Disaster Medicine

A method for decontamination of animals involved in floodwater disasters

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Animals that survive natural or man-made disasters or are deployed to disaster regions as part of a disaster response may become contaminated with debris, toxic chemical compounds, and biological pathogens that may pose serious health risks. For example, a study[1] of injuries and illnesses sustained by working dogs at the Oklahoma City bombing site found that > 20% of the dogs fell ill, with clinical signs ranging from respiratory tract irritation as a result of exposure to cement lime to coughing and eye irritation as a result of exposure to fiberglass. Large-scale disasters can result in the dispersal of hundreds of toxic chemicals and hazardous materials into the environment,[2] with the profile of contaminants released varying with the type of disaster. Earthquakes can rupture gas and oil lines, releasing toxic petroleum products, and can cause buildings to collapse, throwing clouds of asbestos-laden dust into the air. Volcanic ash released by eruptions is highly abrasive and can lead to skin, eye, nose, and throat irritation as well as various signs of respiratory tract disease.[3] Floodwaters, such as those that inundated 80% of New Orleans following Hurricane Katrina,[4] often contain high numbers of fecal coliform bacteria, high concentrations of heavy metals such as lead,[5] and a wide range of volatile organic solvents and other compounds.[6] Animals caught in these floodwaters may suffer from rashes and burns to the skin and mucosal membranes, along with gastrointestinal tract problems arising from ingestion of chemical residues and pathogens. Floodwater also provides ideal conditions for the growth of fungi and mold and provides optimal conditions for the spread of arthropod-borne diseases,[6–8] and people and animals exposed to floodwaters following a natural disaster are at risk of developing a variety of serious illnesses.[9]

The decontamination of animals exposed to the hazards dispersed by natural disasters is an important component of responsible emergency management. For instance, the deployment of search-and-rescue dogs to disaster sites necessitates careful decontamination of each animal after each shift to remove any hazards picked up on-site.[10,11] Similarly, following Hurricane Katrina, the rescue of abandoned and stranded animals that had been exposed to floodwaters necessitated the development of precautionary animal decontamination protocols to minimize the spread of pathogens and harmful compounds throughout animal intake facilities and to ensure worker safety. However, observations made by members of the Disaster Response Division of the Oceanographic Environmental Research Society who were deployed to Louisiana and Mississippi following Hurricane Katrina indicated that there was substantial heterogeneity and inconsistency in the protocols that were used by the various animal intake centers, with some centers not having any decontamination procedures in place at all. In addition, active methods of measuring and monitoring hazard levels as a measure of the efficacy of decontamination procedures were largely absent at most centers. Currently, the literature lacks readily available information about effective, comprehensive animal decontamination protocols to be used during disasters. Wismer et al[10] highlighted the need for rapid decontamination of search-and-rescue dogs exposed to toxic chemicals and recommended washing with liquid dish detergent to remove hydrocarbons, polychlorinated biphenyls, and phenols from coat hair. Otto et al[11] mentioned that search-and-rescue dogs working at the World Trade Center site following the terrorist attacks were bathed with detergent to remove oil-based contaminants. Within the US National Response Plan, the comprehensive all-hazards approach to managing disaster incidents, there is an identified need for effective decontamination procedures as part of the incident response.[12] However, although this plan outlines general strategies that can be used when responding to any incident, it does not provide detailed operational templates of decontamination procedures. The purpose of the present report, therefore, was to describe an animal decontamination protocol that aligns with current principles of the National Response Plan and can be used following water-related disasters such as floods, hurricanes, and tsunamis that expose animals to superficial contaminants. This protocol represents a modification of the decontamination protocols used by the Humane Society of the United States during the Hurricane Katrina animal relief effort in Hattiesburg,

Abbreviation

PPE Personal protective equipment

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Miss, and carried by the Oceanographic Environmental Research Society's Disaster Response Division to facilities in Gulfport, Miss. Although the main emphasis is the decontamination of small animals, the theory and principles of decontamination would be equally valid for and applicable to large animals, with the only adjustments required related to the size of the animals and the number of handlers needed.

Safety Requirements for Human Members of Animal Decontamination Teams

In keeping with principles outlined in the National Response Plan, safety requirements for the human members of any animal decontamination team should be developed by the safety officer on site, who is part of the incident command staff that is responsible for managing all disaster response operations and for developing priorities, objectives, and strategies. The safety officer must assess the on-scene hazards and risks to responders and develop appropriate personal safety measures that comply with Occupational Safety and Health Administration standards.[13]

Medical requirements for personnel—All personnel involved in the direct decontamination of incoming animals should obtain medical clearance for the physical requirements of the protocol because back injuries and strains have been identified to be a major occupational hazard when working with animals.[14–16] Ideally, personnel should receive prophylaxis against likely biological hazards that may be present at the disaster site, such as *Clostridium tetani*, enterotoxigenic *Escherichia coli* in floodwaters, and, potentially, rabies virus in rescued animals.

PPE—The safety officer is responsible for determining the appropriate level of PPE that should be worn by personnel involved in the decontamination protocol. The safety officer must also ensure that personnel are properly trained in using PPE and are aware of its limitations. In general, the level of PPE required is determined by a critical assessment of the types of hazards that are present, as well as their magnitude.[13,17] The National Institute for Occupational Safety and Health has identified a number of potential health and safety hazards associated with caring for displaced domestic animals. These include bites, scratches, and crushing injuries; exposure to zoonotic organisms and bodily fluids; injuries related to sharp, jagged debris; and heavy-lifting injuries. Accordingly, National Institute guidelines for PPE to be worn when handling animals include gloves, protective eyewear, durable clothing, and protective footwear.[18] For disasters involving flooding, PPE issued by the safety officer should incorporate the necessary elements of the National Institute's guidelines related to PPE for workers involved in a hurricane flood response.[19] Because each disaster poses its own distinct health and safety risks, however, these recommendations are general guidelines only and should not be expected to anticipate or account for all possible dangers. In addition, because the disaster landscape varies with both the region and time of deployment, it is important that the safety officer and command staff closely monitor current conditions at deployment sites so that elements of the PPE can be modified as necessary. A more comprehensive discussion of the types of protection provided by various levels of PPE and recommendations on when to use a particular level can be found on the US Department of Labor's Occupational Safety and Health Administration Web site[20] and in previous publications.[17]

For disasters involving flooding, the main risk to personnel involved with animal decontamination is related to direct contact with contaminated animals. Although floodwater may contain a variety of contaminants, including physical, chemical, and biological hazards, it typically does not contain a large number of highly concentrated contaminants, and the types and concentrations of contaminants are generally similar to those seen in stormwater.[4,21] Accordingly, for animal decontamination protocols, PPE that can protect against these hazards should be selected. Coveralls or long-sleeved pants and shirts should be worn to protect against animal bites and scratches. A lightweight, waterproof overgarment can be worn to prevent liquids from soaking through the undergarments.

Other factors to consider when selecting protective clothing include the mobility of the user and the susceptibility of the user to heat stress while working. Knee-length rubber boots with slip-resistant soles and thick, nitrile or polyvinyl chloride gloves should be used for foot and hand protection.[20] Nitrile and polyvinyl chloride gloves offer good protection from gasoline, diesel fuels, grease, and other oils as well as protection from acids and other chemicals that are typically found in floodwaters. They are also durable and resistant to abrasion and tearing.[22] However, to provide additional protection against bites and scratches, double gloving with an outer heavy fabric glove may be required.

There is a relatively lower risk for airborne contaminants when handling animals, compared with the risk for skin contamination. However, to protect against spray mists during decontamination, personnel should be issued N-95 particulate respirators approved by the National Institute for Occupational Safety and Health. For these respirators to be effective, they must form a tight seal around the user's nose and mouth and, therefore, require proper fitting prior to use. During large-scale disasters, however, when appropriate testing for a proper fit cannot be reasonably accomplished for every responder and the relative risk of airborne contaminants is low, simple field tests can be used to check for a tight seal around the user's nose and mouth.[17]

Eye protection may also need to be worn when decontaminating animals to protect against splashing. Safety glasses do not protect against splash hazards, so tight-fitting goggles should be used instead. Full face shields can be worn for major splashing and to protect against claws and flying debris. However, when face shields are used, the user must still wear safety glasses or goggles.[17]

Decontamination Site Layout

Hazard sites are traditionally divided into 3 zones—hot, warm, and cold.[17] The hot zone is the area that contains the hazard, the warm zone is a buffer zone between the hot and cold zones, and the cold zone is the area free from any hazards. These zones should

be clearly demarcated, and access points to the zones should be monitored to prevent tracking of contaminants from the hot zone into the warm or cold zone. Decontamination takes place in the warm zone, in what is known as the contamination reduction corridor. The contamination reduction corridor extends from the outer boundary of the hot zone to the point of entry to the cold zone.[17] Thus, entry into the cold zone must always be preceded by decontamination in the contamination reduction corridor. The cold zone is the location for the medical treatment rooms, animal kennels, and personnel quarters.

When selecting a site for animal decontamination, care should be taken to survey the surrounding physical environment. The site should be on high ground to minimize the risk of recurrent flooding. Wind direction is also critical, as the decontamination site should not be situated such that spray mists associated with washing and disinfecting are carried into the animal facility or personnel quarters in the cold zone. Protection against the sun is important, as excessive exposure can lead to dehydration and heat exhaustion in animals and in handlers wearing PPE.

Decontamination Protocol

Effective planning and preparation are essential for the smooth operation of any animal decontamination protocol. Although there may be different kinds of decontamination protocols depending on the nature of the disaster, the protocol described in the present report is a suggested method that can be used to effectively decontaminate animals exposed to floodwaters. The focus in the present report is on small animals; however, by modifying the number of handlers and the relative sizes of the wash stations, this decontamination protocol may be used for large animals as well.

In essence, the decontamination protocol involves leading contaminated animals through a series of sequential decontamination stations that each remove a particular type or category of contaminant. The sequential removal of contaminants is important, as decontamination solutions targeting 1 type of contaminant may be incompatible with the presence of other contaminants.

Decontamination stations should be prepared before any animals arrive. Three stations should be established. The first station (station 1) is for removing any contaminated objects on the animal, such as leashes, collars, and halters. The second station (station 2) is for washing the animal with detergent to remove organic matter. The third station (station 3) is for washing the animal with an antimicrobial solution to kill any microorganisms.

Station 1—This station should contain 2 bins. One bin is for the disposal of contaminated leashes, collars, and other items worn by animals at the time of rescue. It is important to discard these items, as they may be heavily contaminated and may trap contaminants against the skin or hair coat of the animal. However, before any items are removed, a photograph of the animal should be taken while it is still wearing its original collars and any other identifiable items. The photographs can then be uploaded onto existing online databases where owners can search for their missing animals. As well, items with the animal's name or address should not be discarded but stored in a safe location in the hot zone. It is important to have a system that keeps track of the items that will be kept. One such system might involve assigning the animal and its items the same unique identifier, such as a string of numbers. This identifier can be written on the new collar given to the animal and on the bag in which the old items are kept. It is likewise important to obtain as much information about the location where the animal was rescued, as this will provide additional information about the possible hazards the animal was exposed to as well as help with the animal-owner reunion process since it narrows down the likely area of residence of the animal.

The second bin should contain clean leashes and other restraining devices, including collars, harnesses, and muzzles. At a minimum, all dogs must be kept on a leash and all cats must be placed in a harness. Once the contaminated items have been removed and replaced by clean items, personnel assigned to station 1 may then transfer the animal to station 2.

Station 2—Station 2 should consist of a large tarp laid on the ground; 2 large basins with shallow, rigid walls; and a water source connected to a hose with a spray bottle. Cleaning materials should consist of a detergent solution, such as liquid dish detergent, and various scrub brushes. A team of 2 washers is generally sufficient for most small animals; generally, one restrains the animal while the other washes. The animal should be washed in one basin and rinsed in the other. The tarp beneath the basins serves to catch water dripping from the animal as it is transferred between basins. The basins should be large enough to accommodate 1 animal and 2 people, since it may be necessary in some cases for the washers to enter the basin to restrain the animal. As some animals may be reluctant to enter these basins, the walls of each basin should be just high enough to contain the wash and rinse water so that it does not spill over and contaminate the surroundings.

Prior to washing, if necessary, the eyes of the animal should be flushed with saline solution to remove debris and chemical contaminants. An artificial tears gel may then be applied if there is a concern about eye irritation when the animal is washed with soap or detergent. Washing is done by spraying the animal with appropriately diluted detergent solution from the spray bottle attached to the hose. The detergent solution should be thoroughly agitated into the hair of the animal. The animal is then led into the rinse basin, where it is thoroughly rinsed with clean water. The length of time that should be spent washing and rinsing the animal may depend on the scale of the disaster. In humans, it is suggested that no longer than 3 minutes should be spent on each individual in the event of a mass decontamination. The aim in such cases is to decontaminate as many individuals as possible.[17] This aim is equally relevant for animal decontamination. To date, however, there are no guidelines on the recommended time for an animal to be decontaminated. Nevertheless, there are some simple qualitative tests that can be employed. Many contaminants, such as phenols or petroleum products,

have distinct odors that can alert the wash team to their presence. Similarly, a greasy, oily feel to the hair may indicate that decontamination was inadequate. In such cases, the animal should be washed again. Hair matted with contaminants that cannot be washed off should be clipped.[10] Once the animal has been washed and rinsed, it may then be transferred to station 3.

The dirty water in the wash and rinse basins must be emptied before the next animal arrives. The wastewater can be transferred to a second container or poured into a lined pit until it can be appropriately disposed of.[17] In some cases, it may be permissible to release the water into the environment, away from the cold zone, if the Safety Officer determines that it does not pose any health or environmental risk.

Station 3—Station 3 is entirely similar to station 2, except that an antimicrobial solution is used in place of detergent. As with station 2, it may be difficult to determine the amount of time that each individual animal should spend at this station, as there are no simple tests that can be used during disasters to test for microbes in the hair of animals. However, many antimicrobial products have recommended contact times that should be known by the washers and can be used as an indication of the time that should be spent washing the animal.

Once the animal has been decontaminated and well rinsed, it is transferred to a handler just outside the clean zone to be towel dried. If decontamination was adequate, the animal can be permitted to enter the cold zone. Therefore, it is important at this point for the handler to carefully examine the animal for the presence of any residual contaminants and to return the animal to the appropriate station for additional decontamination if contaminants are found. If the animal passes visual inspection, it is delivered by the handler to the triage room for treatment by the veterinary care team. If the vaccination history of incoming animals is unknown, there is some debate as to whether animals should be immediately vaccinated. It is thought by some that there is an increased possibility of vaccination failure or adverse reactions if stressed animals are vaccinated. This school of thought suggests that animals sheltered for prolonged periods (> 3 to 7 days) should be vaccinated after a 24-hour acclimatization period to their new cage quarters. Animals that will be returned to their owners may not need to be vaccinated. However, it was our experience during Hurricane Katrina, when > 3,000 animals were vaccinated immediately upon arrival at the facility where we were deployed, that there were no significant detectable reactions seen, nor were there any disease outbreaks. This suggests that during such large-scale disasters, erring on the side of caution and vaccinating animals upon admission may prove prudent. Accordingly, we recommend that incoming animals that are not clinically ill and that are > 6 weeks old should be vaccinated if the vaccination history is unknown. Although the specific vaccines administered may vary depending on region, dogs should generally receive distemper, adenovirus, parvovirus, parainfluenza, and *Bordetella* vaccines, and cats should receive feline viral rhinotracheitis, calicivirus, and panleukopenia vaccines. Dogs and cats > 4 months old should be vaccinated against rabies. All animals should also receive prophylactic treatment for fleas and worms prior to admittance to the facility's housing units. Other interventions, such as treatment for heartworm, should be determined by the veterinary care team.

Discussion

Several important considerations must be taken into account when designing an animal decontamination protocol that is to be operational during disaster situations. Foremost, the decontamination protocol should complement and coexist with the many other ongoing activities and operations carried out at emergency intake facilities, as some of these other operations may have relevance to the decontamination teams and vice versa. For example, when an animal arrives at a facility, information gathered by the field rescuers about the location of rescue of the animal should be carefully reviewed and made available to the decontamination teams as well as other teams for which such information might be useful. Knowing the location of rescue would be useful to the decontamination teams, as this will give an idea of the type of hazards that the animals were exposed to. This information would also be useful to the teams that work to reunite the animals with their owners. Although these and other issues are important and may influence the fine-scale design of a decontamination protocol, they remain beyond the scope of the paper and will not be dealt with further. Other important considerations are that during disasters, resources are limited, which places a substantial constraint on the types of equipment available for decontaminating incoming animals. In addition, the necessary personnel required to carry out a comprehensive protocol may be lacking, and those available usually rotate on a 1- to 2-week basis. This means that the protocol must be simple enough that incoming responders can quickly learn it. Finally, depending on the scale of the disaster, there may be a large number of animals requiring decontamination. To prevent a bottleneck of contaminated animals arriving at the intake facility, the decontamination protocol must be such that a large number of incoming animals can be processed in an efficient and timely manner.

The animal decontamination protocol described in the present report requires little in the way of resources. All the necessary equipment is readily available at local home-improvement stores. The required manpower is also minimal, as a total of 8 personnel is all that is needed: 1 individual at station 1, 2 individuals each at stations 2 and 3 to wash the animals, 1 individual at the cold zone entry point to dry the animal, and 2 individuals to staff the veterinary care team. Apart from the veterinary care team, this protocol allows personnel to be readily cycled through the various decontamination roles so that workers in more labor-intensive roles (eg, washing) can be given a relief without having to shut down operations.

It is important that animals pass through each decontamination station in the order described. In particular, it is an absolute requirement that station 2 precede station 3. Station 2 is concerned with removing as much organic matter (eg, soil, grease, oil, fecal material, and body fluids) from the animal as possible. This step is

important for a number of reasons. Organic matter acts as a physical barrier that can prevent disinfectants used in station 3 from reaching the microorganisms. Organic matter may itself also contain high numbers of pathogens. In addition, many disinfectants are inactivated in the presence of organic matter, greatly reducing their efficacy.[23–25] Therefore, diligent washing at station 2 not only removes harmful physical contaminants and organic matter from the animal, but also greatly improves the overall efficacy of station 3 and the decontamination protocol in general.

An important consideration in any decontamination protocol is the choice of disinfectant. The disinfectant used depends on the profile of contaminants animals were exposed to during the disaster. It should be assumed that animals rescued from floodwaters have been exposed to contaminants typical of storm water, including physical debris and sludge, household and industrial chemicals, and biological pathogens such as fecal coliforms. Accordingly, the disinfectant solution should be chosen to target these contaminants. Additional information about the profile of contaminants may be obtained from field rescuers. For example, animals rescued near a submerged car lot may be assumed to have been exposed to relatively higher concentrations of gasoline, oil, and antifreeze. The characteristic odor of particular contaminants, such as phenols, may also aid in identifying the types of contaminants present on the animal.[10]

Because the purpose of station 2 is to remove organic matter, the disinfectant used should be a soap or detergent. Soaps and detergents, also known as surface-active agents, work by acting as emulsifiers or surfactants to surround and lift the organic matter from the hair, which can then be rinsed away with water. Soaps and detergents can be further divided into cationic and anionic compounds, depending on the net charge that is carried. Those that are cationic have good biocidal properties but poor detergent properties, while the converse is true of anionic compounds. Despite their differences, both are effective in removing grease, oil, soil, and dirt from the hair of a contaminated animal.[26–28] They may also be used against other hydrocarbons, polychlorinated biphenyls, acids, alkalis, and phenols.[10] The surfactant and emulsifying capability of soaps and detergents also makes them effective against pathogens with outer lipid envelopes.[26] Common liquid dish detergent is a good choice, as it is effective, readily available, inexpensive, and safe to use.[10] Another important consideration in selecting an appropriate detergent is its compatibility with disinfectants. Anionic detergents are incompatible with cationic disinfectants as well as several other disinfectants.[27] It is therefore important that when an animal is washed with soap or detergent, the hair be thoroughly rinsed to prevent residues of the cleaning agent from inactivating the disinfectant.

As the purpose of station 3 is to remove biological contaminants, the choice of disinfectant is considerably more complicated. There is no single disinfectant that will neutralize all possible contaminants, and often the choice of disinfectant is constrained by practical considerations such as cost, availability, and personnel and environmental safety. When the profile of biological contaminants is unknown or incompletely characterized, it is best to select a disinfectant that is active against a broad spectrum of microorganisms.[25] One choice would be chlorhexidine, which was used in Hattiesburg and Gulfport, Miss, following Hurricane Katrina. Chlorhexidine is a broad-spectrum biguanide that kills microorganisms by altering the permeability of the cell membrane. Biguanides are broad-spectrum disinfectants at a 4% dilution[29] and are suitable against a wide range of the gram-positive and gram-negative bacteria (including fecal coliforms), mycoplasmas, and some viruses and fungi[25] that are likely to be present in floodwaters.[30] An additional advantage of chlorhexidine is that it is fast acting, requiring less than 20 seconds to exert its biocidal effects.[23] Short contact times allow for a large number of animals to be decontaminated in a relatively short period of time. However, as with all disinfectants, there are a number of limitations associated with using chlorhexidine as a disinfectant (**Appendix**). Also, most disinfectants require dilution prior to use, but diluted solutions are often unstable and must be used shortly after preparation.[34] A related issue involves neutralized and used solutions. Some disinfectants change color to indicate that a new solution needs to be prepared[35]; however, many offer no indication, and it may be difficult to determine the potency of prepared solutions. The decontamination protocol described in the present report avoids these issues because the disinfectant solutions are sprayed onto the animal, so that stock solutions do not come into contact with the animal and are only mixed with water at the time of use.

Perhaps the most troublesome component of any decontamination procedure is the selection of reliable endpoints that can be used to gauge the efficacy of decontamination. Traditional methods such as bacterial culture may not be practical for animal decontamination during disasters. Accordingly, surrogate markers should be established that do not rely on bacterial culture. Sometimes, all that may be possible is careful observation of the animals in the holding facility for signs of contamination. As an additional line of defense, daily cage-washing procedures should be implemented to prevent accumulation of soiled matter inside the facility, which may provide breeding grounds for microorganisms. Cage-washing procedures should mirror those used for animal decontamination, with initial washing with a detergent to remove organic material followed by application of a disinfectant solution.

As described in the present report, the decontamination protocol would require that all incoming animals be ambulatory. This may not necessarily always be the case, particularly following disasters. However, the decontamination protocol is equally capable of processing ambulatory and nonambulatory animals, since the protocol does not require the active participation of the animal. In the case of a nonambulatory arrival, once the animal's condition was stabilized, it could then be brought to each station in the contamination reduction corridor for decontamination.

The basic principles of this decontamination procedure can be translated across disasters. All of the concepts described in this report—establishing hot, warm, and cold zones; establishment of a contamination re-

duction corridor consisting of separate stations each dedicated to removing a specific type of contaminant; and appropriate selection, preparation, and use of disinfectants—are valid for any disaster that exposes the hair and skin of affected animals to contaminants. For example, search-and-rescue dogs working at the site of the Oklahoma City bombings or the World Trade Center attacks were regularly inspected for cuts and lacerations, then bathed with water at the end of each shift. If contamination with oil was suspected, the dogs were washed with dish detergent. The eyes of some dogs had to be flushed with saline solution to remove debris.[11] In such instances, several stations could be established to inspect animals for injuries, wash any dust or debris from the animals' eyes, and bathe the animals to remove contaminants. Because each station would be independent from the others, there would be no need to sequentially visit each station.

The decontamination protocol described in the present report could also be used for decontamination of large animals. Although the physical setup of the individual stations would likely need to be modified for large animals, with for example wash bays used instead of shallow basins, and the number of individuals required would likely need to be increased, the basic principles would be the same.

In conclusion, during disasters, decontamination of animals is an important first step in the management of emergency animal intake facilities. Implementing a simple and efficient decontamination protocol will ensure continuous operation even during times of high intake or depleted resources. Decontamination protocols such as the one described in the present report may minimize the risk of contaminants spreading through animal intake facilities, preserving the health and safety of the facility's animal population and relief workers.

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Appendix

Characteristics of common disinfectants.[25,27,31–33]

Disinfectant	Spectrum of activity	Advantages	Disadvantages	Dilution
Quaternary ammonium compounds	Gram-positive and gram-negative bacteria, and fungi; limited activity against lipid-enveloped viruses	Broad spectrum of activity, low irritation, newer compounds may be active in the presence of organic material and hard water, some detergent properties, rapid action, stable, effective at high pH	Older compounds inactivated by anionic detergents and organic material, activity reduced by hard water, must prevent runoff from entering waterways (toxic to fish)	400 ppm, 0.1% to 2%
Biguanides	Gram-positive and gram-negative bacteria; limited activity against enveloped viruses and fungi	Broad spectrum of activity, low irritation, residual activity, fast acting (15 s)	Inactivated by organic matter and anionic soaps, activity reduced by hard water, active only at pH 5 to 7, must prevent runoff from entering waterways (toxic to fish)	0.05% to 4%
Peroxygen	Gram-positive and gram-negative bacteria, viruses, and fungi	Broad spectrum of activity, low irritation, active in presence of organic material, good detergent properties, fast acting (30 s), effective over broad pH range, effective at high and low temperatures, effective in hard water	Must prevent runoff from entering waterways (toxic to aquatic life)	20 g/L, 1%
Iodophores	Gram-positive and gram-negative bacteria, enveloped viruses, and fungi	Fast acting, low toxicity, may have detergent properties	May burn tissue, inactivated by organic materials, may corrode metals	100 ppm iodine
Alcohols (ethyl, isopropyl)	Gram-positive and gram-negative bacteria, enveloped viruses, and fungi	Fast acting, compatible with other disinfectants	Rapid evaporation limits contact time, volatile, flammable, eye irritant, inactivated by organic material	70%
Hypochlorite (bleach)	Gram-positive and gram-negative bacteria, enveloped viruses, and fungi	Broad spectrum of activity, low cost, readily available, fast acting, effective in hard water	Inactivated by organic, material, irritant to skin and mucous membranes, corrosive, strong odor, diluted solutions are unstable, evolves chlorine gas in presence of urine (ammonia or acid)	Varies with intended use, 100 to 500 ppm, 0.5% to irrigate wounds