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A method for measuring the cleaning effect of flushing disinfectors

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SUMMARY

A method is presented with which the mechanical cleaning effect of flushing disinfectors can be estimated independently of the thermal disinfecting effect of the hot flushing water. This makes it possible to specify the demands to be placed on the disinfecting effect of flushing with water of 85 °C or more.

Bacillus stearothermophilus spores suspended in faeces were used as indicators because of their non-sensitivity to the hot-water temperature. Their elimination by flushing could thus be attributed to the mechanical effect of the water and not to the disinfecting effect of the temperature. A simple bacteriological technique was used, and the elimination factor (EF) was calculated as the ratio of the number of micro-organisms in the contamination before and after flushing. By using flushing water below 50 °C for 130 s the EF on a bedpan was about 10^4–10^6. The effect of flushing with water of the same temperature for only half that time was somewhat weaker and when the temperature was raised to 85 °C after half the flushing time the effect was somewhat stronger.

It can be presumed that the conventional disinfecting phase with hot (85 °C) water for about 45 s in the commonly used flushing units could be substantially shortened and the costs of their use thereby reduced.

INTRODUCTION

Disinfection of non-disposable hospital items with hot water in a flushing disinfector is gradually ousting chemical disinfection. This is because the use of hot water is more reliable and more readily acceptable from the point of view of the environment. Unfortunately, however, such disinfection is sometimes more expensive than the use of chemicals, a disadvantage that is becoming increasingly important because of increasing fuel prices and, in some areas, the increasing scarcity of water. It is therefore desirable to reduce the consumption of water, especially hot water, wherever reasonably possible without jeopardizing the effect of disinfection. Only on rare occasions is it necessary to disinfect the contents of, for instance, a bedpan. It is the bedpan and preferably also the interior of the

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disinfector itself that have to be disinfected. Normally the faeces can be flushed directly into the drain.

Manufacturers of flushing units for hot water have for many years been somewhat uncertain about the actual requirements of their goods, owing to the lack of well-defined functional requisites of such units. In Scandinavia they have accepted the recommendation of Kallings (1970) to flush the item with hot (85 °C) water for at least 40 s. To be on the safe side some manufacturers have increased the time to about 55 s.

The flushing units widely used for disinfecting mainly bedpans and urine flasks consume as much as 50–70 l of water – of which about half is at least 85 °C – every time they are used. Normally only one bedpan or urine flask is flushed at a time. It must therefore be seriously questioned whether such a procedure is economically defensible.

Spri (The Swedish Institute for Planning and Rationalization of Health and Social Welfare Services (1977)) has recently published a series of specifications of washing and flushing disinfectors. These specifications give the demands to be placed on the units expressed as inactivating factors (IF), i.e. the ratio between the number of viable test organisms before and after the disinfecting procedure. Niléhn (1972) described an excellent method for measuring IF in which she uses a suspension of bacteriophages enclosed in polythene capillaries. According to Spri's (1977) specification, the IF should be at least 10^7 on the article to be disinfected and at least 10^5 on the inner surface of the flushing unit. Conventional flushing with hot (85 °C) water for 40 s achieves an IF of more than 10^8 without difficulty.

This type of function test measures only the disinfection by the heat and ignores the mechanical effect of the water. Several methods have been used to assess the mechanical effect of the actual flushing with water (Koller, 1978; Niléhn, 1972) but all of them are difficult to standardize, and none are suitable for a graduated assessment of the effect. The test object is experimentally contaminated, and after having been flushed the effect is judged by ocular examination, or, if bacteria are included in the contamination, by culture. In experiments with *Streptococcus faecalis* or other bacteria sensitive to the temperature of the water used, the effect observed is due not only to the cleaning capacity of the flushing unit, but also to the disinfecting effect of the high temperature.

This paper describes a method for assessing the purely mechanical cleaning effect of the flushing units, i.e. exclusive of the effect of the conventionally high temperature of the water used. Once this is known, the demands to be placed on the subsequent expensive disinfection can be more realistically specified, and if the mechanical cleaning is effective, disinfection with an IF far below 10^7 will presumably be sufficient.

MATERIALS AND METHODS

Media

In the experiments with spores the media used were: Tryptone glucose yeast (TGY) agar and broth (Bacto tryptone 0·5 %; yeast extract, Difco, 0·3 %; $Na_2HPO_4 + 2H_2O$, Merck; 0·2 %, Bromthymol blue 1·2 % of a 0·2 % solution; Dextrose,

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0·5 %). The plates contained 2·5 % agar. In the experiments with *S. faecalis* blood agar and nutrient broth were used.

Strains

Bacillus stearothermophilus (strain NIH 7953) was cultured on TGY agar and was harvested with distilled water after incubation at 55 °C for about 24 h. The suspension was then heated to 80 °C at which it was kept for 10 min, and then concentrated by gentle centrifugation.

Colony counts of aliquots of the suspension remained unchanged even after storage of the suspension at 4 °C for several weeks. The concentration of the bacteria in the suspension was also determined by counting in a Buerker chamber. Microscopic examination showed that more than 95 % of the bacteria were in the form of spores.

Streptococcus faecalis (strain EF 2844) were cultured in nutrient broth at 37 °C for 24 h, after which the suspension in the broth was concentrated to a suitable degree by gentle centrifugation. The suspension was then used immediately and at the same time a colony count was made on blood agar.

Technique

Stainless-steel square plates (5 × 5 cm) with a surface finish similar to that of a bedpan were contaminated with micro-organisms suspended in faeces or blood. The plates were then dried and fastened with adhesive tape to the inner wall of the flushing unit and to a bedpan placed in the unit.

In one experimental series untreated human faeces were carefully mixed with an equal volume of a suspension of *Bacillus stearothermophilus* spores. The mixture contained 10^9 spores per ml. Of this, 0·2 ml was smeared over about 15 cm^2 of one side of the test plate, i.e. 2×10^8 spores. In a smaller experimental series citrated rabbit's blood was used instead of faecal material. After having been fan-dried for 1 h at room temperature the plates were used for the test within the next hour.

In a third experimental series designed to elucidate the combined mechanical cleaning and disinfecting effect, enterococci were used instead of *B. stearothermophilus* spores. *Streptococcus faecalis* were mixed with autoclaved faeces and applied to the test plates in the same way as in the experiments with the spores. Each plate was smeared with 5×10^7 bacteria.

Four prepared test plates were used in every experiment, two of which were fastened to the inner surface of the bottom of a bedpan and two to the inner surface of the front wall of the flushing unit. In addition, two plates were not flushed and served as controls.

Within 1 h of the flushing procedure the test plates were examined at the laboratory. The number of remaining viable bacteria was estimated in the following way. Each plate was submerged in a beaker containing 20 ml sterile distilled water (plates with spores) or sterile physiologic saline (plates with enterococci). While still submerged the plates were carefully wiped clean with a small cotton swab. Colony counts were made from serial dilutions of the fluids in which the plates had been washed. In the experiments with enterococci 10 ml of the fluid

Table 1. *Water consumption and water pressure of the experimental flushing unit: means of six measurements*

Flushing phase	Time (s)	Water consumption per flushing period		Water pressure during flushing (kp/cm²)		Maximum water temperature (°C)
		CW	HW	CW	HW	
CW	5	2·3	—	4·2	—	*c.* 12
CW+HW	61	17·4	14·5	4·9	4·8	48
HW	49	—	18·5	—	4·2	90
CW+HW	3	1·1	1·0	4·9	4·8	48
Total	118	20·8	34·0			

CW = cold water, HW = hot water.

Water pressure before flushing: CW, 5·3 kp/cm²; HW, 5·5 kp/cm².

was also added to 50 ml of nutrient broth, which was then incubated for 2 days at 37 °C and examined for growth of enterococci. After having been used, the swabs were left in tubes containing TGY broth (spores), which were then incubated for 2 days at 55 °C, or in tubes containing nutrient broth (enterococci) incubated for 2 days at 37 °C, after which any growth was noted.

The elimination factor (EF) was calculated as the ratio between the average number of bacteria on the control plates and the number still on the flushed plates. The counts on the control plates ranged from 70 % to 120 % of the expected number.

Experimental flushing unit

The unit used was a Minispolo S-15 manufactured by Växjö Rostfritt, Sweden. The same unit was used in all the experiments. The pressure, consumption and temperatures of the water are given in Table 1, which shows the mean values noted during use of the unit on six different occasions. The range of variation of the values found on different occasions was narrow.

The normal flushing programme of the unit is shown in Fig. 3. In the experiments with spores three flushing programmes (A, B and C) were used, and in the experiments with *S. faecalis* two programmes (A and D).

The respective flushing programmes are shown in Figs. 1–4. Temperatures and durations of the flushing periods are shown in Table 2.

Table 2. *Approximate temperatures and flushing periods in the four programmes*

Programme	Temperature (°C)		
	> 10° < 40°	> 40° < 50°	> 85°
A	10 s	55 s	—
B	2 × 10 s	2 × 55 s	—
C	10 s	55 s	45 s
D	10 s	55 s	10 s

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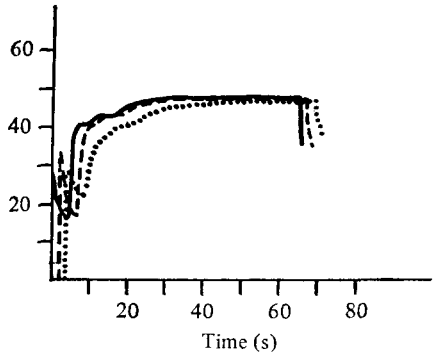

Fig. 1

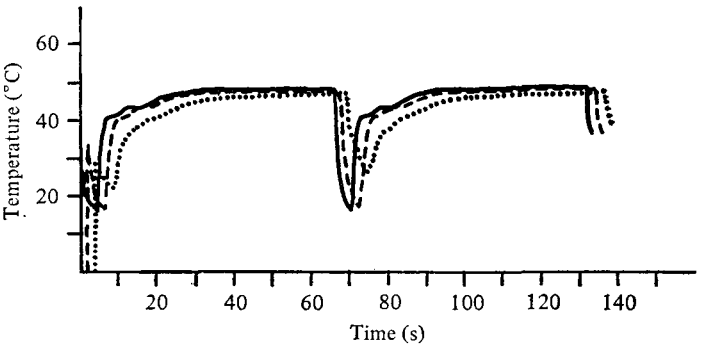

Fig. 2

Fig. 1. Flushing programme A. Temperature curves for flushing water at nozzle (continuous), at bottom of bedpan (dashed) and at inner wall of flushing unit (dotted).

Fig. 2. Flushing programme B. Temperature curves for flushing water at nozzle (continuous), at bottom of bedpan (dashed) and at inner wall of flushing unit (dotted).

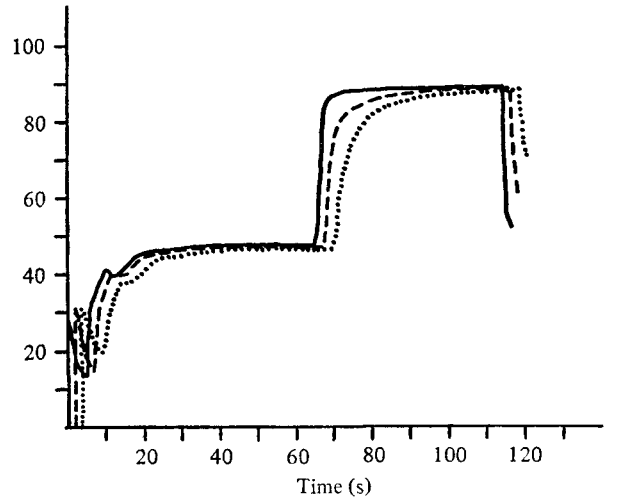

Fig. 3

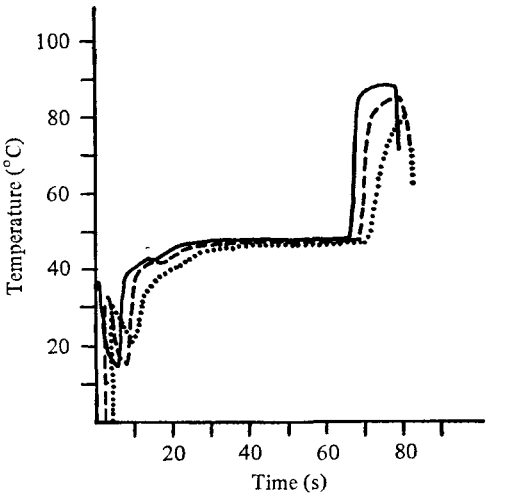

Fig. 4

Fig. 3. Flushing programme C. Temperature curves for flushing water at nozzle (continuous), at bottom of bedpan (dashed) and at inner wall of flushing unit (dotted).

Fig. 4. Flushing programme D. Temperature curves for flushing water at nozzle (continuous), at bottom of bedpan (dashed) and at inner wall of flushing unit (dotted).

The temperatures were recorded with a Chessel writer type 301 with a copper–constantan thermo-element. The temperature was recorded simultaneously at three different sites:

(1) In the stream of inflowing water at a nozzle.

(2) On the inner surface of the bottom of a bedpan.

(3) On the inner surface of the anterior wall of the flushing unit.

The temperatures of the surfaces of the bedpan and of the unit are also given in Figs. 1–4. Like those of the flushing water they varied but little from one occa-

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sion to another, but naturally rose somewhat more slowly than the temperature of the water.

RESULTS

The effect of the various flushing programmes was judged from the elimination factors, which are a measure of the reduction in the number of viable micro-organisms.

Experiments with B. stearothermophilus *spores*

The results are given in Fig. 5. Faecal specimens from 6 different persons were used. The specimens were selected so as to differ widely in appearance and

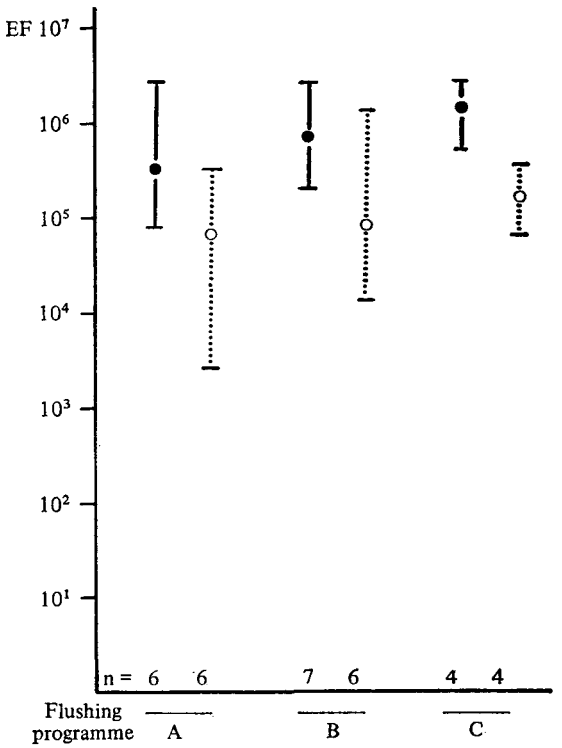

Fig. 5

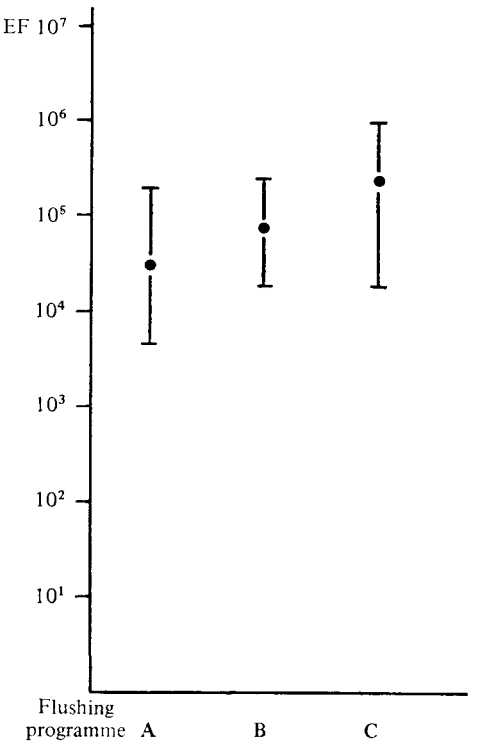

Fig. 6

Fig. 5. Cleaning effect of the flushing unit after contamination with *B. stearothermophilus* spores in various human faecal samples. Elimination factors (means and distributions) noted on bedpan bottom (bold verticals) and on inner wall of flush casing (dotted verticals). Figures at the bottom indicate number of test plates used.

Fig. 6. Cleaning effect of the flushing unit after contamination with *B. stearothermophilus* spores in one sample of human faeces. Elimination factors (means and distributions) noted on bedpan bottom. Ten test plates used in each programme.

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consistence, and it is obvious from the results that they differed substantially from one another in range of variation of the EF. The individual faecal specimens here were not evenly distributed among the flushing programmes.

Fig. 6 gives the results obtained with 3 different flushing programmes when the same faecal specimen was used in all the experiments. The test plates were placed only on the bottom of the bedpan.

After the bedpans had been flushed the test plates were examined with the naked eye. Most of the plates appeared clean, but in some cases a closer examination in more suitable light revealed a faint grey coating. This strongly suggests that such contamination of bedpans is often missed at ordinary routine examination.

In all the experiments with faeces the EF on the bottom of the bedpan exceeded 10^3. For flushing programme A the mean was 2×10^4 and for programme C 3×10^5. The EF on the inner surface of the wall of the unit in the various experiments ranged from 10^2 to 10^5.

In the comparative experiments (Fig. 6) the results were as follows (mean EF):

Flushing programme	
A	$3{\cdot}2 \times 10^4$
B	$8{\cdot}5 \times 10^4$
C	$2{\cdot}4 \times 10^5$

The difference in effect between programmes A and C was significant ($P < 0{\cdot}01$), that between A and B non-significant ($P > 0{\cdot}05$) and that between B and C probably significant ($P < 0{\cdot}05$).

In the experiments with blood the EF score was largely equal in all three programmes (Fig. 7). The values found for the bedpan were higher than 10^5 and most of the values for the wall were higher than 10^4.

Experiments with Streptococcus faecalis

Only a small number of experiments were done with this test organism (Fig. 8). With programme A the EF ranged from 10^3 to 10^5, while with programme D, which was concluded with hot (85 °C) water for 10 s, it was more than 10^7. In fact no viable bacteria were demonstrable after the flushing procedure in the latter experiments.

DISCUSSION

Bacillus stearothermophilus was chosen as a test organism in experiments designed to exemplify the purely mechanical washing effect of the flushing unit. The elimination factors (EF) are attributable exclusively to this mechanical effect since the organisms used were not sensitive to the temperature of the hot water. Thermal inactivation of the bacteria can therefore be excluded. The tolerance of these spores to the temperatures used is well known. In addition some simple experiments in which suspensions of the spores used were enclosed in plastic capillaries showed no measurable reduction in the number of viable bacteria after exposure of the capillaries to boiling water for 5 min. In the experiments with the spores, then, the number of residual viable spores can be regarded as a measure of the residual contamination (faeces or blood).

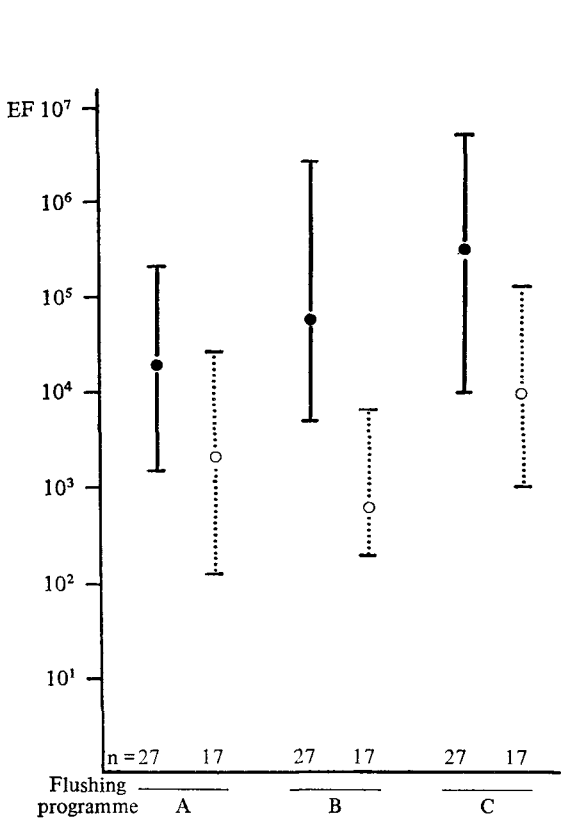

Fig. 7

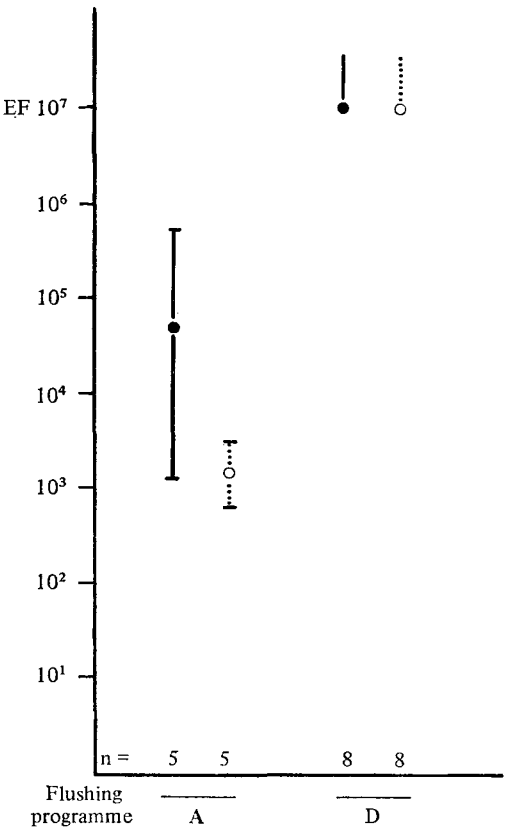

Fig. 8

Fig. 7. Cleaning effect of the flushing unit after contamination with *B. stearothermophilus* spores in blood. Elimination factors (means and distributions) noted on bedpan bottom (bold verticals) and on inner wall of flush casing (dotted verticals). Figures at the bottom indicate number of test plates used.

Fig. 8. Cleaning effect of the flushing unit after contamination with *S. faecalis* in human faecal samples. Elimination factors (means and distributions) noted on bedpan bottom (bold verticals) and on inner wall of flush casing (dotted verticals). Figures at the bottom indicate number of test plates used.

In experiments with spores in faeces where the flushing procedure was especially effective (bottom of bedpan) the EF ranged from 10^3 to 5×10^6 (Fig. 5) and varied mainly with the character of the faecal sample used and the times and temperatures in the respective flushing programmes.

All the experiments included in Fig. 6 were performed with the same faecal sample and therefore show the relative efficacy of the flushing programmes. The differences in effect between the three programmes probably depend on both the flushing time and the temperature of the water but it is obvious that the differences are small.

As expected, the effect of flushing on the bedpan was better than that on the wall of the unit. This can be explained by the position and direction of the nozzles in the apparatus.

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The experiments with spores in blood were relatively few, but indicated that all the flushing programmes had largely the same cleaning effect (Fig. 7). The EF was, on the average, ten times greater than in experiments with faeces. The tests did not use coagulated blood, but dried citrated blood. This was because blood that had coagulated on the stainless-steel surface crumbled when flushed or mechanically handled and these fragments could not be broken down sufficiently by shaking to allow the release of enclosed bacteria and a representative colony count.

In experiments with *Streptococcus faecalis* (Fig. 8) and water hotter than 60–70 °C the results reflect the combined effect of mechanical cleaning and disinfection by heat. The purpose of the experiments was thus to check whether the effect of flushing with water below 50 °C on this organism was largely the same as that on spores in corresponding experiments and whether the use of water at 85 °C effectively inactivated any residual bacteria. The very high EF after flushing with such hot water is thus ascribable to the combined effect of EF and IF (inactivating factor). It should be mentioned that this effect, expressed in EF, was more than 10^7 after flushing with water below 50 °C for 55 s followed by flushing with water at 85 °C for only 10 s.

It should also be mentioned that the EF noted in experiments with *S. faecalis* in flushing programme D, i.e. with water of at most 50 °C, agree well with those in corresponding experiments with spores. With water of this temperature the results reflect exclusively the effect of the mechanical cleaning.

The purpose of the method described with *B. stearothermophilus* spores was to provide the possibility of quantitatively and objectively measuring the residual contamination after flushing in the unit used. The spores may be regarded as indicator particles eliminated exclusively by the mechanical effect of the flushing and not by hot water disinfection. The bacteriological technique is simple and does not require any complicated equipment. The spores can be handled without any special precautions.

With knowledge of the degree of residual contamination after the first step in the flushing unit the disinfecting step can be adjusted better to the actual requirements than hitherto. If the mechanical effect of the flushing has an EF of 10^4, a further EF of 10^3 would be sufficient to achieve the desired IF 10^7. This can be done within a time shorter than 40–55 s.

In the light of what we know about the thermal tolerance of relevant vegetative bacteria (Niléhn, 1972; Williams *et al.* 1966) and of what has been shown in the experiments with *S. faecalis* it seems justifiable to accept a much shorter disinfection period than that hitherto recommended. This would imply a substantial saving of both water and fuel. One might also consider the possibilities of using some means other than hot water.

In practice, however, one must be cautious because a bedpan may be more difficult to clean than the test plates used in the present investigation. One might thus imagine that any folds in the metal handle of the bedpan might be contaminated with faecal material and not readily accessible to the water. On the other hand, improvements in the mechanics of the flushing procedure and in the design of bedpans should be able to diminish such risks.

Suitable equipment (both the flushing unit and the item to be cleaned) should be designed in such a way as to permit adjustment of the disinfection according to the mechanical cleaning capacity of the unit. This would reduce the costs of the use of such equipment to a reasonable minimum.

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