Carcass Disposal: A Comprehensive Review

National Agricultural Biosecurity Center Consortium
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Chapter

16

Decontamination of Sites & Carcasses

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Abbreviations

APHIS	Animal and Plant Health Inspection Service
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BSE	bovine spongiform encephalopathy
END	exotic Newcastle disease
FDA	Food and Drug Administration
FMD	foot and mouth disease
QACs	quaternary ammonium compounds
USDA	United States Department of Agriculture

Section 1 – Key Content

1.1 – Situation Assessment

The first, and most important, step in the process of decontamination is the identification of the disease agent present.

The Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) decontamination procedures manual identifies three categories of viruses that should be considered. These three categories are:

- **Category A** includes those viruses that are lipid-containing and intermediate-to-large in size. These viruses are very susceptible to detergents, soaps, and disinfectants because of their outer lipid envelope. Examples include paramyxoviridae and poxviridae.
- **Category B** viruses are hydrophilic and resistant to detergents. They are also sensitive, but less susceptible to other disinfectants. Classical disinfectants like quaternary ammonium compounds are not effective against them. Examples include picornaviruses and parvoviruses.
- **Category C** viruses are between Category A and Category B viruses in sensitivity to the best antiviral disinfectants. Examples include adenoviruses and reoviruses.

1.2 – Possible Infectious Agents

A list of selected possible infectious agents would include bovine spongiform encephalopathy (BSE), foot and mouth disease (FMD), exotic Newcastle disease (END), swine vesicular disease, vesicular stomatitis, and anthrax. Each of these diseases has specific symptoms and concerns, which are addressed in Section 2. Table 1 summarizes the information available on these particular diseases, and further information can be gathered by visiting the Animal and Plant Health Inspection Service (APHIS) web sites listed for each agent in the References section.

1.3 – Six General Groups of Disinfectants

The six most common disinfectant groups include soaps and detergents, oxidizing agents, alkalis, acids, aldehydes, and insecticides. Choosing the correct disinfectant is crucial to ensuring the most efficient decontamination. Example compounds from each group are described in Section 2, and summarized in Table 3.

1.4 – Decontamination Preparation

After a presumptive or confirmed diagnosis is made, a state quarantine should be placed on the farm, and a zone of infection established (USDA, 2002e). Within this infected zone, movement restrictions will apply, and no animals or animal products will be allowed to leave.

Decontamination of personnel is essential for the prevention of cross-contamination so that people can leave an infected premise with minimal risk of transporting the disease agent (ARMCANZ, 2000). There should be an area designated near an exit point of the property as the site for personnel decontamination. The area should be decontaminated with the proper disinfectant and be equipped with a water and drainage supply. A disinfectant should be available at this site for anyone entering or leaving the property. Personnel should be provided with overalls, footwear, head covering, gloves, and goggles. All clothing items should be decontaminated by disinfection every time the person enters or leaves the area. Disinfectant mats or wheel baths filled with disinfectant should be accessible at all vehicle entrances and exits. Every effort should be made to ensure that no vehicles leave an infected property without thorough decontamination.

1.5 – Property Cleanup

The aim of the cleanup process is to remove all manure, dirt, debris, and contaminated articles that cannot be disinfected. This will allow all surfaces to be exposed to detergents and disinfectants. This is the most crucial phase of the cleanup process because the presence of organic material reduces the effectiveness of disinfectants (ARMCANZ, 2000). All gross organic material should be flushed using a cleaner/sanitizer or detergent compound. The entire building should be treated with a detergent solution and left for at least 24 hours if possible. The detergent or sanitizer must be completely rinsed or flushed away after cleanup is complete

1.6 – Disinfection

The selected disinfectant should be applied using a low-pressure sprayer, beginning at the apex of the building and working downwards. Disinfectant must be left on surfaces for as long as possible and then thoroughly rinsed. The property should be left vacant for as long as possible before post-disinfection samples are collected (Kahrs, 1995). Upon completion, the premises should be left empty for some period of time and sentinel (susceptible) animals introduced to detect any remaining contamination (Fotheringham, 1995a).

Section 2 – Situation Assessment

Decontamination can be defined as the combination of physical and chemical processes to kill or remove pathogenic microorganisms and is vital for disease eradication (ARMCANZ, 2000). The importance of disinfection can be assessed according to three factors: mode(s) of transmission, likely contamination of the environment, and susceptibility of the causal agent to disinfectants (Fotheringham, 1995b). The first, and most important, step in the process of decontamination is the identification of the disease agent present. In order to begin decontamination, those involved must understand how the causative agent works and exactly how it spreads.

The Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) decontamination operational procedures manual (2000) identifies three categories of viruses that should be considered and defines them as follows:

- **Category A** includes those viruses that are lipid containing and intermediate-to-large in size. These viruses are very susceptible to detergents, soaps, and disinfectants because of their outer lipid envelope. They are susceptible to dehydration, and are only present in cool, moist environments. Examples include paramyxoviridae and poxviridae.
- **Category B** viruses are hydrophilic and resistant to detergents. They are also sensitive, but less susceptible to other disinfectants. Classical disinfectants like quaternary ammonium compounds (QACs) are not effective against them. Examples include picornaviruses and parvoviruses.
- **Category C** viruses are between Category A and Category B viruses in sensitivity to the best antiviral disinfectants. Examples include adenoviruses and reoviruses.

As indicated by Fotheringham (1995b), decontamination is a vital element in disease eradication. It includes the elimination of the disease agent in infected premises, the reduction of the possibility of dissemination to other areas, and the minimization of the period between slaughter and re-stocking. Infected animals excrete pathogenic microorganisms. Pathogens present within the upper respiratory tract can be expelled to nearby animals through breathing, coughing, and sneezing. Fotheringham (1995b) indicates that dust particles from the animals' coats, bedding, and feed become contaminated with skin, hair, saliva, pus, and body excretions. Also, some microorganisms can survive for long periods in the environment, particularly if protected by organic soiling such as manure.

2.1 – Possible Infectious Agents

Bovine spongiform encephalopathy (BSE)

Bovine spongiform encephalopathy, otherwise known as "mad cow disease," is a transmissible prion disease in cattle that requires inactivation. BSE is a chronic degenerative disease that affects the central nervous system with a prolonged incubation period of 2 to 8 years (USDA, 2002b). Transmission occurs through ingestion of contaminated meat and bone meal that contains nervous tissue from affected animals or, possibly, from scrapie-infected sheep (Geering, Penrith, and Nyakahuma, 2001). The cattle most commonly affected by BSE range in age from three to seven years.

Clinical signs of the disease include changes in animal temperament, abnormal posture, lack of coordination, difficulty rising, loss of weight and appetite, and ultimately death (USDA, 2002b). There is no evidence that BSE is spread by physical contact among cattle, or from cattle to other species.

Most common disinfectants are not effective against BSE. Kahrs (1995) states that prions defy identification, fail to stimulate immunological responses, persist for years, and are resistant to heat and disinfectants. Transmissible degenerative encephalopathies like BSE are fairly resistant to inactivation by standard decontamination procedures, and the only methods that may be effective in worst-case scenarios are strong sodium hypochlorite solutions or hot solutions of sodium hydroxide (Taylor, 2000).

Foot and mouth disease (FMD)

Foot and mouth disease is a highly contagious, viral, vesicular disease affecting cloven-hoofed animals. Geering et al. (2001) defines FMD as a Category B picornavirus with a 3-5 day incubation period. They characterize the virus as one that is excreted from nasal passages, saliva, milk, semen, feces, and urine and, in vast amounts, from ruptured vesicles. FMD is rapidly spread by direct and indirect contact with contaminated individuals, as well as through the air. Cattle remain carriers for at least 27 months and sheep for 9 months (Geering, et al., 2001). Bartley, Donnelly, and Anderson (2002) indicated that the FMD virus could survive in the absence of animal hosts, including at 4° C (39.2° F) on wool for approximately two months, and for two to three months in bovine feces or slurry. Survival is affected by several environmental- and virus-related factors. Potter (2002) finds that high temperatures and low humidity will destroy FMD mainly by desiccation. Exposure to 56° C (132.8° F) for 30 minutes is sufficient to destroy most strains (Potter, 2002). Potter (2002) also notes that FMD virus is stable at a pH of 7.4-7.6, and rapid inactivation occurs below pH 5 and above pH 11. The use of ethylene oxide, formaldehyde, and γ radiation may be an appropriate control measure (Dekker, 1998). The most rapid inactivation of FMD can occur in the presence of acids or alkalis as long as their pH is maintained at appropriate levels (Sellers, 1968).

Clinical signs can include fever and blister-like lesions followed by erosions on the tongue and lips, in the mouth, on the teats, and between the hooves (USDA, 2002c). Animals may also exhibit increased temperatures, reduced feed consumption, lameness, and aborted pregnancies.

If contact is made with infected cattle, it is recommended for individuals to refrain from contact with susceptible livestock for 72 hours (Geering et al., 2001). Following an outbreak, a minimum period of three months must elapse between the last reported FMD case and the declaration of disease-free status (Bartley et al., 2002). The US Department of Agriculture (USDA) (2002c) indicates FMD is not recognized as a zoonotic disease transmissible to humans.

Exotic Newcastle disease (END)

Exotic Newcastle disease is a highly contagious, generalized, viral disease of domestic poultry and caged and wild birds. Geering et al. (2001) defines END as a Category A paramyxoviridae with three strains that vary in virulence: velogenic (high), mesogenic (moderate), and lentogenic (low). The incubation period is between 2 and 15 days. The virus is known to spread via the respiratory tract and in feces, and can spread rapidly within a flock. END is disseminated by direct contact and by carrier state birds for up to 120 days after infection. Indirect transmission can also occur by contaminated individuals, articles, fomites, manure, feed, and vehicles under certain environmental conditions. END has been known to disseminate over a wide area through the air, and flies transmit the disease mechanically (Geering et al., 2001).

END is so virulent that many birds die without showing any clinical signs, and a USDA (2003) report on END projects a death rate of nearly 100% in an unvaccinated flock. Clinical signs include sneezing and coughing, watery diarrhea, depression, decreased egg production, and sudden death. Geering et al. (2001) indicate Newcastle can cause headache and flu-like symptoms in humans, and it is suspected that person-to-person transmission may be possible. This virus is destroyed rapidly by dehydration and by the ultraviolet rays in sunlight (USDA, 2003).

Swine vesicular disease

Swine vesicular disease is a contagious viral disease found in pigs that exhibit clinical signs difficult to distinguish from FMD. Geering et al. (2001) defines this as a Category B enterovirus with an incubation period of 2-7 days. The virus is excreted from ruptured vesicles for up to 10 days and in feces for more than 3 weeks, but a prolonged "carrier" state does not occur. It is spread by direct contact between animals and indirectly by contaminated vehicles, fomites, people, and illegal swill feeding. Sodium hydroxide, sodium hypochlorite, and formaldehyde can be used against this disease agent; however, their effectiveness will be decreased in the presence of organic material (Blackwell, Graves, and McKercher, 1975). Swine vesicular disease is resistant to heating and drying, but is not likely to affect humans.

Vesicular stomatitis

Vesicular stomatitis is a contagious viral disease of cattle, pigs, horses and, possibly, sheep and goats. Geering et al. (2001) defines vesicular stomatitis as a rhabdoviridae (Category A virus) with two distinct serotypes: Indiana and New Jersey. This virus has an incubation period of 1 to 10 days, is shed in vesicular fluid and saliva for a few days, and is spread by direct contact. Transmission is not fully understood, but insect vectors, mechanical transmission, and movement of animals may be responsible (USDA, 2002d).

Vesicular stomatitis is characterized by vesicular lesions on the tongue, oral mucosa, teats, or coronary bands of cattle, horses, and swine (USDA, 2002d). Clinical signs can also include fever, drooling or frothing at the mouth, and severe weight loss, but generally not death. USDA (2002d) indicates that its outward signs are similar to, but less severe than, those of FMD. Human infection occurs through the respiratory tract, conjunctiva, and skin abrasions with disease symptoms similar to influenza (Geering et al., 2001). Phenolic- and halogen-based disinfectants work best in footbaths to control disease transmission (USDA, 2002d). Chlorine bleach at a 0.645 percent concentration is effective enough to destroy the agent with 10 minutes of contact time.

Anthrax

Anthrax is a mammalian disease caused by a spore forming bacterium called Bacillus anthracis that is endemic to the United States and most other countries (USDA, 2002a). Ruminants such as cattle, sheep, and goats are the farm animals most susceptible to anthrax. It is usually contracted through ingestion of soil-born anthrax spores, and infected animals die acutely. Spores may enter the skin through abrasions, swallowing, or inhalation. Anthrax does not spread by contact between living animals, but humans can be exposed to the disease by handling animals or animal products such as hides and wool. Anthrax may be perpetuated in nature by hosts such as wildlife, which may spread the disease to the domestic livestock population. Spores are highly resistant to heat, cold, chemical disinfectants, and drying, and have survived for years in the environment. Environmental persistence may be related to a number of factors, including high levels of soil nitrogen and organic content, alkaline soil, and ambient temperatures higher than 60° F (USDA, 2002a).

Anthrax should be contained quickly to prevent the release and sporulation of vegetative cells from dying or dead animals (Turnbull, 2001). The list of recommended disinfectants includes: 10% formaldehyde, 4% gluteraldehyde, 3% hydrogen peroxide, and 1% peracetic acid. Hydrogen peroxide and peracetic acid will not work in the presence of blood. Soil from areas of anthrax contamination should be removed for incineration or soaked with 5% formaldehyde. Contaminated materials should be incinerated, and non-disposable items should be soaked with 4% formaldehyde or 2% gluteraldehyde (Turnbull, 2001).

A list of common infectious agents complete with basic recommendations on how to handle these agents is listed in Table 1.

TABLE 1. List of common infectious agents with recommendations on disposal and disinfection (ARMCANZ, 2000; Geering et al., 2001)

Agent	Classification	Preferred Disposal Method	Recommended Disinfectants
BSE/ Scrapie	Prion, non-viral	Bury, burn, or alkaline hydrolysis	Bury or burn any contaminated materials, then use soap and detergent followed by sodium hypochlorite
Avian influenza/ Newcastle	Category A virus	Bury or burn	Soaps and detergents, sodium hypochlorite, calcium hypochlorite, VirkonS®, alkalis
FMD/ Swine vesicular disease	Category B virus	Bury or burn	Acids for FMD; oxidizing agents and alkalis for animal housing and equipment; soaps, detergents, and citric acid for humans
Vesicular stomatitis	Category A virus (vector-borne)	Bury or burn	Soaps and detergents; alkalis and acids; insecticides – organophosphates, synthetic pyrethroids, and Ivermectin®
Anthrax	Bacterial spore	Burn	Formaldehyde, gluteraldehyde, hydrogen peroxide, peracetic acid

2.2 – Possible Decontamination Chemicals or Disinfectants

A disinfectant can be described as a chemical, or mix of chemicals, capable of killing pathogenic microorganisms associated with inanimate objects (Geering et al., 2001). A report by Maris (1995) states that disinfectants can impact microorganisms in two different ways: growth inhibition or lethal action. Lethality should be considered the desired outcome. Chemicals usually kill microorganisms by toxic reactions, and effective disinfectants are often toxic for animal and human tissues as well, so they must be used with care (Geering et al., 2001). For an antiseptic or disinfectant molecule to reach its target site, the outer layers of a cell must be crossed (McDonnell and Russell, 1999). If lipid is found within a virus, it is uniformly associated with a high degree of susceptibility to all disinfectants (Maris, 1995). But if a virus is without lipid, and small in size, it could be associated with resistance to lipophilic chemical agents. Many factors can affect the efficacy of the disinfectant (e.g. temperature, pH, the presence of organic materials, composition of the surface), making it difficult to predict efficiency (Tamasi, 1995). The Food and Drug Administration must approve all disinfectants and pesticides used.

General groups of disinfectants

Soaps and detergents

This class is most useful for Category A viruses because it can disrupt outer lipid envelopes. This disinfectant group is used to effectively clean surfaces for decontamination. The most common types include combinations of phenolics, QACs, and chlorines.

Quaternary ammonium compounds (QACs). QACs are not sporicidal, and are relatively ineffective against mycobacterium (Jeffery, 1995). They are usually formulated with compatible non-ionic detergents to increase detergency. Also, QACs can lose some of their activity if the ratio of ingredients is incorrect. Action is rapid, but strong concentrations can corrode mild steel or iron. These compounds work by irreversibly binding to the phospholipids and proteins of cell membranes to impair permeability (Maris, 1995). Also known as cationic detergents, QACs also work well to clean and deodorize hard surfaces (McDonnell and Russell, 1999). Jeffery (1995) states that the only way to prove their efficacy in a given situation is to assess these products in practice.

Oxidizing agents

This category is recommended for most applications on viruses within Categories A, B, and C (ARMCANZ, 2000).

Sodium hypochlorite. Sodium hypochlorite compounds are halogen-releasing. This is a concentrated liquid used against all categories of viruses except in the presence of organic material and warm, sunny conditions over 15°C (59° F) (Geering et al., 2001). Sodium is a good broad-range disinfectant that is only effective at a neutral to moderate pH of 6-9, and has a diminished effect in the presence of organic material (ARMCANZ, 2000). Hypochlorites are toxic to the eyes and skin, and corrosive to many metals (Geering et al., 2001). Jeffery (1995) reports that sodium hypochlorite is usually formulated with a little sodium hydroxide to enhance stability. He also notes potassium hypochlorite is similar to sodium hypochlorite, and neither is stable in solid form.

Calcium hypochlorite. Calcium hypochlorite is a solid used against all categories of viruses but not in the presence of organic material. Because it is stable as a solid, it can be used to formulate a powder. Evans, Stuart, and Roberts (1977) determined that hypochlorites could be effective disinfectants for viruses provided that storage of the concentrate does not exceed the time when chlorine falls below 10 percent. As a result, hypochlorite solutions must be freshly prepared.

Virkon S®. Virkon S® is a powder form that is easy to mix and dilute on site. It is a well-known, name-brand oxidizing agent manufactured by Antec International. This popular disinfectant has a low toxicity and is approved for use on all 17 families of viruses. It may be sprayed on surfaces at a 1 percent dilution rate of 300 mL/m^2 for decontamination. It can also be used to disinfect vehicles at a 1 percent dilution. Virkon S® may be used as a skin disinfectant for personnel decontamination. As with all disinfectants, performance is optimized on a clean surface (Antec International, 2003).

Alkalis

The alkali group is considerably inexpensive and has a natural saponifying action on fats to aid cleaning (ARMCANZ, 2000). This group can be used against all virus categories and even some bacterial spores. They work well in the decontamination of animal housing, yards, drains, waste pits, and sewage tanks. Alkali activity is slow, but can be increased by raising temperatures and using increased concentrations. Alkalis are very corrosive, and must be handled with care. Jeffery (1995) notes calcium oxide, or quicklime, is often used to disinfect animal carcasses.

Sodium hydroxide. Sodium hydroxide, also known as caustic soda, is a strong surface disinfectant, which can kill bacterial spores in high concentrations (Bruins and Dyer, 1995). The pellet form of sodium hydroxide can be used against all three categories of viruses unless aluminum is present. It is caustic to eyes, skin, and mucous membranes, and should always be kept away from strong acids. Water runoff from this disinfectant must be handled with extreme care, because it may have a severe effect on the pH of surface water and plant life. Sodium hydroxide and potassium hydroxide both have good microbicidal properties as well as effective grease and debris removing properties (Jeffery, 1995).

Sodium carbonate. Sodium carbonate is a powder that Geering et al. (2001) recommend for use in the presence of high concentrations of organic material. It is mildly caustic to eyes and skin and should not be used on aluminum.

Acids

The acid group is particularly useful in the inactivation of Category B viruses such as FMD, and can be used for personnel and clothing decontamination (ARMCANZ, 2000). A study performed by Sellers (1968) found that the most rapid inactivation of FMD virus occurred in the presence of acids and alkalis provided the pH was maintained as directed. Jeffery (1995) reports that inorganic acids have microbial properties due to their low pH levels. They are generally slow-acting efficient cleaners, but have strict limitations due to corrosiveness to skin and materials. Organic acids are used in disinfectant formulations to enhance virucidal and fungicidal properties. Their activity is increased in the presence of anionic detergents of the sulphonate or ether sulphate type.

All acids are slow-acting and have a low concentration exponent (Jeffery, 1995). Maris (1995) indicates that both acids and alkalis have their efficiency dependent on the concentration of hydrogen (H+) and hydroxyl (OH-) ions.

Hydrochloric acid. Hydrochloric acid is corrosive for many metals and concrete. It is considered toxic to eyes, skin, and respiratory passages. Hydrochloric acid should only be used when better disinfectants are not available (Geering et al., 2001).

Peracetic acid. Peracetic acid is a very strong oxidizing agent that is also fast-acting (Bruins and Dyer, 1995). This acid is effective against bacteria, viruses, molds, yeasts, and bacterial spores. Peracetic acid is used for the decontamination of serum and other fluids and is effective against a range of viruses (Evans et al., 1977). Peracetic acid can be considered as a viable disinfectant for anthrax-infected properties. The environmental impact of this compound is relatively small, but it is mildly corrosive and should always be handled with care (Bruins and Dyer, 1995).

Citric acid. Citric acid is safe for clothes and body decontamination, and especially useful against FMD (Geering et al., 2001). Citric Acid BP (2-Hydroxyl-1, 2, 3-Propanetricarbolic Acid Anhydrous) in a 5500:1 dilution was approved for use in England in 1999 and 2000 to effectively kill FMD (UK Environment Agency, 2002). Some concentrations of acids and alkalis apart from citric acid are corrosive and caustic, but adding a detergent or soap can reduce harshness and increase wettability and penetrating power (Sellers, 1968).

Aldehydes

The aldehyde group can work in most conditions, even those with heavy soiling (Jeffery, 1995), and can be effective in all virus categories. Aldehydes act slowly, oxidize slowly, and are relatively reactive with other chemicals. Aldehydes can be formulated in conjunction with QACs to obtain more rapid action and higher activity over a wider spectrum.

Gluteraldehyde. Gluteraldehyde is effective on all virus families in low concentrations, and is only mildly corrosive, but is very costly (ARMCANZ, 2000). Gluteraldehyde is normally used as a 2% solution to achieve a sporicidal effect, and is more active at alkaline than acidic pHs (McDonnell and Russell, 1999). It is commonly used in the chemical sterilization of sensitive equipment, and it is at least three times as active as formaldehyde (Jeffery, 1995). Users should avoid contact with eyes and skin.

Formalin. Formalin is an aldehyde that is effective against BSE and scrapie at 8 percent, but is dangerous and toxic (Geering et al, 2001). Formalin can be irritating to the mucous membranes.

Formaldehyde. The gas form of formaldehyde is very toxic, and is rarely used because it must only be applied in completely airtight situations (ARMCANZ, 2000). It must be neutralized before being released into the atmosphere. Maris (1995) states that its action is pH dependent, and it works better at an alkaline pH than one that is neutral or acidic. The aqueous form of formaldehyde is an effective bactericide, tuberculocide, fungicide, and sporicide (Bruins and Dyer, 1995). It is generally used in clinical settings as a disinfectant or sterilant in liquid or in combination with low-temperature steam, but works more slowly then gluteraldehyde (McDonnell and Russell, 1999). Formaldehyde is fairly inexpensive, is only minimally affected by environmental pH and organic matter, and has an unlimited shelf life. Its major drawback is that it is potentially carcinogenic, has a pungent odor, and must be handled with extreme care.

Insecticides

Insecticides can be used to combat insect or vector-borne diseases such as vesicular stomatitis. Major examples of commonly used insecticides include organophosphates, synthetic pyrethroids, aluminum phosphide (Phostoxin), and Ivermectin®. Remember to use these products safely to minimize risk to the environment.

Miscellaneous

Phenols. Phenol compounds are rarely used in present-day situations because of their toxicity. Phenols have an unpleasant odor, and may induce skin irritation and depigmentation (Bruins and Dyer, 1995). They act specifically on the cell membrane and inactivate the intracytoplasm enzymes by forming unstable complexes (Maris, 1995). Formulating with phenols requires great care. Jeffery (1995) defines three phenol categories: clear soluble, white fluid, and black fluid. Phenol effectiveness will be decreased if they are used with soaps containing tallow, tall oil, or oleic acid. Halogenated phenols are less soluble, less corrosive, and less toxic, but also less effective in the presence of soiling material. Chloroxylenol is the key halophenol used in antiseptic or disinfectant formulation (McDonnell and Russell, 1999).

Chlorines. Bruins and Dyer (1995) identify chlorination as the most important water-treatment process in preventing the spread of infectious disease. Disinfectants based in chlorine can be unstable because they are significantly affected by heat and light. These products are also very corrosive to metals, release a strong odor, and are easily neutralized by organic matter.

Disinfectant effectiveness

The major factors that affect the efficacy of disinfection are: choice of disinfectant, dilution rate, application rate, detergency, contact time, temperature, organic challenge, and water quality (Meroz and Samberg, 1995). Regardless of how "good" a disinfectant can be, dilution will dramatically reduce its effectiveness. Citric acid or sodium carbonate can be added to wash water to induce antiviral conditions by raising or lowering pH which helps inactivate disease agents (ARMCANZ, 2000). For safety purposes, acids and alkalis should always be added to water instead of vice versa. Disinfectant should flood the floor for at least ten minutes, and preliminary cleaning must be accomplished before chemical disinfectants are used. Time, dehydration, temperature, and sunlight should all be considered in planning (ARMCANZ, 2000). Most disinfectants have decreased effectiveness in the presence of fat, grease, and organic dirt.

Because surfaces on the property will differ, it is likely that more than one disinfectant will be needed to clean a property. The type of surface and the amount of ceiling and wall space to be covered will be the factors that determine how much disinfectant is needed. The most important factor to consider is the time of contact. Not all products are suitable for all applications. When deciding which formulation to use, determine if heavy soiling is present, and whether or not the product is compatible with the cleaning agent used (Jeffery, 1995). Something else to consider is microbial resistance to disinfectants, which can be a result of natural or acquired properties (McDonnell and Russell, 1999). Table 2 (Bruin and Dyer, 1995) identifies the use and toxicity guidelines for various types of disinfectants. Table 3 provides a summary of background information on these six major disinfectant groups.

TABLE 2. Use and toxicity of various types of disinfectants (Bruins & Dyer, 1995).

Disinfectant type	Bacteria	Mycobacteria	Viruses	Bacterial spores	Yeasts	Molds	Toxicity
Chlorine	++	++	++	+	++	++	medium
Formaldehyde	+	+	+	+	+	+	high
Phenolics	+	+	+/-	-	+	+	high
Peracetic acid	++	++	++	++	++	++	low
QACs	+/-	-	-	-	++	+	low
Hydrogen peroxide	++	+	+	+/-	+	+	low
Iodophors	++	++	++	+	+	+	medium
Sodium hydroxide	+	+	+	+	+	+	high

Legend: ++ kills rapidly, + kills most, +/- kills some, - negligible kill

TABLE 3. Background information on six major disinfectant groups (ARMCANZ, 2000; Geering et al., 2001).

Disinfectant Group	Form	Contact Time	Applications	Precautions
Soaps and detergents				
Quaternary Ammonium Compounds (QACs)	Solid or liquid	10 min.	Use for thorough cleaning before decontamination and for Cat. A viruses	N/A
Oxidizing Agents				
Sodium hypochlorite	Concentrated liquid	10-30 min.	Use for Cat. A, B, and C viruses except in the presence of organic material	N/A
Calcium hypochlorite	Solid	10-30 min.	Use for Cat. A, B, and C viruses except in the presence of organic material	N/A
Virkon S®	Powder	10 min.	Effective against all virus families	N/A
Alkalis				
Sodium hydroxide	Pellets	10 min.	Cat. A, B, and C if no aluminum	Caustic to eyes and skin
Sodium carbonate	Powder/crystals	10-30 min.	Use with high concentrations of organic material	Mildly caustic
Acids				
Hydrochloric acid	Concentrated liquid	10 min.	Corrosive, use only if nothing better is available	Toxic to eyes, skin, and respiratory passages
Citric acid	Powder	30 min.	Use for FMD on clothes and person	N/A
Aldehydes				
Gluteraldehyde	Concentrated liquid	10-30 min.	Cat. A, B, and C viruses	Avoid eye and skin contact
Formalin	40% formaldehyde	10-30 min.	Cat. A, B, and C viruses	Releases toxic gas
Formaldehyde gas	Gas	15-24 hours	Cat. A, B, and C viruses	Releases toxic gas

Section 3 – Disposal and Decontamination

3.1 – Methods of Disposal

The overall goal of carcass disposal is to control the spread of disease. The USDA Disposal Operational Guidelines draft manual (2002) states that carcasses should be disposed of within 12 hours in order to minimize the opportunity for pathogen dispersal. Animals should be humanely slaughtered by chemical, mechanical, or electrical means. Depopulation must not overrun disposal because of the increased risk to animal welfare, biosecurity, and pest infestation. These procedures must prevent the agent from spreading, so disposal must follow euthanasia as soon as possible. There are several options to consider when a disposal situation arises, and selection of the proper method will depend on individual circumstances. Common methods of disposal include burial, incineration, rendering, composting, and alkaline hydrolysis (USDA, 2002e).

The USDA identifies burial as the preferred method of disposal when practical, except in situations involving BSE. Carcasses infected with BSE should be disposed of using an alkaline hydrolysis tissue digester. Compared to other disposal methods, burial is simpler, more economical, faster, and less likely to cause adverse environmental effects (USDA, 2002e). Forty-two cubic feet are required to bury one bovine, five pigs, or five sheep.

The USDA states incineration should only be used when burial is infeasible because burning tends to be difficult and expensive in terms of labor and materials. Burning is also detrimental to the environment. Glanville and Trampel (1997) have identified composting as another alternative that strives to achieve biological degradation of organic residues under aerobic conditions. This provides an option for areas where mass burial is not feasible because of factors like shallow water tables and bedrock.

3.2 – Decontamination Procedures

Disease confirmation

Once again, the first step in this process is to determine the agent involved and how it is spread and transmitted. Viruses that can be spread to remote animals by personnel and equipment contamination will require the most involved plans. USDA APHIS has published an executive summary that details the national emergency response to a highly contagious animal disease (2001). In an emergency response to a highly contagious animal disease, a "confirmed positive" results when a specific agent is isolated and identified. After a presumptive or confirmed diagnosis is made, a state quarantine will be placed on the farm, and a zone of infection will be established. The zone of infection should extend at least 6 miles beyond the presumptive or confirmed infected property (USDA, 2001). This zone is determined by many factors including wind direction, livestock movement, and terrain conditions.

Within this infected zone, movement restrictions are established, and no animals or animal products will be allowed to leave. The USDA APHIS national emergency response to a highly contagious animal disease executive summary (2001) gives the right to state authorities to remove all susceptible animals from this zone. Outside of this infection zone there should exist a surveillance zone established to ensure containment of the outbreak. The zone is placed under surveillance, and all animal health professionals should heighten their awareness for biosecurity issues (USDA, 2001). Preventing and reducing the spread of animal disease depends heavily on the following: good biosecurity, decontamination, disinfection, and sanitation (Ford, 1995).

Personnel decontamination

People – with their clothes, shoes, tools, and machinery – constitute the most often implicated means of spreading disease from one herd or flock to another (Ford, 1995). Decontamination of personnel is essential for the prevention of cross-contamination, so people can leave an infected premise with minimized fear of transporting the disease agent (ARMCANZ, 2000). The goal of personnel decontamination is to safely remove any contamination of the body or clothing. Geering et al. (2001) warn that the heaviest personnel contamination will occur at the inspection of live and dead animals, the site of slaughter, and the disposal site.

There should be an area designated near an exit point of the property as the site for personnel decontamination. The owner or manager of the property should help identify the level of property contamination based on the amount of contact with animals and animal waste (Geering et al., 2001). The chosen site should be one that will allow an easy exit of the property without recontamination. It should first be decontaminated with the proper disinfectant and be equipped with a water and drainage supply. Site managers must ensure that runoff water from contaminated areas does not enter the clean area. A disinfectant should be available at this site for anyone entering or leaving the property. Warm, soapy water is recommended for washing the face, hair, and skin. Heavy plastic garbage bags can be used to dispose of contaminated items such as rubber gloves, and bags containing contaminated items should be sprayed on the outside to aid in disinfection (Geering et al., 2001). These bags can then be burned or buried on property, or can be carried off-site for further disinfection.

Personnel supplies

Personnel should be provided with overalls, footwear, head covering, gloves, and goggles. Clothing items should be decontaminated by disinfecting every time the person moves around the area. A changing area must be provided with a shower or washing facility. Fotheringham (1995a) recommends buckets of disinfectant be used for moving disinfected articles. If the suspected contaminated organism is exotic or has zoonotic potential, or if the disinfectant has toxic, irritant, or corrosive properties, then protective clothing, masks, and rubber footwear must be worn (Kahrs, 1995). Personnel will also need supplies for cleaning and disinfecting that include: plastic buckets, brushes, towels, plastic refuse bags, footbath pans, antiseptic soap, and disinfectant (Ford, 1995).

Foot baths

Braymen, Songer, and Sullivan (1974) report that floors have been identified as reservoirs of infection and are therefore important in disease spread. Footwear is mobile and may serve as a transfer vehicle for moving microorganisms from place to place. A logical place to install footbaths is at the doorways of animal quarters. Fotheringham (1995b) states they probably serve more as biosecurity reminders than as effective disease control mechanisms, but they can be effective if refilled every two to three days. Studies show that footwear accommodate the microflora already existing on the floor, therefore every effort should be made to minimize their cross-contaminating potential (Braymen et al., 1974).

Fotheringham (1995b) warns that in locations where footbaths may freeze, they should be heated, because adding antifreeze or salt could disturb the effectiveness of the disinfectant. These techniques can also be applied to wheel baths for trucks entering and leaving an infected premise.

Property preparation

Vehicles

All trucks, trailers, and other equipment used to transport contaminated animals, feed, bedding, or equipment can potentially spread disease. Carcasses should be soaked with the appropriate disinfectant before they are loaded for transportation. Vehicles must only enter infected facilities if absolutely necessary, and those that do must be thoroughly disinfected before leaving. The route taken by vehicles entering or leaving the contaminated premises should minimize the chance of its contamination by dust or manure (Ford, 1995). The materials required for cleaning and disinfecting vehicles include brushes, sponges, buckets, overalls, goggles, face masks, containers for mixing disinfectants, and high-pressure sprayers that can operate at a minimum of 200 p.s.i. (Poumian, 1995).

Begin with a preliminary rinse at 38-46°C (100.4-114.8°F) (Poumian, 1995). This should be followed by the addition of a cleaning agent and an increase in water temperature to 49-77°C (120.2-170.6°F). All organic material and rubbish from vehicles should be burned or buried. Spray the entire surface of the vehicle with an effective disinfectant, and carefully clean and disinfect the wheels, fender wells, and vehicle frame.

Disinfectant mats or wheel baths filled with disinfectant should be utilized at all vehicle entrances and exits. Every effort should be made to ensure that no vehicles leave an infected property without thorough decontamination. Any rubber floor mats on the driver's side should be removed and scrubbed with disinfectant, and the dashboard, steering wheel, gear stick, and driver's seat should all be wiped with the appropriate disinfectant (ARMCANZ, 2000). Spray aerosol pesticide in the vehicle to kill any insects which may have entered, and allow pesticide to work for a few minutes prior to entry (Ford, 1995). Remove all contaminated clothing and equipment, and thoroughly clean hands and face with antiseptic soap and water before entering a vehicle.

Cleaning/disinfecting supplies

This step in the process will require a generous supply of water. A list of typical required equipment includes brushes, scrapers, pumps, power washers, and knapsack sprayers (Fotheringham, 1995b). Sensitive equipment should be used inside plastic bags where possible, and wiped down with disinfectant after use.

Drainage

When considering the drainage or disinfectant runoff sites, consideration must be given to the proximity of waterways and wells and possible contact with humans, wildlife, livestock, or poultry (Kahrs, 1995). Disinfectants may cause water pollution and pose a risk to sewers. Do not pour unused disinfectant solutions on the ground, but dispose of them in approved containers (Ford, 1995). As noted by an FMD report issued by the UK Environment Agency (2001), some small sewage treatment plants in England were disrupted by disinfectant drainage during their massive FMD outbreak. Temporary lagoons were built to hold disinfectant wash water and slurry, and they were unfortunately constructed in locations where watercourses or groundwater could be affected by spills.

Wildlife/pest control

It is extremely important to control wildlife, pets, insects, and birds from coming into contact with diseased animal carcasses or contaminated runoff. All of these can serve as carriers to spread the disease agent out of the containment area rapidly. The first step to take to prevent this type of spread or cross-contamination is to quickly dispose of carcasses, or cover them until disposal can be performed. Rodent control should be performed immediately and all feed should be removed so as not to attract rodents (Meroz and Samberg, 1995).

Property cleanup

This is the point in the process to remove all animals, utensils, and equipment. Any animal feed material should be removed and disposed of properly. Fotheringham (1995a) reports the necessity to switch off electricity and extractor fans to stop airborne spread of pathogens. Drains and runoffs should be blocked to allow for later disinfection, and gullies and channels emptied and their contents buried.

The aim of the cleanup process is to remove all manure, dirt, debris, and contaminated articles that cannot be disinfected. This will allow all surfaces to be exposed to detergents and disinfectants. This is the most crucial phase of the cleanup process because the presence of organic material reduces the effectiveness of disinfectants (ARMCANZ, 2000). Burn or bury all debris, and break up soil floors to expose them to disinfectants.

Manure

Manure, soiled bedding, and unused feed should be removed using a manual or mechanical scrapper. Water use should be avoided at this point to minimize the volume and weight of runoff to handle (ARMCANZ, 2000). The easiest way to dispose of feces is burial. Bedding and litter that has come into contact with infected stock should be sprayed with a strong disinfectant and burned or buried (Meroz and Samberg, 1995).

Manure and slurry pits may need to be decontaminated by raising or lowering the pH and leaving undisturbed for at least seven days (Fotheringham, 1995a). It is also recommended that semi-solid slurry be treated with caustic soda and allowed to stand. Procedures should be established to control insect and vermin around manure to minimize disease spread. If manure is allowed to remain uncovered too long, feed, insect larvae, and worms in the manure will attract birds and scavengers which may become contaminated and spread pathogens to nearby farms (McDaniel, 1991).

First cleaning

After all manure, debris, and equipment have been removed, gross organic material should be flushed away using a cleaner/sanitizer or detergent compound. Blood, urine, feces, food debris, fats, and dust are the most likely organic soils to be encountered in or on animal housing (Fotheringham, 1995b). Water is the preferred solvent and cleaning medium, and its efficacy can be increased by adding energy, temperature, and cleaning agents (Poumian, 1995). Detergent and hot water should be applied starting at the top of a building and working down. The entire building should be treated with a detergent solution and left for at least 24 hours if possible. Fotheringham (1995b) reports that detergents break down organic soiling and reduce the amount of time required for subsequent cleaning. The detergent should be applied through a power washer, and washing solution should be used at a dosage of 2-10 l/m^ 2. Pressures should remain below 90 bar (1 bar = 10^ 5 Pa), and the appropriate angle for nozzles used in cleaning is 25-45°.

Rinsing

The detergent or sanitizer must be completely rinsed or flushed away upon completion of cleaning. Kahrs (1995) indicates that residual detergent can reduce the effectiveness of the chosen disinfectant by diluting, neutralizing, or inactivating it. After rinsing, the building should be visibly inspected, and allowed to fully dry. Drying can kill sensitive microorganisms, and drying removes the possibility of further diluting the disinfectant (Fotheringham, 1995b). The thoroughness of pre-disinfection cleaning is the most important determinant of the efficacy of the disinfection process (Kahrs, 1995).

First disinfection

The aim of the first disinfection is to inactivate the disease agent using physical and chemical methods (ARMCANZ, 2000). Disinfection will lower the microbial load on surfaces to a level that causes neither the spread of pathogens, nor the reduction of animal productivity. Raising the temperature at which a disinfectant is used will increase its disinfection action. All disinfectants work best at temperatures above 68°F (20°C) (Meroz and Samberg, 1995). Hot disinfectant solutions are more effective than cold to penetrate and disinfect, which is especially important in surfaces with cracks and crevices. An increased contact time will result in an increase in efficacy for the disinfectant. As a result, disinfectants should be left in contact with housing and equipment for as long as possible (Fotheringham, 1995b). Contact time can be greatly increased with the use of foam. Foam takes a lot longer to dry, resulting in increased disinfectant activity (Meroz and Samberg, 1995).

Disinfectants should not be mixed with other chemicals or placed in containers used for other chemicals. The appropriate quantity of disinfectant will vary greatly depending on the circumstances involved. For a polished, nonporous floor, 100 ml/m3 can be sufficient, but this amount may need to be doubled or tripled for porous surfaces such as concrete or wood (Geering et al., 2001). Fotheringham (1995b) recommends disinfectant solution should be used at a dosage of 0.3-1l/m^ 2. Hard water generally reduces the effectiveness of the diluted disinfectant and may cause the precipitation of acids and alkalis, thus reducing disinfectant activity.

Disinfectant should be applied using a low-pressure sprayer such as a knapsack sprayer or a pump with spray attachment, and all areas should be covered to damp down dust, which could spread airborne microorganisms (Fotheringham, 1995b). Application should begin at the apex of the building and move downward. All surfaces should be covered while the creation of pools of liquid should be avoided. Flame guns may be used in some spaces to aid drying of decontaminated surfaces or to reaching difficult areas such as pipes. Flame guns should not be relied upon to decontaminate alone, and they add risks of fire and injury (ARMCANZ, 2000).

Water systems

If possible, water pipes should be dismantled, cleaned, and left to soak in disinfectant for 24 hours (Meroz and Samberg, 1995). The water system should be drained, tanks cleaned, and disinfectant added for a minimum of 10 minutes. They should then be flushed and left to dry (Fotheringham, 1995a).

Disinfection completion

Following decontamination, all equipment and supplies should be thoroughly cleaned and disinfected. Disinfectant must be left on surfaces for as long as possible, then thoroughly rinsed and the property left vacant for as long as possible before post-disinfection samples are collected (Kahrs, 1995). Upon completion, the premises should be left empty for some period of time and sentinel (susceptible) animals introduced to detect any remaining contamination (Fotheringham, 1995a).

Restocking with healthy animals should only be undertaken when post-disinfection tests and/or sentinel evaluation reveal that the premise has a low probability of harboring residual pathogens (Kahrs, 1995).

Disposal areas

Slaughter sites should be disinfected several times a day and disposal sites thoroughly once disposal is completed (ARMCANZ, 2000). Special attention should be given to feed and water troughs, as well as roads, pathways, fences, and gates.

Burial pits will emit large quantities of noxious gas and fluid. Once this emission has stopped, the ground around the site should be broken up and liberally soaked with the appropriate disinfectant (ARMCANZ, 2000). Extreme care should be taken to disinfect personnel, machinery, and vehicles close to the site and not allow recontamination of previously disinfected areas near buildings.

Disinfection failure

Cleaning and disinfection involve the physical and chemical removal of contaminating debris, and the reduction or elimination of pathogenic organisms in or on materials, so that these no longer present a health hazard (Meroz and Samberg, 1995). Causes of disinfection failure include over-dilution of disinfectant during pre-mixing or application, incomplete or inadequate cleaning, poor disinfectant penetration or coverage, insufficient contact time on surfaces, inadequate temperature and humidity while the material is being applied, and/or inactivation or neutralization of the disinfectant due to the presence of residual cleaning liquids which were not adequately flushed away (Kahrs, 1995). McDaniel (1991) identifies the widespread misconception that solutions that are more concentrated than directions indicate will be more effective. In fact, stronger solutions may not be better disinfectants and they are usually more dangerous for personnel, more corrosive, and increase the risk for pollution (McDaniel, 1991).

Section 4 – Critical Research Needs

- Evaluate the use of technologies like VerifEYE available from eMerge Interactive to detect microscopic levels of organic contamination present on presumed-to-be-clean surfaces. This patented technology utilizes a fluorescent signature to detect levels of organic contamination not observable to the naked eye. VerifEYE uses wavelength-specific spectroscopy and image processing to provide instant verification of the presence or absence of organic material on a surface. Because insufficient cleaning and organic surface contamination play such a big role in the effectiveness of a disinfectant, verifying that no organic matter has been left behind after cleaning and before disinfection could provide insurance that the decontamination procedure is successful. http:://www.verifeye.net/tech/.

- Conduct mock training demonstrations that test outlined decontamination procedures, and identify gaps within those procedures.
- Conduct further research on the viability of certain disinfectants on highly contagious animal diseases and the disinfectants' suitability for use in the field.
- Identify levels of resistance developed by various agents of highly contagious animal diseases, along with possible alternatives to combat this resistance with other disinfectants.
- Examine innovative methods of pathogen containment suitable for large-scale application (e.g., at confined animal feeding operations).

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