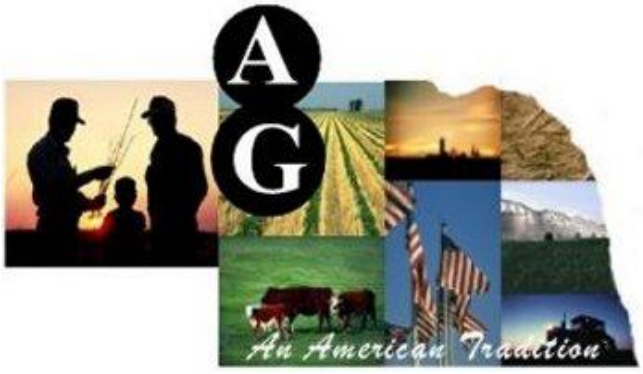
CLEANING AND DISINFECTION

MONOGRAPH No. 004

NEBRASKA DEPARTMENT OF AGRICULTURE
AGRICULTURAL EMERGENCY RESPONSE ACTIONS
LIVESTOCK DISEASE EMERGENCY



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1. SCOPE AND APPLICATION

The purpose of this monograph is to provide functional guidance about the establishment, operation, and maintenance of cleaning and disinfection (C&D) areas during a foreign animal disease (FAD) outbreak. This monograph also covers biosecurity procedures needed for responders to prevent the additional spread of a FAD. This guidance is compatible with Nebraska's State Emergency Operations Plan (SEOP). Local emergency management should use this monograph as a template. It should be modified as appropriate, and it should be made consistent with the Local Emergency Operations Plan (LEOP). Several sections of this monograph contain general descriptions of the scope of operations necessary to implement a particular component of cleaning and disinfection. In most cases, these sections were made general so that local emergency planners could insert or reference more detailed, county-specific operational details. Examples of these sections include Health and Safety and Communication.

This monograph does not address the C&D of premises. The United States Department of Agriculture's Animal and Plant Health Inspection Service provides guidance about premises cleaning and disinfection in its document, "Cleaning and Disinfection," part of the National Animal Health Emergency Management System (NAHEMS) Guidelines (NAHEMS, 2011). This monograph contains information from and is consistent with current NAHEMS guidelines, as of July 2012.

2. SUMMARY OF PROCEDURES

One of the primary means of spread of FADs is through movement of infected animals, animal products, or fomites (e.g., feces, bedding, vehicles, and harness) conveying disease-producing agents to locations where they come into contact with susceptible animals. When responding to a FAD, local responders play an important role in preventing the additional spread of the disease. The actions taken to disinfect equipment, vehicles and personnel involved in the response will directly impact the ability to quickly contain the disease. Correctly applied, C&D will prevent the movement of microorganisms on fomites and prevent the contamination of fomites or

infection of susceptible animals that come in contact with areas where infected animals were housed.

FAD transmission to susceptible species (including humans in the case of zoonotic diseases) may occur in the following three pathways (NAHEMS, 2011):

- Directly, via animal contact with an infected animal or infected animal products, including blood, secretions (e.g., milk and saliva), excretions (e.g., manure and urine), epidermal outgrowths (feathers, hair, wool, horns and hooves), and exhaled moisture.
- Indirectly, via animal contact with contaminated feed and water, fomites (e.g., clothing, tools, equipment, vehicles, bedding, supplies and other inanimate objects), and people or animals (e.g., roaming and scavenging wildlife – including vermin and dogs – on the premises and surrounding areas) who are contaminated with a pathogen, but not infected or susceptible to it.
- Through arthropod vectors (e.g., insects and ticks) that may serve either as mechanical carriers of a disease agent or as an important part of the life cycle of the agent (e.g., mosquitoes that carry the Rift Valley fever agent).

This monograph is designed to outline general cleaning and biosecurity procedures. Most of the information covered pertains to any disinfection and cleaning needed; however, this monograph specifically covers special concerns associated with access corridors, mortality disposal, temporarily housing animals, and continuity of service. Please refer to Nebraska Department of Agriculture (NDA) Monographs 001, 002, 003 and 005, respectively, for additional information about these four topics.

Local emergency managers are encouraged to work with local veterinarians when developing county operation plans associated with biosecurity requirements. In addition, the county also can encourage local producers to implement these procedures at their operations.

2.1. Cleaning and Disinfection

Microorganisms, viruses and spores associated with the spread of a FAD can spread to non-infected animals in many ways. Many mechanisms for disease spread cannot be controlled by responders; for example, disease spread through the atmosphere via wind. Responders can

directly control some mechanisms for spread. These mechanisms involve the spread of a disease through human and animal movement, the reuse of contaminated equipment, and vehicle movement. FAD agents can be found in the soil, fodder, manure, feed and bedding; on building surfaces, equipment and animals; and in the atmosphere at an infected location. Responders can be exposed to, and become carriers of, the FAD agent by simply being in the atmosphere of an infected location or stepping in, handling, or otherwise contacting materials or objects that are contaminated. Besides being found in visible contamination, such as dirty boots or coveralls, the FAD agents can adhere to clothing, respiratory tract, hair and skin. Cleaning and disinfection are the tools that responders have to limit the potential for FAD spread outside of a quarantine zone.

All vehicles, equipment and personnel that exit a quarantine area, infected premises or temporary animal housing facility must be decontaminated and disinfected or their disposable coverings removed and then disposed of. This will be achieved through the physical removal of potentially contaminated materials and through the application of appropriate disinfectant(s). A common problem for all contact disinfectants is maintaining the agent's liquid state on the applied surface. These solutions are generally composed of water, which tends to evaporate prior to the completion of the required contact time. Monitoring of the applied disinfectant and repeated application as it dries can solve this challenge. A general description of common FADs and possible disinfectants is presented in Table 1.

The appropriate place to operate and maintain a disinfection station is at an access corridor and at the entrance/exit of disposal areas, infected premises and temporary animal housing locations. The equipment, design and method for implementing personnel, equipment and vehicle cleaning and disinfection stations are described below.

Table 1

Common Contagious Animal Diseases

Disease	Species Affected	Transmission	Best Disinfectant
African Swine Fever	Swine	Ingestion, contact, ticks	A
Influenza (avian, equine, swine)	Birds, horses, swine	Aerosols, ingestion	A
Newcastle Disease	Birds	Aerosols, ingestion	A
Rinderpest	Ruminants, cattle	Aerosols, ingestion	A
Peste des Petis	Small ruminants	Aerosols, ingestion	A
Foot and Mouth Disease	Cloven hoofed animals	Aerosols, ingestion	B[1]
Swine Vesicular Disease	Swine	Aerosols, ingestion	A
Classical Swine Fever	Swine	Contact, ingestion	A
Porcine Respiratory and Reproductive Syndrome (PRRS)	Swine	Contact, aerosols	A

Notes: Modified from Agriculture and Resource Management Council of Australia and New Zealand, 2008
A = Best disinfectants are detergents, hypochlorites, alkalis, Virkon®, and gluteraldehyde.
B = Best disinfectants are hyporchlorites, alkalis, Virkon®, and gluteraldehyde. Bactericides, like quarternary ammonia compounds and phenolics, are not effective against these viruses.
[1]Acids are effective for Foot and Mouth virus.

2.2. Equipment

The equipment needed to supply a disinfection station is presented below. Three distinct classes of cleaning and disinfection equipment are discussed: personal protective equipment (PPE), equipment for cleaning and disinfection, and disinfectants.

- PPE: water, hard hat, safety glasses or face shield, rubber boots, rain suit (jacket and coveralls), cotton overalls or disposable coveralls, disposable synthetic impermeable under gloves (nitrile, latex, etc.), disposable synthetic impermeable over gloves (nitrile, rubber, etc.), heavy-duty over gloves (cotton or leather), boot tray or bucket, 1- to 2-gallon hand-operated pressure sprayer, short-handled scrubbing brushes, and heavy-duty plastic garbage bags.
- Cleaning equipment: vacuum cleaner, water, high- and low-pressure sprayer, power or fuel for sprayer, plastic sheeting (> 2 mil. thick), long-handled scrubbing brushes, sponges, buckets (pet wash), towels (disposable or cotton), heavy duty plastic garbage bags, berming material (e.g., 4x4s, sand, sand tubes, sand bags, etc.), framing materials to build containment structures, sump pump and power supply, and drums or plastic totes to contain spent cleaning and disinfection fluids.

- Disinfectants: The choice of disinfectants will depend on the particular disease being addressed. State or federal veterinarians could be consulted during the local response planning process to identify specific disinfectants that could be used. Disinfectants can range from dilute solutions of common household products, such as bleach or vinegar, to commercially available disinfectants. Broad-spectrum disinfectants such as Virkon® may be an alternative to identifying and stockpiling multiple types of disease-specific disinfectants. In the Australian Veterinary Emergency Plan (Agriculture and Resource Management Council of Australia and New Zealand 2008), many FADs are reviewed and disease-specific disinfectants are presented. Appendix A briefly describes the disinfectants referenced in Table 1.

Many disinfectants are corrosive to rubber gaskets and metallic parts in pumps and pressure washers. When finished using this type of equipment, all disinfectants should be removed from the equipment as soon as possible. Most disinfectants will include directions for equipment cleaning as part of the label instructions. If this information is not present, the equipment should be flushed with several gallons of fresh water followed by approximately one gallon of warm water containing one or two ounces of light mineral oil or liquid detergent (NAHEMS 2011).

2.2.1. Location Criteria

The selection of an appropriate area to establish a disinfection station is critical to a successful operation. The operation of the disinfection station should not negatively impact the environment, and its location should provide easy access for residents and responders.

The following is a checklist of considerations for selecting an appropriate location for a cleaning and disinfection station:

- Adjacent to or part of an existing traffic control point.
- Generally, flat terrain that is large enough on either side to house the following: disinfection station, water supply, waste water containment, sanitary facilities, and parking for vehicles waiting for disinfection and those that will not be disinfected. To increase efficiency, responders may not leave the quarantine zone in the same vehicle that transported them through the zone; rather, they will undergo personal disinfection and exit onto the non-quarantine side of the station to acquire transportation away from the response.
- The site should not be located in a sensitive environment (e.g., wetlands, well head protection area, etc.).

- The site should not naturally drain into a sensitive environment.
- The site should have good ground cover to increase infiltration during precipitation and to minimize the potential for creating muddy areas.
- It would be beneficial if the site had access to potable water and a sanitary sewer.
- It would be beneficial if the site were adjacent to an electric power source. The use of a drop service will require coordination with the local power company.
- The site should be on a maintained road, preferably with a concrete or asphalt surface.
- The site should be close to burial trenches, areas where the surface soil is considered grossly contaminated, septic tanks or manure storages so that treated disinfection fluid can be disposed of properly.

The location of a C&D station associated with access control points, temporary animal housing and care, and mortality disposal should be at the entrance to the area. This location should be considered a transition zone from "potentially contaminated" (hot zone) on the animal or farm side to "clean" (clean zone) on the opposite side, probably the side where non-contaminated vehicles are parked.

2.2.2. Design

A disinfection station must be designed to provide disinfection at two scales: large scale for vehicles and construction equipment (heavy machinery or construction equipment), and small scale for portable equipment (i.e., cameras, clothing, boots, radios, etc.) and personnel. Once a location has been selected, basic decontamination staging protocols should dictate movement through the station. To prevent the spread of disease by responders, three work zones and a corridor are typically set up. The three work zones and corridor outlined by NAHEMS (2011) are as follows:

- Hot Zone – Exclusion Zone: This zone is a high-risk zone that is potentially contaminated and considered unsafe, and is where infected animals are/were housed. PPE must be worn while in this zone. Activities in this area include appraisal, depopulation, disposal, and decontamination of the facility, site, and equipment. Personnel and equipment entering and exiting the Hot Zone must use designated access points in the Warm Zone – Contamination Reduction Zone.
- Warm Zone – Contamination Reduction Zone: Due to the potential exposure to chemical disinfectants and pathogens, this is a high risk area. PPE is required by all personnel in this zone. Entry into or exit out of the Warm Zone – Contamination Reduction Zone into

the Hot Zone – Exclusion Zone or Cold Zone – Support Zone will occur through designated access points. Final decontamination and doffing of PPE will occur in the Warm Zone – Contamination Reduction Zone.

- Cold Zone – Support Zone: With the lowest risk of exposure to pathogens and chemical decontaminants, this is the "cleanest" work zone. Personnel are not required to wear PPE in this zone, but facilities for donning PPE, for responders going into other zones, will be provided. Support functions such as administrative and clerical are based here. Medical Support is provided in this zone. Eating, drinking and bathroom facilities are provided for personnel in this zone. To ensure the area is free from contamination, air and surface monitoring is conducted. Contaminated equipment, personnel, and any other articles are prohibited in this area. Decontamination activities are also prohibited.
- Decontamination Corridor: The decontamination corridor is the area between the Hot Zone – Exclusion Zone Control Line and the Warm Zone – Contamination Reduction Zone Control Line. Stations for depositing tools, equipment, protective clothing and other items are located in this corridor, as well as the decontamination of personnel and equipment. Levels of contamination from the Hot Zone – Exclusion Zone to the Cold Zone – Support Zone should decrease. Teams entering and exiting the Hot Zone – Exclusion Zone should utilize the access control points at each end of the corridor.

Small-scale cleaning and disinfection stations should be set up on an impermeable surface, such as plastic sheeting. This will help prevent spent fluids from infiltrating into the soil, help contain the spent fluids, and allow for easier clean up of the cleaning and disinfection area. The staging of wash/disinfection stations within this area should provide for gross cleaning and disinfection closest to the quarantine side of the area, leading up to a final rinse at the opposite side of the cleaning and disinfection area – the "clean zone."

A small-scale cleaning and disinfection station should provide mechanisms for removing gross contamination and applying disinfectant to equipment or clothing. This type of disinfection area should have three stations. The first station presents the initial cleaning and disinfection. The second station presents a second disinfection. The third station provides a final rinse.

Tubs are appropriate for equipment that can be submerged, or scrubbed with a disinfectant, such as boots or rain suits. Once the equipment has been thoroughly wetted with the cleaning and disinfection solution, it can be scrubbed with a brush to break up any foreign materials that are adhering to the surface. More delicate equipment that cannot be submerged or is otherwise

sensitive to moisture can be sprayed with disinfectant and wiped down with disposable towels. Spraying can be accomplished by putting the cleaning and disinfection solution in a hand-operated sprayer (garden-type sprayer) or through the use of commercial disinfectants in pressurized spray cans. If commercial sprays are used, caution should be taken to select commercial sprays that will not melt plastic or otherwise damage equipment. After a disinfectant is applied, the clothing or equipment should be set aside for a prescribed period of time to allow the disinfectant sufficient contact time to kill the target bacteria or virus. In some cases, it may be necessary to periodically rewet the materials with disinfectant to keep them from drying out.

Once the contact time has been reached for the equipment or clothing decontaminated and disinfected at the first station, it should be moved to the second disinfection station. The same procedures applied at the first station are repeated at the second. After the equipment or clothing, disinfected at the second station, has reached the required contact time, it can be moved to station three where it should be rinsed with clean water. While this rinse water should not contain any live organisms, viruses or spores, it should be treated in the same manner as the other spent cleaning and disinfection fluids. Decisions regarding the need to containerize spent fluids from the small-scale cleaning and disinfection stations should follow the same rationale as described below for the large-scale cleaning and disinfection stations.

Trash receptacles should be placed alongside the first two stations to allow disposable items to be discarded and contained.

The design of a vehicle and heavy machinery cleaning and disinfection station will be dependent on whether spent cleaning and disinfection fluid must be contained pending analysis or some other criteria. The chemical make-up of the decontaminant and disinfectant, its biodegradability, the disease(s) being addressed, the amount of organic matter potentially suspended in the spent fluid, and the influence of public perception issues will all be considered when determining the need to contain the spent fluids. This determination should be made through consultation between local Emergency Operations Center (EOC) personnel, the NDA, and the Nebraska

Department of Environmental Quality (NDEQ). Both NDA and NDEQ will be part of the Incident Command (IC). To facilitate response planning, EOC personnel should work with local veterinarians and state personnel to select appropriate general purpose disinfectants and determine how the spent fluids will be handled.

The vehicle and heavy machinery cleaning and disinfection station should be designed to efficiently deliver and direct a cleaning and disinfection solution to all areas of equipment or vehicles that have been exposed to a contaminated environment. In addition, it will be necessary for the cleaning and disinfection equipment to be able to dislodge soil, bedding, manure or other potentially contaminated matter from the exterior of vehicles or equipment. Generally, this will be accomplished through the use of low-pressure sprayers and scrubbing brushes. If a target disease can spread in an aerosol form, the use of high-pressure sprayers, with water alone, is not recommended. High-pressure water spray into grossly contaminated foreign matter (e.g., soil, manure, bedding, etc.) can move the disease agent into an aerosol form, increasing the potential for spreading the disease. A mix of water and disinfectant should always be used with high-pressure sprayers.

Gross contamination should be removed at the farm or location where the vehicle or heavy equipment was grossly contaminated. The responding lead veterinarian should be consulted prior to establishing the vehicle and heavy equipment cleaning and disinfection station at access corridors. They can assist with determining the risk associated with the use of high-pressure sprayers.

Similar to the smaller scale cleaning and disinfection station, it will be necessary to keep the disinfected areas wet until the appropriate contact time for the disinfectant has been reached. To increase throughput for this stage of cleaning and disinfection, it may help to provide a holding area where disinfected vehicles or equipment can wait until contact times have been reached. This will allow the physical cleaning and initial disinfection to continue at a faster pace. Generally, it is preferable to set up a large-scale cleaning and disinfection site with the intent to containerize the spent fluids and other matter removed from the vehicles and equipment. This

will prevent the work area from becoming a quagmire, and it will help reduce impact on the environment. To do this, it will be necessary to build a bermed area that drains into a corner containing a sump from which the spent fluids and material can be pumped into a holding tank. Berming can be constructed from sandbags, posts, straw bales or other available material. The berming on the entrance and exit side should be constructed to withstand vehicle or equipment weight or ramps should be constructed to protect the berms at the entrance and exit. This area must be covered with an impermeable material to prevent the fluids from infiltrating into the soil. The dimensions of this containment should be made at least twice as big as the largest vehicle or equipment expected to be disinfected. The additional size will allow adequate working room for cleaning and disinfection personnel.

When dealing with heavy vehicles and equipment, making the area impermeable can be challenging. Initially, the area must be cleared of all loose debris or objects that could puncture any liner material used. In one corner of the area, a sump pit should be excavated. This pit should be large enough to hold a sump pump and 10 to 20 gallons of liquid. The pit should be located along an edge of the area. Building this area on one travel lane of an engineered road will produce a natural drainage toward the edge of the area, assuming the road has the typical crowning at the center. If the area does not naturally drain to this point, a layer of sand should be put down, with a slope or drainage toward the sump. On top of the soil or sand, one or more layers of plastic sheeting or liner material should be put down to make the area impermeable. Thinner sheeting or liner material will require multiple layers to ensure continued impermeability. To further protect the impermeable layer, plywood sheeting should be placed on top of the material to minimize the impact of vehicles and equipment, and disinfection personnel walking on the material. The heavier the vehicles or equipment, the thicker the plywood needed. Generally, a single layer of 0.5-inch plywood will be appropriate for passenger vehicles. As the size and weight of the vehicles being decontaminated and disinfected increase, thicker plywood or multiple layers of thinner plywood will be required to protect the plastic liner.

Along with this containment base, the large-scale disinfection area will need some form of structure to contain spray drift and splash. This can be assembled by framing a wall around the

containment base. The framing should be covered with plastic sheeting to contain the spray drift and splash. This wall should be at least as high as the tallest vehicles being disinfected. The walls on the two ends will need to be moveable to allow vehicles to enter and exit. If high-pressure sprayers are used, these walls may need to be taller to contain the spray drift.

2.2.3. Methodology

In its most simple form C&D can be broken down into these five steps: (1) dry clean (removes gross contamination – solids), (2) wet wash, (3) rinse, (4) drying, and (5) disinfection. The first three steps are critical to remove any organic matter and expose surfaces for disinfection. The fourth step reduces the potential for dilution of disinfectants; however, allowing a vehicle or piece of equipment to drip dry will not leave sufficient water to cause significant dilution of disinfectants (NAHEMS, 2011). A critical aspect of Step 5 involves the application and maintenance of the disinfectant. The application of the disinfectant should be done according to label directions. Disinfectant contact time should be observed carefully and addresses the time a surface remains wet with the disinfectant. A surface to be disinfected should remain "shiny" wet for at least 10 minutes; merely damp is not adequate. Some disinfectants require longer contact times (see Appendix A). The contact time for foaming disinfectants is sometimes easier to monitor as is its coverage on the potentially contaminated surface. Porous and rough surfaces will require more disinfectant than smooth surfaces. A heavy application of disinfectant that runs off and puddles on the floor is not effective or efficient; multiple light applications of disinfectant is one way of keeping the surface wet for the required time.

Cleaning should start at the top of an object and move downward. Detergents should be allowed at least 10 minutes to penetrate organic matter and soil. This penetration will assist the detergent in loosening the material. Once the material is loosened, the object should be rinsed with the high pressure washer. After rinsing off all the organic matter, soil, and detergent, the object should be allowed to drip dry for at least five minutes before being disinfected.

At the conclusion of each step, C&D personnel must inspect the object being cleaned and disinfected to determine if the actions conducted during the step were effective. If they were not, the step should be repeated.

When a vehicle or heavy equipment approaches the access corridor from inside the quarantine zone, it will be inspected for external sources of contamination (e.g., manure, mud, soil, bedding, etc.). If the vehicle is grossly contaminated, it may be turned away and the occupants will be directed to return to the place where it became contaminated for cleaning to remove the gross contamination.

If the cleaning and disinfection personnel deem that the vehicle is free enough of contamination to enter the cleaning and disinfection area, it will be driven into the area. At this time, the occupants will be asked to move to an adjacent staging area while the vehicle is decontaminated and disinfected. After the exterior of the vehicle or heavy equipment has been decontaminated and disinfected, its interior will be inspected for contamination. If necessary, the interior will be decontaminated and disinfected as practical. The interior of the vehicle, carpeting, floor mats and pedals should be washed with a detergent cleanser, wiped clean and then wiped with a cloth soaked in disinfectant (NAHEMS 2011). Any other surfaces inside the vehicle that have visible organic matter or soil contamination should be cleaned and disinfected in the same manner. If the interior or exterior cannot be decontaminated or disinfected to the level required, the vehicle will not be allowed to pass through the access corridor. After the interior and exterior have been decontaminated and disinfected, the vehicle will be moved to a holding area to allow sufficient contact time for the disinfectant to be effective. During this time, the vehicle will be monitored to make sure it does not dry off. If areas are drying, they will be sprayed with disinfectant using hand-held sprayers.

While the vehicle is being decontaminated and disinfected, the occupants will be inspected. The responding lead veterinarian will have developed an exit cleaning and disinfection procedure for residents leaving infected premises, and for any possessions or tools they plan to bring out of the quarantine zone. The occupants will be questioned about their implementation of the lead

veterinarian's plan. Boot washes will be available, if supplemental disinfection is required. If the occupants have not implemented the lead veterinarian's plan, they will not be allowed to pass through the access corridor until they have followed the exit plan developed by the lead veterinarian. A typical plan might include the procedures described below for personal disinfection, particularly if there has been contact with livestock or contaminated areas.

Residents from infected premises or a contact premises and responders who become grossly contaminated will need to wash and disinfect themselves and their clothing before they leave the infected premises. Showering and changing into clean clothing may be acceptable for residents not associated with an infected premises or contact premises, but inside a control area. Use of the following substances as personal disinfectants can be recommended where no other approved disinfectant is available:

- Domestic washing soda (1 part soda to 10 parts hot water).
- Soap (or household detergent) and hot (≥140°F) water for scrubbing.
- Household concentrated chlorine bleach (1 part in 3 parts water to give 2 to 3% available chlorine). **This must not be used on hands, face or skin**.

2.2.3.1. Personal Cleaning and Disinfection

The following procedures can be used for response personnel and residents on infected premises and contact premises before leaving a control area. Residents from non-contact premises, especially those with no susceptible animals, may be allowed to exit the area if they shower and wear clean clothing. The exact procedures for these individuals will be determined based on the disease, climate and the local demographics.

For personnel and residents who are from infected premises or contact premises, and any others who are believed to be potentially contaminated with the FAD agent, on arrival at the disinfection station, a disinfectant solution, safe for skin contact, should be ready in buckets and sprayers. Since there are no antiviral disinfectants that are both effective against all virus families and approved for use on human skin, warm soapy water is recommended for washing face, hair, skin, etc. To increase the virucidal effect of this type of solution, the pH can be raised

by adding sodium carbonate or lowered by adding acetic acid. The direction of the pH shift will be determined by the virus in question. If other skin decontaminants are used, responders must be sure they are effective virucides for the target virus. Heavy-duty plastic garbage bags should be used for disposable items or for items to be removed from the site for further disinfection and cleaning.

Reusable clothing, such as rain suits, can be decontaminated and disinfected at this station by using a combination of a sponge, scrubbing brush and low-pressure sprayer. These items in combination with the appropriate disinfectant should be used to wash the clothing thoroughly, removing gross contamination. This cleaning must target the entire garment, including areas under the collar, zippers and fastenings, and the insides of pockets. In most cases, jackets, pants and boots will have the disinfectant applied through immersion in a disinfectant solution. A sprayer would be appropriate if an initial cleaning and disinfection was needed prior to doffing the protective clothing. In this case, the clothing would be grossly contaminated with organic matter. If underclothing has been contaminated, especially above boot level, it must be removed and placed in a plastic bag, the skin washed, and a clean pair of overalls used for leaving the site.

Reusable clothing, such as coveralls, can simply be removed, soaked in disinfectant, squeezed out, and placed in a plastic bag for C&D. Underclothes and rubber boots should be similarly treated. Plastic bags containing used clothing should be sealed, wiped down with a disinfectant, and placed at the outer limit of the area for collection by courier for laundering. It is best if reusable clothing is disinfected and laundered at the access corridor.

Disposable clothing (i.e., Tyvek® coveralls and gloves) and equipment should be removed and directly placed in plastic bags for disposal.

Once contaminated outer clothing has been removed, personnel should then shower with an appropriate disinfectant, exiting the shower into a “clean” area where clean clothing and footwear is available. After putting on the clean clothing, the personnel can leave the area.

NAHEMS (2005) recommends that even after complete personal disinfection, persons who leave infected premises must not come into contact with any susceptible animals for at least five days.

2.2.3.2. Cleaning and Disinfection in Emergency Medical Situations

If a person in the infected zone, from infected or contact premises, is injured or becomes seriously ill, every effort must be made to aid and obtain medical care for the person as quickly as possible. The very nature of a FAD response means that there is a risk of transporting the infection with the injured person. If it is necessary to initiate an emergency transport of personnel out of the infected zone, for example, the level of initial C&D of a person injured will vary with the seriousness of the injuries. Human life is a priority and every measure must be taken to minimize discomfort or pain. If C&D procedures for the personnel and vehicle must be abbreviated due to the extent of an injury or medical condition, the risk of spreading a disease could be great. In this case, the IC must be notified. The IC will then notify the appropriate hospital authorities of the risk and of the appropriate personal disinfection for the patient and vehicle, which should be carried out as soon as circumstances permit.

To minimize the potential to spread a FAD during an emergency transport situation, the following steps should be taken as soon as arrangements for an ambulance or other vehicle have been made (NAHEMS, 2011):

- The Incident Commander should be notified of the incident.
- An individual experienced in biosecurity and cleaning and disinfection procedures should be sent – along with cleaning and disinfection supplies – to meet the emergency vehicle at the medical facility.
- The Incident Commander or their designee should inform authorities at the medical facility of the existence of the risk of FAD transmission and ensure that cleaning and disinfection procedures for the patient and medical personnel are initiated as soon as appropriate.
- The patient's clothing and any of the medical personnel's clothing that may have become contaminated should be sealed in a plastic garbage bag. Disposable clothing can be worn by the emergency personnel and the victim to minimize the potential spread of contamination. Potentially contaminated clothing should be (a) discarded safely or (b) removed from the bag and laundered, with care taken to dispose of the contaminated bag

safely. Any contaminated medical equipment should be cleaned thoroughly (if possible, autoclaved) and disinfected with an approved disinfectant.

- Any surface – inside or outside the medical facility – that may have become contaminated should be cleaned thoroughly and disinfected with an approved disinfectant.
- The emergency vehicle should be cleaned and disinfected, including the interior, underside, wheels and wheel wells.
- Any clothing or boots of emergency vehicle attendants, orderlies or other personnel who may have become contaminated should be removed, sealed in a plastic garbage bag, and laundered, dry cleaned or disinfected with an approved disinfectant or discarded.

2.2.3.3. Vehicle and Heavy Equipment Cleaning and Disinfection

The following procedures can be used to decontaminate vehicles and equipment (i.e., cars, livestock carriers, feed trucks, milk trucks, carcass transporters, airplanes, etc.) that leave an infected zone. All of these vehicles have the potential to spread a contagious disease out of the quarantine area. If at all possible, the movement of vehicles out of the infected zone should be minimized. Clean vehicles should be available for responders to use after they have undergone the personal cleaning and disinfection described above.

Cars, pickup trucks and other personal use vehicles can be decontaminated and disinfected using the following procedures. All floor mats should be removed for scrubbing with disinfectant. The inside of the vehicle that has had contact with passengers or the driver (e.g., dashboard, steering wheel, handbrake, gear shift and seats) should be wiped liberally with appropriate disinfectant. If the trunk or bed of a truck is considered contaminated, the contents must be removed and the interior of the trunk or truck bed wiped with disinfectant. The contents of the trunk or truck bed must be disinfected before being replaced, or they can be left in a secure location inside the quarantine area. The wheels, wheel wells and underside of the car should be sprayed with disinfectant and all foreign material (e.g., soil, manure, bedding, etc.) must be removed. In some cases, it will be necessary to decontaminate and disinfect the entire outside of the vehicle if it is visibly contaminated or has come from infected premises.

Plain water should not be used with high-pressure sprayers, because the process could release mist and aerosols containing the virus. This can lead to the spread of disease. A mixture of disinfectant and water should always be used with high-pressure sprayers. Generally, decontaminating and disinfecting grossly contaminated vehicles should only be done on the premises where they became contaminated. Doing this gross cleaning at the access corridor raises the possibility of unintentionally spreading the disease.

Decontaminating and disinfecting grossly contaminated vehicles by brushing with a combination of a disinfectant and soap, to dislodge encrusted dirt and organic matter, is preferable to washing with high-pressure water streams.

Vehicles used to transport livestock and poultry will need to be decontaminated and disinfected if they are to leave a quarantine area. The gross cleaning and disinfection should not be carried out at an access corridor; rather, it should be conducted at the location where the trailer is unloaded, inside the quarantine zone. The gross cleaning and disinfection should involve removing all foreign matter (e.g., soil, manure, bedding, etc.) from trailers and bodywork. Vehicles should then be soaked in disinfectant and scrubbed down to bare metal, painted surfaces or wood with a detergent and disinfectant. Fixtures and fittings should be dismantled to ensure that infected material has been removed. Wooden surfaces must be cleaned and disinfected, where appropriate, before removal and disposal. When the crate structure of a trailer has been decontaminated, it should be lifted, if possible, from the chassis, so the undersides and mounting points can be decontaminated. Livestock or poultry transport vehicles must be closely inspected to check whether there are double layers of metal or wood used in their construction. If there are two layers, the top layer should be removed to reach areas where contaminated material could be trapped. Any metal flooring that appears solid should be checked to be sure there is no foreign material under the flooring. Some trailers may carry extra equipment under the chassis, which must be treated. Outer wheels and spare wheels must be removed to ensure adequate cleaning and disinfection and to inspect the spare wheel hangers that can be hollow, which creates a potential to contain contaminated material.

The driver's cab and, where fitted, the sleeping compartment must be thoroughly decontaminated and disinfected. The driver should be questioned as to the disposition of clothing and boots worn when in contact with diseased livestock or poultry. This clothing should be decontaminated and disinfected.

Specialized stock vehicles may carry their own water, food and litter supplies for the animals. Water, feedstuff, and litter carried in the vehicles must be disposed of. Burning or burial are common methods of disposal for these materials.

If dairies are situated in the infected zone, it may become necessary to decontaminate and disinfect milk trucks if it is essential for them to leave the control area.

Disinfectants used to decontaminate and disinfect the inside of the tank must not leave a chemical or taste trace. If a tanker is carrying infected milk, the volume of milk must be determined and the milk mixed with the correct strength of disinfectant. It must be left standing for the appropriate contact time and then disposed of appropriately. The appropriate disposal of contaminated milk, if relevant to the county, should be determined in the emergency planning stage of response preparedness. The exterior and interior of the tanker must be decontaminated, along with all hoses and fittings. The procedures for general cleaning and disinfection follow the procedures discussed for livestock and poultry transport vehicles.

Feed trucks may need to enter and exit the infected zone to service non-susceptible animals, infected animals or other susceptible animals in the zone. If it is necessary to allow a feed truck into a quarantine zone, a specific route should be planned to minimize the potential for contamination of the vehicle. Wherever practical, animal feed should be delivered to the outer limits of a property and then transferred to the animals, so the vehicle and driver do not become grossly contaminated. The vehicle and driver must be thoroughly decontaminated before being allowed to leave. Feed truck cleaning and disinfection will follow the procedures discussed for livestock and poultry transport vehicles. In addition, residual feed in the vehicle must be sprayed

with disinfectant and removed for disposal. The insides of bulk trailers should be decontaminated with approved disinfectant.

If a quarantine zone encompasses an airport, potentially contaminated aircraft should be decontaminated and disinfected before they are allowed to leave the area. Aircraft construction prohibits the use of strong alkaline disinfectants, such as caustic soda, because of corrosion problems with metals, such as aluminum. A mild alkaline disinfectant, such as sodium carbonate, can be suitable for use on aircraft. Care is required when disinfecting specialized equipment in the aircraft.

Heavy machinery used on infected premises will be grossly contaminated. Machinery may include: excavators and backhoes, bulldozers, front-end loaders, forklifts, tractors/trailers, dump trucks, fire trucks (incineration), roll-offs, cranes, chains, hooks, shovels, cargo nets, etc. This equipment must remain on the contaminated site until needed elsewhere. For example, this machinery must be decontaminated and disinfected once carcass disposal has been completed and prior to moving to another site within the infected zone. This gross cleaning and disinfection should follow the guidelines discussed above for livestock and poultry transport vehicles, but this should be conducted at the contaminated site where the equipment had been used. When a vehicle has undergone gross cleaning and disinfection and it needs to be moved out of the quarantine zone, it should be moved to the access corridor for final cleaning and disinfection.

2.2.3.4. Portable Equipment Cleaning and Disinfection

If electrical equipment, such as generators or motors, must be moved out of an infected zone, the following procedures can be used. If there is doubt, consult an electrical contractor. Consider whether cleaning this type of equipment is a priority. It is unlikely that covered electrical equipment will be heavily contaminated. These items are best considered at the end of the cleaning process, when specialists can be more readily consulted.

The most practical method of cleaning involves placing the equipment inside an airtight enclosure, possibly constructed from plastic sheeting, for fumigation. If the equipment can be

easily dismantled, it should be and then all of its parts should be placed in a small enclosed space for fumigation. Some electrical items may be inherently airtight, in which case, they can be safely decontaminated and disinfected by wiping down with disinfectant. A possible fumigant is formaldehyde gas. Serious consideration must be given to the practical and safety aspects of this procedure. It is important to remember that most viruses will inactivate spontaneously with time. Exposure to the ultraviolet light in sunlight may be another option for disinfecting complex equipment.

Hand-held radios, cameras, tape recorders and clipboards are a few of the portable types of equipment that will be used inside a quarantine zone. All of these items can be used while protected inside plastic bags. Inexpensive waterproof cameras can be used to record response actions. The waterproof nature of the camera will allow it to be disinfected. When it is necessary to remove this type of equipment from a quarantine zone, the following procedure should be completed at the small-scale cleaning and disinfection station at the access corridor:

- Wipe protective plastic bags with disinfectant and discard them,
- Wipe the body of the equipment with disinfectant, and
- Replace equipment in a clean plastic bag for removal.

There is a small residual risk of contamination; therefore, these items should only be used in a specific quarantine zone for the duration of the outbreak.

Equipment used to euthanize livestock (i.e., captive bolt guns and firearms) will generally be considered to be grossly contaminated. After use, these devices should be scrubbed with disinfectant at the location where they were used and again at the access corridor.

2.2.3.5. Ground Surface Disinfection

Outdoor ground areas where people, equipment and vehicles pass should be disinfected in cases of a FAD outbreak. Asphalt, concrete or similar substances can be treated with sodium hydroxide, potassium hydroxide, or sodium carbonate. On soil, calcium hydroxide may be

applied in addition to the alkaline solutions mentioned above. In extreme cases, the upper surface layer of soil should be removed and or covered by asphalt, concrete or other appropriate surface material (NAHEMS 2011).

2.2.3.6. Evaluation

NAHEMS, 2011, recommends that following C&D procedures, an inspection of the materials or site should ensure that all C&D measures have been performed. The following factors should be assessed:

- All areas identified to be grossly contaminated have been properly cleaned and disinfected.
- C&D measures have been implemented by personnel for themselves and their equipment.
- Appropriate disinfectants, either one or more, have been selected.
- Manure, unused feed, bedding and other gross debris have been removed and properly disposed of.
- Difficult items to decontaminate have been appraised, removed and disposed of in a way that minimizes the spread of pathogens (e.g., burned, composted, buried).
- All fittings and fixtures have been dismantled, cleaned and disinfected.
- All areas that are infected or suspected to be infected have been properly washed, rinsed and disinfected. To ensure surfaces are clean and no organic material has been left behind, a visual inspection should be conducted.
- Disinfectants, either EPA-registered or exempted, that are effective against the target microorganism were used at the correct concentration.
- Necessary contact times have been followed for the disinfectant.
- C&D effluent has been handled in a manner to minimize or avoid environmental impact.

3. PERSONNEL

C&D is the primary tool responders have to limit the potential of FAD spread from infected animals. In addition, the potential for contamination will be greatly reduced if only essential personnel and equipment are brought into the temporary housing and care area. To reduce the cleaning and disinfection necessary at these sites, vehicles should not be brought into the site.

Personnel conducting C&D activities should have a broad knowledge of FADs, and the general nature of cleaners and disinfectants. Generally, staff working at cleaning and disinfection sites will require training in the following areas: operation and maintenance of disinfection or cleaning stations, biosecurity and FADs. Local veterinary staff can provide training in the latter two areas. The training will allow these personnel to make informed decisions regarding the need for and adequacy of disinfection, and the background to identify possible disease spread vectors inside vehicles or otherwise associated with the travelers.

Often, local fire and rescue personnel have had training in cleaning and disinfection. Other personnel may be obtained from the following organizations: county roads, public works department, Nebraska Department of Roads, the Nebraska National Guard, local citizen's corps, or other organizations with appropriately trained personnel.

4. BIOSECURITY

In order to preserve herd or flock health and prevent the spread of disease, local emergency planners should develop biosecurity guidelines for responders. All personnel associated with the response should be required to conform to the county's biosecurity guidelines. Possible biosecurity guidelines should include the following:

- Workers may be required to wash and disinfect their vehicle or tires prior to entering area. State or federal veterinarians should be consulted on the need for this level of biosecurity.
- Workers should be required to sign in, in order to log all personnel in the area.
- Workers should be required to maintain a 48-hour animal-free period. Visits to state fairs, zoos and other places where animals are housed must be figured into the animal-free day calculation. In the case of poultry, response personnel must eliminate contact with pet birds (even being in the same house) or other bird-gathering areas, such as feeders. Depending on the species involved and the potential risk, these animal-free periods can be modified, especially if unique crews can be assigned to each area.
- Workers should be required to wear clean clothes, which typically include coveralls, head covering and boots.
- Workers may be required to shower before entering and prior to exiting the area. If this is done, local emergency planners must plan for the supplies and equipment necessary to provide this option.

- Workers should disinfect portable equipment prior to entering the area.
- Workers should not wear jewelry.
- Workers should work on animals from areas of youngest animals to oldest animals when phases of production are collocated. Veterinarians should be consulted on this order for the various species considered.
- Workers should utilize boot disinfection solutions provided.

5. HEALTH AND SAFETY

General first aid and access to emergency medical services must be provided at all traffic control locations that are staffed. This portion of a response would be coordinated by the Safety Officer, a member of the Command Staff supporting the Unified Command.

Cleaning and disinfection area personnel should be provided PPE to minimize their exposure to contaminated materials. Unless stipulated by the lead responding veterinarian (possibly a position added to the Command Staff), respiratory protection may not be necessary. Cleaning and disinfection workers should wear waterproof clothing or rain suits, with hoods, that can be disinfected and reused. Rubber gloves and rubber boots also will be needed. These items can be disinfected and reused. Under gloves, cotton or nitrile, should be worn under the outer rubber gloves. The personnel also should wear hardhats fitted with face shields to protect their faces. In addition, dust masks can be worn to protect the workers' mouths and to prevent ingesting splashed materials.

6. COMMUNICATION

Due to the dynamic nature of an emergency response to a FAD, the establishment and maintenance of cleaning and disinfection facilities must be coordinated with the ever-changing understanding of the nature and extent of the disease in question. In order to allow the teams in charge of the cleaning and disinfection areas to quickly respond to changing field conditions, communication between the teams and the IC must be maintained. Real-time communication and pre-shift meetings constitute the required communication needed to support cleaning and disinfection areas.

7. DOCUMENTATION

Throughout the process of conducting cleaning and disinfection, it will be necessary to provide various types of documentation. For indemnity payments to the responding agency or other forms of state or federal reimbursement or cost sharing, it will be necessary to document the resources applied and expended in cleaning and disinfection. These costs can include labor charges, equipment rentals or purchase, costs of expendable equipment or supplies, subcontractor costs, or any other costs associated with providing the cleaning and disinfection services.

Because of the nature of an emergency response, it is critical to identify personnel who will have the responsibility of documenting these issues or monitoring and verifying that other parties are collecting the needed documentation. In some cases, identifying a specific response job that includes documentation will be preferable, especially if personnel will be rotated through shifts and response jobs. This role and responsibility should be identified and described in a county's LEOP.

Possible actions or items that should be included in a documentation checklist include:

Responder time (hours)
Number of responders
Identity of responders
Sanitation services provided
Water provided
Number of people/vehicles decontaminated
Meals provided
Location of each responder
Equipment at each point
Usage time for equipment
Specific quantities of expendables used

Documentation also will be essential to tracking vehicles, heavy equipment, and people who exit and enter the area.

Documentation should be maintained in written form. Video, photographs and tape-recorded messages can be used to supplement the written documentation. Written documentation can be maintained in a logbook format, using documentation worksheets, or a combination of both. Documentation should be recorded with an ink pen, and any entry errors should have a single line drawn through them with the author's initials and date recorded at one end of the line. If a

logbook is used, it should have numbered pages and the spine should be sewn, making the removal of pages both difficult and obvious. Pages should never be removed from a logbook. Anyone making entries in the logbook should sign and date the bottom of each page. If documentation worksheets are used, the author should sign and date the bottom of each worksheet. Sets of logbooks and worksheets should be assigned to each response task (i.e., traffic control, cleaning and disinfection, mortality disposal, etc.) or a master set of logbooks and sheets can be maintained. Logbooks and worksheets should be assigned unique identification numbers. When the logbooks or a group of worksheets are issued to a responder, the identification numbers of the logbooks and worksheets should be recorded and the recipient should sign them out in a document-tracking log maintained by the IC. This establishes a chain-of-custody for the documentation.

If pictures, video, or taped messages or interviews are used to supplement the written documentation record, the following information should be documented for each picture, video segment, or audio-taped message or interview: photographer or interviewer, subject, time, date, person interviewed (video or audio taped), photo and film roll number, direction (pictures and video), and general weather conditions (i.e., temperature, wind direction, humidity, sky condition, etc.).

8. TRAINING

Personnel staffing the cleaning and disinfection station would benefit from training in: the operation and maintenance of the cleaning and disinfection equipment; disinfection procedures; associated environmental protection issues; and the inspection of people, vehicles, pets and other possessions prior to crossing the access corridor. The latter training will require basic training in biosecurity and FAD. Some of these requirements are addressed in NDA Monograph No. 003 *Temporary Housing of Livestock and Poultry*, Section 2.3. In addition, C&D staff should be trained in the physical, chemical and biological hazards associated with their job.

Qualified state and federal employees could be utilized to develop and provide this training for responders that might be assigned these tasks. The incident's health and safety officer could provide health and safety briefings.

9. REFERENCES

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APPENDIX A
DISINFECTANTS

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DISINFECTANTS

Table 1 presents some common FADs that could be encountered during an emergency response to a livestock or poultry disease outbreak. This Appendix presents a brief description of the classes of disinfectants mentioned in Table 1, and other information, such as general contact times. This Appendix begins with a brief discussion of physical disinfection methods. This information was adapted from NAHEMS, 2011. The second section of this Appendix focuses on chemical disinfectants. Chemical disinfectants will be the most common disinfectants used in a large-scale FAD response. This information was adapted or modified from the AUSVETPLAN, 2008 (Agriculture and Resource Management Council of Australia and New Zealand, 2008) and NAHEMS, 2011.

Responders seeking United States Environmental Protection Agency (EPA)-registered disinfectants against animal pathogens should contact EPA for an up-to-date list. In some cases non-registered disinfectants may be used if they have been given a Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Section 18 exemption from EPA (NAHEMS 2011).

SECTION 1 - PHYSICAL DISINFECTING AGENTS

Heat: Can impact the efficacy of many disinfectants. As temperature increases, the rate of chemical reaction increases. This increase in activity results in most disinfectants working better at higher temperatures.

Moist Heat: When heat is used for disinfection purposes it can be applied most effectively by using hot water or steam. All vegetative microorganisms can be killed by 176° F (80°C) for 10 minutes. Anthrax spores will be killed by 212° F (100°C) for 10 minutes but *Clostridium botulinum* and *C. subtilis* spores withstand boiling for hours.

Pasteurization: Is an application of moist heat. Pasteurization does not kill all of the microorganisms in milk or other liquids. It is intended to reduce the bacterial contamination and,

in the case of milk, to kill *Mycobacterium bovis*, *Brucella abortus*, and *Salmonella sp*. without altering the flavor or nutritional quality of the milk any more than necessary.

Autoclaving: An autoclave uses pressure to increase the boiling temperature of water. Water boils at 212° F (100°C) at sea level, while at 15lb/in2 (~1 Atmosphere of pressure), it boils at 250° F (121°C). The higher temperature and moist heat significantly reduces the time necessary to penetrate any porous materials in the autoclave and kill microorganisms.

Dry Heat: The use of flame or baking is less effective than moist heat for disinfection. Vegetative microorganisms are more resistant to dry heat than they are to moist heat, and spores are even more resistant. Some examples of the application of dry heat would include the incineration of carcasses or other biomedical waste, the heating of a bacterial loop in a Bunsen burner flame, the searing of a surface before sample collection, and the cauterizing of a wound.

Ultraviolet Light: Ultraviolet (UV) light is a non-ionizing radiation produced by sunlight or mercury vapor lamps. UV light disinfects by damaging cellular DNA. UV light produces primarily a surface effect and does not penetrate even a thin layer of protein or pigment. It can be used as a supplemental disinfection method in clean areas (e.g., surgical suites or media preparation areas) to reduce bacterial burden in the air. UV light can be used to disinfect water if very thin water layers are exposed to the light. Humans and live animals should not be exposed to high levels of UV light because of skin and eye damage.

Filtration: Filters and ultra-filters can be used to remove microorganisms from gases and fluids. Filtration is used for producing clean water in water treatment plants and is nature's way of cleaning water as it percolates through soil and rock into ground water. Filtering is used to produce microorganism-free solutions when other methods would be detrimental to the product. High efficiency particulate air (HEPA) filters are used to filter the air for FAD responders and in surgical suites, laboratories, industrial processes, and to assure the safety of air discharged from biologic safety cabinets.

SECTION 2 - CHEMICAL DISINFECTANTS

Table 2 summarizes the information presented below. Some chemicals in the list below are hazardous and will require special precautions. These chemicals should only be used under the supervision of properly trained personnel.

Soaps and Detergents

Soaps and detergents are commonly used to clean the surfaces of contaminated equipment or clothing. As a disinfecting agent, soaps and detergents inactivate the cell walls of bacteria and destroy the envelope of enveloped viruses. Often their primary function is to remove organic matter, soil, grease and other surface contaminants. The use of hot water and physical abrasion (scrubbing) will enhance the soap or detergent's ability to remove contaminants. The surfactant action of soaps and detergents effectively removes most Category A viruses from contaminated surfaces.

Many commonly used disinfectants associated with hospitals, dairies and food-processing areas involve soapy combinations of phenolics or quaternary ammonia compounds. These agents are bactericides; however, they have limited use as virucides. While these materials could be used in preparatory cleaning and cleaning, better bactericides and virucides are available that will clean and disinfect at the same time.

Halogens

These agents are commonly recommended as disinfectants, following proper cleaning, for many applications. These agents are highly toxic to aquatic life. These materials should not be discharged into a watershed without proper neutralization. The effectiveness of these solutions is optimal in the pH range of 6-9. As the concentration of organic matter increases in the solution, the effectiveness of halogens as a biocide is reduced. These solutions are negatively impacted at temperatures above 60°F; they rapidly decompose and lose effectiveness as a biocide.

A common halogen disinfectant is liquid bleach or chlorine powder for swimming pools (sodium hypochlorite). In a bleach solution, chlorine is released and is a powerful oxidizing agent and capable of killing all virus groups (Nalepa, 2000). Studies have shown that sodium hypochlorite solutions of around 0.18% provide an effective broad-spectrum biocide. Effective hypochlorite disinfecting solutions can be made from household bleach or chlorine powder used to maintain swimming pools.

Calcium hypochlorite and iodine are additional examples of halogen disinfectants. Calcium hypochlorite also is know as chlorinated lime and is mixed at a ratio of one pound to three gallons of water to produce an effective disinfectant. Iodine is relatively insoluble in water. It is necessary to use potassium iodine to dissolve sufficient amounts of iodine in water. Iodine is more effective than the other halogen disinfectants in the presence of organic matter.

Oxidizing Agents

Virkon S® is a commercially available oxidizing disinfectant that incorporates a high percentage of surfactant. This yields a good cleaning product with virucidal properties. It is supplied as a water-mixable powder. This material is reported to have low environmental toxicity. In 1% solution, it has a pH of 2.6 and thus would be effective as an acid disinfectant if this were its only mode of action. Due to its acidity and oxidizing nature, it is effective against all 17 virus families.

The Material Safety Data Sheet (MSDS) indicates that in 1% solution Virkon S® is non-irritating to skin or eyes; however, this material is not approved for use on skin. There is no occupational exposure limit specified on the MSDS for the 1% solution. Company literature indicates that at dilutions encountered in normal working solutions, the ingredients are decomposed or biodegraded and are comparatively harmless. The powder is corrosive and will cause skin burns and irreversible eye damage. It is harmful if swallowed, absorbed through the skin, or inhaled. Wear impervious gloves, goggles and respiratory protection when handling the

powder. Virkon S® in its powder form should not be subjected to high temperatures because, when heated to 158° F (70° C), it will decompose and create toxic sulfur dioxide gas.

According to company data, the 1% solution has a 10% loss of initial activity after seven days in 350 ppm hard water and the powder form has a 2.3% loss of initial activity after 36 months at 68° F (20°C). Packages of dipsticks are available to check the strength of working solutions of this product.

Alkalis

High pH materials, alkalis, are effective disinfectants. Alkalis kill most bacteria and viruses when the pH is greater than nine. Alkalis are not effective against spores or non-enveloped viruses. Common alkalis include sodium hydroxide (caustic soda) and sodium carbonate (washing soda). These agents are low cost and have a natural saponifying action on fats, which can help in the cleaning process. These materials are virucidal, and they maintain their effectiveness even with high concentrations of organic matter. These agents are often used for the disinfection and cleaning of penning, buildings and manure pits associated with livestock or poultry production.

Calcium hydroxide (air-slaked lime) also has been used as an effective disinfectant. However, this disinfectant is not effective against spores. It has been used to disinfect premises. A 20% solution with water is a common strength used for disinfection.

Acids

Acids with a pH below three can be used against bacteria and enveloped viruses. They are not effective against non-enveloped viruses, with the exception of the Foot and Mouth Disease virus. When using an acid, it is important to match appropriate acid or mixture with the virus being treated. These agents can be useful in disinfecting a broad range of materials from liquid effluent to personal cleaning. Citric acid and acetic acids are weak acids that can be useful

against many acid-sensitive viruses (e.g., Foot and Mouth Disease) and are mild enough to be used on clothing and for personal disinfection. In some applications, acids can be added to detergents to combine the cleaning power of the detergent with the disinfecting ability of the acid.

Aldehydes

The aldehydes are effective against bacteria and enveloped viruses. They are somewhat effective against non-enveloped viruses, bacterial spores and acid-fast bacteria.

Gluteraldehyde is a virucide that is effective against all virus families and many other organisms. It is an oil at room temperature. It is "activated by raising its pH above seven." At a pH above nine, the material decomposes. This agent can be effective at concentrations of 2% and its effectiveness is reduced as concentrations of organic matter increase. Recent studies have suggested possible negative long- and short-term health impacts associated with the inhalation of gluteraldehyde vapors.

Formaldehyde is a gas at room temperature, and is used as an area disinfectant in poultry houses and incubators. The gas dissolves readily in water to form a solution called formalin, which consists of 37% weight/weight (w/w) formaldehyde in water, with 10% methanol added to improve stability. A 40% aqueous solution of formaldehyde gas is an effective disinfectant. A 1:12 dilution of formalin in water produces an 8% solution that is effective against most virus families, but not against scrapie or bovine spongiform encephalopathy. The presence of organic matter decreases its effectiveness.

Other

NAHEMS, 2011, identifies and provides additional detail on surfactants, phenols and coal tar acids, alcohols, heavy metal, dyes and gases as possible disinfectants.

Table 2
Disinfectants Effective on Viruses

Disinfectant Group	Form	Strength	Contact Time (minutes)	Applications
Soaps and detergents	Solids or liquids	As appropriate	10	Cleaning and disinfection. Can be used on Category A viruses (i.e., lipid-containing virus).
Halogens				
Sodium hypochlorite	Concentrated liquid (bleach)	1:5 dilution (2-3% available chlorine), 1 fl. oz. of household bleach per gallon of water	10-30	Use for most viruses, loses effectiveness as organic matter concentrations increase, rapidly decomposes at temperatures >60°F.
Calcium hypochlorite	Solid	4 oz. per gallon (2-3% available chlorine)		
Oxidizing Agents				
Virkon S®	Powder	3 oz. per gallon (2% weight (w)/volume (v))	10	Active against all virus families.
Alkalis				
Sodium hydroxide	Pellets	3 oz. per gallon (2%w/v), or a 2% solution can be made by mixing 1/3 cup of pellets per gallon of water	10	Very effective on most viruses. Not compatible with aluminum or aluminum derived alloys.
Sodium carbonate	Powder (anhydrous)	6 oz. per gallon (4% w/v)	10	Good when high concentrations of organic matter are expected.
	Crystals (hydrated)	14 oz. per gallon (10% w/v)	30	
Acids				
Acetic	Liquid (vinegar is 4 to 8% acetic acid)	4 to 5 % (6.5 fl. oz. of glacial acetic acid per gallon of water)	Not listed	Not a broad-spectrum virucide (e.g., effective for Foot and Mouth).
Citric	Powder	¼ oz. per gallon (0.2% w/v)	30	
Aldehydes				
Gluteraldehyde	Concentrated solution	As appropriate (2% w/v)	10-30	Effective against most viruses.
Formalin	40% formaldehyde	1:12 dilution (8% v/v)		Releases irritating and toxic gas.

(Modified from Agriculture and Resource Management Council of Australia and New Zealand, 2008; and Bayer 1998)