ND	Newcastle disease
PPR	peste des petits ruminants
RAB	rabies
RIN	rinderpest
RVF	Rift Valley fever
SCR	scrapie
SGP	sheep/goat pox
SVD	swine vesicular disease
SWF	screw-worm fly
TGE	transmissible gastroen-teritis
VE	vesicular exanthema
VS	vesicular stomatitis

Chapter 3
Weapons: disinfectants and chemicals for inactivation of exotic viruses and disease agents

INTRODUCTION

This section provides advice for the decontamination of premises where animals infected with a serious epidemic disease have been held. Most such diseases are caused by viruses; these recommendations are made on that basis.

Decontamination

Decontamination is the combination of physical and chemical processes to kill or remove pathogenic microorganisms; it does not necessarily result in sterility. A disinfectant is a chemical or mixture of chemicals capable of killing pathogenic microorganisms associated with inanimate objects.

Basic assessments

The most important initial information is the presumptive identification of the disease agent involved. Once established, the basic properties of the agent, most likely a virus, must be considered. What are the epidemiological characteristics of the spread of the virus? Has transmission occured by aerosol spread, oral ingestion, close contact or insect vectors? From the information gathered, a plan can be devised to establish priorities for decontamination (Prince, *et al*., 1991). Such a plan usually includes:

- buildings with wooden, metallic or masonry structures;
- machinery of mostly metallic components;
- pipework of various types;
- water tanks;
- animal food storage areas;
- sewage waste.

Depending on the disease agent involved, different decontamination procedures and disinfectants are likely to be used for different sites on a property (Kostenbauder, 1991).

In cases where the disease agent does not spread directly from animal to animal, e.g. bluetongue, a comprehensive decontamination of a property is not warranted. In contrast, some viruses, such as swine vesicular disease and foot-and-mouth disease, are relatively stable on inanimate objects and can be spread to remote animals on contaminated people, clothes and equipment. Viruses that can be spread by such contact will require the most comprehensive decontamination programmes.

Preliminary cleaning work is invariably needed before any chemical disinfectants are used. The natural processes of time, dehydration, warm temperature and sunlight will greatly assist the decontamination operation and should be considered in planning. A hot, dry, sunny day will cause rapid natural inactivation of an agent like Newcastle disease virus, whereas cold, damp, overcast conditions will assist its persistence.

Simple cleaning of surfaces by brushing with a detergent solution is effective in removing contaminating viruses and is fundamental for achieving effective chemical decontamination. Most disinfectants have reduced effectiveness in the presence of fat, grease and organic dirt. Every effort should be made to remove such coverings from all surfaces to be decontaminated. Hot water and steam are effective in cleaning many cracks and crevices where pathogens are likely to linger. The insides of pipework can often only be cleaned effectively by steam. If applied long enough for surfaces to approach 100°C, the interior of pipework will be effectively decontaminated.

Choice of disinfectant depends on the method of application and how an adequate wet contact time is to be maintained.

A knowledge of the properties of the contaminating virus is crucial in planning a decontamination strategy. Choosing the most appropriate disinfectant is dependent on the nature of the virus particles. Useful clues for predicting susceptibility are the presence or absence of lipid in the virus particles and the virus size (Klein and DeForest, 1981). In this predictive system, viruses fall into three groups, as given below.

Category A. Category A viruses are of intermediate to large size and contain lipid, which makes them susceptible to detergents, soaps and all the disinfectants listed in Chapter 3. Such viruses are susceptible to dehydration and often do not persist long except in cool, moist environments.

Category B. Category B viruses, e.g. picornaviruses and parvoviruses, have no lipid and are smaller and more hydrophilic. Such viruses are relatively resistant to lipophilic disinfectants such as detergents. Although they are sensitive to all the other disinfectants listed in Chapter 3, they are less susceptible than viruses in Category A. Classical bactericides such as quaternary ammonium compounds and phenolics are not effective against these viruses.

Category C. Category C viruses, e.g. adenoviruses and reoviruses, are intermediate in size and lack lipid. These viruses fall between Categories A and B in sensitivity to the best antiviral disinfectants such as hypochlorites, alkalis and oxidizing agents, e.g. Virkon® and aldehydes.

Table 1.1 groups viruses of veterinary significance in their families and also in terms of their susceptibilities to common disinfectants.

Precautions when using disinfectants

Chemicals usually kill microorganisms by toxic reactions; effective disinfectants are often toxic for animal and human tissues as well. Virtually all disinfectants have to be used with care to avoid occupational injuries or health problems. Table 5 provides some basic information about precautions and contra-indications when using the recommended disinfectants.

SELECTION OF DISINFECTANTS

This manual concentrates on a relatively narrow range of disinfectants that are effective against broad groups of viruses. Consequently, disinfectants are recommended that are generally available in large quantity. It should be remembered that in any large-scale decontamination of a farm or other infected premises, the cost of disinfectants will be relatively minor. Because labour and other operational costs will be high, it would be a false

economy to use disinfectants at less than recommended concentrations. In any case, when disinfectants are diluted they invariably lose their effectiveness.

Flame guns may be useful supplements for drying decontaminated surfaces but they are dangerous and the risk of fire and injury must always be considered. Flame guns are not recommended as a primary means of decontamination.

In general, chemical names of disinfecting substances are used, because they are easily understood by all personnel with basic technical knowledge. This document generally avoids the use of brand or trade names, because such products are subject to change or restriction in their distribution. Appendix 2 shows the names of trade products and the distributors from which supplies can be obtained.

To simplify determinations, disinfectants are grouped into five chemical categories:

- soaps and detergents
- oxidizing agents
- alkalis
- acids
- aldehydes

Each of these classes of disinfectants is discussed briefly here and shown in Table 4.

Commonly used general disinfectants, such as phenolics and quaternary ammonium compounds, are very effective antibacterials but have limited effectiveness against category B and C viruses; they are therefore not included in Table 4.

Products effective for decontamination of viruses on the hands and the skin are limited. Virkon® is reported to have low toxicity and to be effective against members of all 17 virus families but it has not been approved for use on skin. Alternatively, citric acid or sodium carbonate may be added to washing water to induce antiviral conditions by lowering or raising the pH as appropriate for the agent to be inactivated.

Soaps and detergents

Soaps and detergents are essential components of cleaning procedures prior to many of the decontamination procedures described here. In most cases, the primary aim is the removal of organic material, dirt or grease from surfaces to be decontaminated. Most industrial and domestic brands of soaps and detergents are satisfactory. Hot water, brushing and scrubbing enhance the cleaning action. Similarly, steam improves the cleaning and decontamination process by raising the temperature and penetrating crevices. Steam by itself can only be used as a decontaminant, however, if the temperature of the surface can be raised to 100°C and held there long enough for the inactivation of the agent. Because of uncertainties regarding temperatures and times of contact, steam is only recommended as an adjunct to decontamination in this manual.

The surfactant action of soaps and detergents is an effective decontaminant for all Category A viruses, because of their outer lipid envelope. For decontamination procedures involving exotic viruses in Category A, soaps and detergents are thus effective disinfectants in their own right.

Many commonly used disinfectants in hospitals, surgeries, dairies and food-processing areas involve soapy combinations of phenolics or quaternary ammonium compounds. These agents are specifically antibacterial and are effective against category A viruses. They have limited activity against category C viruses, however, and in many cases no activity against category B viruses. Although they may be useful for preparatory cleaning purposes during an exotic virus disease outbreak, they are not therefore recommended in this manual, because more effective cleaning agents and viral decontaminants are available.

Iodophors are combinations of solubilizing agents and a carrier that releases free iodine. It is difficult to define active concentrations with certainty in all circumstances, so iodophors are not recommended in this manual for the inactivation of viruses.

Oxidizing agents

These are the disinfectants recommended for most applications. Chlorine is released from hypochlorite solutions, either sodium or calcium, and is a powerful oxidizing agent effective in killing all virus groups (Dychdala, 1991). Scott (1980) found in test conditions that 0.175 percent sodium hypochlorite was the most effective and practical broad-spectrum disinfectant of 22 products tested against a range of different viruses. The effectiveness of hypochlorite is highest in the pH range 6–9, however, and decreases markedly in the presence of organic material. Hypochlorite powders are readily available as swimming-pool disinfectants or household bleaches and can be diluted for use on site. Hypochlorite solutions are not chemically stable and decompose rapidly as temperatures rise above 15°C.

Virkon® is a modern disinfectant with outstanding virucidal properties. Virkon® is reported to have low toxicity and to be effective against members of all 17 virus families but it has not been approved for use on skin. Its activity is based on a buffered synergized acid peroxygen system containing a high percentage of surfactant. It is relatively safe to use and comes in a powdered form ideal for dilution at the site of an exotic disease outbreak. It can be sprinkled in powdered form over wet or boggy areas but the concentration of disinfectant achieved by that kind of application cannot be accurately controlled.

Alkalis

Alkalis have long been used as effective disinfectants against a wide range of pathogens. Both sodium hydroxide (caustic soda) and sodium carbonate (washing soda) are widely available in large quantities at low cost and both have a natural saponifying action on fats and other types of organic matter, which assists the cleaning process. Because they are virucidal under heavy burdens of organic material, they are ideal agents for decontaminating animal housing, yards, drains, effluent waste pits and sewage-collection areas.

Acids

Acids are generally highly virucidal. With the correct choice of acid, or acid mixture, acids can be used under a wide variety of conditions, ranging from liquid effluent to personal decontamination. Hydrochloric acid is a strong acid, widely available from hardware stores and less toxic than other strong acids. Citric acid is a milder acid, available in solid form, that is active against acid-sensitive viruses and can be used safely for personnel and clothing decontamination. It is particularly useful when added to detergents for the inactivation of foot-and-mouth disease virus.

Aldehydes

Glutaraldehyde. A very effective disinfectant (Scott and Gorman, 1991) active against all virus families and other microorganisms in concentrations of 1 to 2 percent. It remains effective in moderate concentrations of organic material, is chemically stable and only mildly corrosive for metals. For large-scale decontamination, however, the cost is likely to be high.

Formalin. A 40 percent aqueous solution of formaldehyde gas is called formalin and is a useful disinfectant. Formalin diluted with 12 volumes of water produces 8 percent formalin, which is an active disinfectant against most virus families - but not against BSE.

Gaseous formaldehyde. Gaseous formaldehyde can be used to decontaminate air spaces, equipment such as electronic devices that must be kept dry and the insides of motor vehicles. The conditions must be carefully controlled, however, in terms of gas concentration, temperature, humidity, time of contact and even distribution of the gas. Under

emergency conditions on a contaminated property, it is unlikely that all parameters can be controlled adequately. In addition, the space to be decontaminated must be completely sealed to prevent gas escape, because the most effective dwell time for inactivation is an overnight period (Quinn, 1991). Other problems with the use of formaldehyde gas for general purposes include the toxicity of gas, the dangerous nature of its generation in non-laboratory conditions (potassium permanganate reacts violently with formalin), the environmental protection guidelines that prevent the release of formaldehyde gas to the atmosphere and the difficulty of completely purging residual formaldehyde gas from confined spaces.

TABLE 4
Recommended disinfectants and concentrations for inactivation of viruses

Disinfectant group	**Form**[1]	**Strength**[2]		**Contact time**[4]	**Applications and virus category**
		Usual dilution	***Final***[3]		
Soaps and detergents	Solids or liquids	As appropriate	10 min		Thorough cleaning is an integral part of effective decontamination. Use for category A viruses.
Oxidizing agents:					
Sodium hypochlorite NaOCl	Conc. liquid (10–12% available chlorine)	1:5	2–3% available chlorine (20 000–30 000 ppm)	10–30 min	Use for virus categories A, B, and C. Effective for most applications except when in the presence of organic material. Less stable in warm, sunny conditions above 15°C.
Calcium hypochlorite Ca $(OCl)_2$	Solid	30 g/litre		10–30 min	
Vikron®	Powder	20 g/litre	2–3% available chlorine (20 000–30 000 ppm) 2% (w/v)	10 min	Excellent disinfectant active against all virus families.
Alkalis:					
Sodium hydroxide	Pellets	20 g/litre	2% (w/v)	10 min	Very effective against virus categories A,B and C. Do not use in the presence of aluminium and derived alloys.
Sodium carbonate					
anhydrous (Na_2CO_3	Powder	40 g/litre	4% (w/v)	10 min	Recommended for use in the presence of high concentrations of organic material.
washing soda ($Na_2CO_3.10H_2O$)	Crystals	100 g/litre	10% (w/v)	30 min	

Acids:					
Hydrochloric acid	Conc. acid (10 Molar)	1:50	2% (w/v)	10 min	Used only when better disinfectants not available. Corrosive for many metals and concrete.
Citric acid	Powder	2 g/litre	0.2% (w/v)	30 min	Safe for clothes and body decontamination. Especially useful for FMD virus decontamination.
Aldehydes:					
Glutaraldehyde	Conc. solution	as appropriate	2% (w/v)	10–30 min	Excellent disinfectant effective against virus categories A,B and C.
Formalin	40% formaldehyde	1:12	8%(w/v)	10–30 min	Disinfectant; releases irritating, toxic gas.
Formaldehyde gas	Special generation required			15–24 hr	Toxic gas, recommended only if other methods of decontamination cannot be used.

[1] Usual form supplied.

[2] Recommended working strength.

[3] Final concentration.

[4] Required contact time for inactivation of disease agents.

Notes:

- Commonly used general disinfectants such as phenolics and quaternary ammonium compounds are very effective antibacterials but have limited effectiveness against category B and C viruses; they are not included in Table 4.
- Products effective for decontamination of viruses on the hands and the skin are limited. Virkon® is reported to have low toxicity and to be effective against members of all 17 virus families but it has not been approved for use on skin. Alternatively, citric acid or sodium carbonate may be added to washing water to induce antiviral conditions by lowering or raising the pH as appropriate for the agent to be inactivated. w/v = weight/volume (e.g. 2g/100ml)

In general and unless no alternatives are available, the use of formaldehyde gas on rural properties is not recommended. Unfortunately, no satisfactory alternative to formaldehyde for gaseous decontamination is available. Use of ethylene oxide or hydrogen peroxide for gaseous decontaminations must be restricted to carefully controlled laboratory environments.

There is no simple answer to the problem of decontaminating of vehicle cabins and electronic equipment on a farm. A methodical and systematic approach based on first principles may have to be substituted. Cleaned vehicles and other machinery left in quarantine for a week in bright sunshine are likely to decontaminate naturally with respect to most pathogens. Because the parameters for effective formaldehyde decontamination are so

difficult to establish on farm premises, formaldehyde gas is unlikely to produce an absolute result or be significantly more effective than thorough cleaning. Where gaseous decontamination of equipment or machinery is considered to be unavoidable, specialist advice should be sought and the contaminated equipment kept in quarantine until that time. Further information on the practicalities of using formaldehyde gas is given in Appendix 3.

Table 4 shows which disinfectant should be used for inactivating each category of virus and what dilutions/concentration should be used.

Estimation of quantities required

The amount of decontaminating agent necessary for particular jobs varies considerably. For a polished, non-porous floor, 100 ml/m^3 of disinfectant/chemical is probably sufficient. For porous surfaces such as concrete or wood, however, the volume may need to be doubled or tripled.

Generalizations are not useful, because application of liquids to ceilings or vertical walls cannot be well controlled.

It is most important to remember that once a surface has been cleaned, the time it is in contact with the decontaminating agent is of critical importance. For most applications, disinfectant must flood the surface and keep it thoroughly wet for at least 10 minutes.

SAFETY PRECAUTIONS

General safety precautions First-aid boxes must be available on every IP, DCP or where hazardous chemicals are being used. Before commencing operations, it is essential to brief workers and the property owner on safety aspects, including the potentially harmful effects of chemicals on animals, humans and the environment.

The use of any chemical or equipment should conform to the manufacturer's instructions and safety standards. All officers and workers must carry out their duties in accordance with current health and safety legislation. Accidents which require medical attention, however small, must be logged and details reported back to the local disease control centre.

Acids and alkalis

When diluting concentrated chemicals, the concentrate should **always** be added to water, **never** water to concentrate. Do not mix acid and alkali disinfectants: apart from the resulting chemical reaction, the effectiveness of both chemicals is nullified. Contact with concentrates on exposed skin will cause severe burning. All workers engaged in mixing or applying disinfectants must wear boots, overalls, goggles and head covering for protection. Use a full-face guard when applying the diluted chemical. To avoid the danger of inhalation, do **not** apply a mist spray.

If contact occurs:

- wash with copious amounts of water immediately;
- alkali burns: apply vinegar;
- acid burns: apply bicarbonate of soda;
- eyes: wash the eyes copiously with eye-wash solution and refer to hospital;
- refer for hospital treatment if necessary.

Store concentrate containers in one place on the property away from the main area of work to avoid the danger of containers being ruptured inadvertently. Check the containers each day for spillage.

Aldehydes - formalin, glutaraldehyde and formaldehyde gas

These disinfectants should be used only when no alternatives exist and only by experienced personnel with appropriate safety equipment. Gaseous formaldehyde is applicable to:

- all enclosed spaces which can be made airtight (e.g. grainbins, electrical fuse boxes covered in plastic);
- enclosed spaces which contain electronic or electrical machinery;
- delicate equipment which can be enclosed in a plastic tent and fumigated;
- some heavy machinery/vehicle cabins;
- poultry incubator rooms and egg rooms.

The safety of the operator is of primary importance. The method of using formaldehyde is based on safety aspects (see Chapter 4).

These substances can kill operators and even small amounts can have a detrimental effect on all living tissue. If the chemical enters the eye, a wound or an abrasion, it is extremely painful. The fumes damage all mucous membranes.

Always wear a protective face guard when mixing.

This method should only be used when it is impossible to use other procedures.

Warning notices should be fixed to the entrance of an area being fumigated. There should be two people involved in the operation - both equipped with **full-face respirators** effective against formaldehyde gas.

TABLE 5
Special considerations when using disinfectants

Disinfectant	Health aspects	Environmental problems and contra-indications
Hypochlorites	Toxic for eyes and skin.	Strong bleach. Inhibited by high concentrations of organic matter, Corrosive for many metals.
Virkon®	Reasonable care necessary.	
Sodium hydroxide	Caustic for eyes and skin.	Avoid contact with strong acids. Cannot be used on aluminium or similar alloys.
Sodium carbonate	Mildly caustic for eyes and skin.	Avoid use with aluminium and similar alloys.
Hydrochloric acid	Toxic for eyes, skin and respiratory passages.	Corrosive for concrete and many metals. Avoid contact with strong alkalis.
Glutaraldehyde	Avoid eye and skin contact.	
Formalin solution	Releases toxic gas; irritating for mucous membranes.	
Formaldehyde gas	Very toxic for mucous membranes in concentrations down to 2 ppm.[1]	Cannot be used in presence of water, hypochlorites or chlorides. Cannot be released to atmosphere without neutralization. Corrosive for some metals.

[1] ppm = parts per million