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The effect of wiping and spray-wash temperature on bacterial retention on abraded domestic sink surfaces

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R.A. STEVENS AND J.T. HOLAH. 1993. The relative cleanability of artificially abraded stainless steel, enamelled steel, mineral resin and polycarbonate domestic sinks was assessed by examining bacterial retention after cleaning. Two cleaning regimes were used: the mechanical action of wiping combined with a spray-rinse, and spray-washing at a range of temperatures. After wiping, stainless steel retained 0·5–1 log order fewer bacteria than the enamel sinks which in turn were 0·5 log order cleaner than the mineral resin and polycarbonate sinks. After spray-washing, stainless steel retained 0·5 log order fewer bacteria than enamel which in turn was 0·5 log order cleaner than the polycarbonate and mineral resin. Extending the number of wipes or increasing spray-wash temperature enhanced bacterial removal but, in general, did not change the relative cleanability of the sink materials. As a cleaning technique, wiping was shown to be more effective than spray-washing in reducing bacterial numbers. SEM studies showed that bacteria were typically retained in surface imperfections, particularly pits and crevices such that surfaces which sustained the most extensive damage due to abrasion retained higher numbers of bacteria.

INTRODUCTION

Factors to be considered in the comparison of materials to be used as food contact surfaces include durability, cost and cleanability. Surface hygiene is a critical consideration for food preparation areas because of the possibility of contamination of food. Kitchen and catering sinks are sources of contamination by food spoilage and/or pathogenic bacteria. Sink materials that retain fewer numbers of bacteria after cleaning would be the hygienic choice and present the least risk of contamination.

A previous investigation (Holah and Thorpe 1990) assessed the cleanability of stainless steel, enamelled steel, mineral resin and polycarbonate sinks both before and after artificial abrasion. No difference in cleanability of unused sink surfaces was found but stainless steel, abraded to produce a finish not dissimilar to that observed on naturally worn domestic stainless steel sinks, was approximately 10 times more cleanable than the other sink materials subjected to the same treatment. Further to this, extending the cleaning time did not enhance bacterial removal from the other surfaces as compared with stainless steel. This difference in cleanability was thought to be caused by the characteristic surface changes due to the abrasion, with stainless steel being most resistant to surface change.

This work sought to determine the relative retention of bacteria on the same abraded sink materials by investigating additional cleaning factors. These were the influence of wiping, a mechanical cleaning force, combined with a spray-rinse and the effect of spray-wash temperature.

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MATERIALS AND METHODS

Preparation of sink samples

Two examples, from different manufacturers of the following sink material types were purchased: austenitic stainless steel (sinks 1 and 2), polycarbonate (sinks 3 and 4), enamelled steel (sinks 5 and 6) and mineral resin (sinks 7 and 8). Sinks 1 to 8, inclusive, were the same makes and models as purchased for earlier studies (Holah and Thorpe 1990). A ferritic stainless steel sink was also purchased (sink 9). Sample pieces, 40 × 20 mm and 80 × 60 mm in size, were removed from the sink bases and abraded as described by Holah and Thorpe (1990). Surface roughness was assessed before and after abrasion using a surface roughness measuring instrument (Rank Taylor Hobson Surtronic 3P, Leicester, UK) (Anon. 1984a,b).

Cleaning studies

Biofilms of *Acinetobacter calcoaceticus* (Campden Food and Drink Research Association Culture Collection—CRA 296) were attached to sink samples using techniques described by Holah *et al.* (1989). The samples were wiped with an 80 × 60 × 25 mm synthetic open pore sponge held in a stainless steel casing to which a steel block was attached. The combined weight of the casing and the block was 692 g which simulated the mean force measured when volunteers produced a wiping action on a balance pan. For each 80 × 60 mm sink piece, a sponge was moistened with 5 ml distilled water. A 0·5 ml volume of a domestic washing-up liquid (Velvet, Maigret Chemicals Ltd, Daventry, UK) was then pipetted on the centre of the sponge. The sponge/weight was placed on the edge of the sink piece and pulled across its length. For multiple wipes (two, three or five wipes), the sponge was lifted off the sample after the first wipe and placed back on the starting edge for the next wipe. The sink pieces were rinsed with a purpose-built cleaning rig which produced spraying conditions as previously used (Holah and Thorpe 1990). The rig consisted of a 20 l tank, feeding into a centrifugal pump (Stuart Turner, Henley-on-Thames, Oxon), a needle valve for flow control and a relief valve to return surplus flow to the tank. The main cleaning flow passed through a braided hose to a sprinkler head under which samples to be sprayed were positioned. Samples that had been wiped and rinsed were rinsed for 10 s with potable water (11°C). Samples that were spray cleaned were sprayed with a 0·33% v/v aqueous solution of Velvet at a range of temperatures for 5 s. Detergent residues were rinsed off with distilled water from a wash bottle before attached bacteria were enumerated.

Bacteria were enumerated on sink samples by direct epifluorescent microscopy (DEM) (Holah *et al.* 1989). Samples were examined under oil at 1000 × magnification with an epifluorescent microscope linked via a video camera to an Optomax V Image Analysis System (Analytical Measuring Systems, UK). The total surface area covered by fluorescing bacteria was measured for each field and converted to bacteria per cm^2 by dividing the area of coverage by the area of one bacterium and multiplying by the number of field areas in one cm^2. The area of one bacterium was determined by selecting 'Edit Mode' and initiating a measurement of the area of a single cell. This was repeated 20 times and the mean value, $1{\cdot}4\mu^2$, was employed in a user-defined parameter which converted total bacterial count to count per cm^2. An enumeration of 20 fields of view was undertaken for each sample and results expressed as colony-forming units (cfu) per cm^2.

Two-way analysis of variance (ANOVA) was used to test whether there were significant differences between sink materials and whether there was an effect of number of wipes or spray-wash temperature. An interaction term was included in the ANOVA to assess whether the number of wipes or spray-wash temperature had any effect on the relative performance of the sink materials. Conventional significance levels ($P < 0{\cdot}05$) were used. When the ANOVA test indicated a significant difference between materials, a Newman-Keuls multiple range test (Snedecor and Cochran 1980) was carried out. This test was employed to categorize the sink materials into groups for which similar cleanability was obtained.

RESULTS AND DISCUSSION

Surface roughness measurements (not shown) and visual examinations by scanning electron microscopy (SEM) indicated that there was little difference, before and after abrasion, in the sink materials used in this and the previous study (Holah and Thorpe 1990).

For the wiping trials control counts of biofilm development on all sink samples indicated little difference between the sink types, with counts *ca* 5 × 10^6 cfu per cm^2. Mean log counts from 15 wiping trials each at one, two, three and five wipes are shown in Fig. 1. Two-way analysis of variance with interaction (number of wipes × material) showed that extended wiping enhanced cleanability of the sink surfaces ($P < 0{\cdot}001$) and showed a significant difference in cleanability for the different sink materials ($P < 0{\cdot}001$). Where significance was obtained, Newman-Keuls multiple range tests were performed on each set of wiping trial results to categorize the sink materials into groups of similar cleanability using 5% significance levels (Table 1).

The results in Table 1 indicated that stainless steel sinks were significantly more cleanable than the enamel, poly-

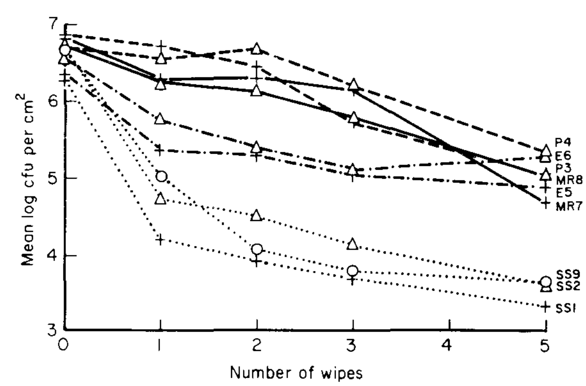

Fig. 1 Mean ($n = 15$) log cfu per cm^2 *vs* number of wipes for a range of abraded domestic sink materials. SS, Stainless steel; E, enamelled steel; MR, mineral resin; P, polycarbonate; ··· + ···, SS 1; ··· △ ···, SS 2; ··· ○ ···, SS 9; — + ––, P 3; — △ ––, P 4; — + —, E 5; — △ —, E 6; — + —, MR 7; — △ —, MR 8

Table 1 Analysis of wiping trial results

Sink material	1 Wipe subscript	2 Wipes subscript	3 Wipes subscript	5 Wipes subscript
Stainless steel 1	a	a	a	a
Stainless steel 2	b	b	b	a
Stainless steel 9	c	a	a	a
Enamelled steel 5	d	c	c	bc
Enamelled steel 6	e	c	c	c
Mineral resin 7	f	de	e	b
Mineral resin 8	f	d	d	bc
Polycarbonate 3	g	ef	d	c
Polycarbonate 4	g	f	e	c

Note: Subscript labels range from a (best) to g (worst), with intermediate materials labelled ab, bc, etc. Materials with no common subscript were found to be significantly different whereas those with a common subscript did not differ significantly.
Materials were graded according to bacterial removal after cleaning with Newman-Keuls multiple range tests (5% significance). Results for each of 1, 2, 3 and 5 wipes were treated independently.

carbonate and mineral resin sinks after one, two, three and five wipes. The enamelled steel sinks ranked next in order of cleanability, with enamel sink 5 performing better at one wipe than enamel sink 6. The enamel sinks were 0·5 to 1 log order less cleanable than the stainless steel sinks but were approximately 0·5 log order more cleanable than the mineral resin and polycarbonate sinks, which achieved similar levels of cleanability.

Sink surface cleanability increased with the number of wipes (Fig. 1) though the rank order of the sinks remained the same. The degree of cleanability achieved by the stainless steel sinks after one wipe was not achieved after five wipes by the other materials.

For the spray-wash temperature trials, control counts of biofilm development on all sink pieces indicated little difference between the sinks with counts *ca* 10^7 cfu per cm^2. Mean log counts from 15 spray-wash trials each at 10°C, 25°C, 40°C and 55°C are shown in Fig. 2. Two-way analysis of variance with interaction (spray-wash temperature × material) showed a significant difference ($P < 0{\cdot}001$) for both material type and temperature with the most significant differences for temperature noted between 25°C and 40°C. Sinks were categorized according to cleanability at each temperature using Newman-Keuls multiple range tests at the 5% significance level (Table 2).

Results in Table 2 showed that the stainless steel sinks were significantly more cleanable than enamel sink 6, both

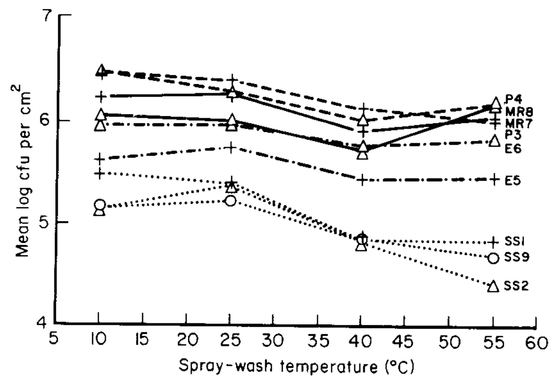

Fig. 2 Mean (n = 15) log cfu per cm^2 *vs* spray-wash temperature for a range of abraded domestic sink materials. SS, Stainless steel; E, enamelled steel; MR, mineral resin; P, polycarbonate; ···+···, SS 1; ···△···, SS 2; ···○···, SS 9; — + ––, P 3; —△––, P 4; — + —, E 5; —△—, E 6; — + —, MR 7; —△—, MR 8

Table 2 Analysis of spray-wash trial results

Sink material	10°C spray-wash subscript	25°C spray-wash subscript	40°C spray-wash subscript	55°C spray-wash subscript
Stainless steel 1	b	ab	a	b
Stainless steel 2	a	ab	a	a
Stainless steel 9	a	a	a	ab
Enamelled steel 5	b	bc	b	c
Enamelled steel 6	c	cd	bc	d
Mineral resin 7	cd	d	bc	d
Mineral resin 8	c	cd	b	d
Polycarbonate 3	d	d	c	d
Polycarbonate 4	d	d	c	d

See footnote to Table 1.
Materials were graded according to bacterial removal after 5s spray-wash cleaning with Newman-Keuls multiple range tests (5% significance). Data obtained at each temperature were treated independently.

mineral resin sinks and both polycarbonate sinks at 10°C and 25°C, and all of the sinks at 40°C and 55°C. No significant difference was shown between the polycarbonate sinks and mineral resin sink 7 at the four test temperatures. At 55°C, enamel sink 6, both mineral resin sinks and both polycarbonate sinks achieved similar levels of cleanability.

Two effects were seen with increasing spray-wash water temperature. First, all of the sink materials showed enhanced cleanability with increased temperature. Secondly, the difference in cleanability between stainless steel and the other materials became more pronounced as the spray-wash temperature was increased. For example, this effect was shown for enamel sink 5 which, although not significantly different from the stainless steel sinks at 10°C and 25°C, was significantly less cleanable than stainless steel at 40°C and 55°C.

Overall results suggest that five wipes followed by a 10 s rinse removed more bacteria per cm^2 than did spray-washing at the highest test temperature (55°C) (Figs 1 and 2). Wiping five times followed by a 10 s rinse removed approximately 1 log order more bacteria than did spray-washing at 55°C for each of the sinks. Similar conclusions were observed by Offiler (1990) who suggested that of the four cleaning factors, mechanical force has a greater influence on cleaning action than solution temperature, chemical type or time of application.

Observations with SEM revealed no apparent difference between areas of bacterial retention after the spray-washing and the wiping trials and bacteria were typically retained in areas that had been most affected by the abrasion process, e.g. pits and crevices. Results from this work, together with those from the previous study, further suggest a relationship between surface topography and bacterial retention after cleaning. This is in agreement with other workers who have demonstrated enhanced bacterial attachment associated with increasing surface roughness (Characklis 1973; Gibbons and Denton 1981) and conversely, reduced cleanability as measured by bacterial retention (Timperley and Lawson 1980; Hoffmann and Reuter 1984).

In conclusion, this and the previous study suggest that polycarbonate, mineral resin and enamelled steel sink surfaces are more readily damaged by abrasion such that they would require a more stringent cleaning programme. With extended cleaning, however, they may still not achieve a degree of surface hygiene comparable to abrasion-resistant materials such as stainless steel. It could be suggested, therefore, that for construction of domestic and catering sinks (and also for other food handling equipment), abrasion-resistant materials would not only be more durable but are also likely to remain more hygienic throughout use.

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REFERENCES

Anon. (1984a) ISO 4287-1 : 1984 *Surface Roughness—Terminology—Part 1: Surface and its Parameters.* Geneva: International Organisation for Standards.

Anon. (1984b) ISO 4287-2 : 1984 *Surface Roughness—Terminology—Part 2: Measurements of Surface Roughness Parameters.* Geneva: International Organisation for Standards.

Characklis, W.G. (1973) Attached microbial growths; 1. Attachment and growth. *Water Research* 7, 1113.

Gibbons, D.B. and Denton, P.H. (1981) Surface roughness and biofouling. In *Proceedings of the 2nd World Congress of Chemical Engineering*, Vol. 1, pp. 430–441. Montreal, Canada: Canadian Society for Chemical Engineering.

Hoffman, W. and Reuter, H. (1984) Effect of surface roughness and other factors on circulation cleaning of straight pipes. *Chemis-Ingenieur-Technik* 56, 328–329.

Holah, J.T. and Thorpe, R.H. (1990) Cleanability in relation to bacterial retention on unused an abraded domestic sink materials. *Journal of Applied Bacteriology* **69**, 599–608.

Holah, J.T., Betts, R.P. and Thorpe, R.H. (1989) The use of direct epifluorescent microscopy to determine surface hygiene. *International Biodeterioration* **25**, 147–153.

Offiler, M.T. (1990) Open plant cleaning: equipment and methods. In *Proceedings of Hygiene for the 90s*, November 7–8, Campden Food and Drink Research Association, UK.

Snedecor, G.W. and Cochran, W.G. (1980) *Statistical Methods*, 6th edn, pp. 273–275. Ames, Iowa: State University Press.

Timperley, D.A. and Lawson, G.B. (1980) Test rigs for evaluation of hygiene in plant design. In *Hygienic Design and Operation of Food Plant* ed. Jowitt, R. Chichester: Ellis Horwood Ltd.

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