

Exposure Assessment of Livestock Carcass Management Options During Natural Disasters

Introduction

Proper management of livestock carcasses following large-scale mortalities protects humans, wildlife, and the environment from chemical and biological hazards. In support of the National Response Framework, the U.S. Department of Homeland Security (DHS) Science and



Technology Directorate funds research in collaboration the U.S. Environmental Protection Agency's (USEPA's) Homeland Security Research Program (HSRP) and the U.S. Department of Agriculture's (USDA's) Animal and Plant Health Inspection Service (APHIS) to support the proper management of animal carcasses following major environmental incidents involving the agricultural sector. Mass livestock mortalities can result from a natural disaster, foreign animal disease (FAD) outbreak, chemical or radiological incident, or other large-scale emergencies. As a product of the collaborative research between USEPA, DHS, and USDA, this research brief summarizes an evaluation of livestock carcass management options following a natural disaster through a comparative exposure assessment. This assessment helps to inform a scientifically-based selection of environmentally protective methods in times of emergency. Future phases of this project will examine a FAD outbreak and chemical or radiological incidents.

In actual natural disasters, many site-specific factors contribute to potential chemical and microbial exposures from carcass management activities. The exposure estimates presented in this summary should not be interpreted as "actual" exposures associated with the management options. However, site managers can use these findings, in conjunction with site-specific factors, to make informed decisions about which carcass management options would minimize risks to human health and the environment for specific locations.

Evaluation Approach

The livestock carcass management options included in this exposure assessment are seven well-established methods with sufficient capacity for large-scale carcass management: on-site open burning (pyre), on-site air-curtain burning, on-site unlined burial, on-site composting, off-site fixed-facility incineration, off-site landfilling, and off-site carcass rendering.

Conceptual models were developed for all seven carcass management options to identify potential exposure pathways resulting from implementation of those carcass management options to address a hypothetical natural disaster scenario (USEPA, 2017).

With the three off-site options, all releases to the environment are restricted by, and are assumed to comply with, applicable U.S. federal regulations. Therefore, chemical and microbial releases from off-site commercial facilities are assumed to be adequately controlled. The number of potential chemical and microbial exposure pathways in conceptual models for the three off-site management options are lower than for the four on-site options. These differences are the basis of a Tier 1 ranking (first tier ranking of the seven carcass management options based on the level of regulatory pollution controls) shown in Table 1.

Table 1. Tier 1 Ranking of Livestock Carcass Management (Offsite vs. Onsite) Options

Tier 1 Ranking	Management Options	Exposure Pathways ^a		Controls and Limits to Environmental Releases
		Chemical	Microbial	
Rank 1: Negligible to minimal exposure - releases regulated to levels safe for human health and the environment	Incineration	6	6	Air emissions regulated under the Clean Air Act (CAA), including pollution control equipment (e.g., scrubbers, filters), with tall stacks to prevent localized deposition; residuals (i.e., ash) managed under the Resource Conservation and Recovery Act (RCRA); wastewater managed under the Clean Water Act (CWA).
	Rendering	3	2	Releases to air and to water regulated under the CAA and CWA, respectively.
	Landfilling	2	2	Landfill design and operation regulated under RCRA; controls include leachate collection and methane recovery.
Rank 2: Higher exposure potential - uncontained releases to the environment	Open Burning	10	10	Uncontrolled and unregulated combustion emissions; possible releases from combustion ash if managed on site.
	Air-curtain Burning	10	10	Partially controlled but unregulated combustion emissions, possible releases from combustion ash if managed on site.
	Burial	6	6	Uncontrolled leaching from unlined burial; slow gas release to air.
	Compost Windrow	6	6	Partially controlled releases from compost windrow (minor leaching, runoff, and gas release to air); where finished compost is tilled into soils, potential runoff and erosion from amended soil.
	Compost Application	2	1	

^a Higher number (10) indicates potential for higher exposure and risk and a low number indicates less potential for exposure. The number of exposure pathways does not necessarily indicate the relative level of exposure among the management options because the potential levels of exposure vary substantially by pathway. Exposure rankings by management option are presented in Table 2.

The top section of Table 2 shows that the Tier 1 assessment for chemicals did not rank the off-site options relative to each other. In a Tier 2 assessment for the on-site management options, potential exposures are ranked relative to one another for a hypothetical site, using a standardized set of environmental conditions, assumptions about the scale of mortality, and how the carcass management options are designed and implemented. Chemical and microbial exposures are assessed independently due to fundamental differences in characteristics influencing transport and fate and in their effects on human health and the environment.

For chemicals, Tier 2 rankings are based on a quantitative assessment in which different methods are applied to estimate combustion releases to air and subsequent deposition to ground level and to assess fate and transport in surface and subsurface soils, groundwater, and an on-site lake. Exposures were assessed for humans breathing airborne chemicals and ingesting chemicals in drinking water, home grown foods, and fish caught in the on-site lake. Some options were not distinguishable from each other given data gaps and uncertainty in modeling. Those options have, therefore, the same relative rank.

Table 2. Ranking of Livestock Carcass Management Options for Chemicals

Tier 1 Description	Management Option		Principal Rationale
The qualitative Tier 1 assessment distinguishes the off-site options from the on-site options based on level of regulatory control. The off-site options are considered to pose lower risk than the on-site options, which have uncontrolled environmental releases. The off-site options are not ranked relative to each other.	Off-site Rendering		Carcasses processed into useful products; wastes released under permits; availability decreasing.
	Off-site Landfill		Carcass leachate contained and methane captured; landfills at capacity are closed and new ones built.
	Off-site Incinerator		Destruction of materials; air emissions are regulated; ash is landfilled.
Tier 2 Description	Rank^b	Management Option	Principal Rationale
The quantitative Tier 2 assessment ranks the on-site options relative to each other by comparing ratio of estimated exposures (from data on source emissions and fate and transport modeling) with toxicity reference values (TRVs).	1	Compost Windrow	Bulking material retains most chemicals.
	1	Burial	Soils filter out chemicals traveling toward groundwater.
	2	Air-curtain burning	Similar release profiles; emissions sensitive to type and quantity of fuels used and burn temperature.
	2	Open Pyre burning	
	3	Compost Application	If no offset from lake; mitigate with offset and erosion controls.

^b Rank 1 poses the lowest relative risk and higher numbers indicate higher relative risk.

In the Tier 2 assessment for microbes, three pathogenic microbes were evaluated to represent prions, bacterial spores, and bacterial cells. For these microbes, all estimated exposures were below available exposure benchmark values. However, because of significant uncertainty about the initial concentration of the pathogenic microbes in healthy livestock, the Tier 2 rankings for microbes are based on the degree of thermal destruction and containment provided by the carcass management options. These rankings assume prions could survive

more management options than spores, and bacteria that do not form spores were most susceptible to thermal inactivation. Thermal destruction can be applied as a criterion for both the on-site and off-site options. Tables 3 and 4 show the microbial exposure rankings for Tier 1 and Tier 2, respectively. Although the on-site options are not ranked relative to the off-site options, some will offer thermal destruction comparable to or greater than off-site options.

Table 3. Tier 1 Ranking of Off-site Livestock Carcass Management Options for Microbes

Tier 1 Description	Rank ^c	Management Option	Principal Rationale
The qualitative Tier 1 assessment distinguishes the off-site options from the on-site options based on level of regulatory control. Among the off-site options, rankings are based qualitatively on the level of thermal destruction. Off-site options are not ranked relative to on-site options, although some will offer thermal destruction comparable to or greater than off-site options.	H	Off-site Incinerator	Thermal destruction of all microbes, ash is landfilled
	M	Off-site Rendering	Thermal inactivation of all microbes except prions, workers protected from prion exposure with the use of personal protective equipment (PPE).
	L	Off-site Landfill	Containment, including liner, leachate collection, cover material, but no thermal destruction; when capacity is reached, landfill is closed and new ones built.

Abbreviations: H = Highest rank; M = Middle rank; L = Lowest rank.

^c Relative and absolute risks from microbial pathogens depends on initial concentrations in healthy cattle, which is unknown.

Table 4. Tier 2 Ranking of On-site Livestock Carcass Management Options for Microbes

Tier 2 Description	Rank ^{d,e}	Management Option	Principal Rationale
Rankings in the Tier 2 assessment are based on quantitative exposure dose estimates for a limited number of exposure pathways. For those pathways and the microbes assessed, all estimated exposure doses were below the available ID ₅₀ values for each representative microbe (<7, 3–4, and ~ 1 order of magnitude lower than the ID ₅₀ for <i>Escherichia coli</i> , <i>Bacillus anthracis</i> , and prions, respectively). Therefore, the rankings reflect the extent of thermal destruction.	1	Air-curtain	Thermal destruction of all microbes
	2	Open Pyre	Thermal destruction of all microbes except prions
	3	Compost: • Windrow • Soil application	Thermal inactivation of most microbes during windrow decomposition phase, incomplete activation of spore-forming microbes and prions with some decay/inactivation expected before the application of finished compost
	4	Burial	No thermal inactivation of any microbes, some decay expected

Abbreviations: ID₅₀ = infectious dose for 50 percent of the exposed population.

^d Rank 1 poses the lowest relative risk and higher numbers indicate higher relative risk.

^e Relative and absolute risks from microbial pathogens depends on initial concentrations in healthy cattle, which is unknown; qualitative ranking is based on thermal destruction and containment.

Uncertainties in the Exposure Assessment

Tables 5, 6, and 7 summarize three types of “uncertainties” in the exposure assessment:

- Parameters with Moderate to High Natural Variation
- Uncertain Parameter Values or Models
- Simplifying Assumptions.

Table 5. Moderate to High Natural Variation in Parameter - Potential Bias from Selected Values

Key Topic	Selected Parameter Value	Bias	Rationale
Natural Disaster Scenario			
Scale of Mortality	<ul style="list-style-type: none"> ▪ Mortality of 100 cattle at one farm with a total weight of 50 tons to match the environmental impact statement. Large-scale mortalities could limit availability of or access to resources. 	Possibly High Underestimate	<ul style="list-style-type: none"> ▪ The scale of mortality is likely to be “small” relative to mass mortalities for which emergency measures at a state and federal level would be required. In general, larger mortalities result in greater potential releases and exposures.
Site Setting and Environmental Conditions			
Surface Water	<ul style="list-style-type: none"> ▪ Hypothetical farm layout includes a 100-acre lake that is large enough to support recreational or subsistence fishing. 	Variable Overestimate	<ul style="list-style-type: none"> ▪ Site design is likely to overestimate exposure. In particular, exposure is overestimated for sites without a fishable pond or lake.
Groundwater	<ul style="list-style-type: none"> ▪ Contaminants leached from the burial trench, temporary storage pile, and buried combustion residuals can reach groundwater. 	Variable Overestimate	<ul style="list-style-type: none"> ▪ The depth to an underground aquifer is likely to be deeper than 1 m. Although the domestic well exposure pathway is possible, a domestic well is not likely to be shallow enough to directly intersect leachate from surface sources.
Meteorological Conditions	<ul style="list-style-type: none"> ▪ One year of meteorological data from a weather station in Iowa, chosen to represent a moderate climate in the U.S. agricultural heartland. 	Moderate Over- or Underestimate	<ul style="list-style-type: none"> ▪ The meteorological data used for this assessment could over- or underestimate relevant conditions in other areas of the country.
Soil Type and Properties	<ul style="list-style-type: none"> ▪ Recommended default soil properties were chosen to reflect national average conditions. Soil properties influence how quickly leachate and rainwater can flow through soils vertically and how likely it is for chemicals and microbes to sorb to soil particles. 	Moderate Over- or Underestimate	<ul style="list-style-type: none"> ▪ Although the soil conditions were chosen to represent national average conditions, sites with different soils could have higher or lower rates of vertical water movement and capacity to adsorb chemicals or viruses.
Exposure Receptors and Estimation			
Human Receptors	<ul style="list-style-type: none"> ▪ Exposures are assessed for three types of farm residents: infants who consume drinking water in their formula, young children (age 1-2 years old), and adults. 	Neutral	<ul style="list-style-type: none"> ▪ Although exposures might be over or underrepresented for receptors or receptor populations included in the assessment, the approach includes a range of age categories and is based on EPA exposure assumptions.
Exposure Factors	<ul style="list-style-type: none"> ▪ Exposure factors (e.g., ingestion rates, body weights) are mean values. 	Neutral	<ul style="list-style-type: none"> ▪ Means are used so that exposure is not over or underestimated by this aspect of the approach.

Table 6. Uncertainty in Parameter Value(s) Selected

Parameter	Description	Uncertainty	Rationale for Uncertainty Category
Natural Disaster Scenario			
Chemicals	<ul style="list-style-type: none"> Chemicals included in the assessment were identified from relevant published sources. 	Low	<ul style="list-style-type: none"> Chemicals included in the assessment does not necessarily include all potential chemicals of interest from actual carcass management.
Microbial Agents	<ul style="list-style-type: none"> Microbial agents included microbes present in healthy livestock. Among those three representative agents were selected for exposure estimation: prions, <i>Bacillus anthracis</i>, and <i>E. coli</i> O157:H7. 	Low	<ul style="list-style-type: none"> The three microbial agents were selected to represent three organisms with three distinct characteristics (e.g., persistence). Exposures for various organisms may be over or under estimated.
Carcass Management Options			
Combustion Fuels	<ul style="list-style-type: none"> Types and amounts of fuels affect the composition and amounts of emissions to air and combustion residuals. 	Moderate	<ul style="list-style-type: none"> Combustion fuel assumptions could contribute to over or underestimation of exposure.
Ash Disposal	<ul style="list-style-type: none"> Combustion ash is managed on site, buried in place using in the assumed length and width of the combustion units. 	High	<ul style="list-style-type: none"> Exposures are overestimated if combustion ash is not disposed of on site.
Releases and Release Rates			
Releases Estimates	<ul style="list-style-type: none"> Data to characterize the composition, quantity, and rate of releases are very limited. 	High	<ul style="list-style-type: none"> Actual releases can vary significantly due to many factors (e.g., unit design, environmental conditions).
Animal Vectors	<ul style="list-style-type: none"> Chemicals or microbes can be transported by insects, birds, or mammals that come in contact with carcasses before or during management. Quantitative evaluation of animal vectors not included. 	Moderate	<ul style="list-style-type: none"> Exclusion of animal vectors from the assessment causes potential exposures to be underestimated. This uncertainty impacts the composting option more than burial or the combustion-based options.
Fate and Transport Modeling			
Models	<ul style="list-style-type: none"> Various screening-level models and calculations to estimate chemical fate and transport through air, water, soil, and terrestrial and aquatic food chains. 	High	<ul style="list-style-type: none"> Data and methods can individually contribute to estimation of exposures. Usage of conservative assumptions and approaches likely result in over-estimates of possible exposures.
Chemical Properties and Other Inputs	<ul style="list-style-type: none"> Modeling uses various chemical properties and numerical inputs (e.g., soil properties, food web composition). 	Moderate	<ul style="list-style-type: none"> Uncertainties might be present in input parameters. Many modeling inputs generally uses central-tendency values.

Table 7. Simplifying Assumptions - Effects on Exposure Estimates

Key Topic	Simplifying Assumption	Effect	Rationale for Effect
Natural Disaster Scenario			
Type of Livestock Affected	Any livestock type can suffer mortalities from natural disasters. Body size ranges from small to large and animal density varies with farming practices. Livestock species differ in terms of body composition, which can affect combustion temperature and residual materials and affect rate of decomposition for other options.	Moderate Over- or Underestimate	Body composition varies among species, but variability is limited by the general similarity in warm-blooded vertebrate bodies.
Site Setting and Environmental Conditions			
Site Layout	Conceptual models and site layout were designed to include all feasible complete exposure pathways.	Moderate Overestimate	Overestimate exposure as the layout assumes a worst-case exposure for each possible pathway.
Carcass Management Options			
Off-site Carcass Management Options	Off-site carcass management facilities comply with applicable regulations and that those regulations are protective of human health and the environment.	Low Underestimate	Underestimated where the facilities do not comply with applicable regulations.
Design of On-site Management Units	Design of on-site management options are based on 50 short tons of carcasses. For larger mortalities, the spatial pattern and nature of environmental releases could be different.	Moderate Over- or Underestimates	Carcass management units could lead to over- or underestimation of exposure.
Carcass Handling Before Management	Workers who handle livestock carcasses are assumed to use recommended personal protective equipment (PPE).	Moderate Underestimate	Exposure to workers is underestimated if no PPE is used.
Temporary Storage Pile	Carcasses are stored in a pile on bare earth for 48 hours during preparations for further management.	Moderate Under- or Overestimates	If animals are in the temporary pile for more time, exposures from the storage pile are underestimated and exposures from subsequent management are overestimated (and vice versa).
Carcass Transportation	Exposures due to carcass transportation are considered insignificant and are not used in ranking the carcass management options.	Low Underestimate	If carcass transportation results in a significant exposure, the assessment underestimates overall exposure.
Fate and Transport Modeling			
Runoff from Compost Application	Application site is immediately adjacent to the lake.	High Overestimate	Overestimates runoff to the lake and human exposure to any metals in the compost.
Exposure Receptors and Estimation			
Homegrown farm Products	Farm residents are assumed to consume only home-grown products.	Moderate Overestimate	Farm residents also rely on store-bought foods.

Conclusions

Off-site options, including incineration, landfilling, and rendering, are subject to air, water, and solid waste regulations designed for adequate health and environmental protection. This assessment finds that, when properly designed and implemented, the four on-site carcass management options as well as the off-site options are unlikely to cause adverse health or environmental effects.

The Tier 2 assessment provides a scientifically based understanding of the relative contribution of specific exposure pathways, hazardous agents, and steps in carcass management processes. These insights can assist selection of environmentally protective livestock carcass management methods in the event of a natural disaster. The assessment also can aid selection and priority setting for mitigation and best management practices to assist State regulators and communities to prevent, prepare for, respond to, and recover from emergencies. The overall outcome of exposure assessments will help development of a decision tool to support selection of management methods in times of emergencies by providing scientifically-based information on potential hazards to human health, livestock, wildlife, and the environment.

Additional Information

U.S. EPA. Exposure Assessment of Livestock Carcass Management Options During Natural Disasters. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-17/027, 2017 (URL: https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=335655)

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