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# Hard Surface Cleaning Performance of Six Alternative Household Cleaners Under Laboratory Conditions

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## Abstract

*In this laboratory study, several commercially available household bathroom and kitchen cleaning products, with and without EPA registered disinfectant properties, were compared to several "alternative" products (lemon juice, vinegar, ammonia, baking soda and borax). High pressure decorative laminate tiles were cleaned mechanically using a Gardner Abrasion Tester. Test criteria included microbial reduction, based on remaining colony forming units of a tracer organism (Serratia marcescens), and soil reduction (of simulated bathroom and kitchen soil formulations) based on subjective grading by a panel of individuals. Among bathroom cleaners, the commercial cleaners and vinegar gave the most effective microbial reduction while a commercial cleaner without disinfectant was most effective at soil removal. Among kitchen cleaners, again the commercial products and vinegar were most effective at microbial reduction while the commercial cleaners and ammonia were most effective at soil removal.*

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**M**any groups and agencies promote the use of alternative household cleaners because of the belief that they are environmentally preferable to commercially formulated hard surface cleaners. These alternative cleaners include food products such as vinegar or baking soda as well as cleaning and laundry aids such as borax or ammonia.

The "recommended uses" of most of the alternative cleaners are for general cleaning, but some of them are also recommended as alternatives for disinfectants. Household cleaners that are registered as disinfectants must meet testing requirements of the U.S. Environmental Protection Agency (EPA) and it is recognized that the alternative cleaners do not meet this criterion. The purpose of this project is to test and compare the efficacy of these alternatives using both soil removal and microbial reduction (which includes both physical removal and cidal action) as the evaluation criteria. These alternative products were tested as single ingredient products even though in actual practice some of them are mixed together in make-your-own recipes.

Several researchers have studied the role of contaminated surfaces in the home and the spread of respiratory and intestinal diseases. According to Gerba(1), household

surfaces can play a significant role in the transmission of viruses and bacteria that cause infectious diseases such as the common cold and flu and intestinal diseases. Proper cleaning methods are a major defense against the spread of these microbes because one is more likely to "pick up viruses from touching contaminated surfaces than from shaking the hand of someone who is infected" (2).

An examination of more than 200 homes in England documented the pattern of bacterial contamination in the home environment. Sites where cleaning methods needed improvement included hard surfaces and textile products in the kitchen and bath areas (3). In a study of food preparation in the household kitchen, work surfaces were identified as potential areas of contamination requiring disinfection (4). The researchers were concerned that "housewives are content if their kitchen appears to be clean." There may be fecal contamination of surfaces in homes with infants and toddlers, and a recent study revealed contamination of surfaces in out-of-home child care settings (5).

## Methods

The surface chosen for these tests was a high pressure decorative laminate. The

material was cut into 17" by 7" sections (tiles). The center section of each tile was artificially soiled with a simulated bathroom soil or a simulated kitchen soil. A microbial agent (*Serratia marcescens*) was applied over the soiled section. Alternative cleaning products and commercially formulated hard surface cleaners (referred to as commercial cleaners in the remaining text) were used to clean the surface; the commercial products were used as a point of reference. Complete soil test methods are available from the authors. For bathroom cleaners, six tiles per cleaning product were tested and for kitchen cleaners, 10 tiles per product were tested.

The simulated bathroom soil test method was a modification of a method being developed by ASTM. The soil mixture was applied to the sample surface by dipping a mini-trimmer paint applicator into the mixture, then "painting" the mixture on the test surface. The soiled samples were heated in a 70°C convection oven for one hour and were cooled overnight. Samples were tested for soil removal within one week after soil application. The soil was composed of the following:

- 4.5 g synthetic sebum
- 3.0 g stearate premix
- 0.6 g carbon black
- 1.5 g super mix dirt
- 40.29 g sodium stearate
- 259.71 g deionized H<sub>2</sub>O

The simulated kitchen soil was a modification of a fatty acid sebum soil. The soil mixture was applied by adding 2.0 ml warm soil to each sample surface using a 10 cc syringe; a mini-trimmer paint applicator was used to spread the soil. The soiled samples were dried and were stored for 12 days prior to cleaning. The soil was composed of the following:

- 20 g stearic acid
- 10 g Crisco®
- 20 g palmitic acid
- 10 g linoleic acid
- 5 g squalene

**Table 1.**  
**Cleaning products and use formulations for simulated bathroom and kitchen soils**

Cleaner	Simulated soil cleaned	Formulation
Synthetic hard water	Bathroom & kitchen	40 ml-0.10 g/l calcium carbonate 0.03 g/l magnesium carbonate warm deionized water
<b>Alternative cleaners</b>		
Lemon juice	Bathroom & kitchen	40 ml undiluted
Vinegar	Bathroom & kitchen	40 ml undiluted
Baking soda	Bathroom & kitchen	10 g baking soda + 40 ml water
Borax	Bathroom	10 g borax + 40 ml water
Ammonia	Kitchen	40 ml 1:1 dilution ammonia with water
Ivory Liquid® hand dishwashing liquid	Kitchen	40ml 1:10 dilution Ivory Liquid® with water
<b>Commercial hard surface cleaners</b>		
Spic and Span with Pine®	Bathroom & kitchen	40 ml undiluted
Clorox Clean-up® (registered disinfectant)	Bathroom & kitchen	40 ml undiluted
Comet Cleanser with Chlorinal® (registered disinfectant)	Kitchen	10 g Comet® + 40 ml water

- 5 g paraffin
- 160 g bandy black research clay
- 160 g isopropyl alcohol
- 10 g oildag

The microbial agent was a 24 hour stock culture of *Serratia marcescens*, approximately  $1 \times 10^7$ /ml concentration, diluted in Butterfields phosphate buffer solution to approximately  $1 \times 10^4$ /ml concentration. This organism was chosen because it is relatively non-pathogenic to immune competent hosts and because it forms a readily identifiable red pigment so that it can easily be distinguished from background microbes on the surface. Thus a definitive picture of before and after counts can be obtained specifically related to the cleaning product used. A sterile cotton tipped applicator was used to apply 0.2 ml of the *Serratia marcescens* mixture to the soiled area of each bathroom tile, 0.5 ml to the soiled area of each kitchen tile immediately prior to cleaning. RODAC plates con-

tained Standard Methods Agar (SMA) with 0.7 g/l lecithin and 5.0 g/l polysorbate 80 for general purpose neutralization. Three RODAC plates were applied to soiled areas of each tile a) immediately after bacterial application and prior to cleaning, and b) to the soiled area immediately after cleaning except in those cases in which the cleaning product specified a five-minute product contact period to allow disinfectant action. Before and after sampling sites were mutually exclusive to avoid interference (colony reduction) attributable to the sampling method. The RODAC plates were incubated at 25°C for 24 to 36 hours, then counted using a Quebec Colony Counter. Only red pigmented colonies were counted. At this dilution, all *before* cleaning plates were Too Numerous to Count (TNTC). Thus, results and comparisons are based only on *after* cleaning counts rather than on percent reduction, with the assumption that the initial inoculation was consistently ap-

plied from the same stock culture for all cleaning products and therefore would not bias the results.

A Gardner Abrasion Tester was used to clean the soiled samples. For each test a cleaning product was applied to the cleaning face of a new sponge which had been soaked in warm synthetic hard water (referred to as water in the remaining text) to add 70 g water to the dry weight of the sponge. The sponges, (3.5" x 5" x 1.5" cellulose) had been previously washed and dried. The tester was set to complete a selected number of cycles: 50 for the samples with the simulated bathroom soil with microbial agent, and 20 cycles for the simulated kitchen soil with microbial agent. The number of cycles was based on trials to determine where obvious differences in cleaning ability between products could be observed. The types of cleaning products and their use concentrations are presented in Table 1. Products were used full strength or diluted according to manufacturers' directions for cleaning heavy soil.

Four alternative cleaning products were used on the simulated bathroom soil with microbial agent: lemon juice, vinegar, baking soda and borax. Two liquid commercial cleaners were used: Spic and Span with Pine® and Clorox Clean-Up®, a registered disinfectant. Spic and Span with Pine®, at the time of the study, was not registered as a disinfectant. It has since been registered. Water was used as a control.

The alternative cleaning products used on the simulated kitchen soil with microbial agent were lemon juice, vinegar, baking soda, household ammonia, and a hand dishwashing liquid (Ivory®). Three commercially formulated cleaners were used. These included Spic and Span with Pine®, a liquid; Clorox Clean-Up®, a liquid and registered as a disinfectant; and Comet® with bleach, a dry cleanser registered as a disinfectant. Water was used as a control.

The outcome data recorded for each cleaned sample were the number of *Serratia marcescens* colony forming units (CFU) recovered after cleaning and an evaluation of soil removal. The cleaned samples were judged for soil removal by a panel of impartial judges. The samples, coded to avoid recognition bias, were compared to a sample board portraying five different levels of soil removal. Each test sample was independently evaluated by eight judges and as-

signed a soil removal score (SRS) from 1 (greatest soil removal) to 5 (least soil removal).

Statistical analyses of the data were conducted on the number of colony forming units on each RODAC plate and the soil reduction score for each tile. Analyses performed included the analysis of variance and the Tukey Test.

### Results and discussion

**Microbial reduction** — Microbial cultures and soil removal results are reported in Tables 2a and 2b for bathroom soil and in Tables 3a and 3b for kitchen soil. For both soils there were significant differences in the microbial reduction within the alternative cleaner group but not within the commercial cleaner group. Among the bathroom soil cleaners, the commercial cleaners, vinegar, baking soda and lemon juice yielded lower microbial counts than borax and water (Tukey analysis at  $\alpha = 0.05$ ). Further application of the Tukey analysis to the low count group revealed that the two commercial cleaners and vinegar had lower group means for microbial counts than baking soda and lemon juice. For kitchen soil cleaners, the three commercial cleaners and vinegar had the lowest group mean. Water and ammonia exhibited intermediate results and dishwashing liquid and baking soda showed the highest counts. Lemon juice results were not included due to a lab error (plate contamination) which resulted in too few observations.

Microbial reduction results must be interpreted with caution. It is clear that for both bathroom and kitchen products, lowest counts are achieved by the commercial products — whether or not registered as a disinfectant. However, vinegar (and to a lesser extent, lemon juice) gave statistically similar results presumably because of its very low pH. It is possible that vinegar outperformed lemon juice because acetic acid is known to be a more effective bactericide than citric acid. *Serratia marcescens* is typical of gram-negative enteric bacteria which are known to be sensitive to acid conditions. Water and ammonia were in an intermediate group while dishwashing liquid and baking soda yielded the highest microbial counts on the kitchen soil. One possible explanation for this phenomenon is that the detergency action of the dishwashing liquid and baking soda tended

**Table 2a**  
Microbial reduction and soil removal of simulated bathroom soil with microbial agent from laminated surface using different cleaning products, six replications

Cleaning product	pH	Mean CFU (SD)*	Mean SRS (SD)**
Water	9.97	78.1 (89.6)	3.667 (1.100)
<b>Alternative cleaners</b>			
Lemon juice	2.93	15.1 (6.7)	4.333 (0.705)
Vinegar	3.09	6.1 (5.7)	5.000 (0.0)
Baking soda	8.43	12.9 (12.2)	3.900 (0.602)
Borax	9.79	54.9 (41.4)	2.650 (0.515)
<b>Commercial hard surface cleaners</b>			
Without disinfectant	9.74	0.2 (0.7)	1.000 (0.0)
With disinfectant	12.57	0.0 (0.0)	4.067 (0.252)

\* colony forming units of *S. marcescens* recovered after cleaning

\*\* soil reduction score on 1-5 scale, 1 indicating greatest soil reduction

**Table 2b**  
Effectiveness of cleaners on simulated bathroom soil as evaluated by differences in group means (Tukey test  $\alpha = 0.05$ )

Cleaner	Microbial reduction	Soil removal
Water	Least effective	High intermediate
<b>Alternative cleaners</b>		
Lemon juice	Intermediate	Low intermediate
Vinegar	Most effective	Least effective
Baking soda	Intermediate	High intermediate
Borax	Least effective	High intermediate
<b>Commercial hard surface cleaners</b>		
Without disinfectant	Most effective	Most effective
With disinfectant	Most effective	Low intermediate

to break up clumps of viable cells to a greater extent and therefore resulted in higher colony counts, although the actual number of viable cells was equivalent to the products with less detergency.

It is also important to note that this sampling protocol does not distinguish between cidal action and physical removal in the lowering of viable counts. Previous research on dilute solutions of the alternative cleaners borax, vinegar, ammonia and baking soda have shown that they did not meet EPA guidelines (cidal action) for registered disinfectants (6). The concentrations of the alternative cleaners in the Rubino study were 16 to 32 times more

dilute than those used in this study, however. Although the commercial products and some of the alternative cleaners clearly resulted in fewer colonies recovered from the tiles, transfer of the microbes to the sponge could have occurred but was not tested. Thus attention to the cleaning mechanism and ultimate fate of organisms physically removed but not killed may be important, as well as the absence of organisms from the hard surfaces.

**Soil removal**—The results are reported as a mean score for 50 cleaning cycles for the bathroom soil and for 20 cleaning cycles for the kitchen soil. With additional cycles

**Table 3a**  
**Microbial reduction and soil removal of simulated kitchen soil with microbial agent from laminated surface using different cleaning products, 10 replications**

Cleaning product	pH	Mean CFU (SD)*	Mean SRS (SD)**
Water	9.97	141.3 (82.4)	4.588 (0.520)
<b>Alternative cleaners</b>			
Lemon juice	2.93	73.9 (101.9)	4.988 (0.112)
Vinegar	3.09	0.6 (2.3)	5.000 (0.0)
Baking soda	8.43	336.4 (132.2)	1.175 (0.382)
Ammonia	11.81	126.9 (82.3)	1.000 (0.0)
Dishwashing liquid	9.81	302.9 (151.8)	2.863 (0.381)
<b>Commercial hard surface cleaners</b>			
Without disinfectant	9.74	0.0 (0.0)	1.000 (0.0)
With disinfectant	12.57	0.0 (0.0)	1.013 (0.112)
Dry cleanser with disinfectant	10.74	0.0 (0.0)	1.000 (0.0)

\* colony forming units of *S. marcescens* recovered after cleaning

\*\* soil reduction score on 1-5 scale, 1 indicating greatest soil reduction

**Table 3b**  
**Effectiveness of cleaners on simulated kitchen soil as evaluated by differences in group means (Tukey test alpha - 0.05)**

Cleaner	Microbial reduction	Soil removal
Water	Intermediate	Low intermediate
<b>Alternative cleaners</b>		
Lemon juice	(not included)	Least effective
Vinegar	Most effective	Least effective
Baking soda	Least effective	High intermediate
Ammonia	Intermediate	Most effective
Dishwashing liquid	Least effective	High intermediate
<b>Commercial hard surface cleaners</b>		
Without disinfectant	Most effective	Most effective
With disinfectant	Most effective	Most effective
Dry cleanser with disinfectant	Most effective	Most effective

all cleaners may have had the same soil removal score. For soil removal under the test conditions, there were significant differences within the alternative cleaner group for both the kitchen soil and bathroom soil. However, within the commercial cleaners, there were significant differences for bathroom soil only. Because the bathroom soil was baked onto the tiles, it was a much more difficult soil to remove.

The results of the Tukey test for the difference in group means divided the cleaners into several groups. For removal of bathroom soil, the high removal group consisted of one commercial cleaner without disinfectant, and the low removal group consisted of one alternative cleaner, vinegar. The alternative cleaner with the best soil removal score was borax. The soil removal scores of the other alternative cleaners—

baking soda and lemon juice—were not significantly different from the commercial cleaner with disinfectant.

For removal of kitchen soil, ammonia, an alternative cleaner, was in the high soil removal group with all the commercial cleaners while, lemon juice and vinegar were in the low soil removal group. Baking soda, dishwashing detergent (hand) and water were in separate middle groupings. Tables 2b and 3b compare the effectiveness of the cleaners on both microbial reduction and soil removal.

### Conclusions

In this laboratory study, alternative household cleaners were used to clean high pressure decorative laminate surfaces soiled with simulated bathroom or kitchen soils over which a microbial agent had been applied. The cleaners were then evaluated on their effectiveness in reducing microbial contamination, as measured by the number of colony forming units cultured after cleaning, and their effectiveness in removing soil. Because the simulated bathroom soil was a tougher soil to remove than the simulated kitchen soil, the soil removal results are somewhat different for the two soil types. The cleaners used were chosen to represent cleaners that are often recommended for cleaning bathroom or kitchen soils and were compared with commercial hard surface cleaners used in those two rooms.

The results indicate that compared to commercial cleaners, the alternative cleaners as a group are less effective in both microbial reduction and soil removal. However, the alternatives vary in their effectiveness. Two alternative cleaners—borax and ammonia—were more effective in soil removal than the other alternative cleaners. However, borax was not at all effective in reducing microbial contamination. Vinegar was more effective in reducing microbial contamination than the other alternative cleaners but was least effective in removing soil.

All of the cleaners, including water, could conceivably have removed the soil from the tiles with enough cleaning strokes. Therefore, consumers who wish to use alternative cleaners may find them effective in removing soil if they are willing to work harder. The microbial reduction in this research could be the result of either cidal

action or physical removal and transfer of the microbes to the sponge. Washing the sponge with a disinfectant or drying the sponge may ultimately destroy the microbes.

Because the microbe used for testing in this research was susceptible to acid conditions, the acidic cleaners, particularly vinegar (acetic acid) were effective in reducing microbial contamination. For cleaning soil with these types of microbes, a vinegar rinse following cleaning with a more effective soil removing alternative cleaner may be effective in reducing microbial contamination. However, when there are specific health related concerns (such as the presence of neonates or immunosuppressed family members) which signify the need for microbiocidal action, consumers should be aware that only registered disinfectants have been tested using standard methods to show cidal action. This laboratory study is useful in evaluating some differences among alternative cleaners. Further testing of these products needs to be conducted in the home environment under conditions of consumer use.

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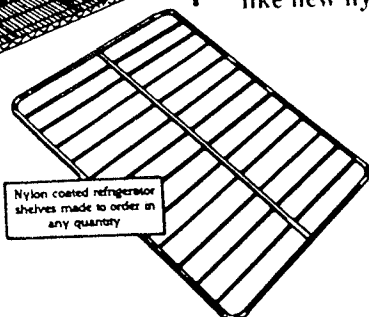
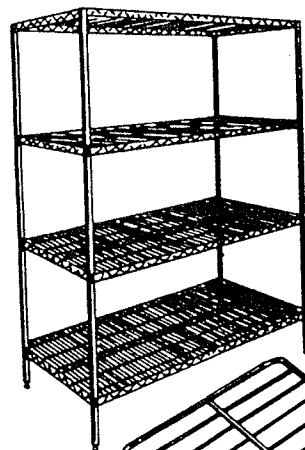
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