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# Glove disinfection and aseptic technique: Creating a schema for the cleanroom and laboratory

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## Introduction

There are different elements that contribute to good aseptic technique within the cleanroom and the laboratory. One such element is the donning of gloves (1), handling items appropriately, and keeping gloves regularly disinfected (2). Glove disinfection is an essential step for bacteriological control, although how successful control is maintained is dependent upon the type of disinfectant (these are generally alcohols for gloved hands) (3), frequency of application, volume of disinfectant, application technique and the contact time. Other variables include purchasing gloves of a suitable material and design, and appropriate training. Aa an added control with more critical areas, the gloves are pre sterilised before donning (often purchased sterile by radiation or ethylene oxide).

As with other types of disinfection, the aim is not 'sterilisation' but to bring any bacterial density present on the gloves down to a level that is as low as possible (what is sometimes referred to as the "irreducible minimum") (4). Assessment, when required, is commonly through the use of agar contact plates onto the fingertips of each gloved hand (four fingers and the thumb) to create the 'finger plate' or 'finger dab'. To avoid false negatives, the agar needs to be formulated with an appropriate disinfectant neutraliser.

For cleanroom and laboratory managers seeking to maximise the maintenance of asepsis, glove control is an important element. This should take the form of a good practice schema and for this to be transitioned into a training module, supported by regular prompts in practice.

In terms of what such a schema should look like, this article appraises the research that underpins an appropriate glove 'sanitisation' schema. This includes the central concerns of *when* and *how* effective glove disinfection is to be achieved (5). The key findings are that a 30 second disinfection time is suitable for both cleanroom and laboratory operations, provided a suitable technique is deployed and an alcohol-based disinfectant used. However, controls need to be in place to avoid the over disinfection of gloves since repeated applications increase the likelihood of microperforations occurring and thereby effective glove disinfection needs to be supported by a regular glove change procedure.

## Microbial risks

The microbial risks to gloved hands bear a relationship to the microorganisms associated with human skin. Three principal types of 'skin flora' are commonly described: resident, transient and, occasionally, infectious flora. The resident flora is found on the surface of the skin and under the superficial cells of the stratum corneum. The microecological conditions of the epidermis favours Gram-positive organisms and are unsuitable for long-term Gram-negative colonization (6). Typical organisms include, in order of abundance: *Staphylococcus epidermidis*, *S. hominis* and other coagulase-negative staphylococci, followed by coryneform bacteria such as propionibacteria, corynebacteria, dermabacteria, and micrococci (7 – 9). The primary fungus is the yeast *Malassezia* (10). The transient skin flora consists of bacteria, fungi, and viruses that may be found on the skin only at times; they usually do not multiply on the skin, but they tend to survive (11, 12). The transient organisms will be more varied, and these will relate to personal practices, habitat and geography.

Whilst facilities will have processes in place for handwashing and hand disinfection, such microorganisms will be present in cleanroom air and on surfaces due to the activities of operators and these may end up on the surfaces of gloves. In addition, gloves are prone to occasional integrity breaches. Contamination can also arise from donning gloves during change procedures or following glove changes. Donning gloves in particular takes time and it provides opportunities for error. For example, disinfection before and after gloves use may be forgotten or gloves may be put on even though the hands are still wet from the disinfectant or handwash. Theoretically, the greater likelihood is with residential skin organisms although transient flora may also be present depending upon the suitability of facility entry and early stage changing protocols.

For entry into the cleanroom and for aseptic laboratory work, the optimal means of reducing contamination levels is through the wearing of surgical gloves and the periodic application of a disinfectant. The use of disinfectants like isopropyl alcohol and ethanol at 60-70% is a long-established practice, dating back to at least 1888 (13), at least for the control of vegetative skin bacteria and the transient organisms (14, 15). The emphasis upon 'vegetative' is important since such agents are not sporicidal (16). No commonly used sporicidal agent is suitable as a hand or glove disinfectant for safety reasons.

Although ethanol and isopropyl alcohols are the most common glove disinfectants, there are variations with their formulation and the possibility of additives being used. In addition, there are alternative handwash and hand rub solutions available. An ideal glove disinfectant (17):

- Will be fast acting.
- Will be easily applied.
- Stay wet for the contact time.
- Where it is alcohol based, it will have a minimum alcohol content of 60%.
- Be persistent (effective for a period of time following application).
- Be cumulative in terms of its efficacy (repeated application may cumulatively inhibit bacterial growth more effectively compared to a single application).
- Be appropriately labelled, including the recommended dosage and the percentage of alcohol contained.
- Not damage the glove, at least over several applications.
- Be sterile, if required.
- Be delivered in a way that avoids re-contamination of the disinfectant.
- Have a low environmental impact.
- Possess a broad spectrum of activity; and
- Be safe to use.

To evaluate surviving microbial levels, this is typically assessed using agar plates of a sufficient size as to allow a replication of the four finger and thumb of each gloved hand to be sampled (an alternative method is using swabs, although this is less common). Such sampling can be organised pre-application of a glove disinfectant and post-application, depending on what is being evaluated. To comply with pharmaceutical regulations like EU GMP Annex 1 for cleanrooms, the assessment of activities in cleanrooms of Grade A and B requires the gathering of data immediately post-activity and prior to the application of the disinfectant. The standard agar for this monitoring is tryptone soya agar. While the commonly used disinfectants - ethanol and isopropyl alcohols – have a fast evaporation rate, it is best practice to incorporate a disinfectant neutraliser into the agar formulation to overcome residual disinfectant and hence to avoid false negative results. The optimal neutraliser is a combination of lecithin, saponin, and polysorbate, based on the Dey and Engley formulation (18). A suitable neutraliser will be one (19):

- That effectively inhibits the action of the disinfectant solution.
- Be a neutraliser that is itself not unduly toxic to the expected microorganisms.
- Where the neutraliser and active agent do not combine to form a toxic compound.

Neutralisers do not, however, aid the recovery of microorganisms that have become sub-lethally injured by exposure to the disinfectant agent (20).

### Gloves and aseptic technique

In cleanrooms and laboratories, unless special protective measures are required from chemicals, surgical gloves are used to protect workers from samples and pathogens and as contributory means towards achieving aseptic technique (21). Importantly, the wearing of gloves should never be seen as a substitute for poor aseptic technique or some type of mitigation measure. Cleanroom and laboratory workers must remain mindful of how microorganisms can be transferred to critical areas through touch and by airflow disruption.

The quality of the glove is important, with latex gloves generally being superior to vinyl gloves for the purposes of disinfection and in being less prone to leakage, compared to other materials like nitrile, which has less elasticity than latex (22), or vinyl, which is more vulnerable to damage from ethyl alcohol and which has a lower tensile strength compared with nitrile or latex (23). To address weaknesses with glove materials, some facilities use double-gloving in aseptic areas to safeguard the consequences of perforations occurring in the glove (gloves are not an absolute barrier to the transmission of skin bacteria) (24). While wearing sterile surgical gloves goes some way towards hand hygiene controls, glove wearing in itself does not prevent overuse or misuse (25). Appropriate additions include regular glove changing (the 2022 revision to EU GMP Annex 1, for example, recommends that gloves are changed following an intervention) and the regular application of a disinfectant, together with a reproducible hand sanitisation technique (26). The frequency of glove changing is sometimes overlooked, yet this is an important consideration since the process of cleansing gloves will, at some point after repeated application, reduce the integrity of the material and this could reduce the integrity normally afforded by the glove (27). This is dependent upon (28):

- Glove thermomechanical performance,
- Duration of use,
- Disinfectant chemical permeation,
- The effects of hand temperature,
- Degree of movement,
- Manipulation of instruments.

However, even under optimal conditions there will be a point when repeated disinfection applications leads to microperforations forming. The creation of these very small perforations appears to occur somewhere between eight and ten applications of a disinfectant when used in conjunction with surgical gloves, according to research. For example, one study found that glove integrity was maintained after eight rounds of glove disinfection (29); whereas, a different study showed that ten applications of 70% ethanol led to a 5% possibility of a loss of glove integrity, with the greatest points of weakness being the interdigital webs and the fingers of the glove (30). This means we can place the point of vulnerability between eight and ten cycles of glove hand disinfection, at which point gloves should be changed or a different operator takes over the activity.

For glove disinfection there are three common agents: 60-70% ethanol, 60-70% isopropyl alcohol (equivalent to propan-2-ol; occasionally propan-1-ol is used as an alternative), and alcoholic chlorhexidine (a cationic biguanide) (31, 32). Alcohols are more commonly used in pharmaceuticals,

with some healthcare facilities preferring chlorhexidine. Sometimes these hand agents are referred to as sanitisers. In the U.S., the Environmental Protection Agency (EPA) classes both sanitisers and disinfectants for surface applications (33); within Europe, 'sanitiser' features in the common lexicon but it does not have a precise definition, hence hand or glove disinfection / disinfectant is the preferred terminology.

Alcohols have a nonspecific mode of action against bacteria, killing cells through denaturation and the coagulation of proteins (34); chlorhexidine targets the cytoplasmic membrane of bacteria. In terms of relative efficacy, this is dependent upon the types of microorganisms likely to be present. Microbial types will vary according to geography, the nature of the cleanroom environment and the health of the individual (including conditions such as eczema) although the central concern will remain bacteria associated with human skin (35). Against skin bacteria, the consensus of studies is with alcoholic chlorhexidine being less effective than ethanol and isopropyl alcohol, and ethanol being slightly more efficacious than isopropyl (36, 37). However, chlorhexidine is less prone to cause dermatitis or contact urticaria syndrome when applied directly to skin (38), although denatured ethanol also has acceptable skin tolerability when made up with suitable emollients or humectants, making both agents generally suitable for bare hands as they causes less skin irritation and dryness compared with untreated ethanol or isopropyl alcohol (39).

With efficacy on gloved hands, the consensus from experimental data is with n-propanol > isopropanol > ethanol (40, 41). Therefore, for bactericidal activity isopropyl alcohol is slightly more bactericidal than ethanol, particularly in relation to Gram-positive cocci (42). However, for virucidal activity, ethanol is more effective than isopropanol (43). The relative performance of the different disinfection agents is provided in Table 1.

In terms of format, the alcoholic disinfectants in liquid form have generally been shown to be more effective than in gel-form (44 – 46). Alcohols are also more efficacious at temperatures above 30$^{o}$C compared with 20$^{o}$C, although this is not practicable for cleanroom use. As well as killing organisms by increasing the likelihood of contact between the disinfectant and the microbial cell wall, the process of rubbing disinfectant into hands may assist with decolonisation via particle removal (47) and vigorous rubbing is more effective at achieving bacterial reductions from gloved hands than more gentle wiping (48).

### Application techniques

The correct and consistent application of the disinfectant to gloved hands is an essential part of contamination control. Whereas the choice between spraying and pouring the disinfectant onto gloved hands does not make any statistical difference (49), the volume applied is important in relation to efficacy and for practical use. Too small a volume of disinfectant, inadequate coverage of gloved fingertips, and a short drying time will all enable bacteria to persist on an operator's hands. Generally, as indicated in Table 1, a volume of 2-3mL appears sufficient (50) and anthropometry studies do not show any great significance between genders or in relation to palm surface area or with hand surface area when this volume range is applied (51). Moreover, too great a volume can lead to a stickier, less clean-feeling and become slower to dry (to dry within 30 seconds, the optimal volume was shown in one study to be between 1.7 and 2.1 mL (52), although this will be subject to local variation). Too great a volume can also result in increased difficulty in handling items post-application. It is standard for manufacturers to recommend a dosage of between 2 and 3 mL. The aim when determining is to avoid the hand or glove from drying out as the disinfectant is applied before the contact time has elapsed (nominally 30 seconds, as the analysis in Table 1 suggests).

A proven application technique across a 30 to 60 second period, as set out by the World Health Organisation (WHO), is (53, 54):

- Palm to palm.
- Right palm over left dorsum and left palm over right dorsum (five times).
- Palm to palm with fingers interlaced (five times).
- Backs of fingers to opposing palms with fingers interlocked (five times).
- Rotational rubbing of right thumb clasped in left palm and vice versa (five times).
- Rotational rubbing, backwards and forwards with clasped fingers of right hand in left palm and vice versa (five times).

Some users advocate beginning with finger-tips first rather than palms (55).

Assessing the required volume and time to achieve an effective reduction from the hands of operators depends upon:

1. Whether gloved hands or bare hands were evaluated (studies suggest this is only of marginal significance and most comparisons are within an acceptable margin of error). Where there is a difference, disinfection efficacy for disinfectant/glove combinations has been found to be greater than for ungloved hands (56). Certainly when residual activity is considered, disinfectants that are formulated with ingredients to protect the skin, such as glycerol, are less effective compared with disinfectants without such additives (57).
2. Glove material type (58).
3. The challenge organism. Due to safety reasons, for bare hands, in the United States this is commonly *Serratia marcescens*, whereas a non-pathogenic *Escherichia coli* is the main contaminant used in Europe (59). For gloved hands, there are fewer restrictions as to the organism type.
4. The starting inoculum
5. The acceptance criteria
6. The robustness of the study

With Europe, there are norms for evaluating hand disinfectants on either bare or gloved hands. These are *in vivo* tests designed to assess post-contamination treatments, hygienic hand wash and hygienic hand rub, where a hand rub is a treatment that involves rubbing the hands without the addition of water (EN 1499 and EN 1500 respectively) (60, 61). Products are evaluated against the challenge bacterium *Escherichia coli* K12 (NCTC 10538) using multiple subjects (15 or 18, depending upon the standard). These standards set the contact time to be tested is either as per manufacturer's recommendation or for a time that is not shorter than 30 seconds and not longer than 60 seconds (± 5 seconds). Products under test are compared with a reference material where the contact time is 60 seconds. According to the requirements of the norm, the formulation under test shall not be significantly less efficacious than a reference material, that is, the product under test must show non-inferiority. In the U.S., the equivalent standard is ASTM E2755-10, deploying a different challenge organism (62). There are differences between the standards with the methods of hand contamination and modes of recovery.

These tests are generally undertaken by manufacturers and it is not commonplace for users to replicate them, although there is nothing to preclude laboratories from doing so if there are atypical organisms to assess and infection risks can be adequately controlled.

To pass, the product must achieve an equal or greater log reduction than the reference material (unmedicated liquid soap, in the case of EN 1499 or propan-2-ol 60% in the case of EN 1500). However,

no set log reduction exists and therefore the evaluation needs to be based on the expected bioburden levels. The assessment of the log reduction is derived from an expression of the pre- and post-values recovered from the fingertips when evaluated against one another, resulting in a ratio commonly called the 'reduction factor' (63). These evaluations are multi-subject human challenge trials (EN 1500 requires 18 to 22 volunteers) and these approaches are regarded as superior, since they more closely replicate in practice conditions, compared to an *in vitro* suspension test.

Predating the EN protocols, since the 1970s there has been an interest in hand and glove disinfection studies with several experiments undertaken. Some studies have examined the natural microbial population, while other studies have used artificially contaminated hands or gloves in order to make the reduction factor evaluation. Through a review of these, it is possible to build a consensus as to the optimal requirements for a pharmaceutical cleanroom or laboratory hand disinfection schema. The review of literature is based on those studies, assessed by the author, and possessing a robust design (such as randomised controlled trials). The output of this meta-review is summarised in Table 1.

**Table 1:** Assessment of peer-reviewed hand sanitisation studies

| **Study** | **Year** | **Volume of disinfectant applied** | **Contact time** | **Miccroorganisms** | **Alcoholic chlorhexidine** | **Ethanol** | **IPA** |
|---|---|---|---|---|---|---|---|
| Lowbury *et al* (64). | 1974 | 5mL | Until dry | Assessment of skin-flora | 0.5%: 2-logs | 70%: 2-logs | 70%: 2-logs |
| Ayliffe (I) *et al* (65). | 1975 | 5mL | Until dry | *S. aureus* | 0.5%: x̄ 3.6 | 70: x̄ 2.6 | N/A |
| Ayliffe (II) *et al* (66). | 1978 | 5mL | 30 sec. | *S. aureus*, *S. saprophyticus*, *E. coli*. | 0.5%: 2.4 to 3.7 logs | 70%: 3.4 to 3.7 logs | N/A |
| Rotter (67) | 1984 | 3mL | 30 sec.<br><br>60 sec. | *E. coli* | N/A | N/A | 60%: 2-logs (30 sec.)<br><br>60%: 4-log (60 sec.) |
| Aylifee (III) *et al* (68). | 1988 | 5mL | 30 sec. | *E. coli* | 0.5%: 2.9 logs* | N/A | 70%: 3·1 to 3·8 logs |
| Babb *et al* (69) | 1991 | 2-3mL | 30 seconds<br><br>2 minutes | Assessment of skin-flora | N/A | N/A | 70%: 1.6 logs<br><br>70%: 1.7 logs |
| Wade *et al* (70) | 1991 | 2-3mL | 30 seconds (assessment up to 3 minutes after challenge) | *Enterobacter cloacae* and *Enterococcus faecium* | 0.5%: 4-logs | N/A | 60%: 4-logs |
| Goroncy-Bermes (71) | 2001 | 2-3mL | 30 sec. | *E. coli, M. luteus*** | N/A | 70%: 5-logs | 70%: 5-logs |
| Guilhermetti (I) *et al* (72) | 2001 | 3-5mL | 30 sec. | *S. aureus* | N/A | 70%: 3.5 logs | N/A |
| Kampf and Hollingsworth (73) | 2003 | 2-3mL | 30 sec. | 13 gram-positive species, 18 gram-negative species, | N/A | N/A | 70%: 3 logs |

| Study | Year | Volume of disinfectant applied | Contact time | Miccroorganisms | Alcoholic chlorhexidine | Ethanol | IPA |
|---|---|---|---|---|---|---|---|
| | | | | and 14 emerging pathogens. | | | |
| Kampf (I) *et al* (74) | 2003 | 3mL | 30 secs | *Pseudomonas aeruginosa, Escherichia coli, Proteus mirabilis, Staphylococcus aureus, Enterococcus hirae and Candida albicans* | N/A | 70%: 5-logs | 70%: 5-logs |
| Kampf and Kramer (75) | 2004 | 2-3mL | 30 sec. | Assessment of skin-flora | N/A | N/A | 70%: 1.5 logs |
| Rotter (I) *et al* (76) | 2006 | 2-3mL | 3 minutes | Assessment of skin-flora | 1-log | 85%: 3-logs | 60%: 2 logs |
| Rotter (II) *et al* (77) | 2007 | 2-3mL | 3 minutes | Assessment of skin-flora | 3-logs | N/A | 60%: 3-logs |
| Kampf and Hollingsworth (II) (78) | 2008 | 2 mL | 15 secs | 11 Gram-positive, 16 Gram-negative bacteria and 11 emerging bacterial pathogens | N/A | 85%: 5-logs | N/A |
| Kampf (II) *et al* (79) | 2010 | 3mL | 30 secs. | *E. coli* | N/A | 60%: 3-logs | 70%: 5-logs |
| Guilhermetti (II) *et al* (80) | 2010 | 3mL | 60 secs. | *E. coli* | N/A | 70%: 5-logs | N/A |
| do Prado *et al* (81). | 2012 | 3mL | 30 secs. | *E. coli* | N/A | 70%: 3-logs | N/A |

| **Study** | **Year** | **Volume of disinfectant applied** | **Contact time** | **Miccroorganisms** | **Alcoholic chlorhexidine** | **Ethanol** | **IPA** |
|---|---|---|---|---|---|---|---|
| Dharan *et al* (82) | 2015 | 2-3mL | 15 secs<br><br>30 secs | *S. aureus, Pseudomonas aeruginosa E. faecalis* | N/A | N/A | 60%: 5-logs (both times) |
| Pires *et al* (83) | 2019 | 2-3mL | 15 secs<br><br>30 secs | *E. coli, S. aureus* | N/A | N/A | 60%: 5-logs (both times) |

N/A = Not applicable (or not stated)

*Residual activity noted, although in general the residual activity from alcohols is low due to the rapid evaporation rate (84).
** No difference reported between *E. coli* and *M. luteus*, the researchers suggest that *E. coli* is a perfectly suitable substitute for skin bacteria.

The consensus of the studies assessed in the table is for sufficient bactericidal and yeasticidal activity to be achieved, especially for ethanol and isopropyl alcohol (85), within 30 seconds. No specific resistance mechanisms are currently known in relation to alcohols (86, 87) therefore the historical nature of some of the research is not called into question by this factor.

Some studies have evaluated times below 30 seconds. For practitioners wishing to conform to EN 1499 or EN 1500 requirements for GMP purposes, it should be noted that times below 30 seconds (such as 15 seconds as used in some studies) are outside the edicts of the standards (88). This is notwithstanding that, in many case, 15 seconds appears to be equally as effective as 30 seconds (89) where the mean bacterial reduction after 15 seconds of hand rubbing demonstrates non-inferiority across several studies. Certainly, there is no consistent case for 60 seconds. It is possible that a short time (below 30 seconds) could also be justified, for cleanroom environments, on the basis that cleanrooms being maintained under aseptic conditions are unlikely to lead to operators carrying any more than 5 CFU on their hands. These are levels considerably below the $10^6$ to $10^8$ challenge inocula used in many of the referenced studies. This reasoning might be less applicable in laboratory settings where concentrated microbial populations are handled and hence a longer contact time is required to address the higher challenge and since gloves might also have traces of reagents which could interfere with the rate of disinfectant activity. When assessing disinfectant efficacy, selecting the desire logarithmic reduction and determining the microbial challenge is important. As this author has pointed out, a 3-$\log_{10}$ reduction, for example, will have a very different meaning depending on the starting point of the microbial challenge (90).

At the other end of the scale, it is important that hand hygiene efficacy studies do not seek to test the efficacy of hand hygiene agents for unrealistically long contact times, such as beyond 60 seconds, otherwise compliance is unlikely to be achieved (91) It could be argued that even 60 seconds is challenging to achieve within a busy cleanroom. To illustrate the challenges of compliance, one meta-study found that across 8 out of 14 studies for the healthcare sector, workers sanitised their hands for less than 10 seconds and the maximum time recorded was 24 seconds (92).

### Cross-contamination via gloves

In laboratories, and to an extent in cleanrooms (depending upon the adequacy of initial training), the wearing of gloves can create what psychologists refer to as the ‘false consensus effect’ (93), such as beliefs that gloves provide enough protection without recourse to periodic or targeted glove disinfection (94, 95), or a misunderstanding as to the relative effectiveness of the disinfectant (96). This is manifest in situations where hand hygiene occurs less often when gloves are worn, such as with laboratory workers more likely to move from dirtier to cleaner tasks when they used gloves without sanitizing their hands (97), or in cleanrooms where hands are not disinfected as often as they need to be. These cross-contamination concerns have been demonstrated using florescent staining methods (98). To address this, the risks around glove-to-surface and surface-to-glove contamination transference need to be included in initial training and reinforced through supervisory oversight. Trainers need to be mindful of consensus bias and be mindful that their own actions relating to good glove sanitization as not necessarily widespread through the general population and hence every potential poor practice needs to be addressed. For training, using non-disruptive ultraviolet markers and ultraviolet lights can prove useful for demonstrating to trainees those areas of their hands or gloves that have been sufficiently treated with a hand disinfectant and those which have not.

### Regularity of application

The relative efficacy of different alcohol hand sanitiser products and application techniques are limited if personnel neglect to apply products to their gloved hands at regular intervals. It is important to

create robust training and awareness schemes so that regular application becomes habitual, such as with ensuring there are sufficient hand sanitisation stations close to where employees work. In terms of access to hand sanitisers, there are different psychological models for cleanroom managers to consider. One is to have a sufficient number of hand sanitisation stations close to where people work, to increase convenience (contextual cuing) (99). The other is to have fewer stations in less accessible areas so the effort is greater and hence adherence becomes more of a conscious act and hence something that is more likely to be executed (100).

In addition to regular application, gloves must be disinfected prior to each critical activity occurring. Critical activities will include open processing and interacting between cleanroom environments of different classifications. The most important scenario is prior to interacting with the aseptic core within a cleanroom (ISO class 5 / EU GMP Grade A environments).

### Contaminated glove disinfection stations

Hand disinfectant dispensers will often accumulate contamination and the numbers of bacteria will increase throughout the day unless the dispensers are periodically disinfected. Because some personnel will associate disinfectants with microbial reduction, the criticality of the dispenser surface may not be at the forefront when surface decontamination is considered (101). Here, experiences from the healthcare sector in relation to emphasizing the contamination transfer risks from ‘high touch’ surfaces could be useful for embedding into training competencies.

### Summary

Alcohol-based hand disinfectant products are effective for cleanroom and laboratory use for the treatment of gloved hands. 60 to 70% ethanol or IPA have demonstrated good activity against vegetative bacteria, mycobacteria, yeasts, dermatophytes, and enveloped viruses, based on a review of the studies presented in Table 1.

The purpose of this article is to help cleanroom and laboratory managers to establish appropriate, science-based guidelines when setting the rules for hand and glove disinfection. Such guidelines should be clear and easy to follow so they become the standard practice. Thus, guidelines are needed that do not leave to the operator a decision as to glove disinfection is indicated at a certain time and by means of a variable application. Instead, such decisions should be core to the standard operating procedure.

The main findings from this paper, which can be used in a protocol or procedure, have been summarised diagrammatically below (Figure 1):


**Figure 1:** Suggested (and essential) points to include in a glove disinfection schema

The main focus of this paper was to establish that a volume of 2-3mL of an alcoholic based hand disinfectant can adequately disinfect gloves, when applied using a standard method, in around 30 seconds. With this established, cleanroom managers can focus more on the *when* rather than the *how*.

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