Carcass Disposal: A Comprehensive Review

National Agricultural Biosecurity Center Consortium
USDA APHIS Cooperative Agreement Project
Carcass Disposal Working Group

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Chapter

8

Non-Traditional & Novel Technologies

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Abbreviations

BSE	bovine spongiform encephalopathy
CAST	Council on Agriculture Science and Technology
CWD	chronic wasting disease
DEQ	Department of Environmental Quality
DHH	Department of Health and Hospitals
EPA	US Environmental Protection Agency
FDA	US Food and Drug Administration
HEPA	high efficiency particulate air
LSB	Livestock Sanitary Board
PRISM	Plasma Remediation of In-Situ Materials
ROI	Renewable Oil International
STI	Sterile Technology Industries
TDE	transmissible degenerative encephalopathy
UK	United Kingdom
US	United States
VOC	volatile organic compound
WR$^{2®}$	Waste Reduction by Waste Reduction, Inc.

Section 1 – Key Content

This chapter summarizes novel or non-traditional methods that might be used to deal with large-scale animal mortalities that result from natural or man-made disasters. It also identifies specific methods that represent innovative approaches to disposing of animal carcasses. These carcass disposal methods include the following:

- Thermal depolymerization
- Plasma arc process
- Refeeding
- Napalm
- Ocean disposal
- Non-traditional rendering (including flash dehydration, fluidized-bed drying, and extrusion/expeller press)
- Novel pyrolysis technology (*ETL EnergyBeam™*)

A key conclusion of the chapter is that pre-processing of carcasses on-site increases biosecurity and will increase the number of process options available to utilize mortalities. Pre-processing methods examined in this chapter include the following:

- Freezing
- Grinding
- Fermentation
- STI Chem-Clav grinding and sterilization

1.1 – Pre-Processing

Several of the carcass disposal methods described in this chapter would benefit from, or require, on-farm pre-processing and transportation of carcasses to central facilities because of their complexity and cost. One possible solution for pre-processing and transporting carcasses involves a large portable grinder that could be taken to an affected farm to grind up to 15 tons of animal carcasses per hour. The processed material could be preserved with chemicals or heat and placed in heavy, sealed, plastic-lined roll-off containers. The containers could then be taken off-site to a central processing facility. Fermentation is yet another method of pre-processing mortalities on site which has been used in the poultry industry since the early 1980s. Carcasses are stored for at least 25 weeks. Fermentation is an anaerobic process that proceeds when ground carcasses are mixed with a fermentable carbohydrate source and culture inoculants and then added to a watertight fermentation vessel. Another approach, likely to be most suitable to normal day-to-day mortalities, is to place carcasses in a freezer until they can be taken to a central processing site. Freezing is currently being used by some large poultry and swine producers. Typically, a truck with a refrigeration unit is stored on site until it is full and then taken to a rendering operation. The refrigeration unit is operated via on-farm power when in a stationary position, and by the truck motor when in transit. This approach might not be feasible for large-scale die-offs or even for large carcasses unless they are first cut into smaller portions.

Any pre-processing option must minimize on-site contamination risks and maximize the options for disposing of, or eventually finding efficient uses for, the raw materials embodied in the carcass material. Transportation of pre-processed or frozen carcasses in sealed containers should minimize the risk of disease transmission during transit through populated or animal production areas.

Several options with limited throughput, such as rendering and incineration, could also benefit from the on-farm preprocessing and central processing strategy. This general approach is referred to here as a "de-centralized/centralized" model: de-centralized preprocessing to produce a stable organic feedstock that can be transported to a centrally-located facility in a controlled, orderly manner. Figure 1 shows a schematic of how the model might work for animal mortalities. Note that it may be necessary to process all manure from the production site as well as carcasses in the event of some types of communicable disease outbreaks. At other times, separated manure solids and other organic material could be transported and processed at the central plant if economical. Note also that processes suited for handling daily mortalities may or may not be appropriate for dealing with a mass die-off of animals or birds.

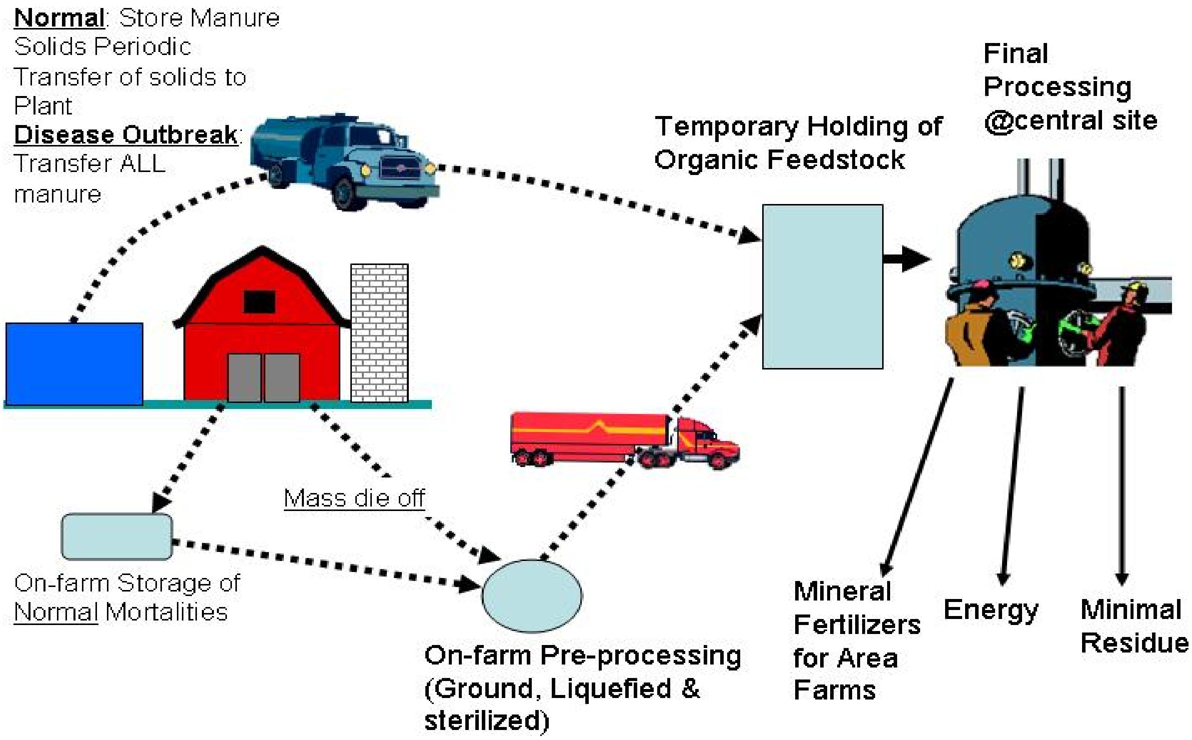


FIGURE 1. Model of decentralized collection and centralized processing. In the event of a mass die off due to communicable disease, it may be necessary to process all affected stored manure on the farm.

1.2 – Disposal Methods

There are several unconventional options for disposing of animal mortalities. Many of these would benefit from the de-centralized/centralized model discussed earlier.

Thermal depolymerization is an intriguing possibility for processing large-scale mortality events. This is a relatively new process that uses high heat and pressure to convert organic feedstock (e.g., pre-processed carcasses) into a type of fuel oil. The thermal depolymerization process has been studied by researchers at the University of Illinois and others. Since depolymerization disassembles materials at the molecular level, it may be effective at destroying pathogens, but this needs to be confirmed. While this alternative is still being evaluated in the laboratory, a large commercial-scale plant is being installed in Missouri to process organic byproducts from a poultry processing plant.

The **plasma arc process** relies on extremely hot plasma-arc torches to vitrify and gasify hazardous wastes, contaminated soils, or the contents of landfills. It can vitrify material in place with reduced costs and less chance of further contamination. The resulting rock-like substance is highly resistant to leaching. When treating landfill contents, it has reduced material volume by up to 90 percent. The process also generates fuel gases that can be collected and sold to help defray operational costs.

There are no references indicating that plasma arc processing has been used to dispose of livestock mortalities; however, it has several potentially useful characteristics from the standpoint of biosecurity that should be investigated. Specifically, it may be useful when coupled with burial systems because of the potential for treating the material in place. Plasma arc technology has been successfully used to process landfill waste, and there is no reason it should not be effective with mass burials of animal mortalities.

Refeeding of animal carcasses is already important in the poultry industry. There are currently a number of poultry producers using predators, particularly alligators, to consume mortalities.

There is typically very little processing involved in the refeeding process, with most carcasses being fed whole. Some poultry and/or alligator producers grind carcasses to create a liquefied feed that can be consumed by hatchling alligators.

While refeeding is an attractive option in areas where alligator farming is legal and practical, particularly in some southeastern states, many questions remain about the ability of such systems to accommodate the volume of mortalities associated with large-scale die-offs. Start-up costs and skill levels for workers on alligator farms can be high. Another concern relates to the potential for disease transmission through the predator herds.

Other non-traditional methods (including flash dehydration, ocean disposal, napalm, fluidized-bed drying and extrusion/expeller press) would require carcass handling and transportation to a processing site or the development of portable systems. Flash dehydration, fluidized-bed drying, or extrusion/expeller processing would result in a potentially useful by-product. Ocean disposal would not directly result in a beneficial or usable product; however, the addition of a protein source could positively impact aquatic life in the area over time.

Table 1 below summarizes the various innovative methods of handling animal mortalities discussed in this chapter.

TABLE 1. Overview of innovative options for processing or disposing of large-scale animal mortality events.

Technology/ Method	Applicable To:		Requires Stabilization or Pre-Processing	Portable?	Centralized ?	Salvage Product(s)	Residue
	Non-Diseased Carcasses	Infectious Diseased Carcasses[a]					
Refeeding	✓	--[b]	✓	No	--	Nutrients	Bones
Thermal Depolymerization	✓	✓	--	Perhaps	Yes	Energy	Minerals
Plasma Arc Technology	✓	✓	✓	Yes	Yes	Energy	Vitrified material
On-Farm Autoclaving[c]	✓	✓	--	Yes	No	--	--
Napalm	✓	✓	--	Yes	--	--	Ash
Ocean Disposal	✓	--	--	No	--	--	None
Extrusion	✓	--	--	No	Yes	Energy	--
Novel Pyrolysis Technology (*ETL EnergyBeam*™)	✓	--	--	Perhaps	Yes	--	--

[a] Infectious diseases are handled in the most part by the various processes discussed here. Transmissible degenerative encephalopathy (TDE) and other prion-related agents need further study in all cases.

[b] (--) indicates an unknown.

[c] Discussed later in chapter as STI Chem-Clav.

Section 2 – Pre-Processing (Pre-Disposal) Methods

2.1 – Freezing

Freezing was one of the first methods attempted to extend the storage time for poultry and swine mortalities, and is in use today at many larger operations. Freezing is a useful pre-processing option for small scale mortalities, however, the equipment and energy costs involved to handle a mass die off may not be readily available. Freezing was recently used in Wisconsin during a chronic wasting disease (CWD) eradication effort to store, prior to ultimate disposal, deer carcasses suspected of harboring CWD.

Cold storage was also used in the Netherlands during a 1997 outbreak of classical swine fever (hog cholera), providing the holding capacity to allow rendering facilities to process the majority of euthanized animals. By coupling temporary cold storage with means to slow animal production (breeding bans, slaughtering pigs at birth, restricting animal movements, etc.), disposal was accomplished almost entirely by the existing rendering capacity. On-site burial or open burning of carcasses was considered; however due to environmental concerns, cold storage with rendering was selected as the best disposal system (Lund, Kruger, & Weldon).

General process overview

Freezing is a relatively straightforward process and uses common refrigeration techniques to lower the body temperature of the carcass to the point where decomposition is retarded. The temperature required depends on the length of storage time required. For extended periods (weeks instead of days) or situations where the mortalities must be transported for several hours before reaching the central processing unit, the carcasses must be frozen.

Personnel requirements

Personnel requirements should be minimal, since the carcasses need only be loaded into the refrigeration unit, and later loaded into a vehicle for transport off farm to a central processing site.

Location considerations

Land area requirements should be minimal; however access to power will be essential.

Resource requirements

The primary resource requirement will be an uninterruptible supply of power.

Time considerations

The time required to lower carcass temperature below 40°F will depend largely on the capacity of the freezer and the weight of carcasses added at one time. Typically, a freezer or refrigerator will hold the mortalities at that temperature until a sufficient quantity has accumulated to warrant a trip to a rendering plant. Such on-farm equipment would likely be sized to handle normal mortalities and probably would not have sufficient capacity for a large die-off event of animals or birds.

Remediation requirements

Remediation requirements should be limited to any spillage that might occur when carcasses are loaded into the freezer unit, since the frozen carcasses would typically be taken to a central site for final processing.

Cost considerations

Morrow and Ferket (1993) reported that a large poultry producer using one-ton capacity freezers estimated a capital cost of $2,000 per freezer unit, and an electricity cost of $1.20/day or $0.01 per pound of carcasses, assuming $0.08 per kilowatt hour.

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. Estimated total costs of using refrigeration in a 100,000-bird broiler operation were about $0.114 per pound (Damron, 2002).

Disease agent considerations

Freezing, especially for a short period, is not likely to significantly affect pathogen survival.

Implications to the environment

Freezing should have no direct negative effects on the environment, except indirectly when fuel is burned to generate the electricity needed to operate the units. Modern refrigeration units no longer use chemicals that could affect the ozone layer.

2.2 – Grinding

A possible solution for pre-processing and transporting carcasses involves a large portable grinder that can be taken to the farm. In order to be feasible for a large-scale mortality event involving mature cattle, very large equipment would be needed. The processed material could be preserved with chemicals or heat and placed in heavy, sealed, plastic-lined roll-off containers for transport off-site to a central processing facility (Morrow & Ferket, 2002).

General process overview

Grinding of carcasses will make most mortality processing systems more effective and more rapid by increasing the surface area where chemical and biological processes can occur. It is required as a component for fermentation of carcasses, which is a method of storing carcasses on farm for several months, until they can be transported to a central site for disposal. Carcasses are typically ground to 2.5 cm (1 inch) or less diameter, although no study could be found in the literature to indicate that this was optimum. Generally, a bulking agent would be needed to absorb the liquid released from carcasses during grinding.

Personnel requirements

Grinding is a mechanical process so a reasonable amount of labor will be required to maintain the equipment. However, grinding equipment should be very heavy duty, so most of the maintenance should be routine. There are a number of manufacturers that produce grinders capable of handling carcasses. One important requirement is that equipment be easily disassembled for cleaning and disinfecting. Two manufacturers that advertise their equipment as being suitable for grinding animal mortalities include the following:

Karl Schnell GmbH & Co.
Mühlstr. 30
D-73650 Winterbach
Tél + 49 (0)7181 / 962-0
Fax + 49 (0)7181 / 962-100
http://www.karlschnell.de/en/produktkategorien/crushers.htm

Supreme International
PO BOX 6450 STN MAIN
Wetaskiwin, Alberta, Canada
T9A 2G2
Phone: 780.352.6061
Fax: 780.352-6056
http://www.supremeinternational.com/

Location considerations

While grinding equipment will generate some noise while operating, it should not be a significant nuisance to the neighborhood. Access by trucks will be necessary to transport carcasses to and from the grinder. Power and water will be needed for stationary units.

Resource requirements

The fuel or energy and equipment requirements will depend on the size and number of carcasses to be ground. A machine for handling the daily mortality from a poultry operation would be considerably smaller than one needed to handle a large cattle feedlot. Also, a smaller grinder could presumably be utilized for mature cattle if the carcasses are cut into smaller portions before entering the grinder. A commercial-sized garbage grinder was used in a University of Minnesota study to process dead piglets. Large vertical tub grinders have also been used to handle entire mature cattle mortalities.

The bulking agent needed to absorb liquid could be cornstalks, straw, sawdust or similar material commonly available on farms. The amount and type of bulking agent used may also depend of the intended use of the ground carcasses. For example, material bound for use as alligator or pet food will require an agent that is digestible.

Time considerations

The time required to process a carcass will depend on the size of the equipment and the size of carcass. However, since there is no chemical or biological reaction time involved in this purely physical action, processing times should be relatively rapid. The largest commercially available portable equipment found appears to be able to handle approximately 15 tons per hour (perhaps over 150 mature cows/day).

Remediation requirements

The output materials generated should be a paste-like material that is essentially all redirected into another, final disposal or processing system.

Cost considerations

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.

Disease agent considerations

Grinding, by itself, will not affect the potential for disease transmission. In fact, it could potentially increase transmission by increasing surface area of carcass tissue. Certainly, it would be wise to store and transport ground carcasses in sealed containers.

Implications to the environment

Grinding will speed biological decomposition of a carcass, so ground material should be used rapidly for additional processing/disposal, or a preservative may be warranted if the material will be stored. Grinding will also increase the potential for odor.

2.3 – Fermentation

General process overview

Fermentation is a process that can allow the on-farm storage of poultry carcasses for at least 25 weeks, and produces a "silage" end project that is nearly pathogen free. Fermentation of carcasses typically proceeds at near ambient temperatures in sealed containers that are vented for carbon dioxide. Carcasses are first ground to 1-inch diameter or smaller, mixed with a fermentable carbohydrate source and culture inoculant, and added to the fermentation container. The result is acidic silage that is stable for some time. A silage pH greater than the optimum pH of 4.3 to 4.5 can result in a secondary fermentation that spoils the silage (Morrow & Ferket, 1993).

Personnel requirements

Personnel requirements should be minimal with this process. The "recipe" for preparing the carcasses is easy to follow and simple to do.

Location considerations

The location chosen for the fermentation container should be near the source of the mortalities. Further, the grinding and mixing process must be designed so that any spills can be contained.

Resource requirements

Electricity must be available for the grinder. Water should be available for cleanup of the preparation area, and the fermentation vessel must be watertight. For lactic fermentation, lactose, glucose, sucrose, whey, whey permeate, condensed brewer's solubles, and molasses are all suitable as a fermentable carbohydrate source, although brewer's solubles works especially well.

Time considerations

Under optimal conditions, the pH of fresh carcasses can be reduced from 6.5 to less than 4.5 in 48 hours (Morrow & Ferket, 1993).

Remediation requirements

A properly prepared silage output from the fermentation process is semi-solid in nature, is stable for months, and can be accepted for rendering. Another potential use, according to Morrow and Ferket (1993), is refeeding to fur animals, ruminant animals, or aquaculture.

Cost considerations

Cost information could not be found in the literature reviewed.

Disease agent considerations

According to Morrow and Ferket (1993), the agent of Aujeszky's disease can survive for nine days at 50°C (122°F). Since mortality fermentation temperatures approximate ambient, this pathogen may survive in cold climates. The low pH of the anaerobic fermentation should kill most pathogens, however.

Implications to the environment

Fermentation should not pose a threat to the environment, as long as the fermentation container is watertight and as long as no spills occur while preparing materials for the fermentor or while removing material from it.

2.4 – Grinding/Sterilization by STI Chem-Clav®

Waste Reduction by Waste Reduction, Inc. (WR$^{2®}$) Companies, headquartered in Indianapolis, Indiana, currently markets a patented non-incineration technology for processing biological and biohazard waste materials called the STI Chem-Clav® (http://www.wr2.net/).

General process overview

The STI Chem-Clav® system has traditionally been used to process regulated medical wastes. The system incorporates negative air pressure and high efficiency particulate air (HEPA) filtration to prevent the escape of airborne pathogens while the waste is being shredded. Shredding maximizes surface area and subsequent exposure to steam. This process renders the waste, including sharps, "unrecognizable" and "unusable."

Process air passes through a HEPA filter chamber prior to exhausting to the atmosphere. A chemical disinfectant (sodium hypochlorite) acts as a deodorant for the waste stream.

Shredded waste enters the auger where low-pressure steam is applied through a system of injection ports (Figure 2). The time spent in this steam auger is approximately 60 minutes. Thermocouples maintain an operational temperature of 96°C to 116°C (205°F to 240°F). STI Chem-Clav® systems operate below the threshold temperature for volatilization of plastics to avoid volatile organic compound (VOC) emissions. Shredding increases surface to area exposure, allowing permeation of steam into the materials. A steam jacket raises the temperature of the shredded waste above 100°C (212°F) to dehydrate the waste.

Venting at the end of the auger creates a low pressure to remove and exhaust moisture. Dry, sterilized waste exits the system into a self-contained/roll-off type container and is typically transported to a sanitary landfill as municipal waste.

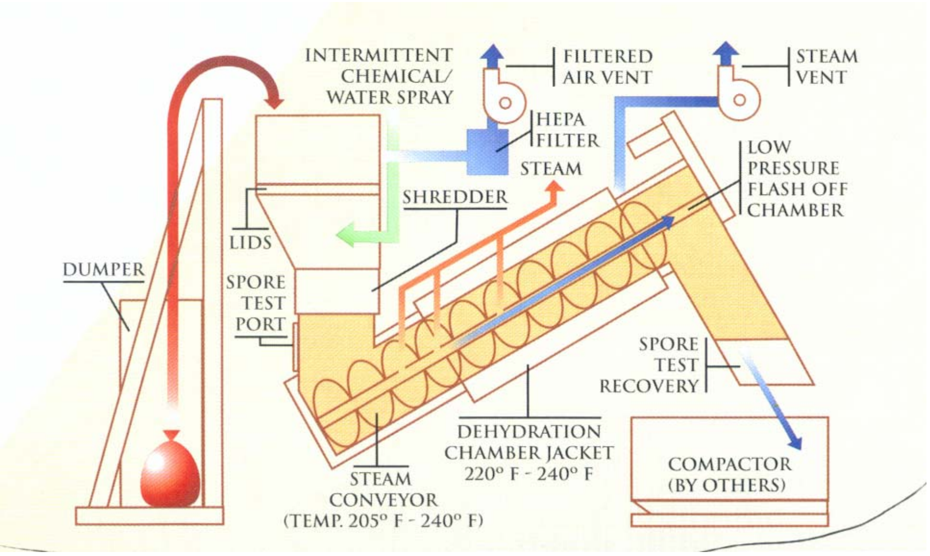


FIGURE 2. STI Chem-Clav® Steam Sterilization Systems (by Sterile Technology Industries, Inc.) has been used to render medical waste sterile into unrecognizable and unusable waste material (http://www.wr2.net).

Personnel requirements

The STI Chem-Clav® system would require trained operators to operate the processing equipment and skilled labor to operate the trucks and material handling equipment.

The STI Chem-Clav® system is available from Sterile Technology Industries, Inc. (STI), a wholly-owned subsidiary of WR$^{2®}$ which is headquartered in Indianapolis, Indiana. WR$^{2®}$ also markets alkaline hydrolysis systems.

Sterile Technology Industries, Inc.
5725 W Minnesota St.
Indianapolis, IN 46241
Phone: 317-484-4200 Fax: 317-484-4201
E-mail: chemclav@aol.com

Location considerations

The STI Chem-Clav® system can be designed as a stationary or portable unit. It can be transported on a flatbed semi trailer to a site. An area capable of supporting large trucks and material handling equipment would be necessary.

Resource requirements

A mobile STI Chem-Clav® unit would require a fuel source such as propane and an electrical hook-up to power the system. In lieu of electrical power, the unit could be hydraulically driven with a diesel engine and hydraulic pump. Material handling equipment such as front-end loaders and leak-proof trucks to transport processed material would also be required.

Time considerations

According to WR$^{2®}$, the STI Chem-Clav® process could be made mobile and optimized for rapid processing, achieving a throughput rate of up to 13,608 kg (30,000 lbs.) per hour (approximately 20 large animals per hour) (J. Wilson, 2003). These units can be built to order and would need to be constructed in advance of a disaster.

Remediation requirements

In situations where the system can neutralize the disease agents involved, or in the case of a natural disaster, the resulting material could be rendered, used in a composting system, deposited in a landfill, put in cold storage for further processing, or utilized in an energy recovery system such as a fixed hearth plasma arc furnace or a thermal depolymerization oil recovery system. Prior planning for the recovery of animal or plant nutrients or energy could reduce the effects on the environment and provide a more useful output.

Cost considerations

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.

Disease agent considerations

The STI Chem Clav technology appears most promising for non-disease related mortalities and animal disease outbreaks involving bacteria or virus-contaminated animals that can be neutralized by steam sterilization or the addition of an alkaline material. TDE agents (prions) would not be neutralized by steam sterilization, and the efficacy of the addition of an alkaline material would need to be examined.

Implications to the environment

In situations where disease agents can be neutralized by this process, the resulting material could be used in a composting system, deposited in a landfill or utilized in an energy recovery system such as a fixed hearth plasma arc furnace or a thermal depolymerization oil recovery system. Prior planning for the recovery of plant nutrients or energy could reduce the effects on the environment.

Advantages and disadvantages

One advantage of this system is its portability. Another advantage, in situations where TDE agents are not a concern, is the ability to process solids and liquids with the same machinery. Waste milk, manure, feed, or even some structural materials could be processed for further disposal.

Disadvantages include the inability to neutralize TDE agents and a high initial cost.

Section 3 – Non-Traditional and Novel Disposal Methods

A variety of traditional carcass disposal methods are used to address daily mortalities in animal production operations. The non-traditional or novel methods outlined in this report could potentially be adapted for daily mortalities, catastrophic losses, or both. This report addresses various mortality causes, including typical production losses, natural disasters, and disease outbreaks of either natural or deliberate (i.e., bioterrorism) origin.

The selection and implementation of mass carcass disposal strategies should be considered within a decision-making process that is part of a national and/or state level contingency plan. The goals and objectives of a contingency plan should endeavor to:

1. minimize the number of animals to be slaughtered in the case of disease or injury;
2. minimize disruption of farming activities and food production;
3. minimize potential damage to the environment;
4. minimize damage to the economy;
5. contain and eradicate infectious disease outbreaks;

6. provide a safe, rapid attainment of disease-free status;
7. maximize use of existing infrastructure;
8. minimize cost to the taxpayer;
9. protect public health and safety; and
10. retain the confidence and support of the public.

Within the contingency plan, the decision-making process should allow for flexibility to utilize disposal methods based on the nature of the problem. Natural disasters may allow more options versus a situation involving infectious diseases that might limit transportation options or require the neutralization of pathogens. In disaster circumstances, or other instances that do not involve an infectious agent, transportation and collection may be suitable if the situation can be handled in a reasonable timeframe. Strong consideration should be given to the general approach of treating mortalities as an organic feedstock having value as opposed to a waste suitable only for disposal.

3.1 – Thermal Depolymerization

Thermal depolymerization, developed by Paul Baskis in the 1980s to reduce complex organic materials to light crude oil, is a promising method of processing waste organic materials, including animal mortalities. The process has been described as follows:

> It mimics the natural geological processes thought to be involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen, and carbon decompose into short-chain petroleum hydrocarbons. Many methods to create hydrocarbons use a lot of energy to remove water from the materials. This method instead requires water, as the water both improves the heating process and supplies hydrogen and oxygen for the chemical reactions.
>
> (Anonymous)

According to Lemley (2003), a thermal depolymerization plant is being constructed at the ConAgra Foods Turkey plant in Carthage, Missouri, to digest 200 tons of turkey processing waste per day. ConAgra previously trucked feathers and other waste to a rendering facility where it was processed into animal feed, fertilizer, and other chemical products. Recent outbreaks of TDE diseases, such as bovine spongiform encephalopathy (BSE or “mad cow disease”), have raised concerns about feeding rendered materials back to animals. This practice is illegal for all livestock in Europe and, since 1997, it has been illegal in the United States (US) to feed rendered mammalian products to ruminants. Since depolymerization disassembles materials at the molecular level, in theory it should be effective at destroying most pathogens. However, it is unclear from the literature if prions are destroyed by thermal depolymerization. The effectiveness of this process on pathogen destruction warrants further examination.

According to Lemley (2003), the ConAgra plant will convert turkey offal—guts, skin, bones, fat, blood, and feathers—into a variety of products. During the first-stage heat-and-pressure reaction, fats, proteins, and carbohydrates will be broken down into carboxylic oil. The second-stage reaction will strip off carboxyl groups (a carbon atom, two oxygen atoms, and a hydrogen atom) from the fatty acids and break the remaining hydrocarbon chains into smaller fragments to produce light oil which can be used as-is, or refined into lighter fuels such as naphtha, gasoline, and kerosene. The process is also expected to yield fertilizer-grade minerals derived mostly from bones and carbon solids.

The Missouri plant expects to produce 10 tons of combustible gas and 21,000 gallons of water per day; the water will be discharged into a municipal sewage system. The plant should generate 11 tons of minerals and 600 barrels of oil, with approximately the same specifications as #2 heating oil. The plant’s designers intend to produce oil at $15 per barrel and eventually drop the cost of production to $10 by fine-tuning plant operations; $10 per barrel approximates current prices for crude oil.

Figure 3 depicts the thermal depolymerization process. The current status of the ConAgra plant is unclear. The company building the plant indicated that it would be operational in late 2002, but as of December 2003 no update on the operational status has been provided. The operational date may be affected by expected incentives in the US energy bill, which is still stalled in Congress.

Thermal depolymerization and pyrolysis will be discussed together, but it must be noted that the condition of feestock required and the type of bio-fuel produced are quite different.

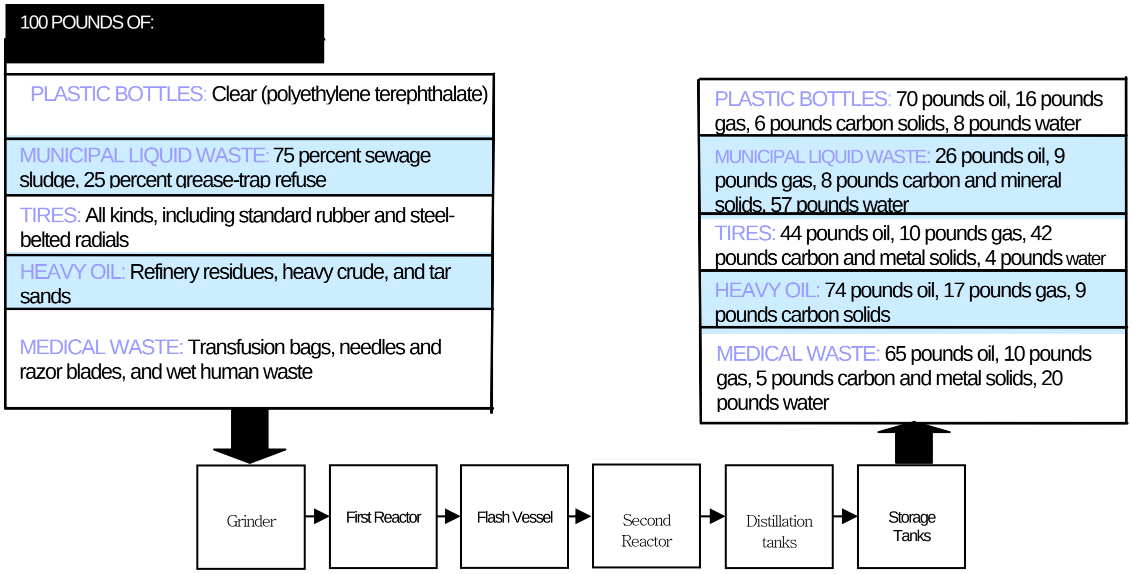


FIGURE 3. Potential outputs from thermal depolymerization of various wastes (Lemley, 2003).

General process overview

Thermal depolymerization works in principle by heating organic matter under pressure in very controlled conditions with the addition of carbon monoxide and steam to produce useful organic products such as bio-fuel. The process was described in more detail in the following way:

> The feedstock material is first ground into smaller particles, and mixed with water if it is especially dry. It is then fed into a reaction chamber where it is heated to around 250°C and subjected to 600 psi for approximately 15 minutes, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals, which are separated out. The hydrocarbons are sent to a second-stage reactor where they are heated to 500°C, further breaking down the longer chains, and the resulting petroleum is then distilled in a manner similar to conventional oil refining.
>
> (Anonymous)

Personnel requirements

These are complex processes and the labor requirements can be expected to be at a relatively high skill level.

The following companies are developing thermal depolymerization or pyrolysis facilities.

Changing World Technologies
460 Hempstead Avenue
West Hempstead, NY 11552
http://www.changingworldtech.com/indusfr.htm
Phone: (516) 536-7258

Renewable Oil International LLC
3115 Northington Court
PO Box 26
Florence, AL 35630
http://www.renewableoil.com
Phone: (256) 740-5634

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.

Location characteristics

The usual restrictions placed on a similar type of plant should apply. For example, the plant should be centrally located to the sources of material to be used as feedstock and near a refinery that can process the bio-oil produced. All-weather roads and ready access to the area's highway system are essential. Since there would be the possibility of an inadvertent spill of a water contaminant or odor release, the plant location should be somewhat isolated from waterways and heavily populated areas. Space requirements should be largely determined by the scale of the plant.

Resource requirements

Thermal depolymerization is a complex process involving very robust vessels, valving, pumps, and other fittings capable of handing high pressures and high temperatures, so the equipment requirements can be expected to be extensive. Also, carcasses would need to be ground into a paste or small particles before being added to the thermal depolymerization process.

Once started, the process appears to be energy self-sufficient. Working with turkey offal as the feedstock, Changing World Technologies reports that its process has energy efficiencies of approximately 85%; in other words, the energy required to process materials could be supplied by using 15% of the energy output. Higher efficiencies may be possible with drier and more carbon-rich inputs (feedstock) such as waste plastic. Laboratory studies at the University of Illinois by Zhang, Riskowski, and Funk (1999) have also indicated a positive energy flow in laboratory studies of thermal depolymerization of animal wastes. In these studies, carbon monoxide was added to improve the quality and yield of bio-fuel produced. The pyrolysis process can utilize considerably dryer feestock.

Time considerations

On-farm pre-processing and transport in sealed plastic containers should allow a large plant to keep up with emergencies. To be able to sustain a large central processing facility so that it is available if needed in an emergency, it would be necessary for the facility to operate on a routine basis with other feedstock whose flow could be suspended in times of emergencies such that priority could be given to processing carcasses.

The Changing World Technologies website indicates that plants smaller than the 200 ton/day unit in Missouri are possible, but they are focusing on larger plants at the present time.

ROI has had a five metric ton/day (dry ton) pilot plant operating with poultry litter as a feedstock since spring 2003, and is developing plans for a very large stationary system (Badger, 2003).

Remediation requirements

Site remediation should not be an issue with thermal depolymerization or pyrolysis because of the points discussed under "Implications to the environment" below. Thermal decomposition produces a light oil product that can be used as a raw material to produce other petroleum-based products, including fuels. The minerals produced should be useable for crop fertilization. ROI indicates an energy content of 80,000 BTU per gallon of bio-oil (Badger, 2003) (http://www.renewableoil.com).

Cost considerations

ROI estimates a capital cost of $3 million for a 120 ton/day operation using a 2.5-MW gas turbine to generate electricity. The ConAgra plant in Missouri has not released its costs at this time.

Disease agent considerations

With on-farm preprocessing and transport in sealed containers, biosecurity issues on-farm, and during the transport between the farm and plant, should be minimized. It is not known at this time if prions can survive the thermal depolymerization or pyrolysis processes; however, other pathogens should be killed. This is an issue that needs to be verified.

Implications to the environment

Environmental implications should be minimal; site residues from the thermal depolymerization and pyrolysis processes are inert. The materials are held in sealed containers before and during processing, and emissions to the environment should be contained.

Advantages and disadvantages

The advantages of thermal depolymerization and pyrolysis include production of a reusable energy source, production of more energy than is consumed, and the potential to be centrally placed in rural areas with plentiful organic residues in order to continuously operate and produce energy. Disadvantages of the process include the requirement that carcasses be preprocessed before they can be added to the reactors, and the lack of existing operational facilities. While cost data are lacking at present, costs are expected to be too high to justify the construction and operation of facilities for mortality disposal alone. Possibly a portable "mini-reactor" could be developed for the purpose of on-site processing in the event of catastrophic mortality losses. ROI is currently developing a mobile pyrolysis unit which is expected to yield oil from organic matter feedstock.

Other

Start-up of the ConAgra thermal depolymerization plant appears to be behind schedule (it was originally to begin operation in April 2003) so problems may have been encountered during construction or during startup. The Changing World Technologies website on April 2, 2003, indicated the plant would be operational in a few weeks, but the website did not indicate that it was operating as of December, 2003. Its current status is unknown, but it may be waiting on potential cost share working in the US energy bill pending in the US Senate.

As this is a relatively new process in the initial stages of commercialization, it is likely that many improvements will be made in the future if it continues to appear to be effective and economical. As with any new process, there will likely be opportunities to reduce complexities and cost to improve performance over time. The portable thermal depolymerization process being developed by ROI, assuming it has adequate throughput, could be of interest to the poultry and animal production industry. The residue material remaining after the thermal depolymerization process is complete should be minimal. It is largely inorganic inert material and could be used as an agricultural soil amendment or placed in a landfill.

3.2 – Plasma Arc Process

The production of plasma results from the ionization of matter by modifying the temperature and electrical characteristics of a substance. Ionization of a gas produces free electrons and ions among the gas atoms, and will respond to magnetic fields allowing control of the plasma. Plasma is a gas that has been ionized by the electric arc of a plasma torch and can therefore respond to electrical and magnetic fields. Almost any type of gas (oxygen, nitrogen, carbon monoxide, air, etc.) in a wide range of pressures (vacuum to 20 atmospheres) can be used to produce plasma. The origins of industrial uses of plasma can be found in the development of tungsten inert gas welding by defense industries in 1941, when a better method of welding steel was required. Plasma technology was further developed for use in cutting metals and for cleansing material surfaces during manufacturing processes (Anonymous, 1999).

Plasma arc torches operate over a wide range of temperatures, from 1500°C to over 7000°C, approximately 1000°C hotter than the surface of the sun. The plasma torch and copper electrodes are water-cooled and the average life of the electrodes ranges from 200 to 500 hours of operation. Electrical requirements are met with a DC power supply unit, and commercial units are available in power levels ranging from about 100 KW to 10 MW capacities (Division of Construction Engineering and Management, 2000).

The plasma arc process is a potential solution to a variety of pollution problems. Utilization of the plasma arc process to dispose of wastes has been conducted in both mobile and fixed facility forms. The mobile form, Plasma Remediation of In-Situ Materials (PRISM), has been studied in-depth at the Georgia Tech Plasma Applications Research Facility. The PRISM process relies on extremely hot plasma arc torches to vitrify or gasify hazardous wastes, contaminated soils, or the contents of landfills via vertical boreholes. Since materials do not have to be excavated or otherwise handled, PRISM can vitrify the material with reduced costs and less chance of further contamination. The resulting rock-like substance is highly resistant to leaching (Johnson; Mayne, Burns, & Circeo, 2000; Solena Group, 1997).

Fixed-facility configurations (fixed hearth plasma arc units) have been used in Honolulu, HI, France, and Japan as commercial tools in the waste disposal sector, as well as in other industries such as steelmaking, and precious metal recovery. Research programs for the study of the basic science of plasma heating, as well as for development and implementation of models and prototypes for different applications, are being conducted in the US, Japan, Canada, Russia, France, and Switzerland (Beck, R.W. Inc., 2003; Anonymous, 2003a).

Fixed hearth plasma arc units in operation for the disposal of waste organics start at 400 kg (880 lb) per day. The Solena Group and Westinghouse have installed over 40 plasma arc waste disposal facilities around the world. Examples of fixed hearth plasma furnace throughput capacity for steel processing is 40 tons of loose cast iron borings scrap steel per hour at a General Motors plant in Defiance, Ohio, and 60 tons per hour at a Geneva Steel plant in Utah. The plant in Ohio began daily production in 1989 utilizing a 1.5MW Westinghouse MARC-11 plasma torch (Solena Group; Gary, Fry, Chaput, Darr, & Dighe, 1998). Fixed hearth plasma arc technology has been implemented by the Mixed Waste Integrated Program through the Department of Energy in cooperation with several national laboratories and corporations

Several disposal projects have utilized fixed hearth plasma arc technologies to incinerate hazardous wastes while capturing waste gases for energy production (Department of Energy, 1994). A pilot project headed by Westinghouse to process harbor sediment in New York/New Jersey is underway to process 76,000 m^3 (100,000 yd^3) per year with 380,000 m^3 (497,000 yd^3) per year planned in a full scale facility (Westinghouse; McLaughlin, Dighe, Keairns, & Ulerich).

A municipal waste processing facility in Lubsko, Poland is using plasma pyrolysis to produce a high energy synthetic gas composed of 80% hydrogen and carbon monoxide. Steam is injected into the reaction chamber resulting in gasification in a few seconds. Without oxygen, no fumes, ashes, dioxins, or furans are formed (Solena Group, 1997).

General process overview

PRISM is a process that relies on extremely hot plasma arc torches to vitrify or gasify hazardous wastes and contaminated soils such as the contents of landfills (Circeo & Martin, 2001; Circeo, 2003). A plasma arc torch can be lowered to any depth via a borehole to melt contaminated materials into a type of magma which cools into vitrified material. Subsequently, the plasma torch is slowly raised and operated at progressively higher levels to thermally convert a mass of soil into a vertical column of vitrified and remediated material called slag (see Figure 4). This slag can be left in place on the landfill to seal the site, more garbage can be piled on top, or the vitrified material can be removed and used as gravel in roadway projects, molded into products like bricks, or used as concrete aggregate.

The gases released through combustion reactions or devolatilization can move freely to the surface through a subsidence zone and into an open pipe for treatment (Figure 4). Water, CO_2, and air are the predominant gases released during processing. At sites containing significant organic matter, H_2 and CO also may also be produced. Thus, secondary combustion of these gases would be required within the remediation process (Johnson; Gibbs, 1993; Anonymous, 1995b; Malloy, 1995; Wright, 1995).

At present, no references could be found to indicate that plasma arc technology has been used to process livestock mortalities. However, it has several features that may prove useful for this purpose (e.g., may have potential in the in situ remediation of large mortality burial sites).

If a fixed hearth plasma arc facility, analogous to the centralized plant described in the centralized/decentralized model, could be used to convert other organic wastes to generate energy on a continuing basis, perhaps the infrastructure and capacity would then be available to handle carcass disposal emergencies.

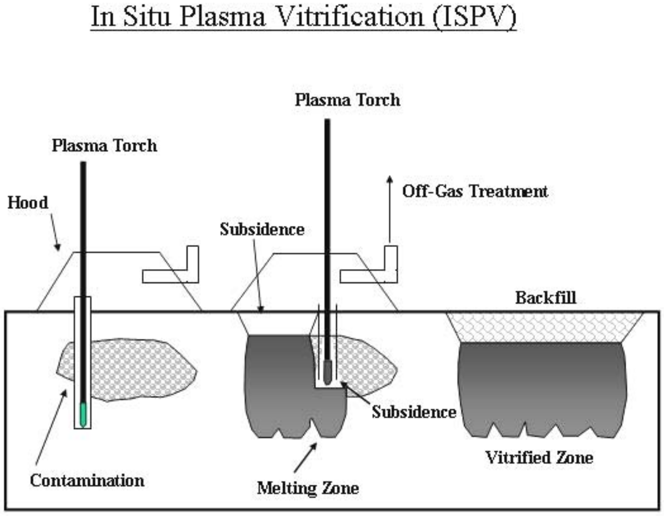


FIGURE 4. Use of in situ plasma arc to remediate landfill (adapted from Circeo & Martin, 2001).

Personnel requirements

This is a complex process and the labor requirements can be expected to be at a relatively high skill level for the operation of the plant.

The following vendors provide various forms of waste disposal utilizing plasma arc technology:

- Pulsed Energy Plasma, http://hometown.aol.com/hypercom59/
- Global Plasma Systems, Solena Group, http://users.erols.com/gpsys/index.html
- Westinghouse Plasma Corporation, http://www.westinghouse-plasma.com/
- Geoplasma, LLC, http://maven.gtri.gatech.edu/geoplasma/about.html
- Earthfirst Technologies, http://www.earthfirsttech.com/home.shtml
- Phoenix Solutions Company & Plasma Energy Corporation, http://www.phoenixsolutionsco.com/main/index.php
- Integrated Environmental Technologies, LLC, http://www.inentec.com/
- RCL Plasma, Inc., http://www.rcl-plasma.com/

Location considerations

A study of existing installations should provide a guide for the required foot print of a plasma arc facility. In agriculture, processing might be related to burial sites used for mortalities. Site selection criteria should be the same as any other industrial plant in the case of a fixed facility location. Issues such as all weather roads, access by heavy trucks, and access to utilities would need to be considered.

The usual restrictions placed on a similar type of plant should apply for a stationary plant. For example, the plant should be centrally located to the sources of material to be used as feedstock and near a facility that could utilize the combustible gas and waste heat produced. All-weather roads and ready access to the area's highway system are essential. Since there would be the possibility of an inadvertent spill of a water contaminant or odor release, the plant location should be somewhat isolated from waterways and heavily populated areas. Space requirements should be largely determined by the scale of the plant.

Resource requirements

Fixed hearth (stationary) plasma arc systems are specifically designed to process waste streams such as metals, plastic, or liquid organic wastes. Carcasses would require pre-processing and transportation in order to be introduced into a stationary furnace. A plasma arc system is a complex process involving very robust vessels, valves, pumps, and other fittings capable of handing high pressures and high temperatures, so the equipment requirements can be expected to be extensive.

The recent development of a portable plasma arc system for the purpose of destroying specific PCB containing material offers the opportunity for a mobile response. Site requirements are AC power, a water supply, and a sanitary sewer or water containment lagoon (Westinghouse). Portable preprocessing or grinding and portable plasma arc processing may be a combination of techniques that could provide a certain destruction of TDE-contaminated animals, but this needs to be verified.

In situ processing would not require pre-processing. A portable plasma arc torch, equipment to bore into a burial site, and gas collection equipment would be required to process in situ.

A DC power supply is required to power the plasma torch with electrical requirements ranging from about 100 KW to 10 MW. Energy to power boring machines to recover gas equipment is necessary for portable processing systems. Based on the size of the torch, varying amounts of cooling water are required. To utilize the methane or combustible gas generated, some form of portable gas-powered electrical generator is required. Systems utilizing gas turbine powered generators would not require large amounts of cooling water (Anonymous, 1995a).

Time considerations

The disposal of carcass material would need to be considered in the design and construction of a stationary fixed hearth plasma facility, as it may not be possible to retrofit existing facilities to accept carcass material. On-farm pre-processing and transport in sealed plastic containers should allow a large plant to keep up with emergencies. To be able to sustain a large central processing facility so that it is available if needed, it will be necessary to be able to operate the plant on a routine basis with other feedstock whose flow can be suspended in times of emergencies. In situ plasma arc processing could be accomplished with truck mounted portable units. In situ units might be available from commercial vendors involved in landfill remediation in the future.

Remediation requirements

When treating a landfill, PRISM can reduce the volume of the material by up to 90 percent. The process generates fuel gases that can be collected and sold or used on site with portable generators to produce electricity to help defray operational costs. Energy production techniques would be similar to those currently utilized at landfills (US EPA, Office of Air and Radiation, 1999). The process also results in a material similar to obsidian that is highly resistant to leaching, durable, and strong (US EPA, 2002; Advanced Technology Research).

Specific requirements for site remediation are not established for processing in situ, buried carcasses.

The utilization of stationary fixed hearth plasma arc furnaces would require planning for secure transportation and decontamination of the transport vehicles. In situ plasma arc vitrification of buried carcasses several months after burial would entail security for the site prior to vitrification. Any material removed when boring access holes would need to be treated appropriately.

Costs considerations

Plasma arc in situ vitrification of large volume carcass burial sites should be technically feasible. Although the economics are still in question, the costs involved in processing landfills should provide some insight. D. Wilson (2003) estimated the cost to treat buried carcasses in situ to be approximately $60 per ton.

Disease agent considerations

It is not known at this time if prions can survive the plasma arc process; however, other pathogens should be killed. This is an issue that needs to be verified. With on-farm preprocessing and transport in sealed containers, biosecurity issues on-farm, and during transport between the farm and plant, should be minimized.

Implications to the environment

The vitrified material produced in situ could become a water impermeable layer that may change ground water flow and drainage at a site where buried or composted carcasses have been processed with the plasma arc technology. The location and information about a site should be recorded at the time of processing and shared with future land owners. The methane generated from the plasma arc process and/or the carbon dioxide from utilizing the methane as power generation could pose risks to local air quality if not captured.

Environmental implications should be minimal; any remaining residues from the fixed hearth plasma arc process are inert. Material is held in sealed containers before and during processing so emissions to the environment should be contained.

Advantages and disadvantages

Advantages of the plasma arc process include the ability to effectively treat most waste materials, production of a reusable energy source, production of more energy than is consumed, and, in the case of a fixed hearth system, the potential to be centrally placed in rural areas with plentiful organic residues in order to continuously operate and produce energy. The PRISM system could also be used to remediate burial pits or trenches which hold animal or bird carcasses.

Disadvantages of the process include the limited number of operating facilities, the requirement that carcasses be preprocessed before disposal, and potentially high costs. While cost data are lacking at present, the cost will likely be too high to justify construction and operation of facilities for mortality disposal alone. Possibly portable publicly owned and operated “mini-reactors” could be developed for the purpose of on-site processing in the event of large die offs. An agricultural waste remediation system has been proposed, and the control mechanism patented by Pulsed Energy Plasma (Anonymous, 2003b; Arnold, 2001).

3.3 – Refeeding (Primarily to Alligators)

The use of whole or cut up raw carcasses as a feed for another species of animal (refeeding) is an alternative technique for salvaging value from either a continuous, non-emergency flow of mortalities or potentially from a large-scale die-off. Historically, carcasses have been rendered and the resulting products, such as meat and bone meal, have been fed back to the same or different species.

General process overview

Direct feeding of raw carcasses has been proposed and/or practiced within the following systems: hunt kennels in the United Kingdom, fur animal operations in parts of the northern US, and alligator production operations in a number of US states. In the US, the most common example of carcass refeeding is poultry mortalities fed to alligators being raised in commercial confined feeding operations primarily in the Southeast. However, refeeding could apply to a range of commercial livestock. Swine carcasses and fish farm mortalities have also been used for alligator feed.

According to Valentine (2003), European farmers are banned from burying or burning animal carcasses after May 1, 2003, by the European Union. Thereafter, the only lawful methods of dead livestock disposal will be rendering, incineration, or refeeding at hunt kennels.

Farmers in the United Kingdom (UK) are being urged by the British Government to join a subscription scheme that will pay for the collection and disposal of fallen stock, with small holdings paying £50 a year, medium-sized farms paying £100, and large units paying £200. Until this program becomes operational, hunt kennels have offered to help farmers deal with fallen stock during that period and beyond. According to Valentine (2003), a spokesman for the Countryside Alliance stated that hunt kennels could provide an indispensable service to farmers and that the Masters of Foxhounds Association has been working with the government to address the situation. Hunt kennels disposed of 366,000 head of fallen stock in 2000, and that rate is likely to increase following the May 1, 2003 deadline. So far, 146 hunt kennels had offered to help with the surplus.

Non-rendered animal mortalities can be used as feed for fur animals in Minnesota, but restrictions include the following (Minnesota Board of Animal Health, 2003):

- A permit and veterinary inspection is required. Carcasses, facilities, and equipment must meet Board of Animal Health specifications for fur farm consumption,
- Fur farms must keep the farm in a sanitary condition,
- Permits allow feeding only to fur-bearing animals that do not re-enter the food chain, and
- The owner of the fur farm assumes the risk of any disease or condition in the carcass that could be detrimental to the fur animals.

According to the National Contract Poultry Growers Association (National Contract Growers Association), alligator farming has become a spin-off of Georgia's booming $2.1 billion-a-year poultry industry. Such operations have become a viable option for disposing of the hundreds of thousands of chickens that die before they reach the processing plant.

A farmer with 350,000 chickens can expect to lose about 21,000, or 6 percent, of the flock each year under normal conditions. A poultry farmer who opened one of the Georgia's newest alligator farms reported that the farm's 6500 alligators devoured about 2,000 pounds of dead chickens per day. Mortalities from the operation's 20 chicken houses are ground into a white paste prior to feeding to the alligators. There are now ten farmers in Georgia who are exploring the synergies of raising chickens and alligators.

Research in Florida, where dead swine were fed to pond-raised alligators, demonstrated a faster rate of gain as compared to alligators fed a diet of meat and fish by-products (Walker, Lane, & Jennings, 1992). One problem with this disposal system is that alligators become less active during cool winter months and are not as effective at disposing of carcasses during this time. The estimated feed-to gain ratio was 4.5 kg (9.9 lbs.) of dry matter intake per kg (2.2 lbs.) of weight gain (Walker, Lane, Jennings, Myer, & Brendemuhl, 1994).

There are restrictions on refeeding in some jurisdictions. In Louisiana, for instance, poultry mortalities cannot be fed to hogs or alligators unless the carcasses are first cooked or rendered (Louisiana State University Ag Center Research and Extension, 2003). A complaint to the Livestock Sanitary Board (LSB), the Department of Health and Hospitals (DHH), or the Department of Environmental Quality (DEQ) concerning noncompliance with these regulations can result in inspections and penalties.

A potential complication in alligator operations is West Nile virus. The virus was found in farm-raised Florida alligators in late 2002, the first time the potentially deadly virus had been observed in the North American species (Bruno, 2002). It is believed that alligators, which serve as an amplification host for the virus, spread the disease among themselves through water in their holding tanks (Bruno, 2003).

According to the Council on Agriculture Science and Technology (CAST), the US Food & Drug Administration (FDA) is currently drafting regulations that will expand its current ban against the use of brains and spinal tissue in cattle feed to include feed for dogs, cats, pigs, and poultry. These new regulations will probably require companies that slaughter "downer" livestock to dispose of the brain and spinal cord before mixing feed and pet food (CAST, 2003). With the recent discovery in the US of an animal with mad cow disease, these regulations may reduce refeeding of carcasses in the US.

Personnel requirements

Collection of carcasses from a large animal production operation is a routine procedure, as is feeding of predator animals in a production setting. No additional personnel requirements are anticipated unless special processing of the mortalities prior to feeding is required.

Location considerations

Carcass collection and feeding should normally be performed on a regular basis (daily) and should happen in rapid succession, minimizing the need for stockpiling space.

Most current examples of refeeding in the US involve poultry producers, primarily in the Southeast. Some producers are co-locating poultry and alligator production facilities in order to take advantage of the carcass disposal opportunity afforded through predator consumption and the low-cost source of nutrition for the predator species.

Alligator production in the US is concentrated in the South and Southeast, in Alabama, Florida, Georgia, Louisiana, Mississippi, and Texas (Masser, 1993). In 2001, the state of South Carolina established a three-year pilot program to determine the feasibility of alligator farming for disposal of poultry mortalities.

Louisiana leads the nation in alligator production, generating over $11 million in revenue annually with about 167,000 farm-raised animals marketed annually and more than 500,000 animals in captivity (Roberts, 2001). North Carolina's only alligator farm aids in the disposal of poultry mortalities (Price, 2003). The 4,500-animal herd consumes 2,000 pounds of carcasses per day.

Alligator production is not limited to the Southeast. Animals are being grown in Idaho where dead stock are used as feed at trout farms. Researchers in Iowa are also investigating the possibility of alligator farms to assist in the disposal of dead pigs from swine operations (Clayton, 2002).

Resource requirements

Carcass grinding equipment would be required for those operations that pre-process mortalities into a paste prior to feeding. Some operators grind poultry carcasses prior to feeding to create a paste that permits hatchling alligators to feed on the mortalities (Hammond, 2001). Equipment needs for grinding depend on carcass size. Experimental work has revealed the challenges of grinding the carcasses of mature animals, even poultry (Clanton, Johnston, & Robinson, 1999).

Cooking or rendering equipment would be necessary in those states that require such processing prior to refeeding.

Time considerations

Capacity is related to the alligator herd size and age distribution of the alligator herd. Growth to market size takes 36 to 42 months. Alligators consume approximately 30 pounds of meat during the first year of growth, 125 pounds of meat in the second year, and 250 pounds the third year (Lane & Ruppert, 1987). Adult alligators in a breeding herd will consume approximately 400 pounds of meat per year (Lane & King, 1989).

Since alligators are cold blooded reptiles, they become inactive in cold weather. Therefore, the capacity of alligator herds to consume animal mortalities is affected by the weather.

Additional information is required to properly gauge the ability of existing predator herds to consume large additional inflows of protein that would be available in the case of a large-scale die-off of animals. Carcasses from a natural disaster would need to be pre-processed to inhibit decomposition and stored in sealed containers or frozen until consumption.

Remediation requirements

The output materials generated are alligators, along with excrement and wastewater from the growing operation. The harvested alligators provide hides, heads, and meat to markets in the US and Europe.

Site remediation concerns with regard to the excrement and wastewater are unknown at this time, but would likely involve dilution and land application of spent water.

Cost considerations

Startup costs for an alligator farm can be substantial. Alligator farms in Florida have an average herd size of approximately 3,200 animals (Clayton, 2002). 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).

A sizable investment—at least $250,000—is required to start an alligator farm. If an alligator hide has not been marred by scratches or bite marks, it may bring $75 in Italy or other markets where alligator hides are used for belts, purses, and shoes. The meat may bring an additional $20 regionally (Sack, 2000).

Disease agent considerations

There is potential for pathogens present in carcasses fed to alligators to be transmitted via the excrement of the alligators. Rodents and birds could also transport pathogens present in carcasses awaiting consumption by predator species if the animals are kept in the open. Biosecurity concerns should be minimal if refeeding is limited to mortalities from natural disasters or noninfectious diseases. Mortalities resulting from infectious diseases or large scale mortality events will likely require other methods.

Implications to the environment

There is potential for pathogens present in carcasses fed to alligators to be transmitted via the excrement of the alligators. Rodents and birds could also transport pathogens present in carcasses awaiting consumption by predator species, particularly if the predators are raised in uncovered enclosures. The refeeding of diseased carcasses should be avoided.

Advantages and disadvantages

Refeeding is a low-technology solution to mortality management. If mortalities are generated near existing herds of predator species such as alligators, refeeding is also a low-cost option for mortality management. Difficulty in timely processing of large scale mortality events would be a disadvantage of refeeding. Carcasses must be incorporated into the diet of predator herds. If pre-processing is used to stabilize carcasses prior to refeeding, modifications may be required to maintain palatability.

3.4 – Napalm

Developed by US scientists during World War II for use in flame throwers and other weapons, napalm is a mixture of gasoline, benzene, and a thickening agent. For most people, napalm conjures up images of warfare, destruction, and horrific human casualties. However, napalm has been used in a variety of peace-time applications, including the break up of oil spills and the destruction of anthrax-infected cattle carcasses in the US.

In 1999, more than 2,271 L (600 gal) of napalm and 181 kg (400 lbs) of explosives were used to destroy a beached cargo vessel carrying nearly 1.5 mil L (400,000 gal) of fuel in an attempt to save Oregon's beaches. The Nevada Department of Agriculture at Reno and the Louisiana State Veterinary Service at Baton Rouge have some experience in peace-time uses of napalm to dispose of animal mortalities (Anonymous, 2001; Southwest Division Naval Engineering Facilities Command).

Anonymous (2001) reported that this highly flammable fuel-based material could be an effective way of speeding up the disposal of thousands of animals slaughtered in the 2001 foot-and-mouth disease crisis in the UK. UK Environment Minister Michael Meacher stated that there are environmental arguments in favor of using the chemical because it was fast and did not produce pollutants (Anonymous, 2001).

Environmental groups and health authorities raised concerns about the toxic effects of pyres that consisted of wooden railway sleepers, coal, and old tires as fuel, releasing cancer-causing dioxins into the air. According to one source, napalm could be an option:

> It sounds ideal: it's very hot, it burns quickly, and it coats the carcasses in a gel while they burn. And it's a lot cheaper than building a pyre. Napalm can reportedly dispose of carcasses in 60 minutes, whereas pyres take up to three days. Napalm also is easier to control and burns slower than gasoline—about 1,000°C (1,832°F) compared to 675°C (1,247°F) for thickened gasoline, ensuring the required destruction of infected carcasses.
>
> (Anonymous, 2001)

Because of the chemical's devastating wartime history and public perception, however, a spokesman for the Department of the Environment, Transport and the Regions in the UK said the use of napalm for handling mortalities was unlikely.

General process overview

Experiments in 2000 by Ron Anderson of the Nevada Department of Agriculture demonstrated that napalm could be sprayed over carcasses and set alight with a Terra Torch. The resulting fire consumed animal carcasses in about 60 minutes (Anonymous, 2001; Anderson, 2004; Firecon, 2002; Jones, 2004).

Napalm could also be combined with other technologies if at some point rapid burning of residues, stored carcasses, or composting operations was deemed necessary. However, Gary Ford of Air Burners, LLC indicated that their company had tried adding diesel fuel and gelled fuel to one of their air curtain incinerators, and the result was increased smoke emission and the explosion potential of the fuel without enhancement of the burning process. Napalm, being a gelled fuel, may not be compatible with air curtain incinerator technology (Ford, 2003).

Personnel requirements

The personnel requirements are poorly understood for this purpose. The level of training required to use napalm effectively is very high from a safety standpoint, but the process should be fairly straight forward (Anderson, 2004).

At present, the only source found in the US for the powdered aluminum soap is:

Fire-Trol Holdings, LLC
2620 North 37th Drive
Phoenix, Arizona 85009
firetrol@firetrolholdings.com

The powder aluminum octoate based gelling agents used in the burning of forestry slash, and even in the cleaning up of oil spills at sea, are manufactured by:

H.L. Blachford Ltd.
977 Lucien L'Allier
Montreal, QC H3G 2C3 , Canada
Tel: (514) 938-9775 ; Fax: (514) 938-8595
http://www.blachford.ca/

The Terra Torch system used by the US Forest Service for controlled burns in forest and grasslands is available from:

Firecon, Inc.
PO Box 657
Ontario, OR 97914
Tel: 541.889.8630, Fax: 541.889.8654
firecon@fmtc.com.

Location considerations

The area required for disposal using napalm disposal should be free of combustible materials and be large enough so that the carcasses are one layer deep. The site selection criteria used should be essentially the same as for pyres.

Resource requirements

The jellied gasoline or napalm of WWII was composed of gasoline mixed with aluminum soap powder derived from napthene and palmitate to produce a sticky, brown syrup that burned slower than gasoline. Napalm-B (super napalm or NP2) is safer than the napalm used in WWII. Current variations of napalm can be formulated by mixing aluminum soap powder polystyrene and benzene with gasoline or diesel fuel to solidify these fuels into a flammable but not explosive material that can be ignited in a controlled manner.

Previous delivery systems used by the military utilized handheld tanks with a pressurized flammable gas such as butane to propel the napalm to a target. Larger systems utilized a bronze rotary pump or a piston pump to pressurize the napalm. Ignition was accomplished with a battery-powered igniter. Napalm can be transported in steel or aluminum tanks. No pre-processing should be required and the fuel can be mixed just prior to use (Anderson, 2004; Jones, 2004).

The recommended fuel mixture for incinerating an adult cow is a mixture an aluminum soap powder in a 70/30 mixture of regular diesel fuel and regular leaded gasoline. If constant agitation is not provided, the powder may settle resulting in a very strong gel being formed on the bottom of the tank. Mixing should be maintained until the gel reaches the minimum viscosity required. Mixing time varies with fuel temperatures, e.g. with 70 percent diesel/30 percent gas the mixing times would be 29 minutes at 10°C (50°F) and 18 minutes at 21°C (70°F). The recommended amount of powder is 0.45 kg (1 lb) per 75.7 L (20 gal) of fuel. It takes 2.2 kg (4.8 lbs) of powder when using a 208 L (55 gallon) tank. The fuel must be secured and managed to ensure worker and animal safety to prevent direct exposure and/or fire. The fuel should be stored away from flammables (Jones, 2004).

In situations requiring continuous operation, two Terra Torch Model 2400 units with 240-gal tanks, a 50 ft fuel fill hose for transferring fuel from one unit to the other, and the terra torch gun with 25 ft of hose could be used. One unit could serve as a support unit, mixing and transferring, while the other continuously fired (Firecon, 2002; Jones, 2004).

Time considerations

The amount of construction or response time required for the use of napalm should be minimal if the delivery units or torches are available.

Remediation requirements

Site remediation should be similar to pyre or trench burning methods. No reports as to the amount of ash or residues were found in the literature. Napalm was used to decontaminate the surrounding soil after carcass disposal in Nevada, and potentially could be used to “sanitize” a site after other types of remediation were used (Anderson, 2004).

Cost considerations

Estimated costs of using napalm for carcass disposal are $25 to $30 per animal, but would 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 numbers of carcasses may be more efficient than dealing with small disposal situations (Anderson, 2004).

The delivery equipment outlined above for continuous operation (large Model 2400 Batch Mixer/Terra Torch with 240 gallon (skid mount) tank, a 50 ft fuel fill hose, Terra Torch Gun, and 25 ft hose) costs approximately $14,700 (Firecon, 2002; Jones, 2004).

Disease agent considerations

Biosecurity issues are largely unknown at this time; however, it is thought that the high temperatures generated by napalm should destroy most pathogens. The fate of prions is unknown and would need to be determined if the use of napalm were to become more common.

Implications to the environment

If handled improperly, napalm fuel could contaminate soil or groundwater, just as other petroleum-derived products can. Smoke and particulates resulting from carcass burning could affect air quality, and ash remaining after burning could be a potential groundwater contaminant. Substituting kerosene for diesel fuel in the mixture may reduce the black smoke (Anderson, 2004). No studies of the environmental effects of napalm could be found in the literature reviewed. Transportation of napalm on public roads may be of concern to public safety agencies and would need to be addressed.

Advantages and disadvantages

Napalm is easy to manufacture, burns at higher temperatures than fuels such as gasoline, and destroys carcasses more quickly than with conventional pyres. The logistics of mixing, delivery, and storage of napalm for carcass disposal pose the greatest challenge. Guidelines for the selection of materials, transport, and implementation would need to be developed.

Concerns include smoke and particulates that could affect air quality. Ash remaining after burning could be a water quality concern. Worker safety and the potential fire hazard posed by storing, handling and using napalm must also be considered. Constraints on the use of napalm are poorly understood at this time, but should be limited only by the availability of napalm and its application equipment and by the space available at the disposal site.

3.5 – Ocean Disposal

Ocean disposal of carcasses was proposed after Hurricane Andrew swept through North Carolina recently. The North Carolina Department of Agriculture reported that the US Environmental Protection Agency (EPA) did not have regulations governing the disposal of animal carcasses beyond territorial limits (D. Wilson, 2003). The Coast Guard states the method can be used as long as there is no floating debris. The EPA has assessed the types and origins of floatable debris and has limited the disposal of animal carcasses related to specific medical research (US EPA, 2002). The disposal of animal carcasses near land can promote the presence of scavengers that can interfere with human activities. Open disposal of large quantities of animal processing waste could result in dead zones in the ocean, and has prompted some animal processors to look for other methods of managing animal remains (Iwamoto, 2003).

General process overview

Carcasses would be loaded onto open barges or into containers, floated beyond territorial limits, and emptied overboard. Eliminating all floating debris may require some sort of packaging or pre-processing.

Personnel requirements

Personnel needs have not been determined, but could be substantial if it only occurs due to a one-time mortality event.

Location considerations

Areas proximal to ports and a designated handling area would need to be identified. Transfer sites at ports that do not disrupt other commerce would need to be identified.

Resource requirements

Barge operators could supply equipment for water transportation. Land transportation schemes would also need to be developed for safe movement of animals to seaports.

Transportation and decontamination would be required for each vessel and truck. Enclosed, secure transportation to prevent contamination or access by sea birds would be required. Carcasses may need to be ground in order to prevent floating.

Time considerations

Capacity constraints are unknown, but should be dependent on the acceptance rate of aquatic life in the region of interest.

Remediation requirements

Potential site remediation would include decontamination of equipment used to transport mortalities.

Cost considerations

One source has estimated the cost of ocean disposal at $1 per ton (D. Wilson, 2003). However, no indication was provided as to whether this estimate included shipping terminal fees and all related transportation costs.

Disease agent considerations

Ocean dumped carcasses should probably exclude disease-related mortalities, especially if the mortalities are from commercial aquaculture operations.

Implications to the environment

The mortalities should provide a protein and energy source for aquatic life in the area.

Specific environmental impacts are not fully defined, but will likely be minimized if steps are taken to ensure there is no floating debris resulting from disposal. Secure transport and temporary storage must be provided.

In addition, nutrient loading limits at the ocean disposal sites need to be defined to reduce potentially negative environmental impacts.

Advantages and disadvantages

Ocean disposal provides a means to rapidly dispose of carcasses from a large die-off with no noticeable residues. It also holds the potential of adding needed protein to the ocean food chain, assuming the transport container is punctured before disposal. There is, however, the potential to overload a disposal area. Effective transport distances are not clear. Carcasses must be handled twice. Carcasses should be in sealed containers during transport and storage prior to disposal. It is unclear at this time if disease could re-enter the domestic bird or animal production system through birds or harvested fish.

Concerns over floating debris and determinations of the maximum acceptable nutrient loading for areas of intent in the ocean need to be dealt with. Utilizing inert, disposable containers that will not float should be explored. Roll off dumpsters with sealed plastic liners could be used for transportation from a farm site. The dumpster could be loaded onto a barge and taken to the disposal site off-shore. The question of whether a loaded sealed liner of carcasses would sink or float without modification would need to be explored.

3.6 – Non-Traditional Rendering

Instead of using conventional rendering procedures, ground non-disease related mortalities can be converted into a feedstuff by fluidized-bed drying, flash dehydration, or extrusion. These technologies were studied at North Carolina State University's Animal and Poultry Waste Management Center and could emerge as economical and environmentally-sound alternatives to conventional rendering of dead pigs. The following provides an overview of the "flash dehydration" process:

> In fluidized-bed drying or flash dehydration, the material flows along a channel of super-heated air. Flash dehydration can be used to dry many types of wet wastes, but it is most applicable for drying animal by-products and offal. Depending on the moisture and fat contents, ground swine mortality carcasses must be blended with an organic carrier to facilitate the flash dehydration process.
>
> (Nesbitt, 2002)

Extrusion and expeller press processing was studied by Middleton, Nesbitt, Boyd, and Ferket (2002) who reported that the processes have been used for a number of years in the soybean industry to fractionate oil from soybean meal, resulting in two high-value products. They evaluated the feasibility of the technology for swine and poultry carcasses.

Middleton et al. (2002) used flash dehydration followed by extrusion and the expeller press extraction of fats and oils. The compositions and material handling characteristics of all resulting products (meals and oils) were studied and their value in broiler diets was determined by least-cost linear programming. A financial *pro forma* for a model county-based cooperative facility employing these technologies was developed.

> It has been used to process human foods for more than 50 years, producing 13 billion pounds of product with a market value of $8 billion annually. If extrusion is used to process carcasses it will most likely be done centrally because of capital costs. However, if it can also be used on site to extrude full-fat soybeans and creep feed, individual farms may be able to justify the cost.
>
> (Middleton et al., 2002)

Morrow and Ferket (2001 & 2002) go on to explain the principles involved in extrusion as follows. They report that finely-ground, high-moisture material is mixed with an organic carrier to a moisture content of about 30% and then subjected to processing by friction heat, shear, and pressure within the dry extruder barrel. In the extruder barrel, a screw (or screws) forces the material through a series of flanged steam locks where temperatures range from 115-1,550°C (239–2,822°F) and pressures of 20-40 atmospheres develop within 30 seconds. The sudden decrease in pressure as the product leaves the extruder causes it to expand and lose 12-15% of its moisture. The food industry mostly uses single screw dry extruders because they are about 50% less expensive, in terms of capital and operating expense. However, double-screw systems can better cope with the high moisture ingredients and therefore may be more appropriate for dead pig disposal.

Personnel requirements

This is a complex process and the labor requirements can be expected to be at a relatively high skill level.

Location considerations

Due to the size of current equipment and the supporting infrastructure, fluidized-bed drying, flash dehydration, and extrusion are not transportable. A fixed processing site with good truck access would be required and carcasses would be transported to the facility.

Resource requirements

Current equipment can evaporate 500 gal of water per hour, using approximately 1300 BTUs per pound of water evaporated. In drying dead pigs, higher efficiencies have been documented, perhaps because the equipment burns some of the more volatile fats in the pigs (Nesbitt, 2002).

Time considerations

These units are built to order and would need to be constructed in advance of a disaster and operate on a daily basis, processing feedstock, to be economical and viable.

Remediation requirements

The high temperatures and short dwell times of flash dehydration cause little damage to protein quality, resulting in superior protein digestibility. If sterilization of the product is required, the meal can be dehydrated to about 10% moisture and subjected to extrusion processing (Nesbitt, 2002).

In situations where this system can neutralize disease agents or in the case of a natural disaster, the resulting material could be used as a protein source, rendered, used in a composting system, deposited in a landfill, put in cold storage for further processing, or utilized an energy recovery system such as in a fixed hearth plasma arc furnace or a thermal depolymerization oil recovery system. Prior planning for the recovery of animal or plant nutrients or energy could reduce costs as well as the effects on the environment and provide a useable output.

Cost considerations

While the operational costs of using flash dehydration followed by extrusion to recycle carcasses 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 907 kg (1 ton) of final product, and $40 per 907 kg (1 ton) if followed by extrusion. These estimates assume $1.10 per 3.8 L (1 gal) for fuel, $0.12 per kWh, and $0.75 per 907 kg (1 ton) for maintenance (Nesbitt, 2002).

Disease agent considerations

Bacteria, molds, and viruses are readily inactivated by extrusion (Morrow & Ferket, 2001). No reference to survival of prions during the extrusion process could be found in the literature.

Implications to the environment

In the situation where a disease agent can be neutralized by this process, the resulting material could be used in a composting system, deposited in a landfill or utilized an energy recovery system such as in a fixed hearth plasma arc furnace or a thermal depolymerization oil recovery system. The recovery of plant nutrients or energy would reduce costs and the effects on the environment.

Advantages and disadvantages

One advantage of this system, in situations where TDEs are not a concern, is that it offers the ability to process solids and liquids with the same machinery. Manure solids, or contaminated feed could also be processed for further disposal.

Disadvantages are its lack of portability, high initial cost, and the need to transport feedstock to a central processing site unless a unit is located on a farm where it is used for processing soybean meal or other feed products. Another disadvantage of this system may be its inability to neutralize TDE agents.

3.7 – Novel Pyrolysis Technology (*ETL EnergyBeam™*)

Energystics Technologies, Ltd. has developed a novel pyrolysis technology, called *ETL EnergyBeam™*, that uses a proprietary technology to concentrate and direct electromagnetic waves at solid, liquid, or gaseous targets (Sheperak, 2004). Rather than converting electrical energy to thermal energy in a conductive medium, this technology directly couples electromagnetic energy with a target material to produce heat. The target absorbs energy, generating temperatures that exceed the melting or vaporization points of the target materials. These temperatures provide the ability to disassociate strong molecular bonds in hazardous materials. Because the technology does not utilize a conductive medium, only a relatively small energy input is required (e.g., requires 400 Watts to vaporize/sublime pure tungsten rods at 3,370°C [6,098°F], compared with a home hair dryer which uses 1,200 Watts to heat air). Advantages of the technology reportedly include instantaneous, controllable heating, a lack of hydrocarbon pollutants or harmful emissions, and reduced energy requirements. Additionally, the technology is reportedly scalable and lends itself to continuous operation and automation. However, the technology has yet to be tested on actual intact carcasses.

Studies at the University of Toledo demonstrated the feasibility of the system for destroying polychlorinated biphenyls, with temperatures outside the coupling zone observed to be in excess of 1,690°C (3,074°F) (Sheperak, 2004). Therefore, the system generates temperatures believed to be adequate for destruction of pathogens, including prions. As a demonstration of the application for animal tissue, a 20-gram sample of beef tissue was pyrolized, resulting in complete dematerialization of the tissue and no visible residues or smoke (Figure 5).

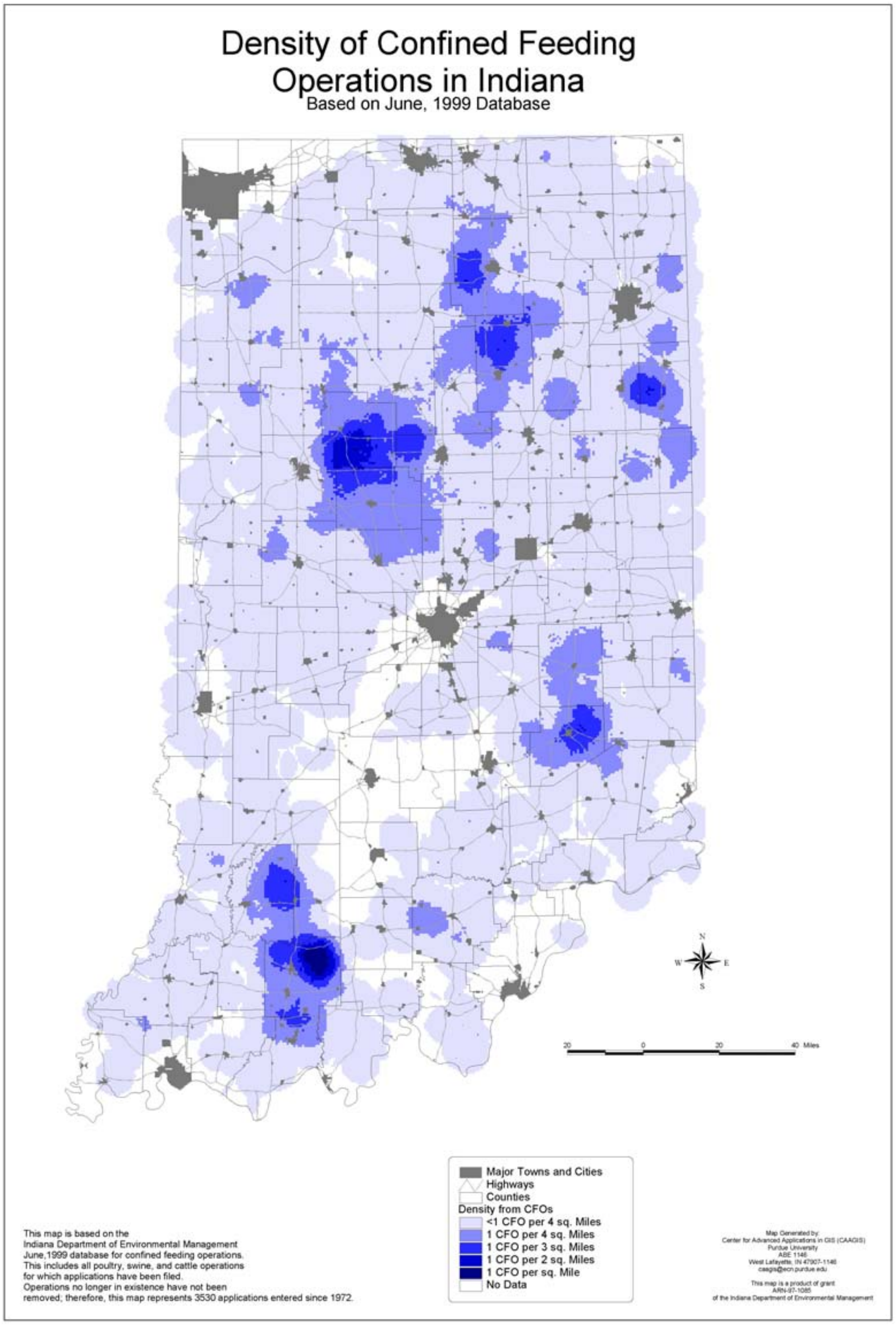
Because the technology is scalable, a system could reportedly distribute energy to carcasses through a unique nozzle design within a pyrolysis chamber. The developers believe carcasses could be efficiently introduced into a unit and any remaining sediment could be removed from the bottom of the unit after pyrolization. Based upon existing empirical data, the developers anticipate that the unit will efficiently eliminate carcasses as well as any hazardous chemical or biological materials (Sheperak, 2004).

An alternative use of the technology is as an "afterburner" for stack gases of existing incinerators to provide additional assurance of destruction of hydrocarbons and pathogens. This application could reduce the capital expense associated with retrofitting existing incineration units to meet more stringent EPA emission requirements.

FIGURE 5. Pyrolysis of a 20-gram sample of beef tissue using the *ETL EnergyBeam*™ (purple/white area) technology (Sheperak, 2004).

Section 4 – A Proposed Model Integrated Disposal System

This report concludes that pre-processing of carcasses on-site decreases biosecurity concerns and increases the number of process options available to utilize mortalities, especially in cases where large scale disposal of carcasses is necessary. If biosecurity can be maintained, processing carcasses on-site would allow neutralization of most pathogens and transportation to a central location where further processing could occur. Figure 6 shows animal production concentrations in Indiana, and demonstrates the potential central location of processing plants, based on transportation times. Figure 6 shows GIS coverage that includes confined feeding operations, cities, and roads in Indiana. Concentrations of animals in certain parts of the state would suggest that two locations—Fort Wayne and Columbus, for instance—would be ideal spots for central processing facilities should large-scale mortality events affect the state. Each of these cities is located in the midst of significant concentrations of livestock. A similar process can be used in other states to avoid moving mortalities across state lines.



This map is based on the Indiana Department of Environmental Management June,1999 database for confined feeding operations. This includes all poultry, swine, and cattle operations for which applications have been filed. Operations no longer in existence have not been removed; therefore, this map represents 3530 applications entered since 1972.

Map Generated by:
Center for Advanced Applications in GIS (CAAGIS)
Purdue University
ABE 1146
West Lafayette, IN 47907-1146
caagis@ecn.purdue.edu

This map is a product of grant
ARN-97-1085
of the Indiana Department of Environmental Management

FIGURE 6. Map of Indiana, showing concentration of confined feeding operations (map obtained by the authors).

4.1 – Example: Grinder-Dumpster System for Pre-Processing and Stabilization of Mortalities

The following system represents a variation of the WR$^{2®}$ STI Chem-Clav process, extended to include sealed, secure transport of pre-processed carcasses.

System components

The following system components have been compiled from Stikeleather and McKeithan (1996).

1. Power plant installed in separate containment pan to retain oil or fuel spills
2. Hydraulic pump to drive sheep's foot rollers, shredders, and/or grinder
3. Hydraulic drive for covered variable speed control – reversible feed of sheep's foot rollers and/or grinder
4. Screw grinder from US Patent 5,547,420 – modified to handle bone fragments of full size bovine
5. Hydrogel or quicklime to mix with ground carcasses to aid in flow characteristics and act as a carrier for disinfectant
6. Large peristaltic pump or screw conveyor if needed to move material (pre-processed carcasses in hydrogel) to final processing or to transport trucks
7. Complete skid system suitable for transport on a flatbed semi-trailer with a containment pan to retain waste liquids for disposal
8. Transport system to be comprised of vacuum tanker or plastic lined roll-off dumpsters

System specifications

1. Desirable processing speed – at least 20 bovine carcasses per hour
2. Volume above sheep's foot rollers = 2 x maximum size bovine to allow for 1 animal to be dropped into the hopper and let the doors close above it
3. End panels of upper – removable for roller removal and cleaning
4. Upper hopper with spring loaded or hydraulically controlled doors that close after an animal is loaded
5. Standard 55' flatbed trailer for transport of roll-off container to central processing
6. Vinyl liners (for roll-off containers) – 10 mil form-fitted bag – from Packaging Research and Design Corp. 800-833-9364

Size	Price
20 yd^3 (15.3 m^3)	$23.00
30 yd^3 (22.9 m^3)	$29.34
40 yd^3 (30.6 m^3)	$32.49
19,000 currently in stock	

7. Utilize Milwaukee® Heat gun or equivalent– seal & tarp or 3M Spray Adhesive

Comment on specification #6 (vinyl liners):

a) Crushed contaminated concrete has been loaded into 10 mil liner, sealed and hauled without damaging the liner
b) Similar liners have also been used at the Hanford, WA nuclear site for the demolition process for contaminated soil
c) Roll off containers easy to fit with liners because of their standard sizing. It is more difficult to fit a semi trailer however.
d) Another alternative source for liners:

   Extra Packaging Corp. 888-353-9732

   This product is composed of a flat sheet (not fitted for the roll-off container) from Mexico.

The system described above could prepare carcasses for transport to a central processing facility. More expensive and more complex processing options would be available under this decentralized-centralized approach if the processing option chosen is also able to continue operating with other feedstock during times when carcasses are not available, as shown in Figure 7. Thermal depolymerization and plasma arc appear to hold the most promise in this regard since they utilize not only mortalities but also other organic matter to produce energy. Both processes are relatively new and require additional research, but both should have potential in agricultural areas where large amounts of organic feedstock are available for the production of petroleum-like products.

Specifically, the following model is proposed here, as shown in Figure 7:

On-site Pre-processing: Grinding of the carcasses into a paste at the animal production site.

Transportation: Loading the mortality paste produced into sealed roll-off containers and transport to a centralized plant.

Central Processing: Utilization of the mortality paste as a feedstock in a centrally-located, continuously-operated plant that is capable of converting organic matter into oil and methane.

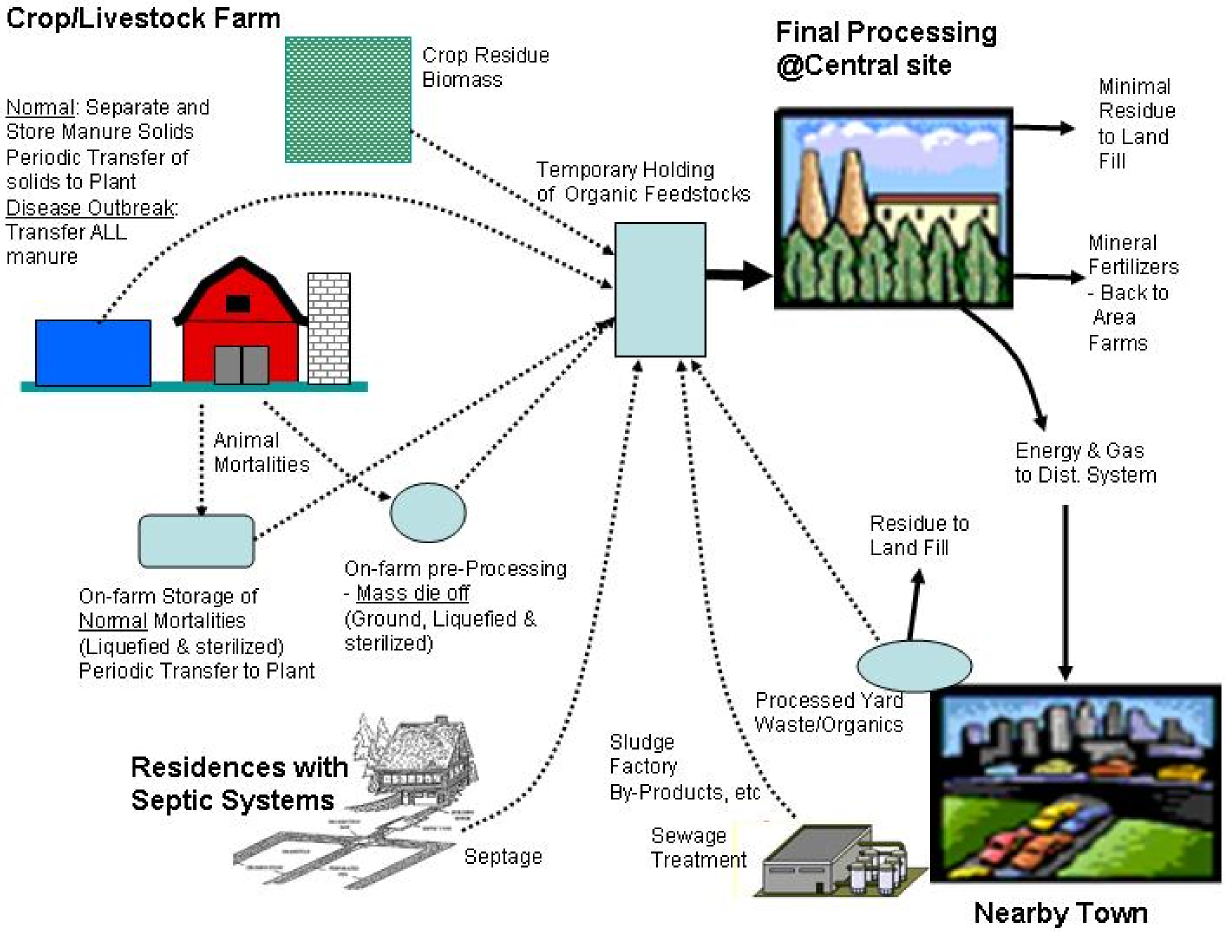


FIGURE 7. Schematic of area-wide comprehensive rural organic processing system. In this scenario, carcass composting becomes only a part of the feedstock.

Section 5 – Critical Research Needs

Much is known about carcass disposal systems; however, many knowledge gaps remain. The list below shows the critical research needs that remain:

1. Investigate the capacity and biosecurity of existing refeeding (e.g., alligator refeeding) operations to accommodate large-volume, temporary input from large-scale mortality incidents.
2. Identify cost information and feasibility of alternative methods of on-farm processing of large and small animal die-off events.
3. Study the feasibility of transporting and storing partially stabilized, pre-processed carcasses.
4. Identify the likelihood of pathogen survival under each of the processing systems.
5. Identify cost information and feasibility of processing ground mortalities using centralized versus mobile plants that employ thermal depolymerization and plasma arc technologies.
6. Investigate the economic sustainability and technical feasibility of centralized plants that would play a role in processing carcasses from rural areas.

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