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Chemical disinfection of non-porous inanimate surfaces experimentally contaminated with four human pathogenic viruses

S. A. SATTAR, V. S. SPRINGTHORPE, Y. KARIM AND P. LORO

Department of Microbiology and Immunology, Faculty of Health Sciences, University of Ottawa, Ottawa, Ontario, Canada K1H 8M5

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SUMMARY

The chemical disinfection of virus-contaminated non-porous inanimate surfaces was investigated using coxsackievirus B3, adenovirus type 5, parainfluenzavirus type 3 and coronavirus 229E as representatives of important nosocomial viral pathogens. A 10 μl amount of the test virus, suspended in either faeces or mucin, was placed onto each stainless steel disk (about 1 cm in diameter) and the inoculum allowed to dry for 1 h under ambient conditions. Sixteen disinfectant formulations were selected for this study based on the findings of an earlier investigation with a human rotavirus. After 1 min exposure to 20 μl of the disinfectant, the virus from the disks was immediately eluted into tryptose phosphate broth and plaque assayed. Using an efficacy criterion of a 3 $\log_{10}$ or greater reduction in virus infectivity titre and irrespective of the virus suspending medium, only the following five disinfectants proved to be effective against all the four viruses tested: (1) 2% glutaraldehyde normally used as an instrument soak, (2) a strongly alkaline mixture of 0·5% sodium *o*-benzyl-*p*-chlorophenate and 0·6% sodium lauryl sulphate, generally used as a domestic disinfectant cleaner for hard surfaces, (3) a 0·04% solution of a quaternary ammonium compound containing 7% hydrochloric acid, which is the basis of many toilet bowl cleaners, (4) chloramine T at a minimum free chlorine level of 3000 p.p.m. and (5) sodium hypochlorite at a minimum free chlorine concentration of 5000 p.p.m. Of those chemicals suitable for use as topical antiseptics, 70% ethanol alone or products containing at least 70% ethanol were ineffective only against coxsackievirus B3. These results emphasize the care needed in selecting chemical disinfectants for routine use in infection control.

INTRODUCTION

Outbreaks of viral infections in institutional settings are quite common and it is not unusual for more than one virus to be circulating simultaneously within a given institution (Meissner *et al.* 1984; Payne, Grilli & Smith, 1984). The exact means of spread of viral agents in many such outbreaks still remain unclear, but, for many viral pathogens, multiple vehicles may be involved. Evidence suggests that virus-contaminated surfaces may play a role (Pattison *et al.* 1974; Maynard, 1976; Hall, Douglas & Geiman, 1980; England, 1982; Pancic, Carpenter & Came,

1980; Hutto *et al.* 1986; Sattar *et al.* 1986; Sattar & Springthorpe, 1987; Ansari *et al.* 1988*a*). Even when aerosolization of infectious virus occurs, settling of coarse particles results in the contamination of surfaces. Therefore, chemical disinfection of environmental surfaces as well as hand antisepsis are routinely practised in an effort to prevent and control the spread of infectious diseases, and may be particularly important in the case of viral infections, where the minimal infective dose is often very low (Westwood & Sattar, 1976; Graham, Dufour & Estes, 1987; Ward *et al.* 1986).

Although many commercial disinfectants are tested for their bactericidal efficacy, their virucidal potential is rarely examined. We have previously demonstrated that many commercial products are ineffective for the disinfection of rotavirus-contaminated inanimate surfaces (Lloyd-Evans, Springthorpe & Sattar, 1986) and skin (Ansari *et al.* 1988*b*). In this investigation a selected range of disinfectants was tested to determine whether the trends observed with rotaviruses could be extended to other types of human pathogenic viruses known to cause outbreaks in institutions.

Since the structure and composition of a given virus determine the degree of its susceptibility to various classes of chemical disinfectants, four representative human pathogenic viruses were chosen according to the following criteria: (1) should belong to a virus group which is known to cause outbreaks of disease in institutional settings such as hospitals, nursing homes and day-care centres, (2) should grow to relatively high titres in cell culture and permit quantitation by plaque assay and (3) should be capable of surviving on fomites long enough to allow virus transmission, and (4) should not require a high level of biohazard containment. On this basis, coxsackievirus B3 (CB-3) was selected to represent the enteroviruses which are considered to be relatively resistant to chemical disinfection, and adenovirus type 5 (AD-5) was used to represent adenoviruses which have intermediate susceptibility to disinfectants.

Even though enveloped viruses are known to be more readily inactivated by chemical disinfectants than non-enveloped viruses, their susceptibility may be overestimated when they are dried onto surfaces in their natural organic load. Two different types of enveloped virus, parainfluenzavirus type 3 (HPIV-3) and human coronavirus 229-E (HCV-229E), were chosen. As a cause of lower respiratory tract infections in young children, parainfluenzaviruses are only second in importance to RSV, and their ability to spread in institutional communities is also well documented (Mufson, Mocega & Krause, 1973; De Fabritis *et al.* 1979; Meissner *et al.* 1984; WHO, 1985; Ford-Jones, 1987). Institutional outbreaks of respiratory (Kaye, Marsh & Dowdle, 1971; Wenzel *et al.* 1974), and possibly enteric (Vaucher *et al.* 1982), coronavirus infections have also been recorded.

MATERIALS AND METHODS

Viruses and cells

A field isolate of CB-3 and a laboratory strain of HPIV-3 were grown and plaque-assayed in the MA-104 line of rhesus monkey kidney cells. Cultivation, maintenance and passage of these cells have been described in detail elsewhere (Sattar *et al.* 1984). AD-5 was obtained from Dr L. Previc, McMaster University,

Hamilton, Ontario, Canada. This virus was propagated and plaque assayed in HeLa cells. HCV-229E was grown and plaque-assayed in L-132 cells.

For virus assays, cell monolayers were prepared in 12-well plastic cell culture plates (Costar, Cambridge, MA, USA) with minimal essential medium (MEM; Autopow; Flow Laboratories, Inc., Rockville, MD, USA) containing 5% fetal bovine serum (FBS) and 50 μg/ml gentamicin (Cidomycin; Roussel, Montreal, Quebec, Canada). The seeded plates were sealed in plastic bags (Philips, Toronto, Ontario, Canada) and incubated for 48 h at 37 °C for monolayer formation.

Plaque assays

Aliquots (0·1 ml) of tenfold virus dilutions in Earle's balanced salt solution (EBSS) were allowed to adsorb to cell monolayers for 1 h at 37 °C; not less than three wells of a 12-well cell culture plate were inoculated for each virus dilution. The overlay media were as follows: for CB-3 and HPIV-3, MEM with 0·6% (w/v) agarose (Sigma Chemical Co., St Louis, MO, USA; type II, product number A6877) and 2% FBS (Gibco); for AD-5, MEM with 0·8% (w/v) agarose (Sigma), 0·1% (w/v) yeast extract (Difco; BDH Inc., Toronto, Ontario, Canada), 5% horse serum (Flow Laboratories, Inc.) and 20 mM magnesium chloride; for HCV-229E, M-199 (Gibco) with 0·6% (w/v) Oxoid No. 1 agar (Oxoid Canada Ltd, Ottawa, Ontario, Canada), 2% (v/v) FBS, 0·005% (w/v) 5-bromodeoxyuridine (Sigma; product number B-5002) and 0·02% (w/v) DEAE-dextran (Sigma; product number D9885). All overlays contained gentamicin at 50 μg/ml.

Overlaid cultures were incubated at 37 °C except those infected with HCV-229E, which were kept at 33 °C. Incubation was continued for 2 days for CB-3, 5 days for HCV-229E and HPIV-3, and 7–9 days for AD-5. Monolayers were fixed overnight in 3·7% formaldehyde in normal saline and stained with a 0·1% aqueous solution of crystal violet to demonstrate virus plaques.

Suspending media

The virus samples tested were suspended in either faeces or mucin. Normal infant faeces, which had been previously tested and found to be free of any indigenous viruses, were suspended 1:10 (w/v) in normal saline and clarified of large clumps of faecal material by centrifugation at 1000 g for 15 min. Aliquots of the virus were diluted 1:10 (v/v) in the clarified faeces before testing. Lyophilized bovine mucin (Sigma, Product No. M-4503) was used at a concentration of 5 mg/ml, which is representative of the levels found in normal human secretions (Diem & Lentner, 1970); the mucin preparation was also found to be free of indigenous viruses. Aliquots of the virus were diluted 1:10 (v/v) in the mucin preparation before testing. Controls were always included to determine the plaque titres of the inoculated virus in the suspending medium used and after drying the inoculum for 1 h on the inanimate surface; infectious virus titres of 10^4–10^6 plaque forming units (p.f.u.)/disk were used to demonstrate a 3 $\log_{10}$ reduction.

Inanimate surfaces

The inanimate surfaces used for this study were stainless steel disks, approx 1 cm diameter, punched from #4 finish polished stainless steel purchased locally. The procedures for the cleaning, decontamination and sterilization of these disks have already been described (Lloyd-Evans, Springthorpe & Sattar, 1986).

Table 1. *Disinfectant formulations tested and their efficacy against selected respiratory and enteric viruses*

Disinfectant			Reduction of virus titre by > 99·9%			
Active ingredient(s) (identifying name)	Concentration (%) and (approx. pH) at in-use dilution	Rationale for choosing	CB3	HPIV3	HCV	Ad5
Sodium hypochlorite (hypochlorite)	0·01 (8·0)	Widely used disinfectant because of low cost and ready availability, used on hard surfaces and for soaking soiled articles	No	No	No	No
	0·10 (9·4)		No	Yes	Yes	No
	0·50 (11·0)		Yes	Yes	Yes	Yes
	1·00 (11·4)		Yes	n.d.	n.d.	Yes
Chloramine T (organochlorine)	0·01 (7·0)	Example of organic chlorine demand-type disinfectant, widely used for hard surface disinfection	No	Yes	No	No
	0·10 (8·0)		No	Yes	Yes	No
	0·30 (8·0		Yes	Yes	Yes	Yes
	0·50 (8·0)		Yes	n.d.	n.d.	Yes
Sodium hypochlorite and potassium bromide (mixed halide)	0·01 (10·0)	Mixed halides have sometimes been reported to have greater efficacy than sodium hypochlorite alone	No	No	No	No
	0·05 (11·5)		No	Yes	Yes	No
	0·10 (12·0)		No	Yes	Yes	No
Povidone-iodine (iodophore)	10·00 (3·0) (1 % iodine)	Widely used for antisepsis and as preoperative skin preparation	No	Yes	Yes	No
Ethanol (alcohol)	70·00 (4·0)	Widely used alone and as basis for many disinfectants and antiseptics	No	Yes	Yes	Yes
Glutaraldehyde (glutaraldehyde)	2·00 (7·0)	Widely used instrument soak and often considered to be a chemosterilant	Yes	Yes	Yes	Yes
n-Alkyl (50% C14, 40% C12, 10% C16) dimethyl benzyl ammonium chloride (quaternary ammonium)	0·04 (6·0)	Chosen as an example of a quaternary ammonium disinfectant with a single active ingredient so that additional chemicals could be added to the formulation	No	No	No	No

n-Alkyl (50% C14,* 40% C12, 10% C16) dimethyl benzyl, ammonium chloride, HCl (quaternary ammonium with HCl)	0·04 (1·0) 7·00	Quite similar to previously tested formulations of toilet bowl cleaners	Yes	Yes	Yes	Yes
n-Alkyl (50% C14,* 40% C12, 10% C16) dimethyl benzyl, ammonium chloride Ethanol (quaternary ammonium with ethanol)	0·04 (5·0) 70·00	To examine the combined activity of quaternary ammonium compounds with ethanol	No	Yes	Yes	Yes
n-Alkyl (50% C14,* 40% C12, 10% C16) dimethyl benzyl, ammonium chloride Sodium metasilicate (quaternary ammonium with metasilicate)	0·04 (11·0) 0·5	To examine how the addition of sodium metasilicate affects the efficacy of the quaternary ammonium	No	Yes	Yes	Yes
Chlorhexidine gluconate Cetrimide, (chlorhexidine)	0·008 (5·0) 0·08	Widely used as general purpose antiseptic and for handwashing	No	Yes	No	No
Chlorhexidine gluconate Cetrimide Ethanol (chlorhexidine with ethanol)	0·05 (4·5) 0·50 70·00	Widely used for preoperative skin preparation	No	Yes	Yes	Yes
o-Phenylphenol *o*-Benzyl-chlorophenol *p*-Tertiary amylphenol, (phenolic)	0·02 (9·0) 0·03 0·01	Representative substituted phenolic which had been effective in some previous antiviral tests	No	No	No	No

Table 1. (*cont.*)

Disinfectant: Active ingredient(s) (identifying name)	Concentration (%) and (approx. pH) at in-use dilution	Rationale for choosing	Reduction of virus titre by > 99·9% CB3	HPIV3	HCV	Ad5
o-Phenylphenol* *o*-Benzyl-chlorophenol *p*-Tertiary amylphenol Sodium lauryl sulphate, (phenolic with SDS)	0·02 (9·0) 0·03 0·01 0·60	Phenolic modified by the addition of extra detergent	No	Yes	Yes	No
o-Phenylphenol* *o*-Benzyl-chlorophenol *p*-Tertiary amylphenol Ethanol, (phenolic with ethanol)	0·02 (6·0) 0·03 0·01 70·00	To examine the combined effect of the phenolic and 70% ethanol	No	Yes	Yes	Yes
Sodium *o*-benzyl-*p*-chlorophenate Sodium lauryl sulphate, (phenolic with SDS)	0·50 (13·0) 0·60	Phenolic disinfectant for general domestic use, especially on bathroom surfaces	Yes	Yes	Yes	Yes

Concentration (%) at in-use dilution for hypochlorite, organochlorine and mixed halide indicates free chlorine concentration measured by DPD method.

* Indicates formulation is modification of commercial product.

CB-3, coxsackievirus B3; HPIV-3, human parainfluenzavirus type 3; HCV, human coronavirus 229E; AD-5, adenovirus type 5.

n.d., not done.

Disinfectants

The disinfectants used were selected on the basis of previous work with a human rotavirus (Springthorpe *et al.* 1986; Lloyd-Evans, Springthorpe & Sattar, 1986); they are listed in Table 1 under their active ingredients. Trade names are not given to avoid recommending a particular product when other similar formulations may be available but have not been tested. Furthermore, many disinfectants are marketed on a local or national rather than an international basis, and the same formulation may be sold under a variety of trade names in different countries. In addition, some of the disinfectants listed in Table 1 are not commercial formulations, but are modifications where the nature of the modification and the concentration of additives may have been suggested by competing products. The nature of the diluent, if any, can markedly affect the virucidal activity of a disinfectant (Sattar *et al.* 1983; Wallis *et al.* 1963). Disinfectants were diluted according to the manufacturers' instructions, using tap water except where 70% ethanol is indicated as an active ingredient and diluent. Determinations of available chlorine by the DPD method used a commercial kit (Hach Chemical Company, Ames, IA, USA).

Test procedure

The test procedure was modified only slightly from that used previously (Lloyd-Evans, Springthorpe & Sattar, 1986). The virus suspension (10 μl) was deposited onto the centre of each disk held in a horizontal position and the inoculum allowed to air dry for 1 h under ambient conditions. The contaminated area on the disk was overlaid with 20 μl of the disinfectant. After 1 min of contact at room temperature (22–24 °C) each disk, with the virus and disinfectant still in place, was dropped into a vial containing 1 ml of tryptose phosphate broth (TPB; Difco) for virus elution. This immediately diluted and neutralized the disinfectant and allowed efficient recovery of the inoculated virus.

RESULTS AND DISCUSSION

The results of this study are summarized in Table 1. The criterion of efficacy for the disinfectants was $\geqslant 3$ $\log_{10}$ reduction in the number of infectious virus units. Each result is based on no less than three trials on each of two batches of the disinfectant. If the $\geqslant 99{\cdot}9\%$ reduction could not be met consistently during the trials, then the disinfectant was regarded as ineffective. Since no difference in disinfectant efficacy was observed when CB-3 was suspended in faeces or mucin, the results shown in Table 1 do not specify the suspending medium. The rationale for the experimental protocols and parameters chosen has already been published (Lloyd-Evans, Springthorpe & Sattar, 1986; Sattar & Springthorpe, 1988), but it is important to restate that the contact time of 1 min is longer than that often used for hard surface disinfectants in the field. Where disinfectants are used in more critical applications as instrument soaks with longer contact times in the field, then the test conditions of 1 min ensure a safety margin for formulations which are deemed effective.

The enveloped viruses, HPIV-3 and HCV-229E, were more readily inactivated

by all the disinfectants tested than were the non-enveloped viruses, CB-3 and AD-5. This is not surprising, and is in agreement with the other studies where comparisons have been made between the susceptibility to disinfectants of enveloped and non-enveloped viruses (Klein & Deforest, 1963; Mahnel, 1974, 1979; Brown, 1981; Klein & Deforest, 1983; Schurmann & Eggers, 1983). In spite of this, not all the disinfectants tested at their recommended in-use dilutions were able to inactivate the enveloped viruses dried onto surfaces.

The different types of chlorine-based disinfectants tested all reliably inactivated the enveloped viruses at 1000 p.p.m. free chlorine. Interestingly, at this free chlorine concentration, the action of sodium hypochlorite against CB-3 was much weaker (a reduction of about 1 $\log_{10}$) than for either the organochlorine or the mixed halide (a reduction of 2–3 $\log_{10}$). All chlorine-based disinfectants are markedly inhibited by organic material, and these results suggest that, subject to any toxicity constraints, organic chlorine compounds which act as demand-type disinfectants, may be more effective than solutions of sodium hypochlorite in the field. Mixed halogens have been reported to be more effective than chlorine alone (Cheremisinoff, Cheremisinoff & Trattner, 1981) although they are not widely used as disinfectants, and the mechanism of their increased efficacy is not completely understood.

Increasing the free chlorine concentration to 3000 and 5000 p.p.m. for the organochlorine and hypochlorite products, respectively, inactivated all the viruses tested. Our previous studies (Lloyd-Evans, Springthorpe & Sattar 1986) suggest that even 5000 p.p.m. free chlorine as sodium hypochlorite may be insufficient to inactivate human rotavirus suspended in faeces and dried onto inanimate surfaces whereas chloramine T, providing a similar concentration of free chlorine, could readily inactivate the virus under the same conditions. It is possible that at least some component of the disinfecting power of concentrated hypochlorite solutions is due to their content of sodium hydroxide; the pH of hypochlorite solutions in the 5000–10000 p.p.m. range is in excess of 11·0, whereas the organochlorine tested here had a pH of approximately 8·5.

In the field, free chlorine concentrations between 25 and 500 p.p.m. are generally used for disinfection of surfaces. On the other hand, the guidelines generally used for disposal of virus-contaminated material or coping with spills of virus-contaminated liquids recommend the use of sodium hypochlorite at a free chlorine concentration of 5000–10000 p.p.m. The results obtained here and previously (Lloyd-Evans, Springthorpe & Sattar, 1986) support the use of these high concentrations when virus contamination is suspected.

The results with chloramine T at 0·01% (100 p.p.m.) show an apparent difference in sensitivity to chlorine between HCV-220E and HPIV-3. This difference may be related to the degree of cell association of the virus; HPIV-3 was harvested from infected MA104 cells as a cell free supernatant, whereas HCV-229E was harvested after cell degeneration and is known to be more closely associated with cellular material.

The high in-use concentration of available iodine (1%) in the iodophore failed to inactivate either of the non-enveloped viruses in this study, although it had demonstrated previously (Lloyd-Evans, Springthorpe & Sattar, 1986) a much greater efficacy against human rotavirus than other iodophores tested under

identical conditions. This iodophore is designed for topical application as a preoperative skin preparation: the pH is approximately 3·0. Other, more acidic, iodophores may have greater activity against the non-enveloped viruses and both iodine and acid activity may be augmented if additional non-ionic surfactant is present (Jordan & Nassar, 1973).

Only CB-3 was not inactivated by either ethanol alone, or when ethanol was introduced as an addition to other disinfectants. In earlier studies on enterovirus disinfection (Drulak, Wallbank & Lebtag, 1978; Drulak *et al.* 1978) ethanol had appeared to be among the most effective disinfectants. However, these studies had been conducted using suspension not carrier tests. Similarly, ethanol alone was also very effective against human rotavirus in suspension (Springthorpe *et al.* 1986) but not in carrier tests (Lloyd-Evans, Springthorpe & Sattar, 1986). Nevertheless, ethanol and products containing at least 70% ethanol were the most effective among antiseptics tested on rotavirus-contaminated hands (Ansari *et al.* 1988*b*).

At the concentration used for disinfection of fibre-optic endoscopes and other instruments (2%), glutaraldehyde was highly effective against all tested viruses as it was against rotavirus (Lloyd-Evans, Springthorpe & Sattar, 1986). It has also been shown to be effective against many viruses in suspension tests, although parvoviruses were somewhat more resistant and required longer contact times (Scott, 1980; Brown, 1981). We are not aware of tests on parvovirus disinfection on contaminated surfaces. The virucidal potential of glutaraldehyde is concentration dependent and claims for the efficacy of formulations with lower glutaraldehyde levels on the disinfection of naturally-contaminated surfaces should be treated with some caution.

The quaternary ammonium compound alone was virtually useless against the test viruses dried onto surfaces; it did not even inactivate the enveloped viruses HPIV-3 and HCV-229E. A similar result was obtained previously with rotaviruses (Springthorpe *et al.* 1986; Lloyd-Evans, Springthorpe & Sattar, 1986). This is important because of the widespread use of quaternary ammonium based formulations for general hard surface disinfection, and the usual recommendation that they be applied to precleaned surfaces is neither safe nor practical. Studies of virus disinfection with quaternary ammonium compounds in suspension tests, have shown various degrees of efficacy, but non-enveloped viruses, particularly picorna-, calici- and parvoviruses, are the most resistant (Klein & Deforest, 1963; Blackwell, 1978; Poli *et al.* 1978; Scott, 1980; Brown, 1981).

The quaternary ammonium/HCl combination is commonly used in formulating toilet bowl cleaners, and its efficacy is believed to be mainly due to the pH of the solution. Similar compounds were shown to be effective against rotavirus (Lloyd-Evans, Springthorpe & Sattar, 1986) although a differential sensitivity of rotaviruses to acids was noted (Springthorpe *et al.* 1986). Addition of ethanol to the quaternary ammonium compound conferred on this combination the same virucidal properties as for ethanol alone and a similar result was obtained when this combination was used against rotavirus (Lloyd-Evans, Springthorpe & Sattar, 1986). Sodium metasilicate is a highly alkaline compound in solution and is widely used alone as a disinfectant for veterinary purposes and at lower concentrations in quaternary ammonium disinfectant and detergent formulations.

Addition of sodium metasilicate to the quaternary ammonium compound resulted in an increased inactivation of all tested viruses except CB-3; a result consistent with that obtained against human rotavirus (Springthorpe *et al.* 1986).

Aqueous chlorhexidine gluconate was effective only against HPIV-3, and even that may have been partially due to the cetrimide present. Chlorhexidine gluconate alone is known to be a poor virucide (Derbyshire & Arkell, 1971; Bailey & Longson, 1972; Gardner & Gray, 1983; Springthorpe *et al.* 1986). As discussed above, observed differences in susceptibility of HPIV-3 and HCV-299E may be due to differences in cell association of the viruses. The alcoholic solution of chlorhexidine, at the concentration recommended for preoperative skin preparation, showed the same spectrum of activity against the tested viruses as ethanol alone and it was also effective against human rotaviruses (Lloyd-Evans, Springthorpe & Sattar, 1986). Due to the potent bactericidal properties of chlorhexidine salts and their residual activity on the skin, their importance in topical antisepsis, particularly in alcoholic solution, cannot be underestimated.

The two phenolics were selected because they were among 4 of the 17 phenolics which proved to be effective against human rotavirus in suspension (Springthorpe *et al.* 1986). However, on surfaces one was effective and the other was not (Lloyd-Evans, Springthorpe & Sattar, 1986). The results of the present study with the two products tested alone showed the same dramatic difference; one was effective against all the test viruses while the other was not effective against any. The relative concentrations of the phenolics (0·5%, w/v for the effective product compared with 0·06%, w/v) are assumed to be responsible for this difference because addition of 0·6% SDS to the ineffective product made it effective against HPIV-3 and HCV-299E only. Addition of ethanol to the ineffective product gave it the same spectrum of efficacy against the tested viruses as ethanol alone.

Disinfection implies that pathogen concentrations have been reduced to levels which no longer pose a risk to the susceptible host. Apart from specialized clinical and research laboratories, field application of disinfectants is inevitably on inanimate surfaces or skin. In view of the results obtained here and in previous studies (Kirchhoff, 1969; Nakao *et al.* 1978; Klein & Deforest, 1983; Schurmann & Eggers, 1983; Lloyd-Evans, Springthorpe & Sattar, 1986), it is essential that disinfectants are tested on contaminated carriers, although suspension tests may be useful for initial screening of formulations (Springthorpe *et al.* 1986).

The known susceptibility of many disinfectant chemicals to neutralization by organic soil suggests that testing of these chemicals should always be conducted with a realistic challenge. Although the organic loads present during these disinfectant tests were designed to simulate natural organic loads, naturally-shed virus, already embedded in an organic matrix such as faeces or mucus, may be even more resistant to inactivation than when the virus is added externally to that matrix. Therefore, caution should be exercised in extrapolating disinfectant efficacy directly from the laboratory to the field. Nonetheless, laboratory tests are capable of distinguishing which of a range of chemical disinfectants is most likely to be effective in the field, and of showing inadequate concentrations. Laboratory tests therefore examine the *potential* of disinfectant solutions but field trials are necessary to determine their true efficacy.

No standard methods are available for testing disinfectant efficacy against

viruses: even those in routine use for bactericidal efficacy are under review. An urgent need exists for testing protocols which use clinically relevant conditions and contact times and can reliably predict field efficacy. Many clinicians believe that most disinfectants are equally effective in the field: we do not think this is true. The majority of antimicrobial chemicals sold in North America are either quaternary ammonium compounds (38%) or phenolics (20%) which behave very poorly as surface virucides under simulated field conditions. It is, however, difficult to define what role *effective* disinfection could play in disease prevention because the present spectrum of disease transmission exists where many of the disinfectants are inadequate. Formulations used in this study were carefully selected after a systematic survey of many products; selection based only on advertising or sales advice is likely to be a lottery at best. Because the minimal infective dose for many viruses is extremely low, and the numbers shed in body secretions and excretions may be high, disinfectants used routinely for controlling and preventing the spread of viral infections in areas such as daycare centres (Klein, 1986) and hospital neonatal and critical care facilities should be chosen with great care.

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