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Reduction of faecal coliform, coliform and heterotrophic plate count bacteria in the household kitchen and bathroom by disinfection with hypochlorite cleaners

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P. RUSIN, P. OROSZ-COUGHLIN AND C. GERBA. 1998. Fourteen sites evenly divided between the household kitchen and bathroom were monitored on a weekly basis for numbers of faecal coliforms, total coliforms and heterotrophic plate count bacteria. The first 10 weeks comprised the control period, hypochlorite cleaning products were introduced into the household during the second 10 weeks, and a strict cleaning regimen using hypochlorite products was implemented during the last 10 weeks. The kitchen was more heavily contaminated than the bathroom, with the toilet seat being the least contaminated site. The highest concentrations of all three classes of bacteria were found on sites that were moist environments and/or were frequently touched; these included the sponge/dishcloth, the kitchen sink drain area, the bath sink drain area, and the kitchen faucet handle(s). The implementation of a cleaning regimen with common household hypochlorite products resulted in the significant reduction of all three classes of bacteria at these four sites and other household sites.

INTRODUCTION

The cost of food-borne disease in the USA has been estimated at $4–$6 billion (Roberts 1988). An increase in food-borne illness has been observed in many countries recently (Sockett 1993), with a high proportion of these outbreaks occurring in the home (Roberts 1982; Sheard 1986). Households often harbour potential pathogens such as total and faecal coliforms (Scott *et al.* 1982), and previous studies have shown that the kitchen is probably the most important area in relation to the harbouring and transferring of infection (Scott *et al.* 1984).

Cross-contamination of kitchen surfaces by contaminated meat products has been demonstrated (DeWit *et al.* 1979). Objects contaminated from raw meat included the sink, dishcloth and cutting board. Contamination of cutting boards by raw chicken has also been documented by DeBoer and Hahne (1990), and cutting boards contaminated with *Salmonella* have been shown to be associated with outbreaks (Sanborn 1963).

Davis *et al.* (1968) reported that domestic dishcloths contained up to 10^8 bacteria. In a similar survey of dishcloths, Scott *et al.* (1982) found several members of Enterobacteriaceae. Studies have shown that contaminated cloths may transfer bacteria to hands or a clean surface in sufficient numbers to represent the possibility of infection if in contact with food (Scott and Bloomfield 1990a).

Kitchen sinks have been found to be rapidly colonized with large numbers of coliforms within 1 week of the occupancy of a new house (Finch *et al.* 1978). It was suggested that the coliforms were derived from food products brought into the home. Kitchen sinks have also been found to harbour the same serotypes of *Salmonella* as those isolated from infants from the household exhibiting symptoms of diarrhoea (Van Schothorst *et al.* 1978). In this case, the authors suggested that kitchen surfaces and hands may contaminate each other in a cyclic pattern. Cross-contamination of kitchen surfaces with *Salmonella* has also been shown to occur from contaminated egg shells (Humphrey *et al.* 1994).

Flushing of a household toilet produces bacteria-laden aerosols which settle on the toilet and bathroom surfaces (Gerba *et al.* 1975). Scott and Bloomfield (1985) showed that bathroom sites such as the toilet bowl surface, flush handle and floor were often contaminated with *Escherichia coli* and other coliforms and that the contamination may have been due to direct transmission from flushing of the toilet. Dis-

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infecting products can be used to minimize this contamination (Yahya *et al.* 1992).

A study by Scott and Bloomfield (1990a) showed that faecal coliform and total coliform bacteria can easily survive for 1 h on a laminate surface with a small proportion of the population surviving for as long as 24 h. Transfer of *E. coli* from the laminate surface to the fingers was as high as 40% up to 2 h after the contamination event, with some transfer occurring even after 24 h. Survival in dishcloths was much more marked, showing high numbers of *E. coli* and *Klebsiella* surviving for 48 h. Indeed, these bacteria exhibited re-growth in soiled damp cloths. Transfer of the bacteria from the soiled dishcloth to the fingers was very efficient, with high numbers transferred even 48 h after the dishcloths were inoculated.

Drying of cloths and surfaces results in reductions of bacterial populations, but drying alone cannot be relied upon to prevent the transfer of infectious microbes from household surfaces to the homeowner (Scott and Bloomfield 1990a). Laboratory tests demonstrated that cleaning with detergent results in a temporary reduction of microbial contamination in dishcloths (Scott and Bloomfield 1990b). However, in a study conducted at a university kitchen, dishcloths were found to be more heavily contaminated after cleaning with a detergent than before, and there was evidence of transfer of the contamination from cloths to surfaces and vice versa (Scott and Bloomfield 1993). Disinfection of cloths with a common household hypochlorite cleaning product was shown to be effective in reducing or interrupting this cross-contamination (Scott *et al.* 1984).

This study was conducted to determine which sites in the household kitchen and bathroom were most heavily contaminated with faecal coliform, coliform and heterotrophic plate count (HPC) bacteria. The effectiveness of different degrees of cleaning and disinfection with hypochlorite solutions was also investigated.

MATERIALS AND METHODS

A total of 15 homes were selected for this study. To qualify, each household included: a housewife who did not have a paid job outside the home, one to two children under 12 years of age, no indoor pets; occupants were not previously heavy disinfectant users, and the homeowners were willing to use products containing hypochlorite on hard surfaces. All of the households were located in Tucson, Arizona.

The total study consisted of three phases of 10 weeks each. During the control period, the homeowners were not given any specific cleaning products or cleaning instructions. They were asked to continue their usual cleaning practices for this test period. During the first intervention, the following disinfecting household products were supplied to the housekeeper with concentrations of sodium hypochlorite shown in parentheses: Clorox Liquid Bleach (5·25%) (Clorox Co., Oakland, CA, USA), Clorox Clean-up Spray (1·84%), Clorox Clean-up Dilutable (1·8%), Soft Scrub with Bleach (1·1%) (Clorox Co.), Clorox Toilet Bowl Cleanser (2·3%) and Tilex Instant Mildew Remover (2·75%) (Clorox Co.). Ultra Dawn Dishwashing Detergent (Proctor and Gamble, Cincinnati, OH, USA) and Windex Glass Cleaner (Drackett Products Co., Cincinnati, OH, USA) were also supplied as uniform products for dishwashing and the cleaning of glass and mirror surfaces. No specific cleaning instructions were mandated during the first intervention, although the occupants were asked to read the instructions on the containers. During the second intervention, the homeowner was given specific cleaning products (Clorox Liquid Bleach, Clorox Clean-up Spray, Clorox Clean-Up Dilutable, Clorox Clean-up Gel (1·1% sodium hypochlorite), Clorox Toilet Bowl Cleanser and Tilex Instant Mildew Remover), most of their existing cleaning products were removed (except for Dawn and Windex), and a cleaning routine was mandated. A cleaning schedule (Table 1) was provided to the homeowner that contained explicit cleaning instructions.

Fourteen household surfaces in the kitchen and bathroom were sampled on a weekly basis. The kitchen sites comprised the sink faucet handle(s), the sink drain rim area, the entire refrigerator handle, 929 cm^2 of counter top in area of activity, 929 cm^2 floor surface next to the kitchen sink, the sponge or dishcloth, and the entire cutting surface of the cutting board. The bathroom sites included the sink drain rim area, the sink faucet handle(s), the toilet flush handle, the top and underside of the toilet, 929 cm^2 floor surface around the base of the toilet, the shower/bath drain rim area, and 929 cm^2 surface of counter top in the area of highest activity.

Surface samples were obtained using a sterile cotton swab moistened in D/E Neutralizing Solution (Difco). This solution contains the following ingredients ($g\,l^{-1}$): Bacto tryptone, 5·0; Bacto yeast extract, 2·5; Bacto dextrose, 10·0; sodium thioglycollate, 1·0; sodium thiosulphate, 6·0; sodum bisulphite, 2·5; lecithin, 7·0; Polysorbate 80, 5·0; and Bacto bromocresol purple, 0·02. The swab was then returned to 2·0 ml of the neutralizing solution and transported to the laboratory on ice. The sponge or dishcloth was sampled by wetting the utensil with sterile buffered saline when necessary, donning new plastic gloves, and squeezing out 2·0 ml of moisture into 2·0 ml of the neutralizing solution. Samples were processed within 6 h of collection. The solution containing the swab was mixed vigorously for 30 s on a Vortex. The swab was squeezed out against the side of the tube and removed.

Samples were analysed for faecal coliforms by the spread plate method on mFC agar plates (Difco) incubated at 44·5 °C for 24 h. Colonies exhibiting a blue colour were defined as faecal coliforms. Coliforms were enumerated on M-Endo LES agar (Difco) following incubation at 35 °C for 20–24 h. The HPC bacteria were enumerated by the spread plate method on *R2*A agar following incubation at 28 °C for 7 d.

Table 1 Cleaning protocol for phase 3 of household disinfection study

	Cleaning and disinfecting method	Cleaning and disinfecting frequency
Kitchen surfaces		
Sink	1. Wash with Clorox Clean-up	1. Daily
	2. Fill sink with water, add 1 cup Clorox Bleach, drain in 10 min	2. Three times per week
Sponge or dishcloth	Soak in Clorox bleach for 5–10 min, rinse, air dry	Three times per week
Counter top, cutting board, handles	Spray with Clorox Clean-up, wipe clean after 30 s	Daily
Floor around kitchen sink	1. Spot clean with Clorox Clean-up, wipe clean after 30 s	1. Daily
	2. Mop with Clorox Clean-up (1 cup/gallon of water), let stand 5 min, rinse	2. Three times per week
Bathroom surfaces		
Sink	1. Wash with Clorox Clean-up	1. Daily
	2. Fill sink with water, add 1 cup Clorox Bleach, drain in 10 min	2. Three times per week
Toilet seat, flush handle, counter top	Spray with Clorox Clean-up, wipe clean after 30 s	Daily
Toilet bowl	1. Add 1 cup Clorox Bleach to bowl, flush after 10 min	1. Three times per week
	2. Apply Clorox toilet bowl cleaner, brush, flush after 10 min	2. Weekly
Floor around toilet	1. Spot clean with Clorox Clean-up, wipe clean after 30 s	1. Daily
	2. Mop with Clorox Clean-up (1 cup/gallon of water), let stand 5 min, rinse	2. Three times per week
Bath/shower drain	Spray entire surface area including near drain with Tilex or Clorox Clean-up, rinse after 5 min	Weekly

All dilutions were made in phosphate-buffered saline (Smibert and Krieg 1994).

The data were analysed using the Statistical Analysis Systems (SAS) software as a repeated measure or longitudinal design. Each house was viewed as a random sample from a population using a randomized complete block mixed model with weeks as a fixed treatment effect. Linear combinations of the weekly means were computed to develop estimates for the three test periods. These estimates were then used to make comparisons between the control period, the first intervention and the second intervention. The null hypothesis was that the cleaning interventions would result in no significant reductions of bacterial populations in the kitchen or bathroom.

RESULTS AND DISCUSSION

This study was designed to determine the densities of faecal coliforms, coliforms and HPC bacteria on 14 different household surfaces evenly distributed in the kitchen and bathroom areas, and the effects of cleaning on those surfaces. During the control period, the homeowners were asked to clean the home in a routine manner. During the first intervention, several cleaners, most of which contained bleach or hypochlorite, were introduced into each household. During the second intervention, all the cleaners put into the household contained hypochlorite and the participants were asked to adhere to a strict cleaning regimen (Table 1).

The first week of each phase of the study was considered to be atypical because the homeowner was likely to be cleaning the house at an unusually intense level. Therefore, the first week of the control period, the first intervention and the second intervention were not included in the statistical analysis.

Geometric mean bacterial concentrations and ranges are shown in Tables 2a, b and c. The minimum concentration shown was sometimes the minimum detection level. This is the case for every minimum shown in the ranges for faecal coliforms (Table 2a). The mean bacterial concentrations usually decreased progressively from the control phase through the first intervention and the second intervention. Two exceptions were a slight increase in faecal coliforms on the kitchen faucet handle(s) and a small increase in HPC bacteria on the bathroom shower drain area between the control phase

Table 2a Geometric means and ranges of faecal coliform colonies sq. cm^{-1} of kitchen and bathroom surfaces during three phases of cleaning and disinfection

Site	Control period	First intervention	Second intervention
Kitchen			
Faucet handle(s)	0·53 (−0·32–4·58)	0·54 (−0·32–6·09)	−0·26 (0·32–1·70)
Sink drain area	2·93 (−0·20–6·60)	2·16 (−0·20–6·75)	0·09 (−0·20–5·10)
Refrigerator handle	−1·14 (−1·61–4·20)	−1·22 (−1·61–2·68)	−1·58 (−1·61–0·99)
Counter top	−0·96 (−1·67–5·41)	−1·35 (−1·67–4·13)	−1·65 (−1·67– −0·12)
Floor	−1·04 (−1·67–4·18)	−1·27 (−1·67–4·10)	−1·67 (−1·67– −1·27)
Sponge/dishcloth (per ml)	5·08 (0·90–8·82)	4·07 (0·90–8·66)	1·27 (0·90–7·56)
Cutting board	0·07 (−1·32–5·14)	−0·59 (−1·32–4·93)	−1·29 (−1·32–1·15)
Bathroom			
Sink drain area	0·66 (0·02–6·90)	0·39 (0·02–4·39)	0·04 (0·02–2·00)
Sink faucet handle(s)	−0·26 (−0·58–3·51)	−0·41 (−0·58–3·80)	−0·57 (−0·58–0·42)
Flush handle	0·27 (0·19–2·66)	0·25 (0·19–3·81)	0·19 (0·19–0·19)
Toilet seat	−1·55 (−1·84–5·85)	−1·74 (−1·84–0·43)	−1·84 (−1·84– −1·84)
Floor	−1·33 (−1·67–3·29)	−1·54 (−1·67–0·93)	−1·60 (−1·67–2·51)
Shower drain	0·27 (−0·04–4·19)	0·07 (−0·04–2·66)	−0·01 (−0·04–3·26)
Counter top	−1·31 (−1·67–4·03)	−1·43 (−1·67–3·92)	−1·67 (−1·67– −1·67)

Values are expressed as $\log_{10}$. Ranges are shown in parentheses.

Table 2b Geometric means and ranges of coliform colonies sq. cm^{-1} of kitchen and bathroom surfaces during three phases of cleaning and disinfection

Site	Control period	First intervention	Second intervention
Kitchen			
Faucet handle(s)	1·38 (−0·32–6·00)	1·10 (−0·32–6·05)	−0·12 (−0·32–3·41)
Sink drain area	4·27 (−0·20–8·40)	3·16 (−0·20–7·29)	0·62 (−0·20–6·29)
Refrigerator handle	−0·08 (−1·61–4·42)	−0·81 (−1·61–4·20)	−1·55 (−1·61–1·08)
Counter top	−0·05 (−1·67–5·12)	−0·87 (−1·67–5·03)	−1·63 (−1·67–0·74)
Floor	−0·37 (−1·67–4·32)	−0·93 (−1·67–3·82)	−1·55 (−1·67–1·82)
Sponge/dishcloth (per ml)	6·51 (0·90–9·76)	5·50 (0·90–8·88)	1·88 (0·90–8·15)
Cutting board	1·52 (−1·32–5·82)	0·23 (−1·32–5·28)	−1·13 (−1·32–2·58)
Bathroom			
Sink drain area	1·79 (−0·27–6·90)	0·95 (0·02–5·79)	0·13 (0·02–2·44)
Sink faucet handle(s)	0·39 (−1·0–5·57)	−0·30 (−0·58–4·35)	−0·54 (−0·58–0·99)
Flush handle	0·73 (0·19–6·67)	0·41 (0·18–5·33)	0·19 (0·19–1·19)
Toilet seat	−0·98 (−1·84–4·94)	−1·62 (−1·84–2·97)	−1·82 (−1·84– −0·35)
Floor	−0·46 (−1·67–6·18)	−1·10 (−1·67–4·81)	−1·53 (−1·67–2·43)
Shower drain	0·89 (−0·04–6·51)	0·24 (−0·04–5·56)	0·03 (−0·04–5·83)
Counter top	−0·69 (−1·67–4·67)	−1·28 (−1·67–4·59)	−1·64 (−1·67–0·65)

Values are expressed as $\log_{10}$. Ranges are shown in parentheses.

and the first intervention. However, the increases in these two cases were not significant ($P = 0{\cdot}80$ and $P = 0{\cdot}51$, respectively). In several cases, the maximum of the range was higher between two consecutive periods, even though the mean was lower, showing that overall levels decreased in spite of the variability observed between houses and sampling dates. In all cases, the concentrations of bacteria decreased between the control period and the second intervention.

Table 2c Geometric means and ranges of heterotrophic plate count colonies sq. cm^{-1} of kitchen and bathroom surfaces during three phases of cleaning and disinfection

Site	Control period	First intervention	Second intervention
Kitchen			
Faucet handle(s)	4·55 (1·21–7·05)	4·20 (0·63–7·57)	2·21 (−0·32–8·76)
Sink drain area	5·22 (0·21–9·27)	5·16 (1·35–7·78)	2·72 (−0·20–8·98)
Refrigerator handle	2·88 (−0·17–8·02)	2·31 (−1·61–6·86)	0·62 (−1·61–4·50)
Counter top	2·43 (−0·29–8·49)	2·10 (−1·11–6·78)	0·52 (−1·67–4·87)
Floor	2·61 (−0·03–6·12)	2·64 (−0·55–7·75)	1·86 (−0·84–7·68)
Sponge/dishcloth (per ml)	8·08 (4·62–11·54)	7·41 (2·90–10·65)	4·28 (0·90–10·28)
Cutting board	3·98 (0·45–9·23)	3·30 (−0·15–6·54)	1·24 (−1·32–6·07)
Bathroom			
Sink drain area	5·63 (0·79–9·42)	4·92 (1·42–8·10)	2·42 (0·02–9·45)
Sink faucet handle(s)	3·89 (0·50–8·26)	3·30 (−0·28–8·22)	1·59 (−0·58–8·48)
Flush handle	3·91 (0·44–8·09)	3·47 (0·19–8·53)	2·10 (0·19–9·49)
Toilet seat	2·27 (−0·73–6·39)	1·87 (−1·84–8·95)	0·32 (−1·84–4·50)
Floor	3·46 (−0·22–6·06)	2·77 (−1·67–6·81)	1·09 (−1·67–4·96)
Shower drain	4·02 (1·43–7·52)	4·14 (1·10–8·26)	3·29 (−0·04–9·08)
Counter top	2·61 (−0·61–6·12)	2·17 (−1·67–7·13)	0·97 (−1·67–4·63)

Values are expressed as $\log_{10}$. Ranges are shown in parentheses.

The four sites with the highest densities and the four sites with the lowest densities of faecal coliform, coliform and HPC bacteria for all three test phases are shown in Fig. 1a, b and c. The sites with the highest densities of faecal coliforms during the control period were the sponge/dishcloth, the kitchen sink drain area, the bath sink drain area and the kitchen faucet handle(s) (Fig. 1a). This pattern remained consistent through the first intervention and into the second intervention, with the exception of the kitchen faucet handle(s) which became the sixth most contaminated site for faecal coliforms by the latter period (Table 2a). Although the flush handle was ranked within the top four sites during the second intervention period, no faecal coliforms were detected on the handle during this time and the value depicted is the minimum detection level. The sites with the lowest concentrations of faecal coliforms during the control period were the refrigerator handle, the bathroom counter top, the bathroom floor around the toilet and the toilet seat (Fig. 1a). The bathroom counter top and the toilet seat remained two of the least contaminated sites in the household.

The sites most heavily contaminated by coliforms were similar to those contaminated by faecal coliforms, although the cutting board ranked within the top four during the control period (Fig. 1b) with the kitchen faucet handles having the fifth highest densities of coliforms (Table 2b). The least contaminated sites tended to be the counter tops and floors, with the toilet seat once again being the cleanest site. In many cases, the values shown for the second intervention period were at or near the minimum detection levels.

The four sites with the highest densities of HPC bacteria were very similar to those most contaminated with faecal coliforms and coliforms, as were the least contaminated sites (Fig. 1c). However, the refrigerator handle was one of the least contaminated sites during the first and second intervention periods.

Over all three categories of bacteria and all three study periods, the highest levels of contamination were (in descending order): the sponge/dishcloth, the kitchen sink drain area, the bath sink drain area, the kitchen faucet handle(s), the flush handle, the shower drain area, the bathroom sink faucet handle(s), the cutting board, the refrigerator handle, the kitchen counter top, the floor in front of the kitchen sink, the bathroom counter top, the floor in front of the toilet and the toilet seat (Tables 2a, 2b and 2c). The kitchen showed more bacterial contamination than the bathroom. Indeed, three of the top four most contaminated sites during the control and first intervention periods were in the kitchen. The most contaminated sites during the second intervention were shared equally between the kitchen and the bathroom.

Overall, the highest bacterial concentrations were found in dishcloths or sponges and in the kitchen and bathroom sink areas. These findings concur with previous studies (Scott *et al.* 1982; Speirs *et al.* 1995). The highest concentrations of faecal coliforms and coliforms were found in the sponge/

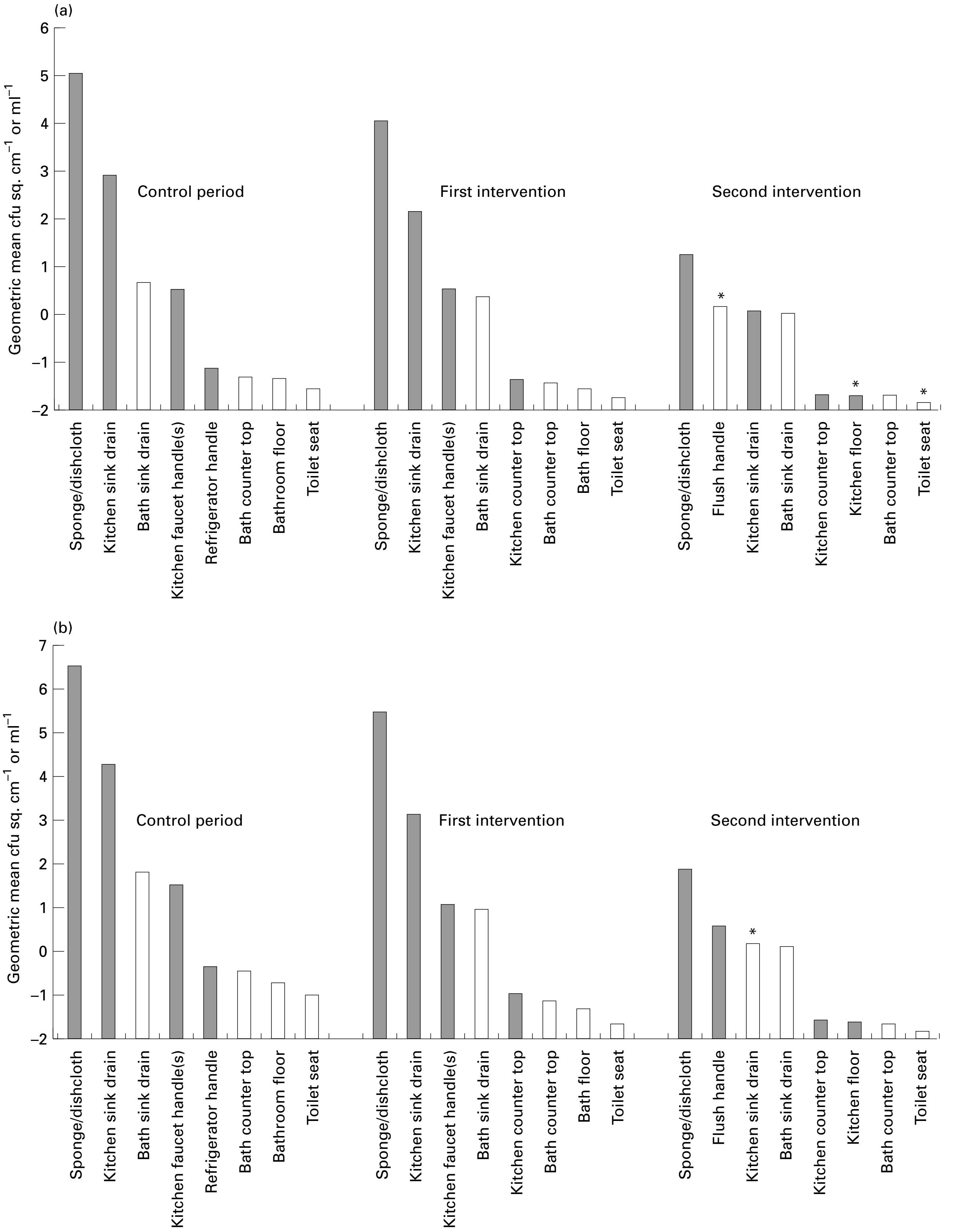

Fig. 1 Ranking of sites by (a) faecal coliform densities; (b) coliform densities; (c) heterotrophic plate count bacteria densities. The four most and four least contaminated sites are shown for each period. Geometric mean values are expressed as $\log_{10}$. *Minimum detection level

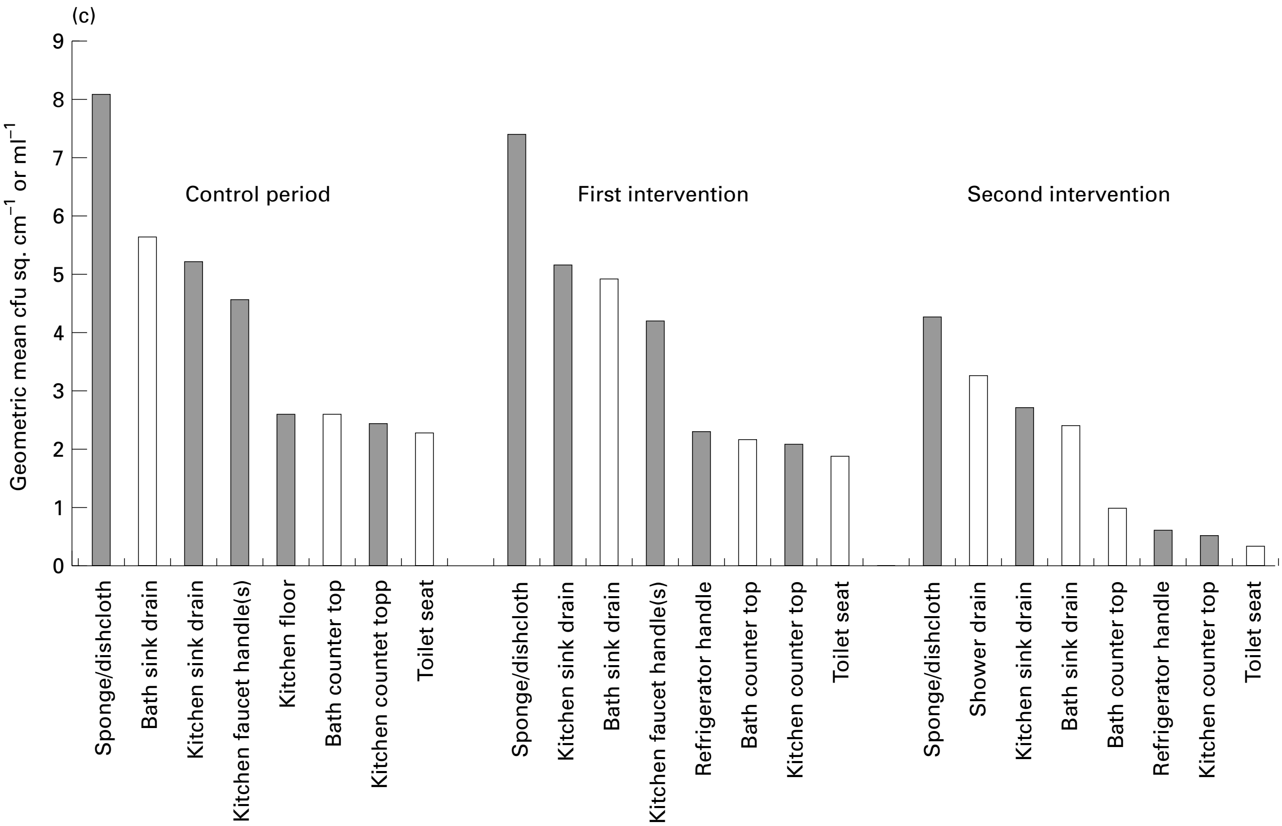

Fig. 1 —*continued.*

dishcloth and in the kitchen sink drain area while the lowest concentrations were found on the bathroom counter top, on the bathroom floor and on the toilet seat. Finch *et al.* (1978) also found more coliform and faecal coliform contamination in the kitchen than in the bathroom, with the kitchen sinks being particularly heavily contaminated.

It was of interest that the toilet seat was found to have the least bacterial contamination in all cases for all categories of bacteria in this study. These findings support and extend those of Finch *et al.* (1978). These investigators also found that there was very little faecal contamination of the household toilet. The latter authors found that homeowners disinfected the toilet regularly and the toilet seat was probably allowed to dry between periods of use, which may have resulted in low levels of contamination.

The greatest reductions of faecal coliforms occurred most often (10 of 14 sites) between the first and the second interventions (Table 2a). The greatest reductions between the control period and the second intervention were observed in the kitchen sponge/dishcloth, in the kitchen sink drain area and on the cutting board, with $\log_{10}$ reductions of 3·81, 2·84 and 1·36, respectively. The areas with the least faecal coliform reductions between the latter two periods were the shower drain area, the bathroom floor around the toilet and the flush handle, with $\log_{10}$ reductions of 0·28, 0·27 and 0·08, respectively.

The greatest reductions in coliform densities occurred most often (eight of 14 sites) between the control period and the first intervention (Table 2b). The sites with the greatest reductions of coliforms between the control period and the second intervention corresponded with the faecal coliform results, showing $\log_{10}$ reductions of 4·63, 3·65 and 2·65 for the sponge/dishcloth, the kitchen sink drain area and the cutting board, respectively. The sites least affected by the interventions were also similar, including the shower drain area, the toilet seat and the flush handle with $\log_{10}$ reductions of 0·86, 0·84 and 0·54, respectively.

The greatest reductions in HPC bacterial populations always occurred between the first and the second interventions (Table 2c). The areas showing the greatest overall decreases were the sponge or dishcloth, the bathroom sink drain area and the cutting board with $\log_{10}$ reductions of 3·80, 3·21 and 2·74, respectively. Those least affected were the flush handle, the kitchen floor by the sink and the shower drain area, with $\log_{10}$ reductions of 1·81, 0·75 and 0·73, respectively.

In most cases, the bacterial reductions between the successive test phases were significant ($P \leqslant 0{\cdot}05$) (Table 3). Indeed, the decreases in bacterial density were often very significant with $P < 0{\cdot}01$. The reductions were most often significant between the control period and the second intervention. The only bacterial reduction achieved between the control period and the second intervention that was not significant was the faecal coliform reduction on the flush handle. In this latter case, no significant reductions were observed between any of the consecutive phases. However, the concentrations of faecal coliforms and coliforms during the second intervention at this site were below minimum detectable levels.

It is apparent that the stringent cleaning routine implemented during the second intervention resulted in higher levels of disinfection than those accomplished during the first intervention when the homeowners were free to continue cleaning at their usual frequencies. The second intervention included more frequent cleaning and a greater emphasis on the use of hypochlorite products than the first intervention. The most marked reductions in faecal coliforms and coliforms between the control period and the second intervention were found for the sponge/dishcloth and the kitchen sink drain area. This may have been due to the practice of allowing a bleach solution to remain in the sink and soaking the sponge/dishcloth in the solution during this time. The same pattern of disinfection was not demonstrated for the bathroom sink drain which was to receive similar treatment. However, the success of disinfection of the sponge/dishcloth and the kitchen is particularly significant as these two sites are more likely to contaminate food during meal preparation than the bathroom sink. Relatively more consistent marked reductions in HPC bacteria concentrations were achieved during the second intervention than seen for the faecal coliforms and coliforms.

Potential health benefits resulting from the use of disinfectant cleaners in the home is difficult to determine as relatively little information is available on the subject. The proportion of household outbreaks of gastroenteritis that arise from surface cross-contamination as opposed to inadequately cooked or stored food is also unknown. However, there is evidence that the survival and transfer of potentially pathogenic bacteria via environmental surfaces is important (Sanborn 1963; Van Schothorst *et al.* 1978; Humphrey *et al.* 1994). DeWit *et al.* (1979) showed that following the domestic preparation of chickens contaminated with *E. coli*, the bacteria were isolated from the cutting board, door handles and faucet handles where hand transfer must have occurred.

Hypochlorite disinfectants have been found to be more effective than phenolic disinfectants on kitchen and bathroom surfaces in a previous home-use study (Scott *et al.* 1984). Although quaternary ammonium compounds can result in a significant reduction in total bacterial numbers on surfaces

Table 3 Statistical analyses by analysis of variance for significant decreases in numbers of faecal coliforms (FC), coliforms and heterotrophic plate count (HPC) bacteria during the cleaning of kitchen and bathroom surfaces

	Control *vs* first intervention			Control *vs* second intervention			First intervention *vs* second intervention		
Household site	FC	Coliforms	HPC	FC	Coliforms	HPC	FC	Coliforms	HPC
Kitchen									
Faucet handle(s)	0·80	0·18	0·06	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Sink drain area	<0·01	<0·01	0·45	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Refrigerator handle	0·47	<0·01	0·02	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Counter top	<0·01	<0·01	0·09	<0·01	<0·01	<0·01	0·02	<0·01	<0·01
Floor	0·05	<0·01	0·97	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Sponge/dishcloth	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Cutting board	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01	<0·01
Bathroom									
Sink drain area	0·01	<0·01	<0·01	<0·01	<0·01	<0·01	0·03	<0·01	<0·01
Sink faucet handle(s)	0·05	<0·01	<0·01	<0·01	<0·01	<0·01	0·15	0·16	<0·01
Flush handle	0·76	<0·01	0·04	0·18	<0·01	<0·01	0·27	0·05	<0·01
Toilet seat	<0·01	<0·01	0·03	<0·01	<0·01	<0·01	0·77	0·43	<0·01
Floor	0·02	<0·01	<0·01	<0·01	<0·01	<0·01	0·46	0·04	<0·01
Shower drain	<0·01	<0·01	0·51	<0·01	<0·01	<0·01	0·65	0·36	<0·01
Counter top	0·31	<0·01	0·02	<0·01	<0·01	<0·01	0·03	0·05	<0·01

P-values shown.

and cloths (Scott and Bloomfield 1993), there was little reduction in the numbers of coliforms in these tests.

While hypochlorite products can significantly reduce bacterial contamination in the home, Scott *et al.* (1984) found that the effect of a single application was short-lived. Also, three repeated applications of a hypochlorite solution did not result in a significant improvement in decontamination when compared with the single application. Re-contamination was thought to be due to the re-use of the sites and local multiplication of residual bacteria not killed by the disinfection process. The present study was designed to include longer periods of disinfection regimens. Hence, more frequent cleaning with a combination of hypochlorite products was found to reduce the numbers of bacteria significantly in most cases (Table 3). This was particularly true when comparing the control period with the results of the second intervention. The introduction of hypochlorite cleaning products into the home in the first intervention resulted in significant reductions of bacteria in 32 of 42 cases. The addition of a strict cleaning regimen in the second intervention led to significant reductions in contamination in all cases except for the faecal coliform bacteria found on the flush handle ($P = 0{\cdot}18$). However, in this latter case, the faecal coliform densities were reduced to non-detectable levels.

Previous work (Scott *et al.* 1984) has also shown that dishcloths are a potential health hazard unless they are thoroughly dried after use which is not often the case. An effective decontamination procedure is required to ensure that the cloths do not transmit pathogens. The present study demonstrated that the use of hypochlorite disinfection products in the home results in significant and marked bacterial reductions in the sponge/dishcloth in all cases (Table 3).

The cutting board is also a household site from which cross-contamination with food products can easily occur. As with the sponge/dishcloth, the introduction and the strict use of hypochlorite cleaning products resulted in significant reductions of all three categories of bacteria in all cases. In contrast, disinfection of cutting boards with four different disinfectants (one of which contained hypochlorite) did not result in significantly greater reductions of bacterial contamination than rinsing with water in a study by Miller *et al.* (1996). However, this latter study was performed in the laboratory with single applications of the disinfecting products, whereas the study described in this report included daily disinfection in the home over a 10-week period.

Previous work suggested that significant decontamination of sites such as household toilets and sinks that are in continuous use could not be achieved by daily disinfection (Scott *et al.* 1984). However, daily disinfection was only practised for 3 d. The study described here comprises 10 weeks of intermediate, and 10 weeks of high levels of disinfection practices. During the second intervention, the toilet bowl was disinfected three times per week for 10 weeks. The toilet seat was disinfected daily with a hypochlorite cleaning product. Hence, significant reductions in bacterial concentrations were consistently found on the toilet seat and the floor around the toilet when comparing the first or second interventions with the control period (Table 3). These findings are in agreement with a previous study showing that disinfection of the toilet bowl can significantly reduce the numbers of bacteria ejected from the bowl during flushing (Yahya *et al.* 1992). Toilet bowl emissions are thought to be a source of contamination of nearby bathroom surfaces. Significant reductions of faecal coliform bacteria were not always achieved for the flush handle in the current study. This was due partly to the initial low numbers of faecal coliforms on the flush handle as no faecal coliforms were detected during the second intervention, yet the reduction could not be evaluated as significant.

In conclusion, this study shows that many sites in the household kitchen and bathroom are contaminated with bacteria. The kitchen is more heavily contaminated than the bathroom, particularly the sponge/dishcloth. The most contaminated sites within the home are those which tend to remain moist, such as the sponge/dishcloth and drain areas, and the site that is most frequently touched, the kitchen faucet handle(s). Ordinary cleaning practices may do little to reduce the microbial load. The introduction of hypochlorite cleaning products into the home results in a significant reduction of bacteria in most cases. Furthermore, the hypochlorite disinfection products in combination with a regular cleaning schedule results in a marked and significant reduction of HPC bacteria and opportunistic pathogens such as the faecal coliform and total coliform bacteria in the kitchen and the bathroom.

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