff points may vary, depending on such factors as transportation, carcass load, animals affected, disposal facility and level of security.)

Trench burial

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

Summary

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

Mass burial

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

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

Mass burial is an engineered technology that requires lead time for proper design and construction as well as prior regulatory approvals. The pits 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.

Coordination and jurisdictional considerations

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

The location of 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.

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

A. Minimum distance from private wells, springs, watercourses, sinkholes, streams, springs (or any source of water used for domestic purposes), and public areas.
B. Minimum distance from residences or property lines.
C. Minimum distance from public wells.
D. Minimum set-back distance 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 ft.^{2}

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

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

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

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

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

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

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

Under no circumstance should you bury in trenches, pits or landfills any carcasses infected with 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.

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

[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 ft^2-area is required at the bottom of trench/pit for one mature cattle carcass.

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

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

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

Also provide machinery and equipment for handling, loading, unloading, cleaning and disinfecting, as well as for lighting and safety, as described in the "Thermal" chapter. The capacity of the equipment depends on the amount of carcasses and the time required (usually 24 to 48 hours, but up to 72 hours in cold climates) for a proper burial process.

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

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

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

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

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

Planning for trench burial

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

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

Do not consider sites that have no cutoffs, drainage or other special design features if water (apparent, perched or seasonal) is likely to emerge just above the level of the trench bottom or if it flows down into the trench or away from the site.

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

Planning for landfilling

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

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

Identify the Type I landfills available for disposal of carcasses. Because they are equipped to collect leachate and gas, modern or Type I landfills are permitted to accept carcasses except those contaminated with prions such as mad cow disease, 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 landfill and 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_selectagent/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.

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

Assumptions

1 - Average weight of carcass = 1,000 lb
2 - Bulk density of carcass = about 62.4 lb/ft^3
3 - Volume ratio for a two-layer or one-layer burial trench = 4 ft^3 of trench/ft^3 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

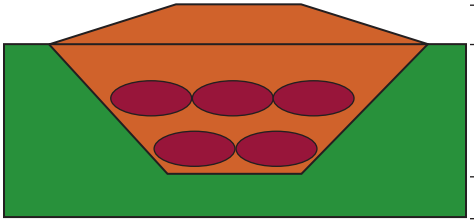
A. Deep trench

1 - Trench length in a deep trench = {(100 cattle)*(1,000 lb/cattle) (4 volume ratio)} ÷ {(62.4 lb/ft^3) (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/ft^3)(4 ft deep) (6 ft wide)} ~ 260 ft
2 - Number of buried cattle in two layers and two rows = {(260 ft)*(2 rows)} ÷ (5 ft long/carcass) = 104 carcasses

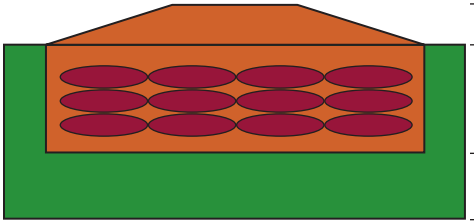
Figure 2. Cross sections (not to scale) of a trapezoidal trench (top) and a vertical trench used for burying carcasses. For massive carcass burial, trenches of up to 12 feet deep with no more than two 3-foot layers of dead animals are recommended. The bottom soil should be highly impermeable, without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



2 ft height of mounding soil with side slopes 3:1

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.

Minimum 2 ft of soil between trench bottom and the water table



2 ft height of mounding soil with side slopes 3:1

5 ft of excavated trenches/pits with the vertical wall containing a maximum of 3 layers of small carcasses (each 1 ft thick)

Minimum of 2 ft of soil between trench bottom and the water table

Procedure for landfilling

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

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

Repeat adding 3-foot layers of solid waste only, and compact each layer until a total height of 10 feet is reached (Fig. 3). The deepest part of landfill is not necessarily in the preconstructed and lined bottom. The landfill may have a depth of 20 feet (about 6 meters) of compacted trash.

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

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

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

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

Procedure for mass burial

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

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

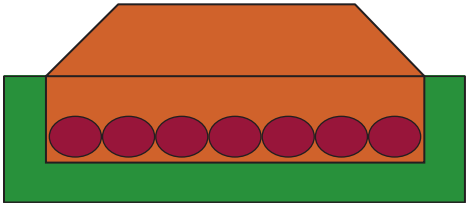
Prepare gravel drainage channels to convey the seepage to the leachate collection sumps. To prevent or minimize seepage, line the inside (walls and bottom) of the trenches/pits with clay or an impermeable membrane.

Divert the upstream runoff by building berms or a cutoff ditch along the up-gradient side of the pit.

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

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

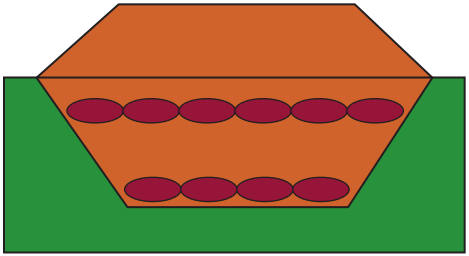
Figure 4. Cross sections of vertical pits (top) for temporary mass burial and of a trapezoidal trench/pit for mass burial of carcasses at preconstructed sites. The walls and bottom of the trenches/pits are built with 2 to 3 feet of impermeable soil such as compacted clay, especially in the deep pits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



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.

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 or animals—except those contaminated with prions—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.

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

[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/repiratoryprotection/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.**

Prion-based diseases include bovine spongiform encephalopathy.

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.

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 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.

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Groundwater pollution

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

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

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

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

Air pollution

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

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

Operating landfills

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

- **Receipt of regulated hazardous waste:** The owner/operator must set up a program to detect and prevent the disposal of regulated quantities of hazardous waste. The program must include procedures for random inspections, record keeping, training of personnel to recognize hazardous wastes and notification of the appropriate authorities if such waste is discovered at the facility.
- **Cover material:** The owner/operator must cover the solid waste with at least 6 inches of earthen material at the end of each operating day to control fires, odors, vectors, scavengers and blowing litter. An approved state or tribe may allow an owner/operator to use an alternative cover material or depth and/or grant a temporary waiver of the cover requirement.
- **Vectors:** The owner/operator is responsible for controlling populations of vec-

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

- **Explosive gases:** The owner/operator must set up a program to check for methane gas emissions at least every 3 months. If the limits specified in the regulations are exceeded, the owner/operator must immediately notify the state director (that is, the official in the state or area responsible for implementing the landfill criteria) and take immediate steps to protect human health and the environment.
- **Access:** The owner/operator must control public access to prevent illegal dumping, unauthorized vehicular traffic and public exposure. Artificial and/or natural barriers may be used to control access.
- **Storm water run-on/runoff:** The owner/operator must build and maintain a control system designed to prevent storm waters from running onto the active part of the landfill. Runoff waters must be managed according to the requirements of the Clean Water Act, particularly the restrictions on the discharge of pollutants into water bodies and wetlands.
- **Surface water protection:** All landfills must be operated in a way that ensures they do not release pollutants that violate the Clean Water Act.

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

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

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

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

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

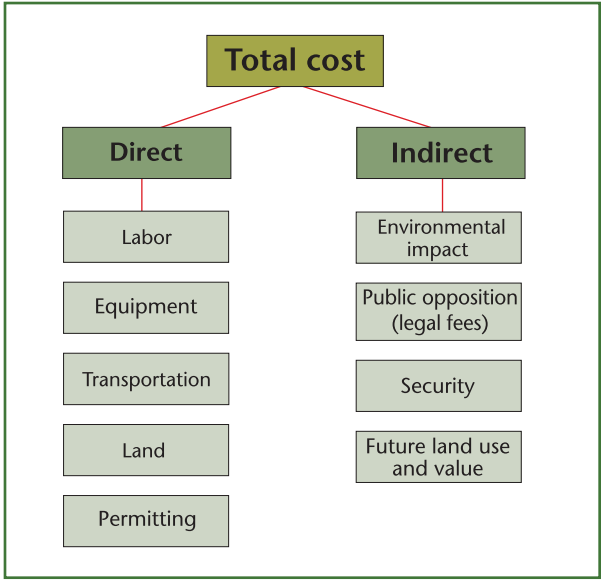

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Table 6. Estimates of direct cost items for on-site carcass burial.

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

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

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

If the hourly labor and equipment costs are \$10 and \$35 respectively, the direct variable (DVC) cost 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:**

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

- **By weight:**

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

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