

Traditional methods of carcass disposal: a review

Abstract

Animal mortality is an integral part of livestock farming and proper disposal of these mortalities is necessary for effective disease control measures. Various disposal methods are being used throughout the world depending upon the legislations which are followed in different countries. In developing countries like India the most widely used disposal methods are the traditional methods like: burying, burning, incineration, rendering and composting. There are some environmental, biosecurity, social and economic issues associated with these methods. Environmental constraints associated with these disposal methods are like: contamination of air, soil and water particularly due to persistency of some infections like TSE (Transmissible Spongiform Encephalitis) and other prion infections. Social concerns with these traditional disposal methods are: odour and fly menace and contamination of drinking water. Similarly the economic constraints are associated with the alarming increase in the costs of raw materials like: kerosene, diesel and wood for burning. Issues are also related with the labor cost, availability of land and transportation of mortalities to site of disposal. In this review, environment and social issues, biosecurity risks and economic constraints will be discussed for each of these traditional methods.

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Introduction

Mortality is an inevitable consequence of livestock and poultry farming. With a large livestock and poultry population of 513 and 729million¹ respectively in India, animals die due to different diseases, accidents and disasters. Mortalities are usually thrown out on the roads, farm lands and rivers,² thus creating different types of menace and environmental hazards. Strategies for carcass disposal especially on larger scale require preparation well in advance of an emergency in order to maximize the efficiency of response. The most effective disposal strategies will be those that exploit every available and suitable disposal option to the fullest extent possible, regardless of what those options might be. Disposal method should be safe, practical, and economical and should utilize the mortalities which is essential for Biosecurity.³ Decision-makers should come to understand each disposal technology available to them, thereby equipping themselves with a comprehensive toolkit of knowledge. Such awareness implies an understanding of an array of factors for each technology, including the principles of operation, logistical details, personnel requirements, likely costs, environmental considerations, disease agent considerations, advantages and disadvantages, and lessons learned for each technology.

Animal carcasses are usually disposed of by traditional methods like burial, burning, incineration, rendering and composting.⁴ However due to implementation of different environmental and social regulations the use of these traditional methods on a larger scale has been forbidden to a large extent. Each of these methods has its unique flaws. Burial of dead birds in a pit can lead to ground water contamination. Incineration is expensive and can potentially pollute the air. Rendering dead birds into by-product meal is constrained by transportation cost and restrictions on the movement of diseased birds from one location to another. Land filling is subject to land availability and limitations on diseased carcass movement. These different methods in general have other disadvantages as well like cost involvements, labour intensiveness, production of environmental pollutants and obnoxious odour.⁵ Nontraditional and novel methods of disposal are a good option for eco friendly disposal of mortalities.

In the following review the traditional carcass disposal methods will be discussed with different biosecurity, environmental and economic issues related to them (Figure 1).

Traditional methods

Burial

It includes disposing of the carcasses in graves, trenches or in open bottom containers called as mortality pits.^{6,7} This method has been banned in most of the developed countries because of the entry of infectious agents in the human food chain and the environmental pollutions.⁸ Large scale burial in different catastrophes and disasters may lead to contamination of ground and surface water with pathogens and the chemical products of decomposition.⁹

The amount of time required for buried animal carcasses to decompose depends most importantly on temperature, moisture, and burial depth, but also on soil type and drainability, species and size of carcass, humidity/aridity, rainfall, and other factors.¹⁰ Mass burial of carcasses poses considerably greater environmental and biosecurity risks than burial of routine mortalities.) The *E. Coli* and *Cryptosporidium* concentrations in ground and surface water were higher due to burial of a small number of carcasses than due to excretion from live animals.¹¹ The different factors like soil type, permeability, water table depth and rainfall significantly affect the movement of pathogens from disposed carcass through soil to groundwater.¹² No studies have been reported in the literature linking the burial of animal carcasses to detrimental effects on either human or animal health, although burial of humans with in a water table has led to incidences of contaminated groundwater.¹³ The use of hydrated lime $\text{Ca}(\text{OH})_2$ in burial has been effectively reduced the survival of pathogens.¹⁴ Avery et al.¹⁵ found no viable *E. coli* cells in contaminated abattoir waste treated with lime applied at a rate of 10 g of CaO lime per kg of waste. Excessive use of lime both during the construction and subsequent operation of burial sites may reduce the growth of all micro-organisms and hence slow the process of decomposition. Despite the low incidence of drinking water contamination due to burial of carcasses,

some infectious material such as anthrax spores or prions can be seen within the soil after carcass decomposition.¹⁶ This may lead to ingesting of contaminated soil and the infectious agents by animals and hence may lead to development of neurodegenerative disease (e.g. BSE or scrapie) in the case of prions,¹⁷ or the reintroduction of anthrax.¹⁸ Burial sites should be located away from livestock fields and at sufficient depth so that the potential for transfer of infectious agents back to the surface^{16,19} is very low.

Burning

Burning of carcasses within a farm on pyres is a common practice in many countries particularly developing ones. Burning of carcasses in disease out breaks like FMD²⁰ and anthrax²¹ has been reported. Despite the potential for pollution to occur from the mass-burning of carcasses, evidence of groundwater contamination from ash burial, soil contamination from pyres, and air emissions from pyres did not significantly affect the environment beyond the immediate vicinity.²² Studies show that the spread of FMD virus via plumes of smoke while burning was very unlikely to occur.²³ Biosecurity concerns due to TSE while burning remains as open-air combustion is not likely to reach a high temperature of incineration.²⁴ Brown et al.²⁵ suggested that the potential for airborne or ground ash transfer of TSEs from animal carcasses is highly unlikely. Complete combustion of carcass for safe disposal is achieved when sufficient labour, air and fuel is provided.²⁶ Human health risks associated with on-farm burning (apart from physical burns and direct smoke inhalation) include the emission of dioxins from incomplete carcass combustion. Dioxins and furans are carcinogens and can negatively affect human reproduction, development and immune systems.²⁷ Although the environmental impact of burning was shown to be minimal, considerable social concerns were expressed regarding odour, unsightliness, etc.²⁸ In fact, there is little evidence to deny or endorse the use of on-farm burning for routine disposal of carcasses and hence more scientific analysis is required to test common conceptions e.g. increased dioxin levels and groundwater contamination.⁸

Incineration

Incineration is burning of animal carcasses at high temperatures (>850°C) to inorganic ash. The process destroys all infective agents.⁹ Ash represents only 1-5% of initial carcass volume,²⁹ although this will depend on the incinerator type, process, fuel and animal species. In developed countries like USA and EU, ash resulting from specified risk material (SRM) (e.g. the spinal cord and brain) is subsequently sent to designated landfill sites.⁹ The principal concern with incineration of carcasses is the gaseous emissions key pollutants represent 60.2% of the total air emissions.³⁰ Adoption of optimum techniques like use of afterburners has significantly achieved reductions in harmful gases like polycyclic aromatic hydrocarbon.³¹ Other health concerns with incineration include the release of dioxins and furans released due to incomplete combustion and can settle in areas around carcass incinerators and could enter the food chain through grazing animals or through human consumption of contaminated crops. However, afterburners fitted to incinerators can dramatically reduce the risk of noxious emissions release.³²⁻³⁴ It is generally accepted that incineration destroys prion proteins more effectively than other methods of livestock disposal (with exception of alkaline hydrolysis.⁹ From a human and animal health perspective, the high temperature of incineration also completely destroys zoonotic and animal pathogens, including resilient spore-forming bacteria such as *Bacillus anthracis* (anthrax).³⁵ One of the main perceived risks related to off-farm

incineration is the transportation of dead livestock between farms and vehicles may cover significant distances between farms while they are laden with carcasses from diseased animals and this has raised significant concerns within the livestock industry.³⁶ Such risks may be reduced via employing good biosecurity practices such as disinfection of collection vehicles and protective clothing between sites; and by having sealed containers which livestock or vermin cannot access and which fluids cannot escape.³⁷ It is clear that further studies are needed to evaluate the risks of disease propagation through transport of carcasses both within and between farms.

Rendering

Rendering is the process of crushing carcasses into small uniform size, heating the particles and separating out the fat, proteinaceous material and water to make useful products like meat and bone meals and tallow.³⁸ Livestock mortality is a tremendous source of organic matter. A typical fresh carcass contains approximately 32% dry matter, of which 52% is protein, 41% is fat, and 6% is ash.⁹ The proper operation of rendering processes leads to production of safe and valuable end products. The heat treatment of rendering processes significantly increases the storage time of finished products by killing microorganisms present in the raw material, and removing moisture needed for microbial activity.⁹ Rendering practice is being discouraged in TSE and prion infected carcass because of the persistency of infection during the heat treatment of the carcass.³⁹ Tallow from rendering can be used in soaps, washing powders, as lipids in the chemical industry and cosmetics.³⁸ It may also be burnt for energy production due to its high fat thus reducing the net environmental footprint of the process.⁴⁰ The main environmental concerns associated with rendering are gas and odour emissions.⁴¹ In rendering 90% of odours can be removed using coldwater washing and using of afterburners, scrubbers or biofilters.³⁸ The effluents generated at rendering plants like suspended solids, oils and greases must be regulated to prevent the release of effluents with high biological and chemical oxygen demand into water bodies. The risk of pollution can be reduced by the efficient filtering, use and reuse of wastewater or by more intensive wastewater treatment on or off-site at sewage treatment plants.⁴¹ NABC⁹ reports that rendering sufficiently destroys most pathogens but recontamination can occur, particularly with *Salmonella*, during handling, storage and transportation of the final product. Although the biosecurity issues for collection and transportation of carcasses remains there for rendering, it does still represent a well established method of livestock disposal for those with access to a central collection service.⁴⁰ Commercial rendering facilities are becoming increasingly less available due to economic pressures on the industry.³⁸ Traditionally farmers are getting remuneration for their livestock mortalities but the inability of the process to completely destroy TSEs has led to the reduction in saleable products in many parts of the world.⁴² Nevertheless, rendering is still a preferred option for disposing of mortalities and is likely to continue to be so, preferably in combination with incineration and a pathogen monitoring regime.³⁷

Composting

Composting process involves the layering of carcasses between strata of carbon-rich substrate such as straw, sawdust or rice hulks with a final covering of carbon-rich substrate over the entire pile.⁹ Larger carcasses are typically placed in single layers while poultry can be multi-layered; and the compost piles are subsequently aerated or turned.⁹ Depending on carcass weights, the waste material may decompose at rates as high as 1-2kg/day⁴³ into a useful product that

can be used as a soil amendment. The process essentially occurs in two phases – a primary, thermophilic phase (temperatures up to 70°C generated for a number of weeks) and a secondary, mesophilic phase (typically 30–40°C) for a number of months.⁴³ When an impermeable base is not used, small-scale composting of mortalities has been shown to contaminate the underlying soil due to the loss of leachate with a high ionic strength from the compost piles⁴⁴ particularly in high rainfalls.

In terms of biosecurity, composting facilities should not be located directly adjacent to livestock production units, and the vehicles associated with operation should be sanitized with appropriate cleaning and disinfecting agents for each trip. The site should be downwind from residential areas, provide a limited or appealing view for neighbors or passing motorists, and possibly have a pleasing appearance and landscape.⁴⁵ McGahan⁴⁶ indicated that runoff from a carcass compost pile may contain organic compounds that could degrade the quality of nearby ground or surface water.⁴⁶ To avoid this, all runoff from the composting facility should be collected and treated through a filter strip or filtration area. The compost facility should be located at least 3ft (1m) above the high water table level and at least 300ft (90m) from streams, ponds, or lakes in the same drainage area.

To minimize the risk of pollution (i.e. leaching and runoff), composting should be undertaken on an impervious base (e.g. hard standing or plastic liner) and a bulking agent utilized to absorb excess liquids produced from the decomposing bodies (e.g. sawdust).⁹ The risk can be further reduced by undertaking the composting process indoors or under gas-permeable covers to prevent entry of rain water into the compost piles.⁴⁷ This precaution should also prevent run-off and leaching of nutrients as well as reducing ammonia emissions. In terms of gaseous emissions, odour levels from the composting of carcasses are considered to be low in comparison to manure-related facilities.⁴⁴ The temperatures generated during the thermophilic phase of carcass composting has been shown to effectively reduce numbers of bacteria, viruses, protozoa and helminthes.⁴⁸ However some bacteria, particularly *Salmonella* can re-colonise the compost when temperatures are reduced near the end of the composting process or if the pile has not been adequately aerated or turned.⁴⁹ It is also possible that opportunistic pathogens may colonise the compost pile if insufficient temperatures are reached.⁵⁰ Schwarz et al.⁵¹ found that numbers of bacterial indicator species in Deer carcass composting were reduced to near zero after twelve months but they recommend that a cautious approach be taken and the compost used in areas with limited public contact (e.g. along road verges) to further negate any risks. Studies have shown that the avian influenza virus can be deactivated at ambient temperatures (15–20°C) in less than a week, or after 15min when mixed with chicken manure at 56°C;⁵² temperatures

easily achieved in composting piles. Further, a recent study by Guan et al.⁵³ showed that composting rapidly eliminates avian influenza and Newcastle Disease viruses in chicken carcasses. A risk-based review of disposal options for avian influenza by Pollard et al.³⁷ placed in-vessel composting on the preferred list of disposal methods on the grounds of exposure assessment. Glanville et al.⁴⁴ showed that a 45–60 cm layer of clean material covering cattle carcasses was enough to prevent the compost piles containing vaccine strains of avian encephalomyelitis and Newcastle Disease virus from infecting sentinel birds.

There is little information regarding the fate of prions or spore-forming bacteria such as *Bacillus Anthracis* during carcass composting. However, Huang et al.⁵⁴ found some initially promising evidence in their study with scrapie-infected sheep, with prion removal in one experiment and prion reduction (but not destruction) in the second. The use of geographical information systems and groundwater vulnerability maps to locate ideal composting sites, along with good composting practices (e.g. using clean and fresh carbon substrate) in tandem with stringent regulation to restrict subsequent land spreading to specific soil types, a pathogen monitoring regime and a maximum mass of carcasses to be disposed, would further decrease perceived risks.⁵⁵

Economic considerations of carcass disposal

A complete and multidimensional strategy is necessary to plan for disposal of livestock mortalities. A critically important part of that strategy is to dispose of large numbers of animal carcasses in a cost effective and socially and environmentally sound manner.⁵⁶ The planning must consider the economic costs and the availability of resources for the disposal of carcasses. A complete cost-benefit analysis of different methods of disposal for various situations is necessary to determine the best alternative.⁵⁷ Major economic factors and implications also need to be identified and the different disposal options need to be compared and contrasted. The impact on the environment, land values, public opinion, and general economic factors must be evaluated and quantified as well. Economics cannot and should not be the sole factor in a decision-making process, but economics should be part of the equation.²⁸ Economically attractive disposal methods may not meet regulatory requirements and hence the most cost effective method of disposal may seem unsound by the state authorities.⁵⁸ In order to minimize the cost involvement in different disposals, technology providers should be negotiated in advance. Improvement of the decision-making process related to large-scale carcass disposal is the ultimate goal. Increased research from the scientific community on each disposal technology will help government and industries to be better prepared for any large-scale carcass disposal event.

Table 1 Environmental impacts of traditional methods of carcass disposal⁶⁰

Method	Environmental impacts		Pollution			Use of end product as fertilizer
	Odour	Green house gas emission	Air	Soil	Water	
Burial	-	-	VG	P	M	NA
Burning	VP	MRN	MRN	MRN	MRN	MRN
Incineration	G	P	G	G	G	MRN
Rendering	M	G	MRN	VG	M	MRN
Composting	G	G	MRN	M	MRN	G

P, poor; VP, very poor; M, moderate; G, good; VG, very good MRN, more research needed; NA, not available

Table 2 Socio-economic and biosecurity aspects of traditional methods of carcass disposal⁶⁰

Method	Socio-economic aspects			Human health (dioxins and furans)	Biosecurity aspects			Transport of animals (Off farm)	TSE/Prion destruction
	Process Spread	Relative Cost	Practicality (for the farmer)		Pathogen contamination				
					Air	Soil	Water		
Burial	M	VG	G	VG	G	M	MRN	VG	VP
Burning	G	M	M	P	MRN	MRN	MRN	VG	M
Incineration	VG	P	VG	M	G	VG	VG	VG	VG
Rendering	VG	M	VG	MRN	G	NA	MRN	P	G
Composting	P	G	M	MRN	M	M	M	VG	M

P, poor; VP, very poor; M, moderate; G, good; VG, very good MRN, more research needed; NA, not available

Table 3 Average cost involvement in different types of carcasses (Dollars/mortality)

Carcass type	Burial	Burning	Incineration	Rendering	Composting
Cattle	10.63	6.03	9.33	8.28	30.34
Pigs	12.45	3.06	4.09	7	14.04
Sheep/Goat	10.45	5.01	6.06	7	11.06
Poultry	2.01	0.15	0.3	0.5	1.02

Table 4 Specifications of burial pit/trench for an individual animal mortality⁶¹

Specification	Average Size(ft)	Remarks
Burial Depth	6-May	Vary depends upon type of carcass and cause of death of animal
Burial Width	4-Mar	Vary depends upon size and carcass type
Minimum distance from Streams	150	Vary depends upon type of infection
Minimum distance from Wells	200	Vary depends upon type of infection
Minimum distance from Dwellings	100	Vary depends upon type of infection

Table 5 Carcass disposal costs and cost involvement indicators⁶²

Disposal method	Cost/Ton of carcass (Dollar)	Direct cost indicators				Indirect cost indicators	
		Initial cost	Transportation cost	Labor cost	Input cost	Environmental/public health	Public perception
Burial	150-200	L	L	H	L	H	VH
Burning	600-675	L	L	H	VH	H	VH
Incineration	400-500	M	H	H	M	M	H
Rendering	200-230	L	L	H	H	L	M
Composting	300-460	M	H	L	M	L	M

L, low; M, medium; H, high; VH, very high

Table 6 Carcass Disposal Methods Advantages/Disadvantages⁶¹

Method	Advantages	Disadvantages
Burial	Inexpensive	Site Selection Critical
	Easy	Not Appropriate in area of Shallow Water Table
	Biosecure (except TSE)	TSE Threat Remains
	Environmentally Sound Except for Ground Water	Aesthetics if Improperly Performed
Burning		Future Stigma for Land
	Biosecure (except TSE)	Fuel/Labor Intensive
	Inexpensive	Inappropriate for Poultry
Incineration		Smoke/odor Potential
		weat
	Biosecure	Fuel Intensive
	Concurrent use with Debris Removal	Technically difficult when Debris included
Composting	Environmentally Sound	Inappropriate for poultry
		equy
	Environmentally Sound	Not Biosecure
	Good for Poultry	Volume Constraints
Rendering	Inexpensive	Slow Process
	uuct	requ
	Environmentally Sound	Capacity Constraints
	Biosecure	Biosecure Concerns in Transport
	Useable end Product	Inappropriate for Poultry

Conclusion

Although carcasses are disposed by different traditional methods like burial, incineration, rendering, or landfilling⁴ but each of these methods has disadvantages. Burial of carcass leads to ground water contamination; incineration involves more capital and pollutes the air. Rendering of carcass is associated with transportation cost. Landfilling has constraints of land availability and carcass movement.^{59–62} There are many other disadvantages like spread of infections like TSE and prions which are not completely destroyed in many of these methods and thus limit their utility in the changing

scenario of current legislation. Because of different legal formalities to follow by the farmers a widespread non-compliance has resulted into potentially greater environmental risk due to illegal dumping etc.³⁶ On-farm disposal of mortalities is favored by the farmers because of environmental, practical, economical and biosecurity benefits. Processes such as rendering and composting have gained popularity in many countries due to their end product utility. There is real need for new methods of carcass disposal to be developed and validated as per the different legislations. It is important that mortality disposal systems are based on a realistic approach to be safe both from the environment and biosecurity point of view. There are some aspects to be further studied in future like use of end products and extraction of valuable products. Further research is also needed into the economic impacts of disposal systems to see their practical utility on-farm as a well as off-farm. Hence developing a technically feasible and economically viable method for this purpose would benefit both large and small scale livestock farms and processing units. In this regard early disposal of animal carcasses with efficient method is an important waste management tool for raising healthy and profitable livestock farming activity.

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Conflict of interest

Author declares that there is no conflict of interest.

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