Carcass Disposal: A Comprehensive Review

National Agricultural Biosecurity Center Consortium
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Chapter

9

Economic & Cost Considerations

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Abbreviations

AI	avian influenza
APHIS	USDA Animal and Plant Health Inspection Service
BSE	bovine spongiform encephalopathy
CWD	chronic wasting disease
DEFRA	UK Department of Environment, Food and Rural Affairs
END	exotic Newcastle disease
FMD	foot and mouth disease
LWDS	livestock welfare disposal scheme
ROI	Renewable Oil International LLC
UK	United Kingdom
USDA	United States Department of Agriculture
$WR^{2®}$	Waste Reduction by Waste Reduction Inc.

Section 1 – Key Content

A complete and multidimensional strategy is necessary when planning for the disposal of livestock and poultry in the event of high death losses resulting from an intentional bioterrorism attack on agriculture, an accidental introduction of dangerous pathogens, or a natural disaster. A critically important part of that strategy is the ability to dispose of large numbers of animal carcasses in a cost effective and socially and environmentally effective manner.

While many technologies exist, the "best" method for carcass disposal remains an issue of uncertainty and matter of circumstance. Contingency plans must consider the economic costs and the availability of resources for the actual disposal, as well as numerous related costs. A complete cost-benefit analysis of alternative methods of disposal for various situations is a necessity to determine the "best" alternative.

This chapter (1) highlights previous carcass disposal experiences and costs, (2) summarizes costs and economic factors related to disposal technologies, (3) presents broad regulatory and policy issues related to carcass disposal, and (4) identifies future research needs.

In 2001, the United Kingdom experienced an outbreak of foot and mouth disease (FMD), which has, to date, provided the best "lesson in history" on large-scale carcass disposal. The Government faced the challenge of disposing of approximately six million carcasses with limited disposal resources in a tight time frame. The large scale of the epidemic made carcass disposal a serious problem. Total expenditures by the Government were estimated to be over £2.8 billion, with over £1 billion related to direct costs of control measures. This included £252 million for haulage and disposal.

During the 1997 FMD outbreak in Taiwan, approximately five million carcasses required disposal. The costs born by the government associated with the epidemic were estimated at $187.5 million, with expenses for carcass disposal of approximately $24.6 million.

In order to understand the economic issues related to carcass disposal, it is critical to understand the cost data available. An effective control strategy will not only limit disease spread but will keep direct and indirect costs low. There is relatively little data on the costs of carcass disposal, and consistency regarding both direct and indirect costs is lacking.

Various direct and indirect costs need to be identified, including those related to direct disposal, transportation, facilities and equipment, energy requirements, environmental impact, and social costs. Major economic factors and implications also need to be identified and the different disposal options need to be compared and contrasted. In this chapter, examples of direct costs are identified and potential indirect costs are discussed relative to each technology. Most existing data applies only to small-scale disposals, and few reliable cost estimates exist for large-scale disposal. In the case of a foreign animal disease outbreak or natural disaster, total actual costs are difficult to estimate. In addition, little to no attention has been paid to indirect costs of these technologies in previous research. The impact on the environment, land values, public opinion, and general economic factors must be evaluated and quantified as well. This type of economic analysis is critical to any decision-making process. Figure 1 summarizes the technology costs found in the literature.

In order to determine the optimal investment in disposal technology and capacity, the cost-benefit ratio of alternative methods for carcass disposal needs to be analyzed. Economics cannot and should not be the sole factor in a decision-making process, but economics should be part of the equation. Economically attractive disposal methods may not meet regulatory requirements; the most cost-effective method may be prohibited by local, state, or federal regulations. Additional efforts are necessary to assess state-by-state regulations, investigate opportunities for individual states and the federal government to work together, have disposal plans in place before an emergency, and delineate clear decision-making responsibilities. Balancing economic considerations with regulatory requirements is necessary to determine the best options for carcass disposal. Furthermore, in order to minimize direct costs, contracts with technology providers should be negotiated in advance.

Improvement of the decision-making process related to large-scale carcass disposal is the ultimate goal. Further review and response to the research needs noted in this chapter will provide regulators and policymakers with the necessary information to make decisions. These results, combined with increased research from the scientific community on each disposal technology, will help government and industry be better prepared for any large-scale carcass disposal event.

Section 2 – Background

2.1 – Overview

Animal agriculture's changing structure to higher production concentration increases the industry's vulnerability to high death losses due to disease or disaster. One infected animal introduced into a concentrated animal facility can affect thousands of animals in a short time period resulting in a potentially devastating economic impact on producers as well as local, state, and national economies. However, concentration also allows a planned defense with a strategy for dealing with such events to be focused on limited geographic areas.

A complete and multidimensional policy strategy is necessary when planning for the disposal of livestock and poultry in the event of high death losses resulting from an intentional bioterrorism attack on agriculture, an accidental introduction of dangerous pathogens, or a natural disaster. A critically important part of that strategy is the ability to dispose of large numbers of animal carcasses in a cost effective and socially and environmentally effective manner (Adams, 1999; Casagrande, 2002; Deen, 1999).

Historical carcass disposal events indicate that a multitude of issues must be considered when determining the appropriate process for disposing of infected and exposed carcasses. In order to develop a decision-making framework, policy makers must balance the scientific, economic, and social ramifications of disposal technologies.

The greatest logistical problem in any large-scale animal death loss is carcass disposal. While many technologies exist, the "best" method for carcass disposal remains an issue of uncertainty and matter of circumstance. Contingency plans must consider the economic costs and the availability of resources for the actual disposal, as well as the numerous related costs. A complete cost-benefit analysis of alternative methods of disposal for various situations is a necessity to determine the "best" alternative (Ekboir, 1999).

Timely disposal may be difficult with a large-scale death loss or depopulation requirement. Resources may not be available for the actual disposal or the numerous related costs. In the United Kingdom (UK) foot and mouth disease (FMD) outbreak, contingency planning should have considered several additional issues, including the logistical problems related to the location of disposal facilities, size and species of animals, and access to farms. Or, the UK could have planned to vaccinate animals to postpone slaughter or freeze carcasses to pace the disposal (Anderson, 2002).

To understand the dilemma, consider the development of an action plan for fighting FMD in the state of California. The California Department of Food and Agriculture action plan states that all precautions should be taken to prevent disease spread and to comply with environmental regulations during disposal of infected and exposed animals. While the state allows the Governor to overrule environmental regulations in the case of an emergency, uncertainty over the long term environmental impacts and public concern will likely delay even proven disposal methods.

The greatest logistical problem defined in the California research is the disposal of carcasses. The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) currently identifies burial as the preferred method of disposal when practical, and considers burning as the alternative. However, burial would require the digging of miles of trench pits that could not be disturbed for years. This alone imposes a major future cost on producers. Carcass burning would require more wood or other fuel than is readily available in a timely manner. The ability to use an air-curtain would be limited to equipment availability and would likely increase disposal time. Landfill usage would be limited because of the need to mix with waste in a fixed portion and the cost imposed on the local communities of filling the landfill. Limited disposal ability and capacity will impact the spread of disease (Ekboir, 1999).

This chapter (1) highlights previous carcass disposal experiences and costs, (2) summarizes costs and economic factors related to disposal technologies, (3) presents broad regulatory and policy issues related to carcass disposal, and (4) identifies future research needs.

2.2 – Historical Experience

United Kingdom – foot and mouth disease

In 2001, the UK experienced an outbreak of FMD, which has, to date, provided the best "lesson in history" on large-scale carcass disposal. The Government faced the challenge of disposing approximately six million carcasses with limited disposal resources in a tight time frame. The large scale of the epidemic made carcass disposal a serious problem. While the UK Department for Environment, Food and Rural Affairs (DEFRA) realized cost control was important, it was also clear that all steps to stop the disease needed to be taken regardless of expense (Hickman & Hughes, 2002). Although some costs are clearly defined, economic impacts on farmers, small businesses, and the tourism industry are more difficult to define.

In Table 1, direct and indirect costs are identified in many areas of disease control (farmer compensation, vaccination, cleaning and disinfecting, staff time, et cetera), including costs resulting from the slaughter and disposal of livestock, either to control the disease or deal with animal welfare (Anderson, 2002).

One portion of these costs were part of the Livestock Welfare Disposal Scheme (LWDS), a voluntary program for farmers to dispose of animals that were not directly affected by FMD but could not be moved to alternative accommodations or markets. The Rural Payments Agency paid farmers £205 million for the slaughter of two million animals from 18,000 farms. The cost to run the program was £164 million, including operating costs, disposal charges, slaughter fees, transportation of animals, and administration (NAO, 2002). The FMD Inquiry commissioned by the House of Commons lists specific costs expended by the Government as noted in Table 1. Total expenditures by the Government were estimated to be over £2.8 billion, with over £1 billion related to direct costs of control measures. This included £252 million for haulage and disposal (Anderson, 2002; NAO, 2002).

In addition to the LWDS, the disposal of infected and exposed carcasses was significant. Goods and services were purchased from a range of private and public sector businesses, including transportation and construction services, materials required to burn pyres, and slaughter services. Landfill operators received substantial sums for receiving slaughtered animals and landowners were paid several million pounds for allowing their land to be used as mass burial sites. DEFRA was forced to pay premium fees to get the work done in the necessary time frame. For example, in order to build the burial pits, crews worked 24 hours a day, seven days a week and were paid substantial amounts of overtime, nighttime, and weekend wages. Similar construction would have taken two years if tight deadlines did not exist. Because many small local firms were fearful of becoming involved with the crisis, there existed shortages of goods and services and, thus, increased costs. Work with infected carcasses was also considered hazardous causing contracting firms to charge premium rates. DEFRA purchased coal and wooden railway sleepers needed for pyres at prices five to ten times higher than normal.

TABLE 1. Expenditures by the Government during the 2001 outbreak of FMD in the UK (Anderson, 2002; NAO, 2002).

Activity	Actual Expenditures to 24 May 2002 (£ million)
Payments to farmers	
Compensation paid to farmers for animals culled and items seized or destroyed	1,130
Payments to farmers for animals slaughtered for welfare reasons (Livestock welfare disposal scheme - £205.4 million; Light lambs scheme - £5.3 million)	211
Total payments to farmers	**1,341**
Direct costs of measures to deal with the epidemic	
Haulage, disposal, and additional building work	252
Cleansing and disinfection	295
Extra human resource costs	217
Administration of the Livestock Welfare Disposal Scheme including operating costs, disposal charges, and slaughter fees	164
Payments to other Government departments, local authorities, agencies and others	73
Miscellaneous, including serology, slaughterers, valuers, equipment and vaccine	68
Claims against the Department	5
Total direct costs of measures to deal with the epidemic	**1,074**
Other Costs	
Cost of government departments' staff time	100
Support measures for businesses affected by the outbreak (includes EU funds)	282
Total other costs	**382**
TOTAL COSTS	**2,797**

Substantial costs were also incurred in protecting the environment and public health from carcass disposal risks; this included costs related to preparing safe locations and transporting to these locations. Construction costs for burial pits, for example, were substantial with DEFRA acquiring land for seven mass burial pits. These pits had to be designed from scratch to be environmentally acceptable and required heavy investment to stop the release of leachate (animal body fluids) into watercourses, protect surface water, and allow for disposal of contaminants. The total cost of the pits alone was £79 million of the disposal costs (included in Table 1), not including restoration, monitoring, and maintenance. In one case, after the site had been partially filled, it was found to be unacceptable. The 18,000 carcasses buried were exhumed and burned at a cost of over £2 million (NAO, 2002).

High temperature incineration was very costly at over £500 per ton. Dealing with the ash from incineration and mass pyres was expensive because of the difficulties in disposal. In dealing with all expenses, DEFRA often found itself in a weak position for negotiating contracts and fee rates. This position forced the department to pay higher prices for almost all goods and services. Purchase controls were also considered weak. Because purchases were often made quickly, DEFRA did not benefit from bulk or surplus purchase prices. Normal procedures for authorization of department expenses were by-passed and contracts were not awarded in a competitive method. Many contracts, amounting to millions of pounds, were agreed to in a few hours instead of the normal period of several weeks. The procurement of supplies and services was highly expensive and the Government did not have a strong negotiating position. The rates charged by contractors for labor, materials, and services varied greatly from one to another. Landfill owners were paid large sums, as were private landowners whose land was used for disposal. By April 2001, DEFRA began to impose some cost controls but was still limited in their ability to truly be cost effective and efficient (NAO, 2002; de Klerk, 2002).

Taiwan – foot and mouth disease

During the 1997 FMD outbreak in Taiwan, approximately five million carcasses required disposal. The costs born by the government associated with the epidemic were estimated at $187.5 million, with expenses for carcass disposal of approximately $24.6 million.

Eighty percent of the carcasses were buried, 15% were rendered and 5% were incinerated or burned in open fields. A comparative cost analysis showed that burying was the least expensive and easiest form of disposal, with 32.5% of total disposal costs covering 80% of the carcasses. Rendering was more costly, with only 15% of the carcasses being rendered for 26.1% of the costs. The most expensive method was burning or incineration with 41.4% of disposal expenses being used to dispose of 5% of the carcasses. In addition to direct costs, the Taiwanese swine industry faced an estimated loss of $1.6 billion as a result of production and export loss. Related industries such as feed mills, pharmaceutical companies, equipment manufacturers, meat packers, auction markets, and the transportation industry all suffered economic losses.

The use of mass vaccination could impact disposal costs, by either delaying the urgency related to large-scale disposal efforts or by reducing the number of animals in need of disposal. Additional analysis implies mass vaccination was the cheapest way to eliminate the spread of the disease and future consideration should be given to cost-benefit analysis of vaccination and limited depopulation versus total depopulation (Ekboir, 1999; Ellis, 2001).

Virginia - avian influenza

Two major outbreaks of avian influenza (AI) have impacted Rockingham County, VA over the last 20 years. In 1984, over 5,700 tons of poultry carcasses required disposal and another 16,900 tons were disposed of in 2002. On-site burial accounted for 87.5% of the carcasses in 1984, with the remaining carcasses being disposed of in landfills. On-site burial cost and landfill costs were $25 per ton for a total of $142,000. In that outbreak, 1.4 million birds were destroyed at a total economic cost of $40 million, and disposal costs accounted for less than 0.5% of total costs (Brglez, 2003).

Carcasses take up to six months to decompose when composted, and can take several years to totally decompose in landfills or on-site burial pits. An example of this occurred in Virginia when a school was built on a 1984 burial site and people were shocked to find the carcasses in near complete condition with little decomposition. This caused a change in state law requiring landowners to agree to record carcass burial on their property deed if they are applying for an on-site burial permit (Brglez, 2003).

In the 2002 Virginia outbreak, landfills accounted for 85% of the carcasses disposed. Two primary landfill sites were used and over 64% of total tonnage was shipped over 160 miles to these landfill sites. The cost to dispose in the landfill was only $45 per ton but over $1 million in transportation in specially prepared trucks was necessary. In one case, the waste management plant associated with a landfill could not handle the ammonia leachate produced (Brglez, 2003).

Four incinerators were used late in the process due to slow negotiations. For 29 days, 76 tons per day were disposed through the incinerators. The total cost of disposing of 3,023 tons was $317,616 at a rate of approximately $105 per ton, including transportation. Transporting the carcasses to the quarry where the incinerators were located cost $267,908 for truck rental and mileage. Other costs included the rental of incinerators and labor totaling $810,389, rent screener and screening of ashes totaling $75,283, removing ashes and delivering as fertilizer totaling $173,466, and wood fuel costs of $477 per ton. This was an expensive process, and created a negative externality in the resulting stench (Brglez, 2003).

Section 3 – Direct and Indirect Costs

In order to understand the economic issues related to carcass disposal, it is critical to understand the cost data available. An effective control strategy will not only limit disease spread but will keep direct and indirect costs low. There is relatively little data on the costs of carcass disposal and consistency regarding both direct and indirect costs is lacking. The available data are primarily related to routine disposal and not disposal in an emergency situation. Costs can be divided into the following categories: (1) direct costs, including fixed costs and variable (operating) costs, and (2) indirect costs.

In order to analyze the economic implications of the different disposal options, various direct and indirect costs need to be identified, including those related to direct disposal, transportation, facilities and equipment, energy requirements, environmental impact, and social costs. Major economic factors and implications also need to be identified and the different disposal options need to be compared and contrasted. In the following section, examples of direct costs are identified and potential indirect costs are discussed relative to each technology. However, most existing data applies only to small-scale disposals and does not attempt to quantify indirect costs.

3.1 – Burial

The two most common forms of burial are disposal pits and trench burial. Both can be used for daily mortality needs, but trench burial is the most likely process used when there is large-scale death loss (Wineland et al., 1997). Few direct cost estimates exist and decision makers usually assume burial is a low-cost option. Most direct cost estimates available are relative to the use of disposal pits for normal mortality use, and the costs in a large-scale disaster situation would differ significantly.

Direct costs

Routine disposal

Burial requires significant labor and equipment, and actual costs are dependent on the availability and accessibility of these two factors. A number of studies have identified costs related to routine disposal efforts. These studies may provide insight into the cost factors in large-scale disposal estimates.

In a study by University of Nebraska researchers to be discussed repeatedly in this section, costs were estimated for the disposal of normal death loss on a hog farm. Nebraska regulations state that burial must occur within 36 hours of death and carcasses must be buried at least 4 feet deep. They also recommend that trenches should be immediately closed, making it a difficult option for routine disposal purposes. Therefore, they paid relatively less attention to burial costs in their research. They did estimate a basic budget that included building one trench to hold one year's death loss of 40,000 lbs. Digging the pit and fencing the area would cost approximately $600. Additional labor costs based on 135 hours for transporting animals to the burial site and covering the carcasses appropriately were included. Estimated costs totaled $3,878 per year, resulting in estimates of $0.097 per pound of mortality ($193.90 per ton) (Henry et al., 2001).

Researchers at the University of Alabama investigated routine poultry carcass disposal. The poultry industry as a whole generates 800 tons of carcasses weekly, thus economically efficient disposal methods are important in daily routines. Disposal pits designed for everyday use are a potential solution for both large and small producers. The cost of the pits varies widely depending on materials used and size of pit. Routine mortality disposal costs were estimated for a flock size of 100,000. Estimates included initial investment costs ($4,500), annual variable costs ($1,378), and annual fixed costs ($829) totaling $2,207, resulting in a cost per hundredweight of $3.68, or cost per ton of

$73.60. For a flock of 200,000 birds, the cost per ton would be reduced to $62.40 (Crews et al., 1995).

Sparks Companies, Inc. (2002) estimated costs of on-farm burial of daily mortalities. They assumed each mortality was buried individually, all environmental safeguard procedures were followed, on-farm burial was feasible, and the only direct costs associated with burial were labor (estimated at $10/hr) and machinery (rental or depreciation estimated at $35/hr). These costs resulted in per mortality costs of $15 per head for cattle over 500 lbs. and $7.50 per head for calves and hogs. These estimates are likely not representative of the costs that may be incurred during a catastrophic mortality loss, since multiple mortalities would be buried together, rather than individually as estimated here. Furthermore, actual hourly rates for labor and equipment may be significantly different during an emergency than estimated here.

A survey of Iowa Pork Producers Association members was conducted in March 2001 to determine the disposal methods used for daily mortalities, as well as associated costs (Schwager et al., 2001). The authors defined the total estimated cost for disposal by burial (including labor, machinery, contractors, and land) as a function of operation size, rather than as a function of the number of mortalities disposed. They estimated that the total cost for burial was approximately $198 per 100 head marketed. A report on various carcass disposal options available in Colorado identified the cost of renting excavation equipment as $50-75/hr (Talley, 2001).

The New South Wales Department of Agriculture Resources states that on-site burial may be the only economic choice because the costs of transport may be expensive relative to the value of the stock. They estimate on-farm disposal can cost A$1-2 per head if machinery is hired (Burton, 1999).

Emergency disposal

Little information exists regarding the costs associated with carcass burial during emergency situations. During the 1984 AI outbreak in Virginia, a total of 5,700 tons of poultry carcasses (about 1.4 million birds) were disposed. Approximately 85% of this total (about 4,845 tons) was disposed by trench burial at an estimated cost of approximately $25 per ton (Brglez, 2003).

The 2001 UK FMD outbreak provides emergency disposal cost examples for mass burial sites. The costs of mass burial sites included purchase and/or rental; construction, operation, and maintenance; and long-term restoration and maintenance. Based on the estimated number of carcasses buried at each site, the approximate cost per carcass has been estimated in Chapter 1 (Burial) of this report. The approximated cost per carcass ranged from £20.41 at the Birkshaw Forest mass burial site to £337.77 at the Tow Law site, with an average cost of £90.26 for the 1,262,000 carcasses buried in five mass burial sites. Although cost per ton would be a more preferred basis for comparison, for all sites except Throckmorton it was not possible to determine this value because few reports provided either the total weight of carcasses buried at each site, or the number of carcasses by species at each site (although reportedly the majority of carcasses were sheep). For the Throckmorton site, based on an estimated total weight buried in the site of 13,572 tons (see Table 12 in Chapter 1), the cost of using this site on a per ton basis is estimated to be £1,665 per ton (NAO, 2002).

Indirect costs

Burial as a method of carcass disposal can result in a variety of indirect costs including environmental costs and impact on land values. The major environmental impact is ground and surface water contamination, particularly in areas with light soil and a high water table. Body fluids and high-concentrate ammonium leachate could pollute the groundwater. Most degradation would occur within 5 to 10 years but leachate could be released for 20 years or more. Calculating values aligned with indirect costs is challenging because individual producers may not have knowledge of or may choose to ignore approved procedures, leading to additional environmental costs.

Predators could also be a problem by spreading the disease or causing an unsightly disturbance if they are uncovering the carcasses. Such disturbances or other unpleasing circumstances may also create negative public reactions. In addition, if anaerobic digestion occurs the hydrogen sulfide created can exceed safe human levels. It is also possible that acid-forming bacteria may exist and decomposition-inhibiting fermentation may occur. Burial on private land can also impact future land use and land values, especially if legislation requires that carcass burial be listed on the property deed. Mass burial offers similar environmental risks at a higher level of significance (Harman, 2001; Morrow & Ferket, 1993; Sparks Companies, Inc., 2002; Wineland et al., 1997).

3.2 – Landfills

The use of public landfills is another potential disposal alternative requiring the cooperation of operators, transportation to the disposal location, and regulatory compliance.

Direct costs

The fee charged by a landfill for accepting waste is typically based on either weight or volume, and may vary with the type of waste deposited. Even though many state regulations allow landfill use for carcass disposal, many municipal authorities refuse carcasses. Many can charge $10-30 per ton, which some have viewed as cost prohibitive (Morrow & Ferket, 1993).

For landfill disposal of small numbers of animal carcasses—such as companion animal remains, carcasses resulting from hunting activities (such as deer or elk), or small numbers of daily mortalities from livestock production facilities—fees may be based either on weight or on the number of carcasses. Fees at three landfills in Colorado were reportedly $10 per animal, $160 per ton, and $7.80 per cubic yard, respectively (Talley, 2001). As of 2003, fees for carcass disposal in Riverside County, California consist of a $20 flat fee for quantities less than 1,000 lbs, and $40 per ton for quantities greater than 1,000 lbs. These fees are slightly higher than those charged at the same facility for general municipal solid waste because animal carcasses are classified as "hard-to-handle" waste as they require immediate burial (immediate cover) (Riverside County Waste Management Department). Landfill costs for disposing of animal byproducts in European countries range from 30 to 80 Euros per ton of material (Commission of the European Communities, 2001).

Following confirmation of two cases of chronic wasting disease (CWD) in South Dakota, the City Council of Sioux Falls established disposal fees for deer and elk carcasses at the city landfill. A mono-fill area (mono-fill indicating waste of only one type) designed to accommodate 10,000 deer carcasses was developed in an unused expansion of the landfill at a reported cost of about $50,000. Fees of $50 per ton were established for deer or elk carcasses originating within the state, and $500 per ton for carcasses originating outside the state. However, private individuals are exempt from the ordinance and may dispose of up to 10 carcasses without charge (Tucker, 2002).

In situations involving significant volumes of carcass material (e.g., an animal disease outbreak), fees would most likely be based on weight (i.e., per ton of carcass material). Costs associated with transportation of carcass material from the site of the outbreak to the landfill must also be considered. In instances where this distance is great, transportation costs can be significant. During the 2002 outbreak of AI in Virginia, tipping fees were approximately $45 per ton for disposing of poultry carcasses at landfills. However, significant additional cost was incurred due to lengthy transportation distance (Brglez, 2003). During the 2002 outbreak of exotic Newcastle disease (END) in southern California, tipping fees were approximately $40 per ton for disposing of poultry waste at landfills (Hickman, 2003).

Indirect costs

Disposal in landfills requires additional daily management leading to increased management costs. The use of a landfill for carcass disposal is likely to impact the location's ability to handle other waste disposal needs creating an opportunity cost. In addition, if landfills are used, the county may be financially impacted if landfill capacity is reduced prematurely. Environmental costs also exist with landfill usage. Disposal of carcasses in landfills can generate very high organic loads and other pollutants for up to 20 years. The odors are also considered a public problem. Landfills offer similar concerns as burial regarding groundwater contamination and predators. If a landfill usage is mandated at a higher level of government, the cost of public perception and poor cooperation could be large as well (Morrow & Ferket, 1993).

3.3 – Incineration/Burning

There are three common forms of incineration: open burning (e.g., pyre burning), air-curtain incineration, and fixed-facility incineration. In the Incineration Chapter of this report (Chapter 2), "intervals of approximation" have been used to describe the costs for each incineration technology. These intervals are listed as $196 to $723 per ton for open burning, $98 to $2000 per ton for fixed-facility incineration, and $143 to $506 for air-curtain incineration. Specific cost examples are provided in this section.

Direct costs

Open burning

An open air pyre requires fuel, which may include coal, timber, pallets, straw, or diesel fuel. While this may seem clear, specific cost data is limited. Cooper et al. estimate open-air pyre burning of cattle carcasses to cost $196 per ton of cattle carcasses (Cooper et al., 2003). During the UK 2001 FMD outbreak, there were concerns about the on-farm burial of pyre-ash. Therefore, pyre-ash was disposed of at landfills at a cost of approximately £317 per ton, or $527 per ton (Anderson, 2002).

Fixed-facility incineration

The most significant costs related to fixed-facility incineration are the fixed-costs associated with construction of the incineration facility and purchase of incineration equipment. These are the most extensive costs for both individual producers and governments preparing for large-scale mortality capability (Harman, 2001). A 500-pound incinerator costs $3,000 and will last for approximately four years (Sander et al., 2002).

Researchers at the University of Nebraska have estimated disposal costs on an annual basis for a pork production system with average annual mortality loss of 40,000 pounds per year. The costs do not include labor or loader use for removing dead animals from the farm, because they assumed no change between alternatives. They calculated fixed costs to include depreciation, interest on the undepreciated balance, repairs, property taxes, and insurance. The incinerator used had a 500 pound capacity and along with a fuel tank and fuel lines costs $3,642. The rate of incineration was estimated to be 78 pounds per hour with diesel fuel consumption of 1 gallon per hour priced at $1.10 per gallon. The incinerator was calculated to last ten years or 5,000 hours. Interest rates were calculated at 10% and annual repairs were calculated as 3% of original cost. This study assumed the incinerator would be taken to the production unit so transportation costs were not relevant. Labor for operation was set at 10 minutes per day. An incinerator with an afterburner may be necessary to reduce emissions and would increase investment costs by $1,000 and increase fuel consumption to 1.35 gallons per hour. The study estimated costs for both types of incineration as depicted in Table 2 (Henry et al., 2001).

TABLE 2. Cost estimates for on-farm incineration of daily mortalities (Henry et al., 2001).

	Incineration without afterburner	Incineration with afterburner
Disposal equipment	Incinerator and fuel tank	Incinerator and fuel tank
Capital investment	$3,642.00	$4,642.00
Labor hours per year	60.7	60.7
Budgeted annual costs	$710.19	$905.19
Fixed costs – disposal equipment		
Machinery operating costs	$572.00	$1,341.44
Labor	$667.33	$667.33
Annual cost per year	**$1,949.52**	**$2,913.96**
Annual cost per pound	**$0.049**	**$0.073**
Annual cost per ton	**$97.48**	**$145.70**

In Alabama, poultry producers utilize incineration when burial is ruled out due to environmental concerns. An incineration unit with gas or oil burners is required, and producers need a concrete slab and shelter to house the unit. Additional cost considerations are fuel costs and burn rate. Initial investment costs are $2,000 at a minimum with annual variable costs of $4,833 and annual fixed costs of $522. These equate to total net costs of $5,355 and a cost per hundredweight of $8.92, resulting in a per ton cost of $178.40 (Crews et al., 1995). In a similar study in Alabama, costs are estimated at approximately $3.50 per 100 pounds or $70 per ton of carcasses assuming fuel costs at $0.61 per pound (Crews et al., 1995).

In a study at the University of Tennessee, the use of incineration for poultry mortality management was studied. Variability in fuel prices will impact the cost of incinerator operation. If propane costs are estimated at $0.75 per gallon, the cost to burn 100 pounds of poultry broiler carcasses will average $4 per 100 pounds ($80 per ton). The amount of fuel needed is impacted by the size of birds and their body fat percentage. The researchers also noted that while incineration is an effective technique, producers should have an alternative plan for handling catastrophic bird loss (Burns, 2002).

The Georgia Department of Agriculture reports that the cost of incinerating 450 tons of dead chickens after tornadoes struck Mitchell County in 2001 was $300 per ton or outsourced for $1600 per ton.

The Incineration Chapter of this report (Chapter 2) indicates that larger, fixed-facility incineration has been approximated by Waste Reduction Inc. at $460-$2,000 per ton of carcass material in the US. This interval captures a forecasted during-emergency price of $1,531 per ton (Western Australia Department of Agriculture, 2002).

Air-curtain incineration

Cost information for air-curtain incineration depends on species type, fuel costs, and ash disposal. The largest single expense related to air-curtain incineration is the expense of the air-curtain incinerator, either by purchase or rental. In a test operation in Texas held by the USDA and Texas Animal Health, a trench burner was leased from Air Burners, LLC for 3 days for $7,500 including transportation to the site and operators. The test operation disposed of 504 head of swine carcasses weighing 91,600 pounds. In this same case, fire wood was used as the fuel and with delivery cost nearly $4,000. Another large expense was the transportation of swine to the location costing over $4,500. All costs noted are listed in Table 3. The project investigators did not include the time of any animal health or emergency professionals nor did they attempt to account for any indirect costs (Ford, 1994). Jordan (2003) and Brglez (2003) estimated per ton incineration costs for poultry to be $143 and $477, respectively.

TABLE 3. Air-curtain incineration project cost based on 91,600 lbs of swine carcasses (Ford, 1994).

USDA/TAHC Incineration Project Cost	
Site and Equipment Preparation	$1,700
Site Rental (by contract)	$650
Air-curtain Incinerator	$7,500
Diesel Fuel	$300
Protective Wear	$2,400
Lumber and Plywood	$135
Firewood and Delivery	$3,960
Truck Rental	$250
Animal Transportation	$4,640
Modification of Chute/Knock Box	$1,285
Miscellaneous Supplies	$225
TOTAL	**$23,045**
Cost Per Ton	**$503**

Indirect costs

The negative impacts of burning include pollution of the environment and release of noxious gases and compounds, including dioxins, which affect the health and well being of the population. Dioxins have been identified as a possible cancer-causing agent and the opportunity exists for uptake by plants or animals and thus for the contamination of the food chain. Public perceptions of pyres combined with emissions of dioxins and the health effects from smoke inhalation are additional negative externalities. Mass slaughter of animals and the large "funeral" pyres in the UK horrified the public, and these televised images contributed to greater economic damage, specifically tourist activity (Franco, 2002; Hickman & Hughes, 2002; Hutton, 2002; National Farmers Union, 2002; Serecon Management Consulting, Inc., 2002). The Canadian Animal Health Coalition concurs that scenes of piles of dead animal burning in farmer's fields would not help the values in Canada's brand in the international market place (Serecon Management Consulting, Inc., 2002).

While incineration is biologically safe, produces little waste, and does not create water pollution concerns, the primary concern is emission of particulates generated during burning. Indirect environmental costs include the impact of emit particles and other products of combustion on air, liquid leakage on soil and water, and the remaining ash that needs disposed. The concern of disease spread through the air is also a concern. The air quality risk will be higher if the process is not properly managed. Smoke and odor are both a concern to neighbors and the general public. Other issues for cost consideration include worker safety precautions, management expenses, and burn permits. The cost of maintaining on-farm incineration permits has escalated as has the inspection and regulatory costs for large incinerators for medical or hazardous waste disposal (Harman, 2001; Morrow & Ferket, 1993; Sparks Companies, Inc., 2002; Winchell, 2001; Wineland et al., 1997). Available estimates do not take into account regulatory-compliance costs as well as public-perception problems, which in the UK during 2001 were tremendous for the tourism industry.

3.4 – Composting

Composting has captured the attention of producers as a means of disposal because they are already familiar with the practice in manure management. It has moved from a novel, experimental idea to a viable, common practice in more industries than just that of poultry (Rynk, 2003). Three types of composting deserve consideration: bin, windrow, and enclosed composting. For individual livestock producers, decisions regarding an appropriate carcass composting system will depend not only on the recurring expenses associated with the method, but also on the initial investment required for construction of the system (bin or windrow) and required agricultural machinery and equipment.

Direct costs

The most important factors involved in cost analysis of carcass composting processes have been described by Mescher (2000) and are ordered in importance as volume and weight of mortality, frequency of mortality occurrence, labor requirements, accessibility and timeliness, impact on the environment, required facilities and equipment (new and existing) and their useful life expectancy. The major rendering costs are construction, equipment, and labor needs. Plentiful carbon sources must also be readily available. Carcass composting has some economic advantages, such as long-life of the facility or pad, minimal cost of depreciation after start-up, similar labor requirements, inexpensive and readily accessible carbon sources in most livestock production areas, and, finally, no need for new equipment (Mescher, 2000).

Bin composting

In the University of Nebraska study, two types of composting units were used for average annual cost estimates. Both structures included concrete floors and bin walls with the higher investment option also including a roof, higher sidewalls, a storage bin for carbon source, and a concrete apron in front of the facility. The estimated construction cost of the high investment version was $15,200 with the low investment version costing $7,850. The lifetime of both was estimated to be 15 years. Researchers estimated that 80 cubic yards of sawdust would be needed at a cost of $4/cubic yard. A skid steer loader would be utilized at $10/hour for transporting dead animals, moving sawdust, and loading materials on the manure spreader. Labor was measured for daily loading of sawdust and animals, moving materials from primary to secondary bins and moving materials to a recycling bin and spreading the remainder. Labor costs for the low investment option are slightly higher, because the carbon source material is not stored in the compost bins and must be moved into the bin (Henry et al., 2001). Estimates do not include indirect costs nor do they show the economic benefit of the final product.

TABLE 4. Estimated costs for bin composting of 20 tons annual routine daily mortalities (Henry et al., 2001).

	Composting High Investment	Composting Low Investment
Disposal equipment	Compost bins and buildings	Compost bins
Capital investment	$15,200.00	$7,850.00
Other equipment needed	Skid steer loader, tractor, manure spreader	Skid steer loader, tractor, manure spreader
Labor hours per year	115	125.9
Budgeted annual costs	$2,305.33	$1,190.58
Fixed Costs – Disposal Equipment		
Machinery costs	$382.19	$447.39
Fixed	$254.79	$298.26
Operating	$320.00	$320.00
Other Operating costs		
Labor	$1,265.15	$1,384.68
Annual Cost	**$4,527.47**	**$3,640.92**
Annual cost per pound	**$0.113**	**$0.091**
Annual cost per ton	**~$226**	**~$182**

In the Alabama poultry study, researchers estimated costs for large-bin and small-bin composting. Poultry producers have readily accepted composting as a means of disposal and over 800 have purchased freestanding composters. The large-bin composting method requires two covered bins with concrete foundations. The initial investment cost is $7,500 and annual variable costs of $3,281 and annual fixed costs of $1,658. The total cost is $4,939, but the value of the by-product for fertilizer use is $2,010 resulting in an annual net cost of $2,929 and cost per hundredweight of $4.88 or $97.60 per ton (Crews et al., 1995).

Sparks Companies, Inc. (2002) estimated the overall cost of small-bin composting carcasses of different species. Their report indicated the total annual costs of composting incurred by the livestock sector to be $30.34/head for cattle and calves, $8.54/head for weaned hogs, $0.38/head for pre-weaned hogs, and $4.88/head for other carcasses.

Windrow composting

Kube (2002) used a windrow system and composted cattle carcasses with the three different methods, each with 1,000 lb carcasses. The first method was conventional composting (no grinding), the second was grinding carcasses after composting, and the last was grinding carcass before composting. The cost analysis of this experiment indicated that, depending on the option selected for carcass composting, the total estimated cost ranged from $50 to $104 per ton of carcasses. While carcass grinding before composting increased the operation cost by about $6/head, it reduced the time, area and management cost needed for composting in comparison with conventional windrow system. Furthermore, he estimated the value of finished compost at a rate of $10-$30 per carcass or $5-$15 per ton and estimated the net cost per carcass to be approximately $5 to $42. In this estimate, no value was assigned to the organic matter of the compost.

Enclosed composting

An enclosed or in-vessel system of composting organics using aerated synthetic tubes called Ag-Bags has been available commercially for the past 10 years. The system consists of a plastic tube 10 ft in diameter and up to 200 ft long. These tubes are equipped with an air distribution system connected to a blower. Raw materials are loaded into the tube with a feed hopper. Tubes used for medium or large intact carcasses are opened at the seam prior to loading raw materials and then sealed for forced air distribution during composting. APHIS used Ag-Bag to compost over 100,000 birds infected with AI depopulated from poultry houses in West Virginia. The structural equipment costs are estimated at $130,000 with additional equipment operating costs of $6-10 per ton (Mickel, 2003). These costs do not include the necessary carbon source expense or labor expense estimates. Virginia AI Ag-Bag composting costs were reported by Brglez at $60 per ton with service from an outside agency (Brglez, 2003).

Indirect costs

The value of the by-product would offset a portion of the estimated costs. No permits would be necessary for composting and it could serve as a temporary step as the virus is destroyed quickly and could be moved and disposed of elsewhere permanently (Brglez, 2003). Odors can be of concern if improperly managed. Risks to water sources do occur if composting is poorly located or managed. Opportunity costs could also exist if the use of the land is impacted while composting is taking place. Keeping the carcasses in public view could also be a public relation problem. In a large-scale outbreak, more compost may be created than can be used, and, therefore, another disposal problem will exist in the long-term. A problem also exists with the attraction of disease vectors such as flies, mosquitoes, rats, and wildlife. Additional record keeping and management time is also necessary (Franco, 2002; Sparks Companies, Inc., 2002).

3.5 – Rendering

Renderers have historically played a critical role in disposal of animal carcasses, accounting for approximately 50% of all routine livestock mortalities and representing the preferred method of disposal. Renderers typically charge modest fees to collect mortalities but they are able to keep the costs low as they profit from the sale of meat and bone meal. However, the role the rendering industry is changing significantly. The risk of bovine spongiform encephalopathy (BSE) has prompted the US and other countries to create safeguards to protect the livestock industry resulting in tight restrictions and bans on rendering livestock carcasses. Changes in regulations are likely to result in large increases in renderer fees to make up for the profit loss associated with the reduction of the meat and bone meal (MBM) market (Sparks Companies, Inc., 2002).

Therefore, the rendering industry has experienced general consolidation in recent years, resulting in higher fees and discontinued service in some areas. There are fewer rendering plants located at a greater distance from the livestock farms that traditionally depended on them to process mortalities. Farms used to be paid by the rendering plants for the mortalities, but renderers no longer find it profitable to pay for the carcasses. Instead, producers are required to pay for the same service. Depressed world market prices for fats, protein and hides, combined with the elimination of use of animal proteins in ruminant feeds are forcing many renderers to leave the industry or significantly increase their fees. Additional regulations that limit the use of rendering will have an increasingly significant impact. Therefore, use of rendering for even daily carcass disposal has become a more significant problem (Rynk, 2003; Doyle & Groves, 1993; Henry et al., 2001; Morrow & Ferket, 1993; Peck, 2002).

The most important factors involved in cost analysis of massive carcass rendering include collection, transportation, temporary storage fees, extra labor requirements, impact on the environment (sanitation for plant outdoor and indoor activities, odor control, and waste water treatment), sometimes additional facilities and equipment. These expenses primarily make the renderers' costs much higher than the cost of usual rendering.

Direct costs

In a University of Nebraska study, cost estimates for routine rendering to accommodate annual mortality of 40,000 lbs were budgeted at four pickup loads a week at a cost of $25 per load. The cost of creating a holding pen away from the production facility and away from public view is estimated to be $300. Labor costs include transporting to and from the holding pen at an average of 70 minutes per week. The values included in the following table refer to the four pickup loads per week and results in a cost per pound of mortality of $0.163. The estimates for one, two, three, five or six load would be $0.066, $0.098,

$0.131, $0.196, and $0.228 per pound of animal mortality, respectively. When calculated per ton, costs range from $132 to $456 per ton (Henry et al., 2001).

TABLE 5. Estimated rendering costs to dispose of 20 tons annual mortality (Henry et al., 2001).

	Rendering (4 pickups per week)
Disposal equipment	Screen storage area
Capital investment	$300.00
Other equipment needed	Skid steer loader
Labor hours per year	60.7
Budgeted annual costs	$51.00
Fixed Costs – Disposal Equipment	
Machinery costs	$364.00
Fixed	$242.67
Operating	$5,200.00
Labor	$667.33
Total annual cost	**$6,525.00**
Annual cost per pound	**$0.163**
Annual cost per ton	**~$326**

Sparks Company, Inc (2002) estimated the labor and equipment (rental or depreciation) costs, respectively, at $10 and $35/hour. As long as the rendering industry can market valuable products from livestock mortalities (including protein based feed ingredients and various fats and greases), collection fees will likely remain relatively low. However, collection and disposal fees will be much higher if the final products can no longer be marketed. Having a commercial value for end products is key to the economic feasibility of carcass disposal by rendering.

For rendering, theoretical estimates were based on a plant owner agreeing to a fee of $80 per ton with one cooker solely dedicated to diseased carcasses as a biosecurity measure. If all tonnage were taken to this plant in 2002 scenario, the total government cost would have been $2,820,206 including the disposal of the rendered product at a landfill resulting in a per ton cost of approximately $167. If the rendered product could be used as a fuel source, the total cost would be $1,565,006 or $93 per ton, and, if the product could be used in feed to local trout farms, the final cost would be $662,606 or $39 per ton (Brglez, 2003).

Indirect costs

Currently in the US, rendering cannot be used for any carcasses that could be infected with a TSE. Therefore, rendering does create an indirect cost related to lack of biosecurity and the risk of disease spread when carcasses are moved to the rendering plant and in the impact on the future use of the rendering plant (Winchell, 2001; Wineland et al., 1997). The environmental costs are minimal if the plants are well managed and control measures are followed (Harman, 2001).

Rendering animal mortalities is advantageous not only to the environment, but also helps to stabilize the animal feed price in the market. Selling carcass meal on the open commodity market will generate a competition with other sources of animal feed, allowing animal operation units and ultimately customers to benefit by not paying higher prices for animal feed and meat products.

Exporting the carcass rendering end products promotes US export income and international activities. For example, US exported 3,650 million lb of fats and proteins to other countries during 1994, which yielded a favorable trade balance of payments of $639 million returned to the US (Prokop, 1996). This export figure is particularly important in view of the shared rendering industry for future marketing of US fats and protein materials and their impacts on the country's economy.

3.6 – Lactic Acid Fermentation

Fermentation was studied in the Alabama poultry study based on 30 tons annual death loss. To practice this method, the producer must purchase a grinder and multiple fiberglass holding tanks. All equipment should be housed in an open shed of approximately 150 square feet. The initial investment cost is, therefore, fairly expensive at $8,200. Annual total costs of $4,052 include variable costs of $2,862 and fixed costs of $1,190.

The value from by-products totals $1,320, resulting in annual net costs of $2,732 and per hundredweight costs of $4.55 or $91 per ton. Other estimates range from $68 to $171 per ton. On-farm fermentation results in reduced transportation costs and safer transport with the fermented product (Crews et al., 1995). Fermentation can hold carcasses for over 25 weeks and the resulting product could be used as fur animal or aquaculture feeds. Acid preservation costs are estimated at $0.10 per pound and could be a fairly low cost alternative (Morrow & Ferket, 1993).

The Lactic Acid Fermentation chapter of the CDWG estimated the costs in an emergency to be about $650 per ton. Their example was based on the disposal of 1000 head of cattle weighing approximately 1100 lbs. This price does not include the sale of by-products to rendering companies or resale of used equipment.

3.7 – Alkaline Hydrolysis

A mobile tissue digester as supplied by Waste Reduction by Waste Reduction Inc. (WR2®) is a specially designed mobile unit for carcass disposal. The units have a 4000 pound capacity and can dispose of that amount in less than 3 hours. For the 2002 Virginia AI outbreak, Brglez estimated that twelve digestors would have been needed operating for 24 hours with one operator per location regardless of the number of units. Each unit is priced at $1 million. The digesters handle 15 tons per day and would have required operation for the full 90 days at a cost of $97 per ton or $1,636,567. Disposal of effluent may also have been necessary if it is not possible to use it as fertilizer (Brglez, 2003).

The cost of operation of these units is low compared to some other means of carcass disposal. Estimated cost of disposal of animal carcasses with the unit operating at maximum capacity and efficiency is $0.02 to $0.03 per pound or $40 – 60 per ton. Estimated cost of the mobile trailer unit with vessel, boiler and containment tank included is approximately $1.2 million. This unit would have capacity of digesting 4,000 pounds of carcasses every 8 hours or approximately 12,000 pounds in a 24 hour day (Wilson, 2003). Others experienced with alkaline hydrolysis have estimated $0.16 per pound ($320 per ton) including costs for power, chemical inputs, personnel, sanitary sewer expenses, and maintenance and repair (Powers, 2003).

3.8 – Anaerobic Digestion

Direct costs

Anaerobic digestion costs were estimated by Chen on a system with one upflow anaerobic sludge blanket and five leachbeds. He estimated the costs for a poultry farm with 10,000 birds at $105-118 dollars per 10,000 kilograms live weight production. Capital costs made up 41% of the costs and economies of scale existed with decreasing costs as farm size increased. With 100,000 bird operations, costs were estimated at $28 dollars per 10,000 kilograms live weight production. Based on Chen's assumption of an 8% mortality rate, the costs per ton of mortality range from $109 -123 per ton for a 10,000 bird operation to $29 per ton for a 100,000 bird operation. Calculating the potential benefits available from the sale of methane could improve the economic impact (Chen, 2000). Scale-up consideration and a costing analysis showed that thermal inactivation was likely to be more suitable and considerably less expensive (Turner et al., 2000).

The various alternatives for construction materials and installation methods will impact the cost of the chosen system. If utilization of the digester is temporary, the construction materials will be less expensive, estimated at less than $50 per kg of daily capacity ($22.73 per lb of daily capacity) and the construction could be done in less than a month. For a permanent installation, concrete construction of the digester takes about six months and would cost between $70 and $90 per kg of fresh carcass daily capacity ($31.82 and $40.91 per lb of fresh carcass daily capacity). Consequently, this type of installation requires construction well in advance of an emergency situation. It would be logical to use the digester for other substances like manure or municipal waste to help alleviate the expense (White & Van Horn, 1998; Boehnke et al., 2003).

3.9 – Novel Technologies

Refrigeration/Freezing

Alabama researchers studied costs related to refrigeration/freezing. The initial purchase cost of a large-capacity freezer combined with on-going electrical costs makes this a very expensive option. Initial costs are estimated at $14,500 with annual variable costs of $5,378 and annual fixed costs of $2,670. The value of the by-products is $1,200 and if combined with total costs of $8,048, results in an annual net cost of $6,848 or $11.41 per hundredweight or $228 per ton (Crews et al., 1995). Freezing has been utilized in the poultry industry. Freezers that hold one ton of carcasses are available for around $2000 and require electricity at approximately $1.20 per day or $0.01 per pound ($20 per ton) (Morrow & Ferket, 1993). A broiler company in Florida developed special weather-proof units that could be moved with a forklift. The freezer unit that cooled the containers never leaves the farm. The loaded containers are either hauled away or emptied at the farm in order to transport the contents to a processing facility (Damron, 2002).

Grinding

Foster (1999) estimated installation costs of $2,000 for a cutter and $6,000 for a grinder for pigs plus $5,000 in associated costs. A shelter to house the equipment plus utilities would increase this estimate. A portable unit should be more expensive because of the associated transport costs and portable power plant required. Also, the cost of the bulking agent is not included. Clearly, the size of carcass involved and the throughput needed will greatly affect cost and type of grinding equipment involved.

Grinding/Sterilization by STI Chem-Clav®

WR²® Companies, headquartered in Indianapolis, Indiana, currently market a patented non-incineration technology for processing biological and biohazard waste materials called the STI Chem-Clav® (http://www.wr2.net/). The cost of a mobile STI Chem-Clav® as described is estimated to be approximately $150,000. This does not include a semi tractor or fuel supply trucks. The addition of a disinfectant into the screw processing mechanism would also add to the cost. If the system were used on a daily basis for processing other wastes (food scraps, medical, etc.), the cost of processing would be decreased; however, the normal flow of feedstock would need to be diverted or stored in the event of a large mortality event.

Ocean disposal

Ocean disposal is a low cost option where available, estimated at approximately $1 per ton. Costs are primarily due to biosecure transportation to the location by truck and then barge rates of $2000/day and tug rates of $2500/day. There would also be a minimal cost for weighting the carcasses to sink. Indirect costs of ocean disposal are minimal. The most significant environmental risk is that of transportation risk. The actual disposal itself is environmentally friendly and is beneficial to marine life. However, appropriate public relations efforts would be necessary in order to avoid significant public disapproval (Wilson, 2003).

Plasma arc

Plasma vitrification generates heat in an efficient and cost effective method. Brglez estimated that four plasma arc torches would have been needed to assist with the Virginia AI outbreak. The units cost $2 million each and the gas collection hoods cost $500,000. Five people would be needed to operate and maintain the torches. The operation costs were estimated to be $120 per ton and the cost of digging the pit was $30 per ton. The total cost for 240 tons of carcasses was $36,000 per day and the total cost for the 2002 AI outbreak disposing of 16,500 tons was $2,475,000 resulting in a per ton cost of $150. There is no odor, little to no environmental risk, it is considered very biosecure (Brglez, 2003). At the North Carolina Disposal Conference, costs were estimated costs to be $60 per ton to treat in situ (i.e., buried) carcasses (Wilson, 2003).

Thermal depolymerization

Renewable Oil International LLC (ROI) uses an approach similar to thermal depolymerization called pyrolysis. Pyrolysis is done at a higher temperature than thermal depolymerization, but uses a considerably dryer feedstock and does not take place in the presence of water. ROI estimates a capital cost of $3 million for a 120 ton per day and a 2.5 MW gas turbine to generate electricity including the cost of feedstock.

Refeeding (primarily to alligators)

Startup costs for an alligator farm can be substantial at approximately $250,000. Some operations, even in the Southeast, raise alligators indoors in temperature-regulated facilities. Alligator waste must be filtered from the water in which they are kept, secure fencing must be provided (Sewell, 1999), and permits acquired (where necessary). Alligator farms in Florida have an average herd size of approximately 3,200 animals (Clayton, 2002). A Mitchell County, Florida farm of 6,500 alligators devoured more than a ton of dead chickens per day.

Napalm

Estimated costs of using napalm for carcass disposal are $25 to $30 per animal but will depend on the cost and temperature of available fuel and on the size of animal. The price of aluminum soap powder varies from $4.60 to $5.30 per pound. The disposal of large number of carcasses may be more efficient than dealing with small disposal situation.

Non-traditional rendering

While the operational costs of using flash dehydration followed by extrusion to recycle mortality carcasses and/or spent laying fowl appear to be economically sustainable, the process is unlikely to attract outside investors since the time to recover capital expenditures ranged from 11.41 to 48 years. The addition of the expeller press technology could be expected to increase the capital costs and reduce the annual profits for the plant even further. Extrusion is not a new technique, having been used in the food industry for some time.

The cost to dehydrate turkey mortalities to 20% moisture is about $27 per ton of final product and $40 per ton if followed by extrusion (Nesbitt, 2002). The use of extrusion methods has high capital costs, but it is possible that farmers could use the extruders for other purposes in creating feeds (Morrow & Ferket, 1993).

3.10 – Cost Comparisons

Foreign animal diseases and the efforts to control them are costly. Disposal methods and other means of disease eradication will have high short-term costs. However, failure to employ an effective strategy will lead to enormous long-term costs. Selection of appropriate strategies should consider both the short and long term costs (Nelson, 1999).

Previous comparative studies

Based on AI outbreaks in Virginia, Brglez compared methods of disposal in the case of a catastrophic avian influenza outbreak. Each method was evaluated on its capacity to dispose of 188 tons of diseased poultry carcasses per day for 90 days. Actual costs of the disposal methods used were compared with hypothetical cost estimates.

Brglez found rendering as the method of choice. The other methods considered included on-site burial, landfill burial, composting, incineration, alkaline hydrolysis, and “in-situ” plasma vitrification. The variables of disposal cost estimated were transportation, labor, materials, land-use fees, and equipment usage. The value of potentially saleable products was also considered. All methods were considered to meet the needs of stopping the spread of pathogens. It was important for the method to be cost effective and quickly accessible. Environmental concerns can be managed with burial, landfill, and incineration management techniques. The objective of the study was to determine the cost, environmental impacts, public perception impact, and complexity of each method.

Brglez examined each method by weighing the four factors on a point scale with good=1, average=2, and poor=3. Any decision making tool needs to consider all factors. The recommended choice in his final analysis was rendering (Brglez, 2003).

TABLE 6. Summary of comparative analysis (Brglez, 2003).

Method	Cost	Environment	Perception	Complexity	Total Score
On-site burial	2	2	3	1	8
Landfills	3	2	2	1	8
Incineration	3	2	3	3	11
Composting	1	1	1	3	6
Rendering	1	1	2	1	5
Alkaline Hydrolysis	3	2	2	2	9
In-situ plasma Vitrification	3	1	2	1	7

Dan Wilson of the North Carolina Department of Agriculture gathered data from a variety of vendors and presented a simple cost comparison at the Midwest Regional Carcass Disposal Conference held in Kansas City, Missouri on August 18-19, 2003. His data appears in Table 7 (Wilson, 2003).

TABLE 7. Estimated cost per ton and technology capacity for various carcass disposal methods (Wilson, 2003).

	Cost	Capacity
Rendering	$86	35-40 ton/hour
Burial	$30-60	10 ton/hour
Composting	$40-60	Equipment Limit
Air-curtain incineration	$30-200	5-6 ton/hour
Landfill	$40-100	Transport Limit
Alkaline hydrolysis	$45-260	4 Hours/Cycle
Plasma	$60	.25 to 7.5 tons/hr
Ocean disposal	$1	Transport Limit

A 2002 study commissioned by the National Renderer's Association and conducted by the Sparks Company investigated methods of disposal for livestock and their potential costs. The evaluation was completed to look specifically at the economic impact of regulations on rendering as an alternative for daily mortality disposal because of the related risks to BSE. Their estimates were based on 2000 annual mortality rates in the US of 3 billion pounds of livestock and 346 million pounds of poultry (Sparks Companies, Inc., 2002). These estimates are calculated at a per ton rate that do not include capital costs for specialized facilities (Table 8).

Renderers typically charge modest fees, but still prove to be highly cost effective because of the operating and fixed costs associated with other methods. However, if regulations keep renderers from selling their by-product their fees will likely increase significantly. The viability of disposal options for producers will depend on logistics, mortality quantity, facility locations, soil type, topography, labor availability, and equipment accessibility. Estimated costs will be driven by producers' attitudes toward the environment, management preferences, and government regulations. Results indicated rendering is a top preference assuming current rendering rates. If rendering prices increase, producers will likely choose other methods and, depending on method choice, could increase costs on society through environmental degradation, groundwater pollution, or spreading of disease. Furthermore, if the costs of "approved" methods increase, the use of "unapproved" methods may increase as well leading to greater environmental risks. Methods with high capital investment costs will be challenging for small producers especially. Therefore, any regulations impacting disposal methods need to carefully analyze all the benefits and costs of any proposed change (Sparks Companies, Inc., 2002).

TABLE 8. Cost estimates for methods of mortality disposal (Sparks Companies, Inc., 2002).

Species	Rendering		Burial	Incineration	Composting
	MBM sold for feed	MBM not sold			
Total (Sector-Wide) Operating Costs ($1,000)					
Cattle and calves	34,088	99,619	43,902	38,561	125,351
Weaned Hogs	48,020	79,061	51,450	16,906	58,018
Pre-weaned Hogs	5,533	7,786	8,300	1,226	4,209
Other	5,828	8,003	6,245	1,184	4,063
Total Operating Costs	$93,470	$194,470	$109,898	$57,879	$191,643
Cost per ton ($)	$55	$116	$66	$35	$115
Operating Costs, Dollars per Mortality ($/head)					
Cattle and calves	$8.25	$24.11	$10.63	$9.33	$30.34
Weaned Hogs	$7.00	$11.53	$12.45	$4.09	$14.04
Pre-weaned Hogs	$0.50	$0.70	$2.01	$0.30	$1.02
Other	$7.00	$9.61	$1.51	$0.29	$0.98
Total (sector-Wide) Fixed Costs for Specialized Facilities ($1,000)					
Beef Cattle				797,985	1,241,310
Dairy Cattle				333,630	518,980
Hogs				158,031	245,826
Other				90,000	140,000
Total Fixed Costs				$1,379,646	$2,146,116

In a study completed at Iowa State University, data was analyzed from pork producers on the disposal methods used, satisfaction with method and costs associated with each method, including capital investment, labor, and operating costs. Incineration requires the highest capital investment while burial requires the lowest investment. However, this investment level changes if feasible burial land is not available. Composting does require an initial capital investment, but often an existing facility was converted to a composting bin. Burial had the highest labor costs, and rendering required the least labor as renderers picked up the dead stock. Depending on the labor available to the producer, it became a critical factor in method selection. Since composting is a fairly new method for these producers, labor costs are high but are likely to decline over time. Due to equipment costs, total operating costs were the highest for burial followed by composting. If the producer already owns the necessary equipment, these costs would be relatively lower. When calculated for 100 head, rendering was the least costly. When satisfaction is considered, rendering and burial are the least satisfactory; meanwhile composting, a more expensive alternative, had the highest satisfactory level (Schwager et al., 2001).

While rendering is a common current option, regulatory changes in the ability of renderers to use dead animal by-products may increase the cost to producers for rendering services. This will in turn deter rendering and result in an increase of on-farm disposal. Small producers are more likely to change activities than large producers, yet small producers may spend just as much in appropriately disposing of their death loss on their own property (Food and Drug Administration, 1997).

In the University of Nebraska study which estimates cost for routine disposal, incineration at $0.049 per pound ($98 per ton) is the lowest cost alternative followed by the incinerator with afterburner at $0.073 ($146 per ton). Low investment composting comes next at $0.091 ($182), followed by burial at $0.097 per pound ($194). (Researchers do not consider burial as a viable option). High investment composting is next at $0.113 ($226) and rendering is the most expensive at $0.163 per pound ($326) (with four loads per week) (Henry et al., 2001).

Alabama researchers found small-bin composting to be the most efficient method at a cost of $3.50 per hundredweight ($70 per ton). The size of the production unit has an impact on the identification of the most economic method. Three size operations were compared: operations with 40,000, 100,000 and 200,000 chickens. Large-bin composting showed economies of scale when comparing a farm of 40,000 to 200,000 with a reduction in net costs of 53%. Increasing flock size reduced net costs of fermentation by 60%. Burial pits were the least responsive with the operation size increase showing a reduction of only 26% while small-bin composting costs were reduced by 26% and incineration costs declined 30%. Refrigeration costs only decreased by 11% (Crews et al., 1995).

Incineration and composting of poultry (broilers, broiler breeders, and commercial layers) were compared by researchers at North Carolina State University. Cost analysis is based on fuel consumption, composter capacity needs, and labor requirements. Analysis was based on 100,000 head of broilers, layers and broiler breeders. The capital investment for incineration of layers and broiler breeders was $2500 and $1400 for their composting. The additional cost to incinerate layers was $1730 and to compost was $2237. For broiler breeders, the cost to incinerate was $1612 and to compost was $1976.50. Broilers are more expensive to dispose because they are larger. The capital investment for incineration was $3500 and $3750 for composting. The fixed and variable costs of incineration were $4003.50 and $4093 for composting (Wineland et al., 1997).

The Canadian Plan Service compared methods of disposal of poultry mortalities. They considered regulation compliance, reliability, biosecurity level and economic factors, such as amount or carcasses, capital costs, equipment availability, and labor costs. They considered four methods: incineration, rendering, composting, and farm burial. Catastrophic losses would require alternative plans be in place as no single method could likely handle the disposal needs. Incineration costs will vary depending on the types of poultry to be destroyed and the most significant cost is capital expense followed by fuel costs. Delivery to a rendering plant for the producer is the easiest, lowest cost method but is dependent on a rendering plant being nearby. Composting costs include the building of the compost bin, material, labor, and the positive value of the fertilizer. Burial on-farm was the most common, but the least recommended. But, it may be necessary in the case of a catastrophic death loss (Winchell, 2001).

Cost models

In a study by the University of California Agricultural Issues Center, the total estimated cost of a FMD outbreak (direct, indirect and induced costs) is estimated in a two-component model: an epidemiologic module that simulates a FMD outbreak in the South Valley and an economic module that estimates the economic impact. The economic model has three parts: (1) calculating the direct cost of depopulation, cleaning and disinfection, and quarantine enforcement; (2) using an input-output model of the California economy to estimate direct, indirect and induced losses; and (3) estimating the losses caused by trade reduction. The first component includes only cattle and swine. Carcass disposal costs are included in a summed depopulation cost with compensation payments and euthanasia costs. Depopulation cost per individual animal is estimated and multiplied by the expected loss from the first module. The model assumes all disposal occurs through burning and burial. Recommendations from the study not only state that depopulation costs would exceed the financial resources available but also includes the following statement: "Depopulation and carcass disposal would face serious difficulties - timely availability of sufficient human, physical and financial resources, availability of burning materials, lack of knowledge of the cost imposed on different social groups by alternative carcass disposal methods, environmental and legal issues, etc" (Ekboir, 1999).

Summary of technology costs

While numerous cost examples are available in the literature and have been highlighted in this chapter as well as in the disposal technology chapters, few reliable cost estimates exist for large-scale disposal. In the case of a foreign animal disease outbreak or natural disaster, total actual costs are unknown. Both operating and variable costs are simply approximates developed from a small number of experiences and routine disposal estimates. In addition, little to no attention has been paid to indirect costs of these technologies. The impact on the environment, land values, public opinion, and general economic factors must be evaluated as well. This type of economic analysis is critical to any decision making process.

The numbers available do provide the opportunity to compare expected fixed and variable costs per ton of carcasses; however, these comparisons should be considered with caution because 1) these estimates are the result of an extensive literature review which utilized numerous different sources; 2) the data available from these various sources are based on a variety of assumptions, including differing circumstances, cause of death, scale of disposal efforts, species, dates, and geographical locations; and 3) these various sources do not consistently incorporate capital, transportation, labor or input costs into the estimates. Despite these limitations, the following table summarizes the cost information identified in the literature. Because of the minimal cost data available on novel technologies, these innovations are not included in the table.

For each technology, Figure 1 provides summarizes the available cost data. The table included highlights the following information: (1) the range of cost estimates cited in previous studies and experiences; (2) comparative representation of cost indicators for capital, transport, labor and input costs ($ - low, $$ - intermediate, $$$ - high, $$$$-very high); (3) comparative representation of indirect cost indicators, including environment/public health and public perception; (4) an example of other indirect cost considerations; and (5) an indication of the existence of valuable or beneficial by-products. The chart reflects the high and low cost estimates as well as the most likely representative estimate. The representative estimate was derived by analyzing the data and weighting the average costs found in the literature.

Technology	Range of cost estimates per ton of carcass material disposed[a]	Direct Cost Indicators				Indirect Cost Indicators			Creates valuable or beneficial by-products
		Initial Capital[b]	Transportation[c]	Labor	Inputs	Environment /Public Health	Public Perception	Other cost considerations	
Burial (on- and off-site)	$15-200	$	$	$$$	$	$$$	$$$$	Land use and values Predator activity	
Landfill usage	$10-500	$$	$$$	$	$	$$	$$$	Municipal costs Management costs	
Open burning	$200-725	$	$	$$$	$$$$	$$$	$$$$	Disposal of ash Permit Fees	
Fixed-facility incineration	$35-2000	$$	$$$	$$	$$	$$	$$$	Disposal of ash Permit Fees	
Air-curtain incineration	$140-510	$$	$$	$$	$$$	$$	$$$	Disposal of ash Permit Fees	
Bin- and in-vessel composting	$6-230	$$	$	$$$	$$$	$	$$	Land use Time efficiency	√
Windrow composting	$10-105	$	$	$$$	$$$	$	$$	Land use Time efficiency Predator activity	√
Rendering	$40-460	$$	$$$	$	$$	$	$$	Biosecurity risk	√
Fermentation	$65-650	$$$$	$	$$	$$	$	$	Time efficiency	√
Anaerobic digestion	$25-125	$$$$	$	$$	$$	$	$	Time efficiency	√
Alkaline hydrolysis	$40-320	$$$	$$	$	$$	$	$	Disposal of effluent	

[a]These estimates are the result of an extensive literature review which utilized numerous sources. The data available is based on a variety of assumptions, including differing circumstances, cause of death, scale of disposal efforts, species, dates, and geographical locations. In addition, different cost estimates do not consistently incorporate capital, transportation, labor or input costs.
[b]Includes capital costs directly associated with carcass disposal only.
[c]Transportation costs depends on the location of the technology. These indicators assume minimal transportation for more likely available technologies.

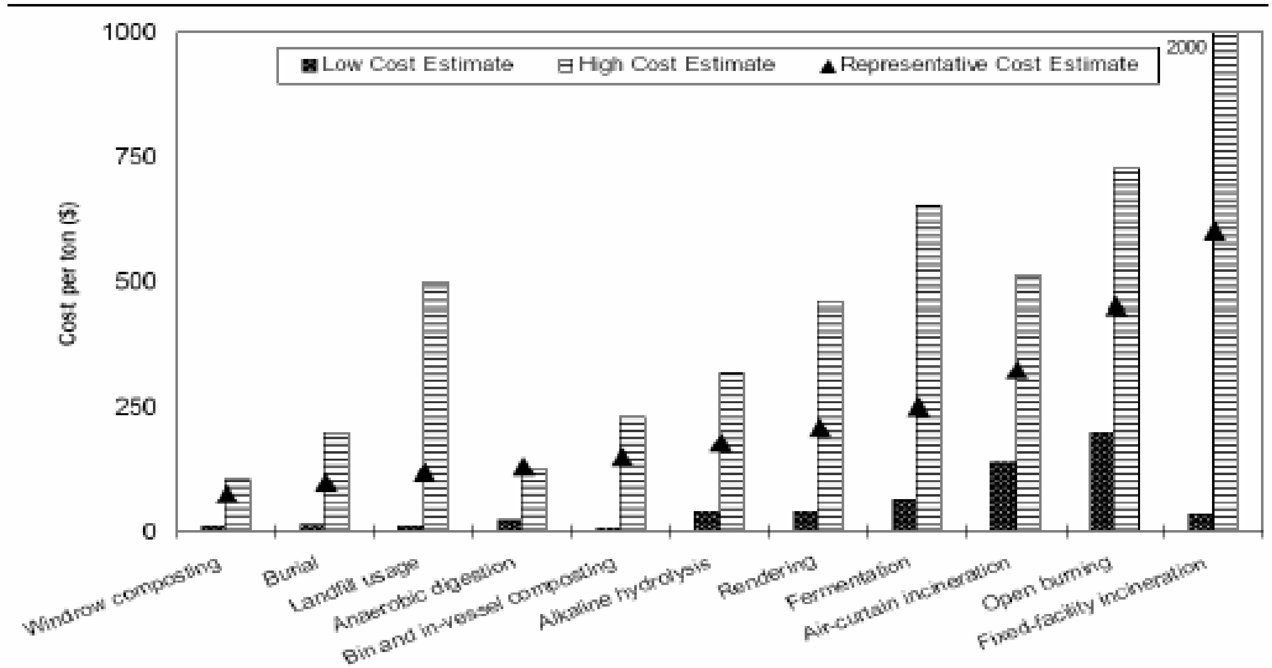

FIGURE 1. Summary of technology costs.

3.11 – Agreements and Contracts

In order to have efficient and immediate action in the case of an outbreak of a foreign animal disease and to reduce the uncertainties, agreements must already be in place with all parties involved and as many decisions as possible should be made prior to the outbreak. Agreements should be in contracts. Contracts should be in place to allow for the increase of expert staff and resources so situations will be controllable. It is easier to negotiate prices with service providers during a disease-free time period. Contracts should be negotiated with providers responsible for laboratories, rendering plants, slaughterhouses, cold storage plants, incinerators, disinfection companies, equipment suppliers, employment agencies, large machinery owners and operators, shower trucks, livestock haulers, communication systems, accommodation suppliers, and others. Any required licenses should be confirmed at this time as well. In order to ensure proper use of public funds when commercial operators are involved, sound management with consistent and sound financial control is necessary. Government agencies should utilize and delegate to specialists available in the private sector to deal with a large animal death loss (de Klerk, 2002; National Farmers Union, 2002).

During the 2001 outbreak of FMD in the UK, organization and management of contracts and the increasing number of contractors created serious challenges in disposal operations. Material for pyres became difficult to obtain, and rapid price inflation existed on fuel sources. Poor quality coal made achieving combustion difficult and a lack of available manual labor caused efforts to be less efficient than in the 1967 outbreak (Scudamore et al., 2002).

The disposal of thousands of animal carcasses in North Carolina in the wake of Hurricane Floyd resulted in additional provisions regarding carcass handling. In the County Plan recommended by the North Carolina State Animal Response Team, the Mortality Management Section coordinators, Drs. Jim Kittrell and Dan Wilson, identify the need to prearrange contracts for resources to handle dead animal removal, burial and disposal. Under the State Plan, it is recommended to work out financing so counties can arrange local contracts with understanding of reimbursement. An important consideration in any contract is how the contracted work is to be measured and compensated. In developing such contracts, consideration should be given to how the animal will be handled and the condition of the carcass. Both parties of the designated contract, the payee and payer, must be able to accurately and consistently measure and count the unit (Ellis, 2001; Kittrell & Wilson, 2002).

Section 4 - Policy Considerations

There are numerous factors that will impact large-scale carcass disposal decisions. It is necessary to identify the factors that must be considered. One of the first factors to be highlighted is the cause of death. If death is due to a contagious disease, then finding a biosecure solution is critical. Biosecurity concerns outweigh nearly all other concerns when a highly contagious disease is involved. In those cases, public exposure must be limited, transportation should be minimized and performed in a manner that will ensure containment of the infectious agent, and biosecurity measures must be the priority. If, instead, deaths are due to a natural disaster, then emphasis should be placed on an environmentally friendly solution. Each method has a different impact on the environment and creates different lasting impacts. The USDA Veterinary Services agency provides a list of environmental decisions to be made, and encourages decision makers to consider impacts on groundwater, wildlife, air quality, surface water, climate, public health, solid waste, cultural resources, utilities and vegetation. It is critical that greater consistencies exist in state regulations and the mechanisms to waive those regulations.

The scale (numbers of carcasses) and scope (species) of the death loss are also important factors. Certain technologies can handle only limited numbers and may not be efficient enough in the case of a major emergency. Some disposal methods are more acceptable with cattle than poultry and vice versa. Logistical issues regarding location of the carcasses, spread of the animal deaths, and proximity to facilities and resources (e.g., fuel) becomes of critical consideration as well. The best solution for one state may differ from another because of the location of large animal numbers and the distance to major population centers. Public health must always be considered as the over-riding factor in determining the most appropriate method of disposal (Ellis, 2001, p. 35). One factor often not discussed in the decision process is the economic impact of the disposal method and the direct and indirect costs, including those related to direct disposal, transportation, facilities and equipment, energy requirements, environmental impact and social costs.

Any final regulatory policy that provides emergency response personnel and animal health officials decision-making guidelines must include consideration of:

- Cause of death loss
- Diseases involved
- Scale of death loss
- Site and facility availability
- Fuel and resources
- Water table and resources
- Transportation options
- Distance to disposal sites
- Costs and economic impacts
- Proximity to population centers
- Public health
- Species involved
- Public perception
- Environmental life cycles
- Soil types.

Any animal health plan must include at least these points for consideration when determining the appropriate disposal technology. Any plan should include multiple methods of disposal and steps need to be taken prior to an emergency to prepare for the usage of multiple disposal methods (Ekboir, 1999; Harman, 2001). If plans are based solely on what is cheap and fast, poor decisions may be made. For example, in Alberta, "Dr. Gerald Ollis noted that burying carcasses is the cheapest disposal method because rendering and incinerating can cost several times more than an animal is worth" (Teel, 2003).

Animal health officials are examining pre-emptive slaughter strategies across the country. In Kansas, as an example, the regulation that all animals within a 1.5-mile radius should be destroyed is being questioned. Feed yard concentration may impact such regulations. If an animal in a feed yard is infected, it may not be necessary to destroy animals more than ½ a mile away if there are no cattle immediately surrounding the feedlot. There may be no way for the disease to be carried from one lot to another and the hot, dry climate of Western Kansas does not lend to easy survival of FMD (Bickel, 2003).

The impact on the environment will be greatly impacted by any change in rural economy and agricultural policy regarding large animal death loss and specifically carcass disposal. Water, air, soils and biodiversity should all be considered. Recent outbreaks have proven that limited time to select burial or burning locations, rapid authorization of disposal permits, communication difficulties between agencies, and public contentions all were directly related to environmental concerns (Harman, 2001). The impact on public health as a result of environmental impacts as well as other physical and psychological issues is also a concern.

Another issue to be discussed is the need for interagency cooperation and clearly defined responsibilities amongst those agencies. State interagency coordination is fundamental to being prepared to handle an animal health emergency (Ekboir, 1999). These issues need to be addressed between local, state, and federal governments as well as between agencies at any government level. Jurisdictional conflicts exist and must be resolved prior to the onset of an emergency situation. Few states have comprehensive disposal plans in place although such plans are critical to making efficient and effective decisions in the face of both small- and large-scale death losses. Therefore, there is a critical need to further review and recommend policy and regulation guidelines (Ellis, 2001). In the US every state has regulations regarding the disposal of dead animals; therefore, each state must approve the disposal method before it is used (Morrow & Ferket, 1993).

An issue that needs further policy consideration is the combination of vaccination and slaughter to control disease. In some countries, where FMD stamping-out is feasible, compete slaughter is the most cost effective alternative, but, in other countries, vaccination may be more cost effective. Introduction of a foreign animal disease will elicit a rapid attempt to control and eradiate the disease (including carcass disposal), and the short-term economic damage may be greater than the cost of the disease itself. Regardless of the costs, the control mechanisms are necessary as the long-term economic impact of the disease becoming endemic would be greater than the control and eradiation costs (Wheelis et al., 2002).

Rushton et al. developed a decision analysis structure to assist policy makers in the selection of control and eradication strategies. They utilized epidemiology, rural economy, export issues, and livestock systems in a matrix together with epidemiological and economic models to determine costs of different strategies. They estimated and compared four strategies: complete stamping out, stamping out with vaccination and slaughter of vaccinates, stamping out combined with vaccination, and vaccination alone. The results indicate that slaughtering infected and suspected animals and vaccinating contiguous flocks/herds is the most cost effective strategy. Methods of disposal of those slaughtered are not clarified. Using decision analysis and a more flexible approach could help reduce cost, maintain producer and public support, and confine and shorten the epidemic (Rushton et al., 2002).

The issue of producer compensation is also important and has significant policy implications. Most states have policies in place regarding this issue. Consider, for example, the wording in Kansas statute 47-626: "The cost of all animal euthanasia and disposal of animal carcasses will be paid by the State of Kansas" (Kansas Animal Health Department, 2002). However, a great deal more thought must be given to when and how producers will be compensated for death loss and disposal costs.

Section 5 – Critical Research Needs

In the event of a large-scale animal health emergency, the slaughter and disposal of infected and exposed animals is an instrumental part of controlling and eradicating the disease. Available technologies offer multiple options for disposal, including rendering, burial, incineration/burning, composting, alkaline hydrolysis, and other emerging concepts. Selection of an appropriate technology, or combination of technologies, will depend on a number of factors, including cause of death, availability of necessary technology and resources, public health, environmental concerns, public perception, transportation needs, location, climate, regulatory issues and economic considerations.

At times, location and technology availability may give producers and animal health officials little to no choice regarding the disposal technology used. Public health should always be a priority if an infective disease agent is involved. In the case of no threat to public health, biosecurity risks related to the livestock industry are of paramount concern. Short-term and long-term impact on the environment should also play a key role in the technology selection process. Economic considerations, including but not limited to direct cost of the disposal methods, must also be a part of the decision making process.

Economic analysis must go beyond the direct costs of disposal (e.g., technology, equipment, transportation, storage, site acquisition, fuel, facilities, and labor) and must include other economic estimates, such as the impact on the environment, tourism, future land values, and other social costs.

The method of carcass disposal used can impose heavy costs on society. Some methods could result in costs incurred not solely by producers, but by society as a whole through environmental degradation, elimination of tourism opportunities, or the spreading of disease. The impact on the environment of certain disposal methods could be unrecoverable. Burial of carcasses will likely cause land used for pits to be lost for production for several years, therefore affecting producers future economic well-being. Tourism can be greatly affected simply by carcass disposal images portrayed to the public. If landfills are used, the county may be financially impacted if landfill capacity is reduced prematurely. Estimating this impact requires an in-depth examination of future land use.

In order to determine the optimal investment in disposal technology and capacity, the cost-benefit ratio of alternative methods for carcass disposal needs to be analyzed. Joint programs between states and/or the federal government to invest in disposal equipment should be evaluated as a possibility. The costs to producers, processors and local communities for each disposal method should be carefully considered. Regulations requiring contingency plans for rapid depopulation of livestock premises should be considered.

For example, in a qualitative disposal risk assessment completed by the UK Department of Health, the chemical and biological sources of greatest concern were combustion gases, air-borne particles, bacteria spread through water, water-borne protozoa and BSE from cattle. The Department of Health assessed rendering, incineration, licensed landfill usage, pyre burning, and on-farm burial for their ability to minimize the previously listed hazards. They noted the importance of following prescribed guidelines in all technologies and found rendering to be the best choice. It was also noted that potential risks to pubic health if disposal is delayed might be greater than risks associated with alternative disposal methods. While a qualitative approach allows for numerous issues to be discussed, no quantitative impact on public health was examined nor was it determined how these issues might formally become part of decision making processes.

Economics cannot and should not be the sole factor in a decision-making process, but economics should be part of the equation. Economically attractive disposal methods may not meet regulatory requirements; the most cost-effective method may be prohibited by local, state, or federal regulations. Additional efforts are necessary to assess state-by-state regulations, investigate opportunities for individual states and the federal government to work together, have disposal plans in place before an emergency, and delineate clear decision-making responsibilities. For example, in order to minimize direct costs, contracts with technology providers should be negotiated in advance. It must be clear who takes on this responsibility. Balancing economic considerations with regulatory requirements is necessary to determine the best options for carcass disposal.

In consideration of further research, the following issues should be addressed:

- Identify direct costs of each disposal technology in the case of large-scale, emergency disposal. Cost estimation models need to include equipment, transportation, training, site acquisition, fuel, facilities, labor, storage, and other direct disposal costs.
- Estimate costs to regulatory agencies of preparing, training, and organizing staff for each disposal technology. This should include an analysis of different levels of preparedness compared to the costs of the outbreak (i.e., the cost of preparedness at level A would be X and the costs of the outbreak given this level of preparedness would be Y).
- Identify a method to estimate direct environmental costs with each technology, including impact on air, water, soil, wildlife, climate, and vegetation and estimate such costs. The method of carcass disposal used can impose heavy costs on society, including environmental degradation. Therefore, estimating the economic impact beyond direct disposal costs is critical to any complete economic analysis. Previous economic work related to similar industries (e.g., waste disposal) could be used in creating economic models.
- Estimate other indirect costs and economic impacts of large-scale disposal efforts on national economies, particular sectors, and society as a whole (including production,

processing, public health, and tourism). Examples of factors to be considered include the impacts of different disposal technologies on land-values, tourism, consumer consumption of animal agriculture products, and the public health costs of stress on producers and emergency workers.

- Develop a cost-benefit analysis model incorporating control, preparation, and direct and indirect costs of disposal technologies.
- Consider the role of the public sector in providing compensation for carcass disposal and minimizing direct and indirect costs to producers (this would include the estimation of recovery costs). This includes estimating the economic impact on different sectors, including producers, local communities, and government. Investment partnerships in technology and training should also be evaluated.
- Consider the role that cost factors should play in government regulation and how economic criteria and biological criteria should be balanced in a decision-making framework. Improvement of the decision making process related to large-scale carcass disposal is the ultimate goal.
- In addition to further defining policy regarding carcass disposal, consideration should be given to vaccination, euthanasia, and animal welfare policies. The depopulation of animals for disease control or animal welfare purposes is a complex issue and deserves significant investigation. Future research should investigate various technologies and kill policies, along with their relationship to animal welfare and behavior, transportation, disposal, economic impact, environmental effect, public relations, public health, and related industries. The following research issues need to be addressed:
    - Identify current policies and regulations related to depopulation and euthanasia at local, state and federal levels.
    - Examine the technologies available for the euthanasia of animals for disease control or animal welfare purposes.
    - Examine current emergency vaccination policies and their relationship to the destruction of animals for animal disease control and welfare purposes.
    - Investigate the impact of different euthanasia technologies on animal welfare and animal behavior.
    - Identify the primary issues related to the use of these technologies and their relationship to transportation and movement, disposal, economic impact, environmental effect, public relations, public health, and related industries.
    - Investigate the impact of certain mass destruction methods, laws and policies on animal producers or caretakers.

Improvement of the decision making process related to large-scale carcass disposal is the ultimate goal. Further review and response to the research questions noted would provide regulators and policymakers with the necessary information to make decisions. These results, combined with increased research from the scientific community on each disposal technology, will help government and industry be better prepared for any large-scale carcass disposal event.

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