



## **HYGIENE PROCEDURES IN THE HOME AND THEIR EFFECTIVENESS: A REVIEW OF THE SCIENTIFIC EVIDENCE BASE**

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**This paper reviews the scientific evidence base which was used in the preparation of the IFH consensus paper "Recommendation for selection of suitable hygiene procedures for use in the domestic environment".**

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## 1. Introduction

The evidence reviewed in the IFH keynote paper “The need for a home hygiene policy and guidelines on home hygiene” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)) shows that infectious diseases arising in the home setting are a significant concern. Although a proportion of these infections arise from direct person to person interaction or consumption of contaminated food, increasingly the evidence shows that significant numbers of infections, not only food-borne but also person-to-person infections, relate to cross contamination via the hands or other surfaces etc, and that improved standards of hygiene could do much to reduce the spread of this infection. The data supporting this view is reviewed in the IFH paper “The infection potential in the domestic setting and the role of hygiene practice in reducing infection” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)).

Although many of the respiratory and gastrointestinal infections relating to the home, particularly those caused by viruses, are relatively non-serious and self-limiting (coughs and colds, etc.), they still represent a significant economic burden. Social and demographic changes now also mean that increasing numbers of people who have reduced immunity to infection are cared for at home. For these groups, the elderly, neonates, pregnant women, immune-compromised patients discharged into the community, patients taking immuno-suppressive drugs or using invasive systems (indwelling catheters) or inhalation systems or devices, the consequences of infection can be much more serious and may require hospitalisation. These people need to be cared for in the home by a carer (who is quite likely to be a family member) who has a good knowledge of hygiene and may be called upon to carry out procedures, similar to those performed in hospital, which carry considerable infection risks. The increase in the number of “at risk” people in the home is likely to continue; estimates from the US and UK suggest that approximately 20% of the population of these countries can now be classified within an “at risk” group (Gerba *et al.* 1996, Bloomfield 2001). WHO estimates suggest that, by 2025 there will be more than 800 million people over 65 years old in the world, two-thirds of them in developing countries (WHO 1998).

Developing effective hygiene policy for the home must start from an acceptance that pathogenic and potentially pathogenic species (bacteria, viruses, fungi and protozoa) are continually and inevitably introduced into the home on people, food, pets, insects and sometimes via the air. Contaminated water is also a problem, not only in low-income countries but also many European countries and North America. Additionally sites where stagnant water accumulates such as sinks, U-bends, toilets, and cleaning cloths readily support microbial growth and can become a source of infection. Although organisms achieving this are for the most part only a risk to vulnerable groups, primary pathogens can also be present e.g. recent studies show that *Salmonella* can become resident in the toilet and dishcloths for a more or less extended period in homes where a *Salmonella* case has been reported (Wilson *et al.* 1998, Barker and Bloomfield 2000). Pathogens from food, people etc also occur “transiently” at these sites, and, as discussed in the IFH review cited above, on all types of hand and food contact surfaces where they can remain viable for considerable periods.

Fundamental to developing infection prevention policy is the need to recognise that the home is an environment where all human activities occur including food hygiene, personal hygiene (particularly hands) and hygiene related to care of vulnerable groups, and that all of these aspects are based on the same underlying microbiological principles. In recent years the concept of HACCP (Hazard Analysis Critical Control Point) has successfully controlled microbial risks in food and other manufacturing environments. Traditionally the public has tended to regard good hygiene as creating an environment free of germs. To devise hygiene policy that has real health benefits the IFH believes (as also suggested by other workers (Bloomfield and Scott 1997, Griffith *et al.* 1998, Jones 1998)) that a risk-based approach must also be developed and promoted for the home. In applying this approach, the first step, hazard characterisation, involves identifying the sites and surfaces where pathogens are most likely to be found. Consideration must also be given to whether these microbes are likely to be present in numbers that represent an infectious dose. The number of organisms necessary to cause infection varies for different species and is likely to be lower for vulnerable groups compared with healthy family members. The final stage, risk assessment, depends on considering this information together with an assessment of the probability of human exposure to the hazard.

A consideration of the home setting suggests that hygiene policy based on risk assessment can be achieved by categorising sites and surfaces in the home into a number of groups:

- Harmful microbes are likely to occur on the **hands** of people who are designated carriers. This applies for example to carriers of *Staphylococcus aureus* but carriers of faecal pathogens are equally of concern, particularly following toilet visits. Pathogens are also likely to occur on the hands following contact with contaminated food, people, pets or other contaminated surfaces. Since the hands are probably the main vector for transfer of pathogens in the home, hand hygiene is of particular importance.
- For **potential reservoir sites** such as sink U-bends or toilets, which provide an ideal environment for microbial growth, although the probability of contamination is high, the risk of transfer under “normal” conditions, is relatively small – but can increase considerably in certain situations (e.g. where someone has fluid diarrhoea).
- For **reservoir/disseminator sites** such as wet cleaning cloths which carry a high risk of transfer and thus exposure, it is imperative that these sites are decontaminated in a suitable manner.
- Although the probability of contamination for **hand contact and food preparation surfaces** is, in relative terms, much lower, it is still significant particularly following preparation of contaminated food or contact with faecal material. Since there is constant risk of cross contamination, preventative measures are critical for these situations.
- Where an infected or carrier person is present in the home **laundry** may become contaminated and carries a risk of transfer to clean laundry during handling and the laundry process. This represents a risk mainly to those handling the laundry.
- For **other surfaces** (floors, walls, furniture etc.) there is little case for hygienic decontamination except where there is known risk e.g. soiling of floors by pets.

For situations where significant risk is identified, an effective hygiene procedure must be applied to prevent cross contamination. It must be remembered that the purpose of this procedure is to reduce micro-organisms to a level which is not harmful to

health. It is not intended to achieve sterility and some microbial exposure is expected. Promotion of a risk-based or targeted approach to home hygiene is compatible with concerns that some exposure to micro-organisms is important in maintaining a “healthy” immune system. By targeting hygiene selectively and ensuring, as far as possible, that the level of “hygiene assurance” (i.e. the level of residual contamination after the application of the hygiene procedure) is commensurate with the extent of the risk associated with microbial exposure, the risk of infection is minimised whilst some exposure to microbes is maintained.

In order to achieve a hygienically clean (as opposed to a visibly clean) site or surface either the organisms must be removed or they must be killed *in situ* by a disinfection process. Alternatively a combination of the two processes may be used. Methods of achieving decontamination of sites and surfaces thus include detergent-based cleaning followed by rinsing, and the use of biocidal agents and/or heat. In selecting the appropriate hygiene procedure for a particular situation a number of factors need to be taken into account including the pathogenicity of likely contamination, the vulnerability of the potential recipients, the nature of the site, and the conditions (overcrowding, facilities, access to clean water etc) within the home.

In 1998, as a first step in improving home hygiene standards, the IFH produced a set of guidelines for home hygiene. The guidelines are based on the risk assessment or targeted approach to hygiene, which specifies that infection prevention through reduced exposure to pathogens is most effectively achieved by identifying the sites and situations in the home which represent the greatest infection transmission risk and targeting practices at these sites at the appropriate time. A second amended version which takes account of issues specific to developing countries has now also been produced. The Guidelines are based on the available scientific evidence as documented in the IFH consensus paper “the infection potential in the domestic setting and the role of hygiene practice in reducing infection” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)). The guidelines focus on specifying where and when hygiene procedures should be applied in order to reduce the risk of exposure to pathogens.

Subsequent to the development of these guidelines IFH have also now produced a set of “Recommendations” which detail the procedures to be used where a hygiene risk is identified ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)). These recommendations address both general situations in the home and situations of specific risk. The following paper is an assessment of the scientific evidence base, which was used in drafting the “recommendations”.

In formulating the Guidelines and Recommendations documents IFH took account of the fact that, in many respects, the domestic environment is very different from settings such as hospital and food manufacturing environments. Although overall the infection risks in the home may be less than in environments such as hospitals, hygiene knowledge and understanding, and the quality of the facilities available in the home is often much lower. Whereas in institutional and other environments implementation of hygiene procedures is regulated and sanctions can be implemented for non-compliance, this is not the case in the home. The benefit derived from the application of a hygiene procedure depends not only on the effectiveness of the procedure but also the manner in which it is applied, which in turn depends on the knowledge and understanding of the person applying them.

This paper thus takes into account not only theoretical but also practical considerations i.e. not just what people ought to do in their home – but what field studies indicate that they actually do. For these reasons, the IFH believe that in recommending hygiene procedures for a particular situation in the home there is need for considerable flexibility, in that the final decision should be made on the basis of a risk assessment which relates to the local conditions, and may thus vary considerably from one locality to another and one home to another.

## **2. Hygiene procedures which are applicable in the home and their effectiveness**

### **2.1 Detergent-based cleaning as a means of achieving hygiene**

It is acknowledged within the food industry that the most common cleaning medium is water (Sprenger 1989) which has the ability to dissolve many residues and form a solution that can be washed away. However, since water is not efficient in dissolving many of the residues encountered in food preparation and other situations, chemical agents such as detergents are also required. In principle hygiene can be achieved by detergent-based cleaning, but since this depends on physical removal of the organisms from the surface, not only mechanical action but also a thorough rinsing process with clean water must form an integral part of the procedure.

Relatively few quantitative studies have been carried out to establish the effectiveness of detergent-based hygiene procedures, and most of these relate to commercial premises used for food production or to handwashing, particularly in the hospital setting. Many of these reports relate to the use of “sanitisation” procedures which involve a combined cleaning and disinfection process and only relatively few relate to detergent-based cleaning alone.

In a study of the cleanability of unused and abraded sink materials, Holah and Thorpe (1990) showed that spray cleaning with water for 10 seconds reduced the count of biofilms of *Acinetobacter calcoaceticus* containing about  $10^7$  cfu/sq. cm attached to stainless steel, enamelled steel, mineral resin and polycarbonate surfaces by 3 logs to about  $1.5-3.7 \times 10^4$  cfu/sq. cm. When the study was repeated using abraded surfaces, the cleanability was significantly reduced to around a 2 log reduction for enamelled steel, mineral resin and polycarbonate surfaces. These workers (Stevens and Holah 1993) showed that wiping of contaminated abraded surfaces using a sponge followed by a 10 second rinse produced a 3 log reduction in contamination of stainless steel surfaces but only a 1 to 1.5 log reduction on enamelled steel, mineral resin and polycarbonate surfaces. Scanning electron microscope studies showed that bacteria were typically retained in surface imperfections, surfaces sustaining the most extensive damage retaining higher numbers of bacteria. Ak *et al.* (1994) also demonstrated that although new wood and plastic chopping boards were relatively easy to decontaminate, by contrast, used boards, and particularly plastic boards, were more difficult to clean.

The importance of rinsing was demonstrated by Scott and Bloomfield (1990a) who showed that where contaminated surfaces are wiped using soap and water only, this

merely spreads residual bacteria around the surface and onto the cloth to be spread to other surfaces.

Krysinski *et al.* (1992) studied the effects of cleaning agents on 24h cultures of *Listeria monocytogenes* surfaces ( $5 \times 10^4$  cfu/sq. cm) attached to stainless steel and polyester/polythene. Following 10 min exposure to a range of cleaning agents including an alkaline detergent, a chlorinated alkaline detergent, an anionic detergent and an "enzyme blend", it was found that a reduction to less than  $2 \times 10^2$  was achieved for stainless steel but the reduction for the polyester/polyurethane surface was as little as 0.4 log up to a maximum of 1.5 log.

McEldowney and Fletcher (1988) demonstrated that bacterial desorption varied with surface composition (glass, tin plate, polypropylene, stainless steel and nylon) and the type of bacterial species (*Staph. aureus* and *A. calcoaceticus*) colonising the surface. Where cleaning treatments lead to bacterial desorption, there is a potential for subsequent contamination of other surfaces. Zottola and Sasahara (1994) recommended that, to minimise microbial dispersal, two step cleaning and sanitising procedures should be applied. Cleansing agents generally include components that 'wet' and penetrate the soil, thereby facilitating its removal. Disinfectants and sanitisers are considered to be more efficient after organic material has been removed from the surface, as this enables more effective contact with surface-attached micro-organisms.

## 2.2 Chemical disinfectants as a means of achieving hygiene

For the most part, the bactericidal, fungicidal or virucidal activity of disinfectant products is established by laboratory tests which are quantitative suspension or surface tests which demonstrate the ability of the product at use concentration to produce a given log reduction (usually a 3-5 log reduction) in the number of recoverable organisms in a challenge inoculum, within a specified contact period. The tests are usually carried out using test strains and test conditions (contact time, soiling, hard water etc) which relate to intended conditions of application.

In using data from laboratory tests to set establish disinfectant use concentrations, it is a fundamental requirement that the methods adequately predict use conditions, but in practice there is little data to confirm whether this is the case. "Clinical" or "in use" trials of disinfectant effectiveness are sometimes reported in the literature but, once activity under practical conditions has been established, there is rarely any attempt to relate this back to results of laboratory tests. In a significant proportion of practical situations, surfaces provide a site for adhesion and/or the development of biofilms in which cells are embedded in a polymeric matrix and may be growing under conditions of nutrient limitation. The resistance of resident and transient biofilms to biocides may be very different from that of surfaces dried films prepared using laboratory grown inocula (Brown and Gilbert 1993, Bloomfield 1995).

A further limitation is that the current CEN and AOAC surface test methods give useful data related to organisms attached to hard surfaces but are not applicable to other situations e.g. organisms attached to laundry, cleaning cloths, sponges or to airborne contamination

### 2.2.1 Use of chemical disinfectants for hand hygiene

For hygienic hand disinfection the activity of products which meet the requirements of standard bactericidal, fungicidal or virucidal suspension tests can be further established by tests or trials, such as the CEN handrub and handwash tests (Anon 1997a,b). These tests involve panellists, and as such could be regarded as field trials. In these tests a test organism (*E. coli*) is applied to the hands and the effectiveness of the product in reducing the “release” of bacteria from the hands assessed. For handrubs the product is applied to the skin with a rubbing action for a specified period, whilst for handwash products, the product is applied to the hands and a specified mechanical action is carried out before the hands are rinsed under running water. In each case the residual number of bacteria present on the skin is assessed and the log reduction determined.

Since the initial microbial bioburden on the hands is variable and the number of organisms required to cause infection (the infectious dose) also varies according to the nature of the organism and the susceptibility of the potential new host, for the most part performance standards for hand hygiene procedures are based on what is achievable relative to a benchmark product such as *n*-propanol, and what is known from experience to be associated with satisfactory results under use conditions.

At the present time the approach used for hand hygiene products is to specify that:

- in order to make a claim that a product is a hygienic handrub it must, when evaluated by the appropriate CEN test, produce a log reduction in the release of bacteria from the hands which is at least equivalent to that produced by *n*-propanol (approx. 5 log in 1 min).
- in order to make a claim that a product is a hygienic handwash the log reduction in the release of transient bacterial contamination, when evaluated by the appropriate CEN test, must be significantly greater than that achieved with unmedicated soft soap (approx. 3 log in 1 min).

An approach which can be used to compare the effectiveness of hand hygiene procedures involves determination of microbial quality assurance levels (or more appropriately in this situation “hygiene assurance levels”). This approach, now used routinely in processing of foods or pharmaceutical products, assumes that if a hygiene procedure is applied to a surface (either hands or inanimate surface) contaminated with a given initial microbial bioburden then, according to the log reduction achieved by the hygiene procedure, a quantitative assessment of the risk reduction can be calculated by extrapolation as illustrated in Figure 1. Using this approach the effectiveness of hygiene procedures involving detergent-based physical removal, destruction of microbial contamination, or a combination of both processes can be compared on a quantitative basis.

From the results of such tests it is inferred that, in a practical situation in a hospital, home etc, hands treated with products which meet the specifications of the CEN handwash and handrub tests carry a significantly lower risk of transferring infection than untreated hands or hands washed with unmedicated soap, and that the greater the log reduction the lower the risk of cross infection. However, apart from the observations of Semmelweis relatively few studies have evaluated the relative effectiveness of handrub or handwash product relative to non-medicated products on infection rates *per se*. Where such studies have been carried out however they

support the premise that use of a hand disinfectant in a targeted manner results in reduced infection rates compared with use of unmedicated soap or no handwashing. These studies are reviewed in section 3.1.

### **2.2.2 Use of chemical disinfectants for environmental sites and surfaces**

For disinfectants intended for use on environmental sites and surfaces the activity of products which meet the requirements of standard bactericidal, fungicidal etc suspension test can be further established by surface tests such as the CEN or AOAC surface tests. These tests involve drying a test inoculum onto surface carriers. The surface film is exposed to the disinfectant at use dilution and the log reduction in the release of viable bacteria determined. A comparative study (Bloomfield *et al.* 1991, 1993) of a range of disinfectant products representing those most commonly used in the UK using the proposed European suspension and surface tests indicated that the majority of products at recommended use concentrations produced a greater than 5 log reduction in viable numbers (indicated by no detectable survivors) within 5 min against suspensions of a range of bacterial species, but the same concentrations of some agents/products produced only a 2-4 log reduction when tested against the same organisms dried onto surfaces.

Although, as illustrated in Figure 1, it is appropriate to demand that disinfectant products used for immersion of critical surfaces of hospital medical equipment should produce a minimum 5 log reduction in viable count within the specified contact period, for institutional or domestic environments where surface hygiene is usually achieved by a combination of mechanical action (mopping or wiping) applied with the disinfectant, it may be appropriate to set lower pass/fail criteria for such products commensurate with less stringent “hygiene assurance levels”.

However, unlike CEN hand hygiene tests, no standard tests equivalent to the CEN handwash and handrub tests are available which allow a quantitative assessment of the effectiveness of detergent-based cleaning as compared with the combined effects of mechanical removal (washing) and disinfection, or disinfection alone. Equally standard surface test methods as currently drafted give no indication of their effectiveness when used by a group of panellists in a controlled setting – particularly in relation to their knowledge of hygiene practice.

By contrast with the hand hygiene situation however there is a growing number of studies as reported in section 3.2.6 which illustrate the relative extent to which different hygiene procedures give a reduction in microbial risks when used by participants in the home.

### **2.2.3 Antiviral activity of hand and surface hygiene products**

Transfer of enteric and respiratory viruses in the domestic environment is a particular concern (Sattar and Springthorpe 1996, Bidawid *et al.* 2000, Barker *et al.* 2001). Developing technologies for identification of viruses now show that the greatest increases in GI infection in the UK are attributable to viral agents. The most recent UK review suggests that Norwalk-like viruses (NLV), rotavirus, astrovirus and calicivirus are now responsible for up to 48% of reported IID outbreaks (Evans *et al.* 1998). Indications are that only a relatively small proportion of these viral infections relates to consumption of food purchased from retail outlets, the major proportion relate to person to person transfer via aerosols (vomit), hands and environmental

surfaces. There is also increasing evidence that hands and hand contact surfaces are significant in the transfer of flu and particularly cold viruses. Since viral infections are not treatable by antibiotics, this reinforces the need for prevention through hygiene.

Although the range of handrub, handwash and surface disinfection products currently in use generally have good activity against bacterial pathogens, activity against viral contamination is variable and depends on the type of virus. Experimental evidence suggests that although alcoholic products may be effective against enveloped viruses such as influenza, parainfluenza, HIV, Herpes and Respiratory Syncytial Virus (Groupe *et al.* 1955; Klein and Deforest 1963), activity against non-enveloped viruses such as rotaviruses, Rhinovirus, Poliovirus, Adenovirus, Small Round Structured Virus and Hepatitis virus is limited unless extended contact times (up to 10 minutes) are used. Similarly, agents such as triclosan and chlorhexidine have some activity against enveloped virus but are not considered effective against non-enveloped viruses. Naked viruses such as enteroviruses are inactivated by high concentrations of alcohols (Schurmann and Eggers 1983), the most effective of which is reported to be ethanol (Klein and Deforest 1963). In a recent study Wutzler and Sauerbrey (2000) showed that addition of 80% ethanol enhanced the efficacy of 0.2% peracetic acid, producing inactivation of enveloped vaccinia and papova virus, and non-enveloped polio and adenovirus within a 1 min contact time. The authors propose that the short exposure time and lack of toxic and allergenic properties of this formulation meet the requirements for use as a hand disinfectant.

*In vivo* hand hygiene tests have shown that the effectiveness of alcohols against some difficult viruses such as enterovirus and rotavirus is significantly better than that of hand washing with unmedicated soap (Steinmann *et al.* 1990; Ansari *et al.* 1989; Schurmann and Eggers 1985). Absolute ethanol reduced the viral release from the hands by 3.2 logs, 80% ethanol by 2.2 logs and absolute *n*-propanol by 2.4 logs (Steinmann *et al.* 1990), but with a disinfection time of 10 mins. In contrast, individual hand washing for 10-55 seconds caused a reduction of only 1 log. Schurmann and Eggers (1985) concluded that the commercial high-alcohol content preparation was effective against enteroviruses only under favourable conditions (high temperature, large disinfectant/virus volume ratio, low protein load).

Seventy percent ethanol or isopropanol was approximately 100 times more effective than tap water or liquid soap in reducing the release of human rotavirus from the hands (Ansari *et al.* 1989). Ansari *et al.* (1991) also demonstrated the relative efficiency of handwashing agents in the elimination of rotavirus from fingerpads. Isopropanol (70%) was more effective against rotavirus (98.9% reduction after 10 secs exposure) compared to mediated liquid soap and unmediated liquid soap (72 and 77% reduction respectively). Mbithi *et al.* (1993) found formulations with germicidal agents were better than unmedicated soap for reducing virus titres on fingerpads. Unmediated liquid soap was the least effective agent (78%) for removing Hepatitis A virus, whilst a medicated liquid soap (0.3% triclosan) was the most effective agent (92% reduction). The smallest reduction of poliovirus was with tap water (85%) whilst medicated soap was the most effective (98% reduction).

Sattar and Springthorpe (1996) and Rotter (1997) review the effectiveness of antimicrobial agents against viruses in more detail.

### 2.3 Heat as a means of achieving hygiene

Heat is an effective form of disinfection although it may not be applicable to large surface areas and may be unreliable in unskilled hands. An early survey by Anderson and Gatherer (1970) showed that, although disinfection of infant feeding utensils can be consistently achieved under controlled laboratory conditions using either hypochlorite or boiling, disinfection failures were encountered more frequently with bottles and teats treated by mothers in the home using boiling (54 and 66%) as compared with hypochlorite (22 and 30%).

Set against this however, heat is the method used to reduce contamination levels in foods to a level that is safe for consumption. The operating temperature of dishwashers is also generally sufficient for disinfection of contaminated cooking and eating utensils and can also be used for disinfection of laundry.

### 2.4 Drying of surfaces as a means of decontamination

A number of laboratory-based studies such as those described by Lowbury and Fox (1953), Petit and Lowbury (1968), Rathmachers and Borneff (1977), McEldowney and Fletcher (1988) and Hirai (1991), demonstrate that drying of surfaces has a significant bactericidal effect, although the effectiveness of the process depends on the nature of the organism, the drying time and the conditions of temperature, soiling, humidity etc. Although these studies demonstrate that drying plays a substantial part in maintaining low levels of bacteria in any environment, other studies such as those by Scott and Bloomfield (1990a) indicate that organisms contaminating inanimate surfaces can survive in sufficient numbers for up to 4 hours, and for some species longer, to allow transfer to others surfaces in sufficient numbers to represent an infection risk. For contaminated cleaning cloths (Scott and Bloomfield 1990b) not only survival, but also rapid regrowth of Gram-negative spp. readily occurred at ambient temperature, particularly where cloths remained in a damp condition. Humphrey *et al.* (1994) reported survival of *Salmonella enteritidis* for up to 24h on Formica surfaces after mixing of artificially contaminated eggs in a bowl. Cogan *et al.* (1999) reported survival of *Salmonella* and *Campylobacter* spp. for up to 3h on hand and food contact surfaces in the domestic kitchen following preparation of a fresh contaminated chicken. Similarly, laboratory studies show how rotavirus, rhinovirus, adenovirus, poliovirus, herpes simplex virus and hepatitis A virus can survive for significant periods on dry surfaces (Nerurkar *et al.* 1983; Abad *et al.* 1994; Sattar *et al.* 1986, 1993; Ansari *et al.* 1988; Ward *et al.* 1991).

Thus although drying is an important process for maintaining surfaces in a hygienic condition, it cannot be considered as process of achieving hygiene *per se*.

### 3. Selection of hygiene procedures for use in the home

Using the classification of sites and surfaces in the home as used in the IFH "Recommendations for selection of suitable hygiene procedures for use in the domestic environment" (and as outlined in 1. Above) the scientific evidence base which was used in the formulation of this document is reviewed in this section.

#### 3.1 Hands

Within the home, as in other settings, the hands are probably the most important cause of cross contamination and cross infection. Reports from WHO and UNICEF suggest that sanitation and water-related disease in the developing world could be reduced by up to 60% if compliance with handwashing after defecation could be achieved (Marieke *et al.* 1993, Anon 1989).

##### 3.1.1 Hand hygiene procedures

There are three alternative methods of achieving hand hygiene:

###### 3.1.1.1 Hand washing using soap or detergent and running water

Using this procedure, hygiene is achieved by removal of microbes from the hands. The soap or detergent aids in removal of soil and micro-organisms. Soap may also have some limited bactericidal effect. This method is only effective if the hands are thoroughly "rubbed" and then rinsed with sufficient quantity of running, potable water.

Table 1 shows the effectiveness of handwashing with unmedicated soap on the release of transient bacteria (*Escherichia coli*) from hands. The greatest reduction is achieved within the first 30 seconds which ranges from 0.6 to 1.1 logs after 15 seconds and 1.8 to 2.8 logs after 30 seconds. Extending the washing time to 1 minute results in reduction of 2.7 to 3.0 logs. Increasing the handwashing process for more than 1 minute does not gain any significant additional bacterial reduction.

In a study (Cogan *et al.* 2002) in which participants were asked to prepare a meal using either a *Salmonella* or *Campylobacter*-contaminated fresh whole chicken, the target organisms could be isolated from the hands of 9/20 and 17/20 participants respectively. For the most part the numbers of organisms recovered was less than 10<sup>2</sup>cfu, but on a significant number of occasions counts of greater than 10<sup>2</sup> and 10<sup>3</sup> were recorded. When repeated, but this time participants were asked to clean up using a typical routine involving a bowl of hot soapy water and a cloth, isolation rates were reduced to 1/20 for *Campylobacter*, but 9/20 participants still showed presence of *Salmonella* on their hands and on 3 occasions the counts recovered were greater than 10<sup>3</sup>cfu. In a further study where participants cleaned up in the same way but then rinsed their hands under running water for 10 secs, no samples were positive for *Campylobacter* but 3/20 participants still showed presence of low numbers of *Salmonella* on their hands.

Rheinbaben *et al.* (2000) showed how, following contact with a door handle and handshaking with a volunteer, both contaminated with a model bacteriophage  $\phi$ X174, the virus could be isolated with high frequency from hands of contacts (Table 2). Successive transmission from one person to another could be followed up to the

sixth person. In a repeat experiment participants washed their hands for a period of 10secs and dried them using a paper towel before contacting the next person. It was found that virus transmission was reduced but not prevented by handwashing with bar soap, although this may in part have been due to the fact that the same soap bar was used throughout the experiment. Studies by Schurmann and Eggers (1985) suggest that enteric viruses, particularly poliovirus but possibly also many other enteric viruses, may be more strongly bound to the skin surface and that the inclusion of an abrasive substance in the handwash preparation such as sand or aluminium hydroxide is advisable to achieve effective virus removal from the hands.

### 3.1.1.2 Hygienic hand-rubs which incorporate alcohol

Hygiene hand rubs are products which incorporate alcohol (ethanol, *n*-propanol or isopropanol) at a concentration between 60 and 90% v/v, either alone or combined with an agent such as chlorhexidine (0.5% w/v). These products should preferably be used after hand washing with soap/detergent and water to remove soiling. Hand hygiene results from the inactivation of microbes on the skin surface.

**Table 1:** Reduction of test bacteria (*E. coli*) from hands by washing with unmedicated soap and water

Duration	Mean Log Reduction	Reference
15 sec	0.6 - 1.1	Ojajarvi 1980
30 sec	1.8 2.3 - 2.5 2.5 - 2.8	Marples and Tower 1979, Lilly and Lowbury 1978 Ayliffe et al. 1978 Lowbury and Lilly 1960, Lowbury <i>et al.</i> 1964
1 min	2.7 3.0	Rotter and Koller 1991 Mittermayer and Rotter 1975, Rotter & Koller 1992
2 min	3.3	Mittermayer and Rotter 1975
4 min	3.7	Mittermayer and Rotter 1975

**Table 2:** Isolation of bacteriophage  $\phi$ X174 from hands following person to person contact and handwashing (Rheinbaben *et al.* 2000)

Volunteer	Phage re-isolation – Log count		
	Horizontal transmission	Vertical transmission	
		hand to hand	Hands washed between contact*
0	7.0	7.0	7.0
1	4.6	4.6	4.4
2	3.7	2.6	3.7
3	3.3	1.0	2.9
4	3.3	1.3	2.7
5	2.4	0	1.0
6	3.3	0	-

Model virus with resistance properties similar to poliovirus or parvoviruses.

\*hands washed with soap and warm water (15 secs), rinsed (5 secs), dried with paper towel; the same piece of soap was used by all subjects.

Products used as a hygienic handrub should comply with the European test for Hygienic Handrubs EN1500 (Anon 1997a), which requires that the mean reduction in the release of test organisms following a 1 min contact period should not be less than that achieved by a reference handrub containing 60% v/v propan-2-ol. Table 3 summarises the efficacy of handrubs as assessed in various studies involving contaminated hands. The alcohols (*n*-propanol, isopropanol and ethanol) as well as the halogens (sodium tosylchloramide and povidone-iodine) appear more effective than aqueous solutions of chlorhexidine diacetate, chlorocresol and hydrogen peroxide. For alcohol-based handrubs there is a correlation between mean log reduction and the alcohol concentration. The efficacy of solutions of sodium tosylchloramide and povidone-iodine compares well with that of 60% isopropanol.

The antiviral activity of handrub formulations is discussed in more detail in section 2.2.3.

**Table 3:** Hygienic handrub: efficacy of various agents in reducing the release of test bacteria from artificially contaminated hands (from Rotter and Kramer 1993)

Agent	Concn (%)	Test bacterium	Mean Reduction Log			Reference
			Exposure time (min)			
			0.5	1.0	2.0	
<i>n</i> -propanol	100 60 50 40	<i>E. coli</i>	3.7	5.8 5.5 5.0 4.7 4.3	4.9	Welwaka <i>et al.</i> 1977 Rotter <i>et al.</i> 1977 Rotter <i>et al.</i> 1977; Rotter <i>et al.</i> 1986 Rotter <i>et al.</i> 1977 Rotter <i>et al.</i> 1977
Isopropanol	70  60  50	<i>E. coli</i>   <i>S. marcescens</i> <i>E. coli</i>	3.5  3.4	4.9 4.8  4.4 4.3  4.2 4.0 4.1 3.9	4.4	Rotter <i>et al.</i> 1977 Rotter <i>et al.</i> 1981 Ayliffe <i>et al.</i> 1988 Rotter <i>et al.</i> 1986 Rotter <i>et al.</i> 1981; Rotter and Koller 1992 Rotter <i>et al.</i> 1980 Rotter and Koller 1991 Rotter <i>et al.</i> 1982 Rotter <i>et al.</i> 1977
Ethanol	80 70   60	<i>E. coli</i>   <i>S. aureus</i> <i>S. saprophyticus</i> <i>E. coli</i>	3.6 3.4 3.7 2.6 3.5	4.5 4.3 4.3 4.0 3.8 4.1  3.8	5.1 4.9  4.5	Rotter <i>et al.</i> 1977 Koller <i>et al.</i> 1976 Mittermayer and Rotter 1975 Rotter <i>et al.</i> 1986 Rotter <i>et al.</i> 1977 Ayliffe <i>et al.</i> 1978 Ayliffe <i>et al.</i> 1978 Lilly and Lowbury 1978 Ayliffe <i>et al.</i> 1978 Rotter <i>et al.</i> 1977
Tosylchloramide (aq soln)	2.0	<i>E. coli</i>		4.2		Rotter and Kramer 1993
Povidone-iodine (aq soln)	1.0	<i>E. coli</i>		4.0-4.3		Rotter <i>et al.</i> 1981

Chlorhexidine diacetate (aq soln)	0.5	E. coli		3.1		Lowbury <i>et al.</i> 1964
Chloro-cresol (aq soln)	1.0	E. coli		3.6		Evans and Stevens 1976, Grun and Schopner 1957
Hydrogen peroxide	7.5	E. coli		3.6		Rotter 1984

Hand disinfection products may be applied directly to the hands or by the use of an impregnated handwipe (Jones *et al.* 1986). Jones *et al.* (1986) assessed the use of alcoholic paper hand wipes at two hospitals, in which the skin flora of the fingers of nursing staff was monitored during normal conditions and during 4-week periods when wipes were also available. Unmedicated bar soap was used for handwashing at one hospital and a liquid soap containing Irgasan DP300 was used at the second hospital. The wipes were paper impregnated with an anionic surfactant in 30% (w/w) ethanol. The weekly mean  $\log_{10}$  total viable counts for the 2 trials showed little change in the resident flora of the fingers resulting from use of the wipes. During the first trial the number of samples positive for *Staph. aureus* and for enterobacteria decreased during the use of wipes, compared with soap and water washing. The results indicate that the wipes provide at least an equal and possibly better means of reducing the transfer of transient flora by hand contact.

### 3.1.1.3 Hygienic hand-wash products

A hygienic hand wash is a blend of soap and an antibacterial agent such as chlorhexidine (4% w/v). Hand disinfection is achieved by the combined effects of removal and bacterial kill. Products that are used as a hygienic handwash should comply with the European test for Hygienic Handwash EN1499 (Anon 1997b) which requires that the mean reduction in the release of test organisms following a 1 min wash period should be significantly greater than that achieved by the reference handwash with unmedicated liquid soap.

Table 4 summarises the antibacterial efficacy of hygienic hand washes as assessed by the European Standard EN1499 (Anon1997a). Chlorhexidine gluconate detergent was better than soft soap. These results compare well with those of Ayliffe *et al.* (1988) who found that *n*-propanol and isopropanol formulations were the most effective, followed by chlorhexidine and povidone-iodine preparations, all of which were significantly more effective than non-medicated soap. Soaps containing triclosan were no more effective than non-medicated soap. It can be seen that, of the 5 products, only povidone iodine liquid soap would meet the CEN pass criteria.

**Table 4:** Hygienic handwash: efficacy of various antiseptic detergents in reducing the release of test bacteria from artificially contaminated hands (Rotter and Koller 1991).

Detergent	Concentration (%)	Mean Log Reduction
Povidone-iodine	0.75	3.5
Chlorhexidine gluconate	4.0	3.1
Triclosan	0.1	2.8
2-biphenylol	2.0	2.6
Octenidine	0.5	2.5
Soft Soap	20.0	2.7

The effectiveness of hand hygiene procedures and antimicrobial agents used in handrub and handwash products are reviewed in more detail by Sattar and Springthorpe (1996) and Rotter (1997).

### **3.1.2 Intervention studies to evaluate the impact of handwashing and hygienic handwash and handrub products on infection prevalence under use conditions**

A number of intervention studies have been carried out which establish the significant impact of hand washing in preventing the transmission of infection in different settings.

In a 36-week handwashing education program in child day-care centres, in the US, Black *et al.* (1981) showed that the incidence of diarrhoea in children was significantly and consistently lower (approximately half) than the incidence in the two control centres. Khan (1982) examined the effectiveness of washing hands with soap and water on the spread of shigellosis in community groups in Bangladesh. The test group was provided with soap and water and instructed to wash their hands after defaecation and before meals. The secondary infection rate was 10.1% in the test group compared to 32.4% for the control group. In a more recent study the practice of handwashing with soap and water was instituted in a periurban slum in Bangladesh (Shahid *et al.* 1996). Special emphasis was placed on the use of soap before eating and handling food and after urination and defaecation. During the surveillance period of one year, a large reduction (2.6 fold) in diarrhoeal episodes was found in the intervention group. There was a 60-69% lower rate of cases enteropathogenic *E. coli*, *Shigella* and *Campylobacter jejuni* and all diarrhoeas in the intervention group. In a child-care centre in Brazil, diarrhoea incidence was 73% higher in groups where hand washing before a meal occurred on <25% of occasions compared to the groups where hands were washed more frequently (Barros *et al.* 1999). In kindergarten, groups where <25% of children had their hands washed after defaecation diarrhoea rates were 63% higher than in classes in which >25% had their hands washed. In a recent study Ryan *et al.* (2001) showed that respiratory infections such as coughs were 45% lower for a group of US Navy recruits who were ordered to wash their hands 5 times a day compared with a control group.

As stated previously although it is inferred from the results of e.g. CEN tests that in practice hands treated with handrub and handwash products which comply with these tests carry a significantly lower risk of transferring infection than hands washed with unmedicated soap, relatively few studies have evaluated the relative effectiveness of hand rub or handwash product relative to non medicated products on infection rates. However where such studies have been carried out they support the premise that use of a hand disinfectants in a targeted manner (i.e in situations where there is significant risk of infection transfer) results in reduced infection rates compared with the use of unmedicated soap or with no handwashing.

In a controlled study by Ehrenkranz and Alfonso (1991), in 11/12 experiments, handwashing failed to prevent the transfer of gram-negative bacilli from health care workers' hands to urinary catheters after contact with heavily colonised patients. After hand treatment with 70% (v/v) isopropanol, bacteria were transferred in only 2 of 12 experiments.

Carter *et al.* (1980) demonstrated that families who used an iodine-base hand disinfectant, known to kill rhinoviruses, had lower rates of infection than families using an inactive hand wash.

An 8 month trial was conducted in 3 intensive care units comparing the effects of 2 handwashing systems (Doebbling *et al.* 1992). During the first month each unit used either chlorhexidine gluconate (4% solution) or an alcohol-soap system (60% isopropyl alcohol hand-rinse with optional use of a separate non-medicated soap). In alternate months the other system was used. It was found that nosocomial infection rates in all 3 ICUs declined to a greater extent when the chlorhexidine system was used as compared with alcohol and soap. The authors concluded that the improvement could be explained, at least in part, by better compliance with handwashing instructions when chlorhexidine was used.

Massanari and Hierholzer (1984) compared 3 handwashing compounds (chlorhexidine, povidone-iodine and a liquid soap containing no antiseptic) in 3 intensive care units using a crossover design. In one ICU the nosocomial infection rate when chlorhexidine and povidone-iodine were used was 33.4 and 34.3 infection/1000 patient days respectively, compared to 62.9/1000 days for the liquid soap with no antiseptic. In the other two ICU's the type of soap did not significantly alter the nosocomial infection rate.

In a recent study, Bidawid *et al.* (2000) studied the impact of various hand hygiene procedures in preventing the transfer of hepatitis A virus from fingerpads to pieces of fresh lettuce. When the fingerpads were treated with topical agents or alcohol before the lettuce was touched, the amount of infectious virus transferred to the lettuce was reduced from 9.2% to between 0.3% and 0.6% (depending on the agent used). Surprisingly no virus transfer was detected when fingerpads were rinsed with water alone although in further experiments where the amount of rinse water was reduced from 15ml to 1ml the rate of transfer was 0.3%.

### **3.1.3 Consensus statement on hand hygiene procedures**

Based on the evidence cited above, IFH considers that in the majority of general household situations thorough handwashing with soap and water is sufficient to reduce the risks of infection transmission. To be effective, handwashing must include rinsing with sufficient good quality (i.e. potable) running water and thorough drying. Where good quality running water is not available and/or available in sufficient quantity the use of an alcohol handrub or handwipe is recommended. In situations where there is significant risk of cross contamination involving pathogens (e.g., presence of an infected person or pets, or handling contaminated foods) or where there are family members with increased susceptibility to infection, the use of a hygienic handrub, handwipe or handwash provides an important added safety margin to the normal washing procedure. It must be borne in mind that although some hygienic handrub and handwash products may have activity against both bacteria and enveloped viruses, activity against non-enveloped viruses is limited.

### 3.2 Hand and Food contact surfaces

The evidence reviewed by IFH in the paper “The infection potential in the domestic setting and the role of hygiene practice in reducing infection” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)) shows that pathogenic organisms coming into the home via an infected source such as contaminated water or raw food, an infected person or pets, etc can be spread to hand and environmental surfaces in significant numbers either by direct contact, or in body fluids/excretions or via aerosol particles. These pathogens can persist on environmental surfaces for significant periods of time and be transferred to other surfaces (including the hands) in sufficient numbers to represent an infection risk. It is known that, even for healthy family members, the infectious dose for some enteric and respiratory pathogens, particularly viruses, can be very small (10-100 viable units or even less for some viruses) and that infection can result from direct transfer from surfaces via hands or food to the mouth, nasal mucosa and conjunctiva. Although the infectious dose for enteric pathogens such as *Salmonella* is generally higher (up to  $10^6$  viable units), in some situations it may be relatively low (<100cfu). For species such as *Salmonella* low numbers can grow to high numbers in a few hours at room temperature if transferred to other foods. Transfer of bacteria, fungi and viruses around the home via hand and food contact surfaces increases the risk of exposure of family members, and hygiene procedures which reduce the risk of cross contamination are thus important for these surfaces.

#### 3.2.1 Hygiene procedures for hand and food contact surfaces

There are 3 alternative procedures for achieving hygiene of hand and food contact surfaces:

##### 3.2.1.1 *Cleaning using detergent (liquid or soap) and hot water*

Detergent-based cleaning is considered sufficient to produce a hygienically clean surface provided that the critical rinsing step is adequately performed. The practical ability to rinse a surface free of microbes with running, good quality (i.e., potable) and preferably hot, water is central to achieving hygiene with detergent and water. Studies as reviewed in section 2.1 indicate that the log reduction in bacteria achieved by detergent-based cleaning varies according to the nature of the surface (surface material and roughness) and the mode of application, but is generally of the order of between 0.5 and 3 logs.

##### 3.2.1.2 *Cleaning using soap or detergent, followed by the application of a disinfectant product*

Products used for achieving a hygienic surface, should have rapid microbicidal action against bacterial, viral or fungal pathogens under conditions appropriate to their intended use (presence of soil, temperature, hard water etc). Although, as discussed in section 2.2.2, standard suspension and surface tests can be used to establish that a product has a given profile of activity (spectrum of action, rate of kill, etc) they give no indication of effectiveness under use conditions e.g. when used by a family in the home, particularly in relation to their knowledge of hygiene practice. Most particularly such tests no indication of the log reduction achieved by the application of cleaning or disinfectant products combined with mechanical action and rinsing i.e. the manner in which they are used in the home. By contrast with hand hygiene (for which standard handwash and handrub tests are available) there is however a growing number of studies as reported in sections 3.2.2-3.2.3 which illustrate the relative

extent to which hygiene procedures achieve risk reduction when used by participants in homes or other settings. In general such studies support the premise that the use of a disinfectant in a targeted manner in situations where there is significant risk of infection transfer produces a greater reduction in microbial risk compared with that achieved using detergent-based cleaning alone.

### **3.2.1.3 Cleaning and disinfection using a formulation which combines detergency and disinfection.**

In hospital practice and food manufacturing, it is specified that, since disinfectants are inactivated to a greater or lesser extent by the presence of soil, surfaces should be cleaned before application of a disinfectant. This is particularly important for heavily soiled surfaces, e.g., food-contact surfaces. Within the home, this may be considered less important for surfaces such as door and tap handles where soiling is minimal. Since the time allocated to cleaning in the home is often limited and insistence on a 2-stage procedure may reduce compliance, use of a formulated disinfectant cleaner may be considered satisfactory in this situation. A limited study in a catering environment showed no apparent significant difference between the level of hygiene assurance achieved on a range of contact surfaces using a combined detergent and disinfectant (active chlorine or quaternary ammonium disinfectant) and that obtained by a 2 stage cleaning and disinfection process (Stekelenburg and Hartog 1999).

### **3.2.2 Laboratory and in use studies to determine the effectiveness of surface hygiene procedures**

In an early study De Wit *et al.* (1979) showed that, following domestic preparation of chickens artificially contaminated with *E. coli* K12, the organisms could be isolated from surfaces such as chopping boards, cloths, the kitchen table and sink surface even after washing up. In 16/26 kitchens hygiene was achieved using detergent-based cleaning, but in 10 kitchens *E. coli* K12 was found after washing-up.

In an "in homes" study (Scott *et al.* 1984), results (Table 5) showed that, prior to cleaning, only 1 in 5 (20%) of 10 selected hand and food contact and other sites in the kitchen, bathroom and toilet could be considered as hygienic (<10 cfu per 25 cm<sup>2</sup>). Over half (56-63%) of sites and surfaces were considered as contaminated (>120 cfu per 25cm<sup>2</sup>). After detergent-based cleaning, the proportion of contaminated sites was actually increased to 68%. After application of hypochlorite (in use concentration 6000 ppm) only 7% of sites remained heavily contaminated. With phenolic disinfectant the occurrence of contamination was reduced to 36%. Disinfection with the phenolic and hypochlorite disinfectants increased the percentage of sites rated as "hygienic" to 38 and 76% respectively.

**Table 5:** Effectiveness of detergent and water cleaning or disinfection at environmental sites in the domestic environment. (from Scott et al. 1984)

	Percentage frequency occurrence of contaminated sites			
	Prior to cleaning*	Soap and water cleaning*	Phenolic disinfectant*	Hypochlorite disinfectant* 6000ppm
Sites contaminated with >120 cfu/25cm <sup>2</sup>	56-63%	68%	36%	7%
Sites contaminated with < 10 cfu/25cm <sup>2</sup>	20%	8%	38%	76%

(\*10 sites and surfaces sampled in 10 homes)

Humphrey *et al.* (1994) investigated contamination of bowl surfaces and fingers following preparation of eggs artificially contaminated with *Salmonella enteritidis*. After cracking eggs 25 out of 150 finger rinses were contaminated. After washing with soap and hot water, 3 out of 170 finger samples were still found to be contaminated, whilst 4 out of 19 samples taken from the bowl interior yielded *S. enteritidis*.

Borneff *et al.* (1988) showed that, during the preparation of a dinner, bacteria from contaminated minced meat were spread over all the utensils and working surfaces. Surface sampling showed that 60% of "difficult to clean" parts of the kitchen equipment were contaminated after conventional cleaning without use of a disinfectant, 40% after application of hydrogen peroxide and 23% after application of sodium hypochlorite. In this study however the numbers of bacteria added to the minced meat were very high ( $10^8$ /g).

Parnes (1997) carried out a lab-based trial in which ceramic and formica tiles inoculated with *Staph. aureus* or *E. coli* were placed in a depression cut into a sterile plexiglass surface surround. After drying at least  $10^6$  viable cfu were recoverable from test surfaces. Surfaces were re-sampled 2 minutes after wiping with a sponge wetted with the test product. Sodium hypochlorite (approx. 1500ppm) eliminated both test organisms from the inoculated surface and the sponge, and prevented transfer to the surrounding plexiglass surface. By contrast, wiping with liquid detergent produced no significant reduction in contamination of the sponge or surrounding area.

Cogan *et al.* (1999) reported a study in 20 homes involving preparation of a meal using chickens contaminated with either *Salmonella* or *Campylobacter*. Results showed that significant contamination was transferred to hand and food contact surfaces with a total of 17.3% of the surfaces sampled showing evidence of the target strain. In a repeat study where participants were instructed to clean up before sampling using a typical detergent-based procedure using a washing-up bowl, there was no reduction in the incidence of contamination, the frequency occurrence of contamination on hand and food contact surfaces remaining at 16% (1 contaminated site for every 6.25 sites). By contrast when hypochlorite disinfection (5000ppm Av Cl<sub>2</sub>) was used in addition to detergent-based cleaning, there was a significant reduction in microbial risk to 2.3% (not >1 contaminated site for every 33 sites). In a more recent study (Cogan *et al.* 2002) involving a limited number of sites (hands, cloths, chopping board, utensils, tap handles) it was found that, respectively, 8.3 and 50% of samples taken immediately after meal preparation showed counts of *Salmonella* and *Campylobacter* exceeding 100 cfus per sample area, with 4.8 and

35% of sites showing counts of >1000. A study involving the hands, cloths and chopping boards showed that a more significant reduction in the risk of contamination could be achieved where surfaces were cleaned using a detergent-based bowl wash routine followed by rinsing under running water (as compared with detergent-based cleaning alone) but, for *Salmonella*, 23% of 60 sites sampled still showed contamination, with 3.3% of sites showing counts of greater than 100 cfu.

### 3.2.2.1 Chopping boards

Chopping or cutting boards must be considered as a special case because of their potential to transfer contamination from raw to cooked foods, and the potentially serious consequences of failure to achieve hygiene. A number of in use studies have been carried out to compare the effectiveness of detergent-based cleaning as compared with disinfectant application for achieving hygiene of chopping boards.

De Wit *et al.* (1979) showed that, following preparation of a frozen chicken artificially contaminated with *Escherichia coli*. In 3/27 kitchens, the chopping board remained contaminated with *E. coli* even after washing up.

In the 1984 “in-homes” study of Scott *et al.* only 1 in 5 (20%) of chopping boards and worktops could be considered as “hygienic” (less than 10 cfu per 25 cm<sup>2</sup>) prior to cleaning. After detergent-based cleaning, this was actually reduced to 5%. By contrast, application of a phenolic or hypochlorite disinfectant (6000 ppm AvCl<sub>2</sub>) produced a significant increase in the percentage of worktops and chopping boards rated as “hygienic” to 50% and 80% respectively.

Ak *et al.* (1994) demonstrated that both new wood and plastic chopping boards inoculated with micro-organisms and treated with chicken fat were relatively easy to decontaminate. In contrast, used boards particularly plastic boards, which had a more or less damaged surface were more difficult to clean. In another study new and worn chopping boards inoculated with *E. coli* were either hand-washed in dishwasher detergent at 55°C using a brush, rinsed, sanitised (200ppm chlorine at 55°C) and dried for 1-2 hrs or machine-washed and sanitized (Welker *et al.* 1997). None of the plastic boards harboured any viable *E. coli* but 6 out of 39 wooden boards harboured low numbers of bacteria especially those that were hand-washed.

Miller *et al.* (1996) evaluated the effectiveness of washing with water or with a commercial cleaner in reducing microbial contamination on new wooden and plastic chopping boards contaminated by contact with ground beef. None of the commercial cleaner formulations (one of which contained hypochlorite and another a quaternary ammonium biocide and hydrogen peroxide) produced a significantly greater reduction in contamination than that produced by rinsing with water alone. For the plastic boards a reduction from 3 log to around 0.1 log cfu/cm<sup>2</sup> was recorded, whilst for the wooden boards the residual contamination after cleaning was of the order of 0.5 log cfu/cm<sup>2</sup>.

The “in-homes” study involving preparation of *Salmonella* or *Campylobacter*-contaminated chickens as described previously (Cogan *et al.* 1999, 2002) showed that up to 60% of chopping boards were contaminated after meal preparation. High counts (>100 and >1000) of both species occurred on chopping boards despite the fact that participants had been asked (although not instructed as to how) to “clean”

the chopping board after preparing the chicken, before cutting up vegetables. When participants were instructed to wash the chopping board in a washing up bowl of hot water and detergent, using a cloth, the risk of contamination with *Salmonella* or *Campylobacter* was reduced to 15% (1 in 6 contaminated boards). Where boards were cleaned in the same manner and then disinfected with hypochlorite (5000ppm available chlorine, contact time 5 min), none of the boards were found to be contaminated. A further study (Cogan *et al.* 2002) showed that, following meal preparation, 35% and 80% of boards respectively were contaminated with *Salmonella* and *Campylobacter* with 5 and 55% of boards respectively showing counts >100 cfu per board area. Following detergent-based cleaning using a bowl-wash routine the frequency of contamination with *Campylobacter* was reduced to 20%, but, for *Salmonella*, remained at 40%, with 10% of boards showing counts >100cfu. Where boards were bowl-washed followed by through rinsing under running water for 10 secs, no boards were contaminated with *Campylobacter*, but 2/20 boards were contaminated with *Salmonella* (1-2 logs).

Zhao *et al.* (1998) showed that surfaces of chopping boards could become heavily contaminated after cutting and handling poultry artificially contaminated with *Enterobacter aerogenes* and could readily cross-contaminate vegetables subsequently prepared on the board. Approximately 3 log cfu/g were recovered from vegetables after they were cut on a contaminated board. Treatment of the board with a quat disinfectant (0.1%) for 1 hour reduced contamination from 2.7–4.8 log cfu/sq cm to 1.7–2.0 cfu/sq cm. After disinfectant treatment, 52% of vegetables cut on the boards had no detectable bacteria, but 43% had counts of 1.0-1.7 log cfu/g and 5% had counts of 2-2.3 log cfu/g.

Although this requires further investigation, it is interesting to compare the results of the 2 investigations cited above against their efficacy as predicted from standard laboratory tests. A comparative study by Bloomfield *et al.* (1991,1993) showed that although both a hypochlorite formulations at 2500ppm and a 0.2%w/v quaternary ammonium biocide formulation produced a consistent >5 log reduction in a standard suspension test, in a surface test the hypochlorite formulation still produced a consistent >6 log reduction but the quat formulation produced only a mean log reduction of 3.2.

### **3.2.3 In vivo studies of the effectiveness of hygiene procedures in preventing cross contamination in the home.**

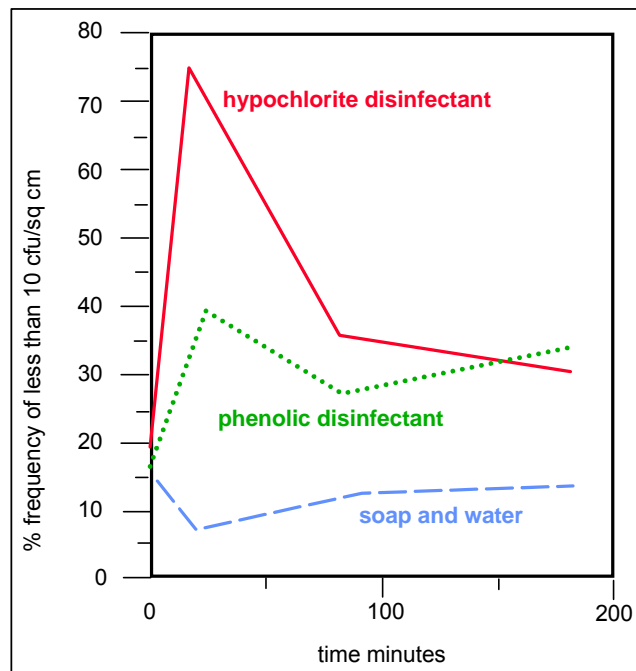
Although laboratory and in-homes studies, as described in 3.2.2, demonstrate the relative effectiveness of different hygiene procedures in eliminating contamination from surfaces, a factor which is never fully appreciated is that preventing infection transfer in the home depends not only on the effectiveness of the procedure but also the way (i.e. time and method of applications) in which it is applied.

The 1984 in-homes study of Scott *et al.* (Figure 2) showed that, although products were effective in reducing microbial risks, the effects were relatively short lived. After a relatively limited period (90 mins to 3 hours), most sites and surfaces become substantially recontaminated. This is probably due to reuse or, for wet sites or surfaces (e.g. for damp cloths), the regrowth of residual survivors not destroyed by the hygiene process. In a further study of the effects of daily application of

disinfectant over a period of 3 days, there was no evidence of any sustained or cumulative effect in terms of the frequency occurrence of sites rated as “hygienic”.

Similar data was obtained by Josephson *et al.* (1997) who concluded that casual or irregular use of disinfectant cleaners is unlikely to reduce the risk of pathogens on kitchen surfaces. In this study the effects of disinfectant usage involving a product containing 0.1% of a quaternary ammonium biocide on a range of hand and food contact sites in the home was determined over a period of 6-9 months. In phase 1 of the study sites were cleaned without disinfection. In Phase 2 of the study homes were supplied with a disinfectant and encouraged, but not instructed, how to use it. In phase 3 of the study the target surfaces were cleaned and disinfected immediately (5-10 min) before sampling. Although unfocussed disinfectant usage had little impact, in almost every case as shown in Table 6 the incidence of contamination significantly decreased with targeted use of a disinfectant.

**Figure 2:** Effectiveness of disinfection of soap and water cleaning at environmental sites in the domestic environment (From Scott *et al.* 1984).



**Table 6:** Number of samples with contamination in kitchen areas with and without use of a disinfectant cleaner (Josephson *et al.* 1997)

Phase	Percentage of samples with contamination in 10 households				
	Heterotrophic Bacteria	Staphylococci	Pseudomonas	Total coliforms	Faecal coliforms
No disinfectant	98.8	57.4	4.9	46.4	30.0
Irregular use	95.2	46.4	6.7	42.6	27.4
Targeted Use	58.4	11.1	2.8	12.5	3.0

By contrast other studies have demonstrated that where disinfectants are used for a specific purpose at a specific time they can be effective in interrupting the chain of bacterial and viral transmission under use conditions in the domestic situation. Studies by Ward *et al.* (1991) and Sattar *et al.* (1994) demonstrated the ability of disinfectants to interrupt the transfer of Rotavirus contamination. These workers showed that phenolic, phenol/alcohol and hypochlorite disinfectants at recommended use dilutions were effective in preventing transfer of Rotavirus contamination from dried stainless steel discs to finger pads. Oral consumption of the disinfectant-treated virus by licking the fingertips caused no infection in 14 subjects, whereas 13 of 14 subjects who consumed the untreated virus became infected. In a similar set of experiments these workers showed that the phenol/alcohol disinfectant prevented transfer of Rhinovirus contamination from dried surfaces to hands (Sattar *et al.* 1993).

### 3.2.4 Consensus statement on hand-contact and food-contact surfaces

On the basis of the evidence presented above, IFH consider that, where rinsing with ample running, potable and preferably hot, water is possible, hygiene of hand and food contact surfaces can be achieved by detergent-based cleaning, followed by rinsing and drying. Evidence from lab and “in homes” studies shows that use of disinfectants in a targeted manner can produce a significantly greater reduction in the frequency occurrence of contaminated surfaces than that achieved by detergent-based cleaning alone. Use of a disinfectant in addition to (or in conjunction with) cleaning in order to give a higher margin of safety is considered advisable in situations where a mechanical action and thorough rinsing of surfaces with safe water is not possible (e.g. for kitchen worksurfaces, tap and door handles). In particular disinfectant use is considered advisable where failure to achieve hygiene with soap and water is a real possibility and/or carries a higher risk of serious consequences. Since the infection transfer risks from hand and food contact surfaces can vary considerably from one situation to another, the IFH advocate that the individual responsible for giving advice must decide on the appropriate hygiene procedures to be recommended, based on risk-benefit considerations. Decisions on where and when to use a disinfectant should take into account local conditions in the community and, if necessary, within the individual home. The use of a separate chopping board for raw meat poultry etc is recommended

IFH recognise that the efficacy of cleaning and disinfection procedures can be compromised if the disinfectant product is not used at the correct dilution and in the correct manner. Since, under use situations, the effects of applying a hygiene procedure are relatively short-lived, the time of application is important.

### 3.3 Reservoir/disseminators: cloths, sponges and other cleaning utensils

Used correctly, cleaning cloths, and items such as sponges, play an important hygiene role as they aid detachment of particles from surfaces and can remove a significant proportion of the soil and microbes present on that surface. However, as they frequently remain wet for long periods of time and always contain some residual soil, they provide ideal conditions for survival and growth of microbes. Particularly when used on several surfaces consecutively, cloths can pick up contamination from one surface and redeposit it on another. By the nature of their function they represent a serious risk in terms of their potential to increase exposure of family members to harmful microbes. Hygiene procedures applied to kitchen cloths thus have an important role in preventing the spread of microbes via surfaces in the home.

#### 3.3.1 Hygiene procedures for cleaning utensils

IFH considers that, for cleaning utensils, detergent-based based cleaning is insufficient to eliminate microbial risks, particularly where cloths have become heavily contaminated. The evidence for this is reviewed in the following sections. There are 3 alternative procedures that IFH considers suitable for achieving hygiene of cloths and other cleaning utensils:

- Rinsing with detergent and hot water followed by immersion in water held at 90°C or more for 2 minutes.
- Rinsing with detergent and hot water followed by a laundering or dishwasher cycle at minimum temperature of 60°C.
- Rinsing with detergent and hot water followed by application of a disinfectant. Considerations on the choice of disinfectant products as described in section 3.2.1.2 also apply to cleaning utensils.

#### 3.3.2 Laboratory studies to evaluate the effectiveness of hygiene procedures applied to cleaning utensils

Scott and Bloomfield (1990b) investigated the effectiveness of hygiene procedures for decontamination of cloths returned to the lab after use in the home. Contamination levels were high, varying from  $10^2$  to  $10^6$  cfu/sq. cm. Results (Table 7) showed that detergent-based cleaning with rinsing produced little or no reduction in contamination levels indicating that the micro-organisms were strongly adhered to cloth fibres. By contrast, hypochlorite and phenolic disinfectants produced significant reductions in microbial contamination. Although hypochlorite achieved better results than the phenolic, giving no detectable survivors in 10/13 cloths, compared with 5/13 for the phenolic, neither disinfectant could be regarded as consistently satisfactory, particularly where cloths were heavily contaminated. Further tests showed that, for consistently effective decontamination, detergent-based cleaning followed by drying at 80°C for 2h was required. The results demonstrate that post disinfection storage of cloths produced regrowth of residual survivors even though some cloths were apparently “sterile” immediately following disinfection.

Cogan *et al.* (2002) further demonstrated that detergent-based cleaning using a typical bowl-wash routine without rinsing was insufficient to consistently restore cloths to a hygienic state. For *Salmonella* in particular detergent-based cleaning without rinsing was relatively ineffective as a means of achieving hygiene. Immediately after wiping boards where *Salmonella*-contaminated chickens had been prepared, and after overnight storage, 9/10 cloths were contaminated with *Salmonella* and counts of >100 and >1000 were frequently isolated. Where cloths were treated immediately after use, counts of *Salmonella* were reduced by detergent-based cleaning alone, but 3 cloths still showed counts of >100. Where cloths were washed with rinsing a further reduction in *Salmonella* contamination was achieved, but 6/10 still showed counts of between one and 100. For cloths which were stored overnight, detergent-based cleaning, either with or without rinsing, was significantly less effective. *Salmonella* counts of >100 were observed in 4/10 and 7/10 cloths following detergent-based cleaning with and without rinsing respectively. Without rinsing 4/10 cloths showed *Salmonella* counts of >1000.

**Table 7:** Total counts recovered from contaminated cloths after disinfection with hypochlorite 4000ppm available chlorine and Stericol 2% v/v (From Scott and Bloomfield 1990)

Colony forming units per cm <sup>2</sup> cloth					
Cloth Sample	Stericol 2% v/v			Hypochlorite 4000 ppm AvCl <sub>2</sub>	
	Initial count	After treatment	After treatment & 24 hr storage	After treatment	After treatment & 24 hr storage
1	5.0 x 10 <sup>2</sup>	0	0	0	0
2	7.5 x 10 <sup>2</sup>	0	0	0	0
3	1.0 x 10 <sup>3</sup>	0	0	0	0
4	8.5 x 10 <sup>4</sup>	2.5 x 10 <sup>4</sup>	4.5 x 10 <sup>4</sup>	0	0
5	4.0 x 10 <sup>5</sup>	2.5 x 10 <sup>5</sup>	2.5 x 10 <sup>5</sup>	2.5 x 10 <sup>2</sup>	8.5 x 10 <sup>4</sup>
6	5.0 x 10 <sup>5</sup>	5.0 x 10 <sup>4</sup>	0	0	0
7	6.0 x 10 <sup>5</sup>	3.0 x 10 <sup>5</sup>	2.5 x 10 <sup>5</sup>	0	5.0 x 10 <sup>3</sup>
8	1.1 x 10 <sup>6</sup>	5.0 x 10 <sup>3</sup>	2.5 x 10 <sup>2</sup>	2.5 x 10 <sup>3</sup>	4.5 x 10 <sup>4</sup>
9	2.5 x 10 <sup>6</sup>	3.0 x 10 <sup>3</sup>	0	0	0
	Initial count	After treatment	After treatment, neutralisation & 24 hr storage	After treatment	After treatment, Neutralisation & 24 hr storage
10	5.0 x 10 <sup>2</sup>	0	1.1 x 10 <sup>5</sup>	0	1.0 x 10 <sup>3</sup>
11	2.0 x 10 <sup>3</sup>	0	3.0 x 10 <sup>5</sup>	0	3.7 x 10 <sup>3</sup>
12	3.7 x 10 <sup>4</sup>	2.5 x 10 <sup>3</sup>	8.0 x 10 <sup>4</sup>	0	4.5 x 10 <sup>3</sup>
13	6.5 x 10 <sup>4</sup>	3.0 x 10 <sup>5</sup>	2.5 x 10 <sup>3</sup>	4.5 x 10 <sup>5</sup>	

In recent years, a range of detergent-based dishwash products containing antibacterial agents have been promoted for disinfection of discloths and sponges. Although further work is required to evaluate the extent of the hygiene benefit derived from such products to cloths and other cleaning utensils, Kusumaningrum *et al.* (2002) showed that one such product was effective in reduction of *E. coli*, *S. enteritidis*, *Staph. aureus* and *Bacillus cereus* using a modified CEN suspension test, but was not effective in reduction of pathogens in used sponges.

### 3.3.3 In homes and other studies to evaluate the effectiveness of hygiene procedures in preventing cross contamination via cleaning cloths

De Wit *et al.* (1979) showed that, following preparation of a frozen chicken artificially contaminated with *E. coli*, in 3/27 kitchens, the cloth remained contaminated with *Escherichia coli* even after washing up.

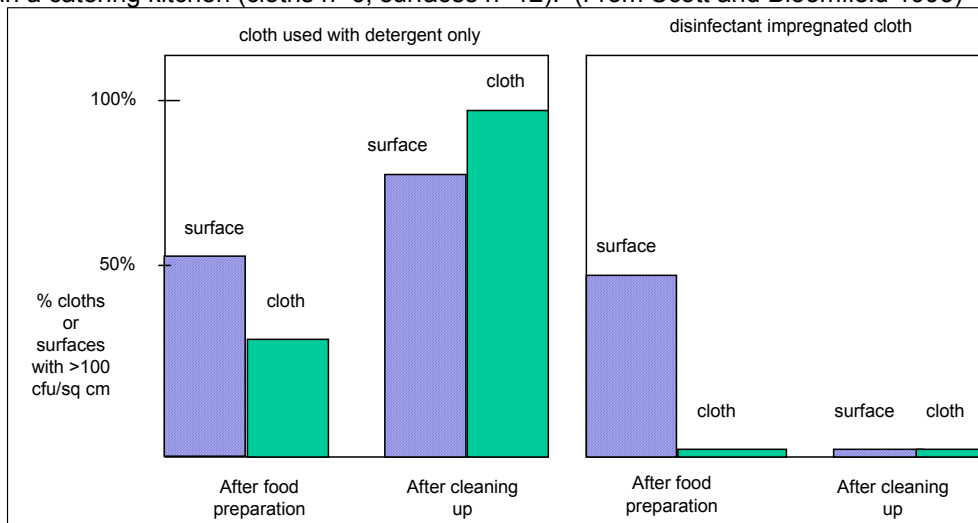
Parnes (1997) simulated the use of a product applied to a sponge and wiped across a surface to be cleaned/disinfected. Glazed ceramic tiles and formica were inoculated with *Staph. aureus* or *E. coli*. At least  $10^6$  viable cfu were recoverable from test surfaces after drying before use of a disinfectant (control tiles). Two minutes after wiping with sponge (4 strokes) the surfaces were sampled for viable organisms. Bleach eliminated both test organisms from the original surface and the sponge, and also prevented the transfer of the organisms to surrounding areas.

Hilton and Austin (2000) evaluated transfer of contamination from unrinsed and rinsed cloths and sponges taken from domestic homes and inoculated with  $10^8$  *E. coli*. Although rinsing of clothes and sponges produced a significant reduction (1 and 2 logs for cloths and sponges respectively) in the numbers of organisms transferred to a chopping board surface, even where rinsed cloths were used, significant numbers of organisms ( $10^4$ – $10^5$ ) were still recovered from the surface after wiping.

The “in-homes” studies involving preparation of *Salmonella* or *Campylobacter*-contaminated chickens as described previously (Cogan *et al.* 1999, 2002) showed that, following meal preparation, the target organism was isolated from 20% (1 in 5) of dishcloths. When participants were instructed to wash the cloth in a washing-up bowl of hot water and detergent there was no significant reduction in the incidence of contamination, and there was evidence that the cloth was actually spreading contamination during the cleaning up process. With a third group of participants who were instructed to apply hypochlorite disinfectant (5000ppm avCl<sub>2</sub>) to the cloths, the incidence of contamination was reduced to 3% and contamination was isolated from the cloth on one occasion only.

These results reinforce earlier studies by Scott and Bloomfield (1993) in which the relationship between bacterial contamination of food preparation surfaces and cleaning cloths was evaluated during morning food preparation activities in a college kitchen. The results as summarised in Figure 3 show that cloths used with only detergent became heavily contaminated during food preparation and the post preparation cleaning process. Some increase in the contamination of surfaces after cleaning compared with after food preparation was also observed indicating transfer of contamination from cloths to surfaces during the clean up process. By contrast where cloths impregnated with quaternary ammonium disinfectant were used throughout the food preparation and cleaning activities, there was a significant reduction in contamination of both surfaces and cloths. This was also associated with a reduction in the frequency occurrence and numbers of enterobacteria and pseudomonads isolated.

**Figure 3:** The hygiene of cloths in relation to surfaces during the preparation of food in a catering kitchen (cloths n=6; surfaces n=12). (From Scott and Bloomfield 1993)



#### 3.3.4 Consensus statement on reservoir/disseminators

On the basis of the evidence presented above IFH consider that, for cleaning cloths and other cleaning utensils, detergent-based cleaning alone is insufficient to achieve a hygienic state particularly where these items have become heavily soiled. IFH thus considers that, as a routine all non-disposable cleaning cloths and sponges should be made hygienic with a hygiene procedure which involves cleaning and microbial kill – either by the action of heat or a chemical disinfectant. Where cloths have become heavily soiled over a period of time, disinfection is only consistently achieved by heat disinfection applied for an extended period. In all cases cloths must be dried immediately after decontamination and stored dry until next use to prevent regrowth of residual contamination.

Cleaning utensils should be made hygienic and dried after each cleaning activity in the home. Daily or weekly decontamination is not considered sufficient. Most particularly cloths must be made hygienic immediately after contact with raw food or items which have been in contact with raw food. Alternatively a fresh clean cloth must be used for further food preparation activities. Similarly after cleaning of toilets and toilet surfaces a fresh cloth must be used, or the cloth must be decontaminated before cleaning of other surfaces in the home.

### 3.4 Laundry

There is evidence that transfer of microbes between contaminated and uncontaminated items of clothing and linens can occur during washing, which is only partially removed by subsequent rinse cycles (Kundsinn 1966, Wiksell *et al.* 1973, Davis and Ainsworth 1989, Larsen and Duarte 2000). Thorough drying of laundry however, in most cases, further reduces contamination to a level where it no longer represents a significant risk. Although there is a risk of infection transmission via

clothing laundry in the domestic setting, under normal daily conditions the risk is low or infrequent compared with risks from cloths, hand and food contact surfaces, since the risk is predominantly to the person handling the laundry. There are two points where laundry can act as a disseminator of infection, firstly when it is handled before laundering, and secondly if the laundry process fails to fully remove microbial contamination and the laundry remains damp for a period before being handled. If laundry is left damp overnight, there is the chance for growth of residual microorganisms, such that clothes can then become a source of microbes.

Changes in laundry practice have taken place in the last ten years in Europe and North America dictate a need to re-evaluate the hygiene of laundering processes. Where previously laundering was carried out using water temperatures of 60°C or above, in recent years there has been a trend towards reducing laundering temperatures, water volumes and usage of phosphates and bleach in the powders, all of which can effect the efficacy of the laundering process as a hygiene procedure.

#### **3.4.1 Hygiene procedures for laundry**

The following processes are considered suitable for achieving hygiene during laundering of clothing and linens:

##### **3.4.1.1 Washing at 60°C (or above)**

This is considered to give consistent hygienic decontamination across all species of organisms (bacteria, fungi and viruses) by a combination of physical removal and heat inactivation.

Wiksell *et al.* (1973) demonstrated that, although large numbers of bacterial spores and other microorganisms were recoverable from wash and rinse water indicating physical removal from clothes during the wash, *Serratia marcescens* was not recovered from fabric or wash water when temperatures of 57°C or 68°C were used. A wash temperature of 57°C resulted in >90% reduction in *E. coli* T3 bacteriophage counts compared with lower wash temperatures. However, T3 phage were not detected after washing at 68°C. For *Staph. aureus* a log<sub>10</sub> reduction of 4.5 at 57°C and 4.3 at 68°C was achieved.

In a review of 11 reports published since 1938, Battles and Vesley (1981) concluded that most vegetative organisms are killed by laundering at 60°C, and 66°C is effective for more resistant species such as *Streptococcus*. They concluded that chlorine bleach greatly enhances the lethal effect of heat. For laundering linens from health care facilities, the use of 60°C with addition of chlorine bleach is recommended (Walter and Schillinger 1975, Jaska and Fredell 1980, and Belkin 1998).

##### **3.4.1.2 Washing at 30-40°C using an activated bleach-containing powder**

This process produces decontamination of fabrics from bacteria by a combination of physical removal and chemical inactivation. Decontamination from some types of fungi and viruses, which are harder to inactivate, may be less complete however.

Wiksell *et al.* (1973) showed that an increase in wash temperature from 35 to 46°C and from 46 to 57°C significantly reduced number of viable cells of *Staph. aureus* recovered. For *Bacillus stearothermophilus*, significantly fewer spores were

recovered from samples laundered at 46 and 57°C than at 24 and 35°C. Using soiled nappies from infants who had previously received a polio vaccine, Jordan *et al.* (1969), tested the use of sodium hypochlorite at 45°C and 55°C. Poliovirus was not inactivated after 2 minutes exposure to water at 45° but was inactivated at 55°C. However the addition of 200ppm available chlorine was effective in inactivating poliovirus at 45°C.

There are a number of studies which show that the addition of bleaching agents is the most important bactericidal step for low temperature washing procedures:

Blaser *et al.* (1984) examined soiled sheets and terry cloth items from a hospital laundry. At a low temperature (22.5°C) washing cycle without laundry chemicals the number of bacteria isolated from the rinse water indicated that agitation, dilution and drainage achieved a 3-log<sub>10</sub> reduction of bacteria from the laundry. When low temperature laundry chemicals were used, the number of organisms detected in the rinse water was lower than in the wash without chemicals. Mean bacterial levels fell by 2-3 log<sub>10</sub> after bleach was added (AvCl<sub>2</sub> 125mg/l).

Using samples from a hospital laundry, Christian *et al.* (1983) found that wash temperatures of 73.9-77.2°C generally ensured levels of <1cfu/cm<sup>2</sup> for total coliforms and <0.1cfu/cm<sup>2</sup> for staphylococci. They found however that wash conditions at lower temperatures (47.8-60°C) were equal to or more effective than washing at the high temperatures, but concluded that this was due to different formulation usage at the low temperatures which delivered higher chlorine concentrations.

Smith *et al.* (1987) showed that a low temperature wash (avg 31°C) and bleach (100-120ppm) reduced bacterial counts in fabric by 3 log<sub>10</sub> (99.9%). A bacterial elimination of >5 logs in wash water effluents was achieved in both low and high temperature (avg 67°C) washes, therefore a reduction of 1.5-1.8 log<sub>10</sub> without chemicals, and 3-4 log<sub>10</sub> is due to temperature and chemicals. A fall in microbial viability in rinse water samples was more obvious in the earlier phases of high temperature washing than low temperature washing. However, the addition of bleach (100-120ppm) rendered the counts similar in the two temperature processes.

Ainsworth and Fletcher (1993) showed that for both a laundry powder with activated bleach and liquid detergent alone disinfectant action against *Enterococcus faecalis* was substantially better at 50°C than at 30°C. Both detergents improved the antimicrobial action of the wash compared to hot water (50°C) alone.

Use of a bleach system also led to less odour on garments immediately after washing, and after storage of damp laundry (for 24 and 48hrs) (Sheane 2000).

#### **3.4.2 Washing at or below 40°C using a non-bleach product**

Washing exclusively at temperatures of 40°C or below in a non-bleach containing product is considered to carry a risk of inadequate decontamination.

The survival of *Staph. aureus* was determined from inoculated swatches laundered in either a phosphate detergent or phosphate-substitute detergent (Jaska and Fredell 1980). At a wash temperature of 27°C the average log<sub>10</sub> reduction with each detergent was 0.83 and 0.77 respectively and with no detergent present was 0.38. At

38°C the average log<sub>10</sub> reduction was 4.26 and 3.4 respectively, and with no detergent 1.91.

Regularly washing at or below 40°C without the use of a bleach product may result in the build up of biofilms in machines. In a recent study, after 3 weeks of use a stale odour was produced in washing machines run with detergent but no bleach. Malodour is indicative of bacterial build-up. After 6-8 weeks machines where activated bleach product was not used were deemed to have an unacceptably high level of malodour (Sheane 2000). A formulation containing an activated bleach system showed significant benefits in eliminating the build-up of slime in the washing machine. **The use of an activated bleach system of tetra acetyl ethylene diamine (TAED) totally prevented malodour formation in the machine.**

#### 3.4.3 Ineffectiveness of laundry procedures at temperatures less than 30°C

Cunliffe *et al.* (1988) showed that a greater degree of cross-contamination occurs from infected test pieces to sterile test pieces in the wash cycle using cold water (15°C) and detergent compared with samples washed at 50°C with detergent. Davis and Ainsworth (1989) also confirmed this. As the temperature of the wash was lowered, the disinfectant action was less efficient as more bacteria (*Enterococcus faecalis*) remained on infected test pieces.

The survival of *Staphylococcus aureus* was determined from inoculated swatches laundered with a phosphate detergent, a phosphate-substitute detergent or no detergent (Jaska and Fredell 1980). At 27°C with both detergents and no detergent the average log reduction of *Staph. aureus* was less than one.

Work by Ainsworth and Fletcher (1993) indicates that temperature plays a major role in disinfectant action as they showed that the number of organisms surviving washing with detergent powder at 30°C is greater than the number of surviving washing at 50°C with no detergent. Also at 30°C with a liquid detergent the number of organisms transferred to sterile fabric and the wash or rinse waters was higher than at a 50°C wash with no detergent.

#### 3.4.4 Thorough and prompt drying of laundry as a means of disinfection

Wiksell *et al.* (1973) demonstrated that drying at a low temperature of 46°C resulted in significant reduction in counts of 4 test organisms (infectious T3 phage, *S. marsecens*, *Staph. aureus* and *Bacillus stearothermophilus*. Blaser *et al.* (1984) showed that drying removes an additional 1-2 log bacteria.

#### 3.4.5 Sharing of facilities

Buford *et al.* (1977) swabbed the interior of machines in a self-service laundry facility and isolated viable bacteria, with mean counts of log 1.26 to 2.5 per sq.cm Therefore potential exists for transfer of bacteria from the previous user of the equipment to the load of the next laundry user.

Evaluation of water samples drawn before disinfectant treatment revealed that bacteria were transferred from the interior of the washer to the wash water of the subsequent cycle, in numbers ranging from log 2-3.9. When disinfectant was used in the wash water the overall log mean survivors decreased in all instances.

In a recent study by Larsen and Duarte (2000) 398 households in a US inner city population (96.4% Hispanic) were surveyed to determine the relationship between home hygiene practices and prevalence of infectious disease symptoms among household members. In this study it was found that use of communal laundry and lack of bleach use in the laundering process were significantly predictive of increased risk of transmission.

#### 3.4.6 Consensus statement on laundry hygiene

On the basis of the evidence presented above it is considered that all soiled clothing and household linens which routinely carries a risk of contamination with faecal, skin-borne or other pathogens should be laundered at 60°C, or at 40-60°C using an activated bleach powder. Where clothing is heavily soiled and likely to be contaminated with pathogens, or where people who are particularly vulnerable to infection are present, it is recommended that all clothing and linens should be laundered at 90°C or at 60°C using an activated bleach powder. It must be borne in mind however that some clothes will not tolerate a temperature of 90°C. Laundry must be dried immediately after washing is completed. It is important to ensure that laundry is not carried out using polluted water, particularly where it is carried out outside the home. This is a particular problem in some developing countries. For washing machines, a high temperature wash or chemical disinfectant should be used at least once a week to prevent the build up of biofilms within the machine. In all situations, clothing items, linens and cloths which carry a risk of faecal, or other pathogenic contamination should be segregated from items such as cleaning cloths and tea towels that are used during food preparation.

### 3.5 Reservoir sites

Sites in the home such as toilet bowls, U-tubes, showerheads, and washbasin and bath overflows can become reservoirs of micro-organisms either permanently or intermittently, which may include opportunist pathogens and primary pathogens. The presence of moisture and residual amounts of soil at these sites provides an ideal substrate for supporting the growth of a resident microbial population. Scale on the surfaces of sinks or toilet bowls can also harbour a resident population of microbes.

As far as the toilet is concerned, IFH consider that, although splashing and aerosol formation (which could subsequently be transferred to other parts of the toilet area including hand contact surfaces such as the toilet seat and toilet flush handles) can occur as a result of toilet flushing, the risks of exposure to pathogens from the toilet bowl and water in the toilet are relatively low under normal conditions in homes where the family is healthy. Where members of the family have fluid diarrhoea however, then transmission of infection via this route (splashing and aerosol formation) may be a real risk.

In homes where there are family members who are immune-compromised aerosol transmission from all types of reservoir sites may be a hazard. Opportunist pathogens such as *Stenotrophomonas maltophilia*, and *Pseudomonas aeruginosa* are quite often found as resident contaminants of reservoir sites in the home environment (Denton *et al.* 1998) and can infect children with cystic fibrosis. A number of hospital-acquired outbreaks involving *Ps. aeruginosa* have been traced to

reservoirs such as sinks and also tap water (Piper *et al.* 1997, Ferroni *et al.* 1998). Evidence of aerosol transfer of *Ps. aeruginosa* from hospital toilets was reported by Scott and Bloomfield (1985). Doring *et al.* (1991) demonstrated transfer of *Ps. aeruginosa* from contaminated hospital sinks to the hands during hand washing. A hospital investigation in Germany showed a correlation between *Ps. aeruginosa* strains isolated from infected cystic fibrosis patients and from environmental sites such as sink u-tubes, toilets, cloths and other sites (Zimakoff *et al.* 1983, Doring *et al.* 1989, 1993, Doring 1993). In an in homes study Denton *et al.* (1998) reported widespread environmental contamination with *Stenotrophomonas maltophilia* in 36% of 41 homes of children with cystic fibrosis and 42% of homes of non-colonised children. They concluded that the high frequency of occurrence in this setting indicates the home as a setting for acquisition of this organism.

### 3.5.1 Hygiene procedures for the toilet

The following procedures may be used to achieve hygiene in the toilet:

#### **3.5.1.1 Cleaning using a detergent product and mechanical action followed by toilet flushing**

Toilet flushing is considered effective as a hygiene measure provided that a minimum of 15-17 litres of water is used for each flush. Detergent-based cleaning is effective as a hygiene procedure for the toilet surfaces only if the processes are applied under the flushing rim of the toilet as well as the surface of the toilet bowl.

#### **3.5.1.2 Cleaning using a detergent product and mechanical action followed by application of a disinfectant and toilet flushing**

Disinfectant products used for achieving toilet hygiene should have rapid microbicidal action against bacterial, viral, fungal, etc pathogens under conditions appropriate to their intended use. For sites such as toilets, sinks etc, compatibility with water hardness, effectiveness at the expected soil level and the contact time necessary for disinfection are primary considerations.

#### **3.5.1.3 Routine cleaning and descaling as above supplemented by the use of a toilet cistern or rim block which delivers a measured dose of disinfectant into the toilet bowl during flushing**

These formulations are intended to release a low level of biocide such as chlorine into the toilet each time the toilet is flushed in order to maintain a low level of microbial contamination in the toilet between flushes.

Although, as discussed in section 2.2.2, standard suspension and surface tests can be used to establish that disinfectant products used in the toilet have the required profile of activity (spectrum of action, rate of kill, etc) they give no indication of effectiveness under use conditions by the family in the home particularly in relation to their knowledge of hygiene practice. Most particularly they give no indication of the log reduction achieved by application of cleaning or disinfectant products combined with mechanical action and rinsing. A number of studies as reported in sections 3.5.2 illustrate the relative extent to which toilet hygiene procedures achieve risk reduction when used by participants in homes and other settings.

### 3.5.2 Laboratory and in-use studies to measure the effectiveness of toilet hygiene procedures

Studies such as those by Darlow and Bale (1959) and Gerba *et al.* (1975) indicate that toilet flushing is sufficient to remove most of the microbial contamination from the toilet bowl, and the surface of the bowl.

In their in-homes study, as shown in Table 8, Scott *et al.* (1984) showed that although disinfection was effective in reducing microbial contamination associated with toilets, as compared with detergent based cleaning, the effects for hypochlorite disinfectants were relatively short lived. Where toilets were re-sampled 90 and 180 mins following disinfection, the frequency occurrence of contaminated sites returned to levels similar to those recorded prior to the hygiene procedure. It is thus concluded that, in order to prevent infection transmission, the disinfectant must be added to the toilet immediately before flushing. It is assumed that, since biocides are adversely affected by presence of organic soil, disinfectants when used to disinfect toilets contaminated by e.g. vomit or diarrhoea should be used at high concentrations to provide a margin of safety against inactivation. It should be noted however that no studies have been carried out to confirm these recommendations. It is assumed that continuous release toilet block since they delivers only low doses of disinfectant into the toilet will not be effective in this situation because of the high levels of soil which are likely to be present, which are likely to inactivate the active agent, but again this has not been studied.

**Table 8:** Effectiveness of detergent and water cleaning or disinfection of toilets in the domestic environment. (from Scott *et al.* 1984)

	Percentage frequency occurrence of sites Contaminated with < 10 cfu/25cm <sup>2</sup>		
	Detergent-based cleaning*	Phenolic disinfectant*	Hypochlorite disinfectant* 6000ppm
prior to cleaning and disinfection	80%	80%	70%
15 mins after cleaning or disinfection	20%	80%	98%
90 mins after cleaning or disinfection	50%	95%	90%
180 mins after cleaning or disinfection	80%	95%	80%

(\*10 homes)

Studies by Gerba *et al.* (1975) and Barker and Bloomfield (2000) indicate that, where an infected person is present in the home, significant transmission of pathogens can occur by splashing and other mechanisms. In a study of homes where there has recently been an outbreak of *Salmonella* and also studies using toilets seeded with *Salmonella*, Barker and Bloomfield (2000) showed the presence of *Salmonella* two to five weeks after the infected person has gone back to work or after the initial seeding of the toilet. The contamination was found on the scaly biofilm on the surface of the

toilet, in the biofilm under the flushing rim and, in the toilet seeding studies, on one occasion, in the toilet water (although in very low numbers). In one of the homes, *Salmonella* was found under the flushing rim of the toilet on a return visit to the home, despite the fact that the family member had disinfected the toilet with bleach. It was found that in order to eradicate the organisms it was necessary to disinfect the flushing rim using a suitable container with a curved neck which allowed the disinfectant to be delivered effectively under the flushing rim.

In a study of the effectiveness of cleaning and disinfection procedures in hospital and institutional toilets (Scott and Bloomfield 1985) showed (Table 9) that whereas daily use of hypochlorite or quaternary ammonium disinfectant produced relatively little in the way of a sustained reduction in contamination in the toilet, installation of a continuous release chlorine block produced substantial and sustained reduction in risk. During a 2 week sampling period it was found that 95% of toilet water samples had counts of less than 10 cfu/ml (compared with 18% for toilets which were disinfected daily and 4.6% for toilets which were cleaned daily), and 64% of bowl and rim samples had counts of less than 10 cfu per sample area (compared with 28% for toilets which were disinfected daily and 23% for toilets which were cleaned daily).

In this study Scott and Bloomfield (1985) also showed that although continuous release disinfection is effective in maintaining a low level of contamination in the toilet, reduction in contamination of coliforms and enterococci at surrounding surfaces such as the toilet seat, toilet handle and floor was limited suggesting that faecal contamination on these surfaces arises mainly by direct contact. By contrast, in hospital toilets it was found that whereas *Ps. aeruginosa* was isolated from toilet surround surfaces (toilet seat, flush handle, and floor) in 8 out of 144 samples taken from toilets cleaned daily but not disinfected, no samples positive for *Ps. aeruginosa* were obtained from surfaces associated with toilets where a continuous release disinfectant was installed.

Yahya *et al.* (1992) showed that detergent based continuous release toilet bowl cleaners can also reduce the numbers of bacteria ejected from the toilet bowl during flushing, the cleaner containing the greatest amount of surfactant being the most effective in aerosol reduction.

**Table 9** - Disinfectant activity of a chlorine-releasing toilet block in 16 college, hospital and foodstore toilets (from Scott and Bloomfield (1985))

	Percentage frequency of occurrence*		
	Untreated toilets	Daily (am) disinfection	chlorine release toilet block
“Hygienic” toilets i.e. less than 10 orgs/0.5ml toilet water	10%	21%	95%
“unhygienic” toilets i.e. greater than 100 orgs/0.5ml toilet water	59%	51%	3%

\*samples taken at 10am and 3pm daily over a 2 week period

### 3.5.3 Sink and bath u-tubes and overflows, and drains

For sinks, handbasin and bath u-tubes and sink overflows there is some evidence that splashback of stagnant water can occur, but how serious a risk this creates in the home is not clear. Currently there is insufficient evidence to support disinfecting U-tubes for the prevention of infection transmission, although there may be other motives for using disinfection at this site such as the eradication of smell. There is some evidence that opportunist pathogens such as *Pseudomonas* spp., *Enterobacter* spp., *Serratia* spp. and *Legionella* can reside in areas such as the sink u-tube and the overflow of washbasins especially where there is a siphon. Since these sites cannot be thoroughly cleaned mechanically it is considered that these sites should be disinfected, not daily but regularly, to prevent the establishment of a persistent biofilm that may harbour pathogens. In homes studies by Scott *et al.* (1984) (Table 10) showed that although disinfection was effective in reducing microbial contamination associated with sink u-tubes, as compared with detergent based cleaning, the effects were relatively short lived. Where u-tubes were re-sampled 90 and 180 mins following disinfection, the frequency occurrence of contaminated sites returned to levels similar to those recorded prior to the hygiene procedure.

**Table 10:** Effectiveness of detergent and water cleaning or disinfection of sink u-tubes in the domestic environment. (from Scott *et al.* 1984)

	Percentage frequency occurrence of sites contaminated with < 10 cfu/25cm <sup>2</sup>		
	Detergent-based cleaning*	Phenolic disinfectant*	Hypochlorite disinfectant* 6000ppm
prior to cleaning and disinfection	0%	0%	10%
15 mins after cleaning or disinfection	0%	55%	70%
90 mins after cleaning or disinfection	20%	35%	35%
180 mins after cleaning or disinfection	0%	18%	28%

(\*10 homes)

**3.5.4 Consensus statement on hygiene of reservoir sites**

On the basis of the evidence presented above it is considered that toilet flushing is sufficient to remove most of the microbial contamination from the toilet bowl, and the surface of the bowl, provided that an adequate amount of water (minimum 15-17 litres of water) is used for flushing. Since toilet flushing does not achieve decontamination under the flushing rim of the toilet, the toilet requires regular application of a hygiene procedure which will maintain a low level of contamination in the toilet bowl and under the flushing rim to prevent build up of biofilms or scale which could harbour pathogens.

In situations where an infected person is known to be, or have been, present or where there is a high incidence of diarrhoeal disease, disinfection of the toilet is advised. Regular cleaning and disinfection of toilets and washbasins should be continued for at least 3-4 weeks after symptoms have subsided. Descaling of the toilet bowl surface is important to prevent the build up of resident populations of pathogens such as *Salmonella*. Since significant transmission of pathogens can occur by splashing and other mechanisms where an infected person is present in the home, disinfection of toilet surfaces and other hand contact surfaces in the toilet area is also advisable.

Disinfection of sinks and sink u-tubes and overflows as well as toilets is recommended in homes where there is a person who is infected or is particularly vulnerable to infection. Toilet blocks may be useful in protecting vulnerable groups by continuously maintaining a low level of contamination in the toilet. Routine disinfection as well as cleaning of sinks, sink u-tubes and overflows, and drains is considered as the appropriate means to prevent build up of microbial biofilms at these sites.

### 3.6 Floors, walls and other surfaces in the home

For the most part the risks of exposure to pathogens as a result of microbial contamination on floors, home furnishings etc in the home is considered very low. Thus it is judged that procedures which eliminate pathogenic microbes from these surfaces are not necessary as part of routine cleaning under normal conditions.

The exception to this is mould growth which is considered as a significant health risk. It is accepted that, where present, mould should be removed using cleaning agents such as a detergent containing bleach which optimise the detachment of fungal growth from surfaces.

Routine disinfection of floors is also opposed on the grounds that it would do little to reduce cross infection risk in the home, were such a risk to exist. This position has been established on the basis of studies such as those by Ayliffe *et al.* (1966) who demonstrated that about 90% of floor contamination may be removed by washing with soap and water alone, but when surfaces are left uncovered, contamination returns to pre-cleaning levels within a few hours. They also showed that although contamination may be further reduced by use of disinfectants recontamination to pre-cleaning/disinfection levels occurs within a very short period. The overall implication from such studies is that the practice of daily or weekly application of disinfectants as part of a routine cleaning program achieves little and should not be encouraged.

Hygienic cleaning of the general environment involving the use of disinfectant product may however be advisable in specific situations of increased risk, most particularly those involving the presence of an infected person in the home. There is evidence that Gram-positive spp. such as MRSA and  $\beta$ -haemolytic streptococci are shed into the environment from people who are carriers or who are infected (Masterton *et al.* 1995, Sarangi and Rowsell 1995). These organisms can survive for significant periods on floors and furnishings as well as other surfaces. Control of MRSA is now recognised as a community as well as a hospital problem. Significant increases in MRSA infections acquired in the community amongst hospitalised children without predisposing risk factors have been reported by Herold *et al.* (1998); Zylke (1998) and Dancer and Crawford (1999). MRSA carriers shed organisms onto all types of surfaces which can remain viable for significant periods. Masterton *et al.* (1995) showed that MRSA carriage in a nurse was not eradicated until topical antimicrobial therapy was combined with environmental decontamination in her home.

Disinfection in addition to cleaning is also advised for walls, floors or furnishing surfaces where there have been spills of vomit, blood or faecal material, although this may be difficult when dealing with fabrics, in which case steam cleaning may be the only option. Under these circumstances it may be advisable to wear a face mask during cleaning. If the material is considered particularly infectious, e.g. vomit associated with SRSV infection, it may then be advisable to apply disinfectant to the infected material before cleaning in order to protect the person doing the cleaning. Disinfectant should then be reapplied to the surface after cleaning. Cheesbrough *et al.* (1997) reported carpet fitters who became ill after removing a carpet from a room next to a hospital ward where an outbreak of SRSV had occurred 13 days before removal of the carpet.

Following recurrent outbreaks of SRSV viral gastroenteritis on a cruise ship the ship was cleaned and disinfected at the end of the fourth cruise in order to interrupt infection transmission (McEvoy *et al.* 1996). Fewer than 10 cases presented on subsequent cruises compared to 195 cases during the fourth cruise. Control measures included cleaning and disinfection of cabins, crew and staff quarters and communal bathrooms and steam cleaning of soft furnishings. Similarly during a hospital gastroenteritis outbreak caused by SRSV, the attack rate among patients decreased in several wards following the implementation of environmental hygiene procedures (Chadwick and McCann 1994). Infection control measures implemented included cleaning and chemical disinfection (ward floors, toilet areas, toilet seats, taps and spillages of vomit and faeces) to reduce environmental contamination. Hypochlorite solution (1%) was used for disinfecting places contaminated with vomit or faeces and 0.1% hypochlorite for general disinfection of ward floors and toilets areas.

There is some very limited evidence to indicate that disinfection of floors may be considered in homes where very young children are present – particularly where pets are also present. Recent studies of homes in which there was an infant infected with *Salmonella* suggested that environmental sources, together with other family members and pets, were more significant risk factors than contaminated foods (Schutze *et al.* 1999).

#### 4. Hygiene intervention studies in community settings

Significant evidence indicating the impact of hygiene practice in the prevention of disease transmission comes from case control studies in which the effects of the hygiene intervention procedures on infection rates have been monitored. Although none of the investigations cited relate specifically to the home, a number of studies have demonstrated the transmission of disease from day-care centres to the home where it is transferred among family members (Morrow *et al.* 1991, Fornasini *et al.* 1992, Osterholm *et al.* 1992). These studies are reviewed in more detail in the IFH review paper “The infection potential in the domestic setting and the role of hygiene practice in reducing infection” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)). In a significant proportion of these interventions the impact of hand hygiene alone was studied. Some examples of these studies are given in section 3.1.2. In other studies handwashing combined with environmental decontamination or other control measures was considered. Only two studies, relating to outbreaks involving SRSV infection, highlight the importance of environmental surface disinfection in the containment of an outbreak (McEvoy *et al.* 1996, Chadwick and McCann 1994).

A limitation of these studies is that, since they mostly involve the implementation of infection control programs involving multiple intervention steps, it is impossible to assess the effectiveness of any single intervention relative to another and thereby rank the relative importance of the different aspects of hygiene.

Indeed, as discussed by Huskins (2000) the results do not prove that the various interventions had a direct effect in decreasing infection rates. It could be argued that the reduced rates were due to variations in individual susceptibility to infection or to a

lower incidence of the pathogen amongst the case control groups. Nevertheless, overall, there is convincing circumstantial evidence to suggest that improved standards of hygiene can have a significant impact in reducing the rates of respiratory, intestinal and other viral infections in child-care facilities, domestic homes, hospitals and adult care centres and the transfer of infections between these communities.

## 5. Conclusions

In a previous review paper “The infection potential in the domestic setting and the role of hygiene practice in reducing infection.” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)) IFH evaluated the potential for infection and cross infection the home. This data was used in the production of a set of “Guidelines for the prevention of infection and cross infection in the domestic environment” ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)). The guidelines follow a risk-based or “targeted” approach in which sites, surface and situations in the home which carry a significant risk of exposing family members to infectious microbes are identified and hygiene procedures targeted at these sites and surfaces at the appropriate time.

In this paper the considerable laboratory and field data evaluating the effectiveness of hygiene procedures in the home has been reviewed. This represents the evidence base used by IFH to develop their “Recommendations for selection of suitable hygiene procedures for use in the domestic environment” which detail the procedures to be used where a hygiene risk is identified ([www.ifh-homehygiene.org](http://www.ifh-homehygiene.org)). The data presented in this review paper shows that the effectiveness of a hygiene procedure in interrupting the chain of transmission of infection depends on a whole range of factors which include the efficacy of the procedure, the nature of the site or surface, the manner which it is applied, the facilities available, and the knowledge of hygiene practice of family members.

Overall however it can be concluded that application of good hygiene practice in the home can have a significant impact in reducing the impact of infectious disease.

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**Figure 1 A Quality Assurance Approach to Hygiene**

