

The Influence of Soap Characteristics and Food Service Facility Type on the Degree of Bacterial Contamination of Open, Refillable Bulk Soaps

Rutgers University has made this article freely available. Please share how this access benefits you.
Your story matters. [\[https://rucore.libraries.rutgers.edu/rutgers-lib/54180/story/\]](https://rucore.libraries.rutgers.edu/rutgers-lib/54180/story/)

This work is an **ACCEPTED MANUSCRIPT (AM)**

This is the author's manuscript for a work that has been accepted for publication. Changes resulting from the publishing process, such as copyediting, final layout, and pagination, may not be reflected in this document. The publisher takes permanent responsibility for the work. Content and layout follow publisher's submission requirements.

Citation for this version and the definitive version are shown below.

Citation to Publisher Version: Schaffner, Donald W., Jensen, Dane A., Gerba, Charles P., Shumaker, David J. & Arbogast, James W. (2018). The Influence of Soap Characteristics and Food Service Facility Type on the Degree of Bacterial Contamination of Open, Refillable Bulk Soaps. *Journal of Food Protection* 81(2), 218-225. <http://dx.doi.org/10.4315/0362-028X.JFP-17-251>.

Citation to this Version: Schaffner, Donald W., Jensen, Dane A., Gerba, Charles P., Shumaker, David J. & Arbogast, James W. (2018). The Influence of Soap Characteristics and Food Service Facility Type on the Degree of Bacterial Contamination of Open, Refillable Bulk Soaps. *Journal of Food Protection* 81(2), 218-225. Retrieved from [doi:10.7282/T36H4MBK](https://doi.org/10.7282/T36H4MBK).

Terms of Use: Copyright for scholarly resources published in RUcore is retained by the copyright holder. By virtue of its appearance in this open access medium, you are free to use this resource, with proper attribution, in educational and other non-commercial settings. Other uses, such as reproduction or republication, may require the permission of the copyright holder.

Article begins on next page

The Influence of Soap Characteristics and Food Service Facility Type on the Degree of Bacterial Contamination of Open, Refillable Bulk Soaps

Donald W Schaffner^{1*}, Dane Jensen¹, Charles P. Gerba², David Shumaker³ and James W. Arbogast³

(1) Department of Food Science, Rutgers, The State University of New Jersey, New Brunswick, NJ, (2) Department of Soil, Water and Environmental Science, University of Arizona, Tucson, AZ, (3) GOJO Industries, Inc., Akron, OH

* corresponding author, schaffner@aesop.rutgers.edu ,+1 732-982-7475

Key Words: Handwashing, Bulk Soap, Contamination, Coliforms

To be submitted to JFP

Abstract (2000 character limit, currently at 1997)

Concern has been raised regarding the public health risks from refillable-bulk soap dispensers because they provide an environment for potentially pathogenic bacteria to grow. This study surveyed the microbial quality of open refillable bulk soap in four different food establishment types in three states. Two hundred and ninety-six samples of bulk soap were collected from foodservice establishments in Arizona, New Jersey, and Ohio. Samples were tested for total heterotrophic viable bacteria, *Pseudomonas*, coliforms and *Escherichia coli* and *Salmonella*. Bacteria were screened for antibiotic resistance. The pH, solids content and water activity of all soap samples was measured. Samples were assayed for the presence of the common antibacterial agents triclosan and parachlorometaxyleneol. More than 85% of the soap samples tested contained no detectable microorganisms, but when a sample contained any detectable microorganisms, it was most likely contaminated at a very high level (~ 7 log CFU/ml). Microorganisms detected in contaminated soap included *Klebsiella oxytoca*, *Serratia liquefaciens*, *Shigella sonnei*, *Enterobacter gergoviae*, *Serratia odorifera* and *Enterobacter cloacae*. Twenty-three samples contain antibiotic resistant organisms, some of which were resistant to two or more antibiotics. Every sample containing less than 4% solids had some detectable level of bacteria, while no samples with greater than 14% solids had detectable bacteria. This finding suggests dilution and/or low-cost formulations as a cause. There was a statistically significant difference ($p=0.0035$) between the fraction of bacteria positive samples with no detected antimicrobial (17%) and those containing an antimicrobial (7%). Fast food operations and grocery stores were more likely to

have detectable bacteria in bulk soap samples compared to convenience stores (p<0.05). Our findings underscore the risk to public health from use of refillable-bulk soap dispensers in foodservice establishments.

Washing hands with soap and water is a universally accepted practice to reduce cross contamination and the incidence of nosocomial infections (9, 12-14, 16, 18, 20, 26, 29, 33). The United States Food and Drug Administration (FDA), the US Center for Disease Control and Prevention (CDC) and the World Health Organization (WHO) suggest proper hand hygiene with soap and water and/or an alcohol based hand sanitizer in healthcare and food preparation settings (3, 35, 39). The CDC and WHO recommend alcohol based hand sanitizer as the primary means for hand hygiene at key moments in healthcare settings (3, 31, 39), while food handling guidance from FDA (35) supports gloving or hand washing for primary prevention. The respective hand hygiene guidance from these three public health agencies all have language which indicates that a hand wash is not complete without the use of soap (3, 35, 39). However, concern has been raised that the use of refillable-bulk soap dispensers is a public health risk because they provide an environment for potentially pathogenic bacteria to grow, especially if the bulk soap is being diluted with water to reduce cost (8, 21, 25, 30, 40).

Outbreaks associated with contaminated soap have been extensively documented in healthcare settings (1, 2, 5, 24, 27, 30, 38), but none to date have been connected to food service settings. Organisms found in bulk soaps are primarily Gram-negative bacteria (8), and these bacteria include microorganisms that are commonly associated with nosocomial infection in hospitals (3, 19). *Klebsiella pneumoniae*, a bacterium associated with contaminated bulk-soaps, can cause community-acquired pneumonia and proper hand hygiene is a good way of preventing cross contamination by these bacteria, as healthcare workers' hands can be vectors for

these organisms (7). Outbreaks of *S. marcescens* have also been traced to contaminated soap (2, 5, 27, 30, 37). Although no outbreaks in foodservice have been directly linked to contaminated bulk-soap dispensers, roughly 50% of foodservice linked outbreaks can be traced to food worker's hands as the source of pathogens (16). While soaps and other cosmetics are not required to be sterile, Good Manufacturing Practices for soaps and cosmetics require that any bacteria present should not constitute a hazard to consumers during regular use (32). Several factors contribute to bulk soap contamination, which include design of dispenser, soap formulation, and economically motivated dilution of soap (5, 25). While sealed dispensers are refilled by replacing new cartridges into the dispenser that contain soap sealed inside with a new nozzle, open refillable bulk soap dispensers are refilled with soap from a larger bottle and a permanent nozzle is reused. A top fill reservoir design allows for "topping-off" the soap. While this potentially reduces soap waste, it also allows mixing of multiple soap lots and types, and exposes the soap to an open-air environment, increasing the risk of contamination (3, 25, 40). Furthermore, top fill design dispensers may never thoroughly be rinsed out as commonly recommended by dispenser manufacturers. The CDC recommends that bulk liquid soap dispensers be thoroughly cleaned every time before adding fresh soap (3, 8, 14). However, as pointed out by Lorenz et al. (21), no data exist to show that cleanings in between soap re-fills actually prevent contamination of soap. Regardless, bulk soap can quickly become contaminated due to biofilm formation inside the dispenser (up to 9 log CFU/mL), and can support growth in as little as 24 h (25). Once pump mechanisms are colonized with bacteria,

cells from the biofilm continue to contaminate soap, even if completely new bacteria-free soap is used to fill the container (15). Soap formulations will often include preservatives to prevent growth, but these preservatives are concentration dependent, and dilution (as a cost savings measure) can render them ineffective. There has been no evidence of contamination in soap samples collected from dispensers in sealed disposable refills to date.

Potentially harmful bacteria will remain on hands after using contaminated soap (8, 30, 40). While the bacteria may not be a health concern for the hand washer, these bacteria can transfer from hands to food, objects and surfaces (6, 9, 12, 13, 16, 17, 22, 29). Hands are one of the main sources of cross contamination in both healthcare and food service (12, 20).

The purpose of this study was to survey the microbial quality of open refillable bulk soap sampled in four different food establishment types, within three different states, and determine the influence of formulation factors on the degree of contamination.

MATERIALS AND METHODS

Sample collection

Samples were acquired from foodservice establishments around New Brunswick, NJ; Tucson, AZ; and Akron, OH. The categories of merchants that soap samples were collected from were convenience stores, grocery stores, “sit down” restaurants, and fast food (quick serve) restaurants. Categories were sampled based on prevalence of the types of establishment in the areas, and the likelihood of finding bulk soap in the establishment. Soap was collected from the bathrooms of these establishments.

Men's and women's restrooms were sampled in approximately equal frequency. While soap color was noted, no attempt was made to sample specific colors. Samples were shipped to the University of Arizona for microbiological analysis, and to GOJO for physical and chemical analysis. One hundred samples each were collected from Arizona and New Jersey, and 96 samples were collected from Ohio. Soap samples were collected in a 50-ml sterile conical tube (Corning, Union City, CA) with a minimum volume goal of 45 mL. Two tubes of soap were collected from most establishments, except in a few instances where a facility only had enough soap for one tube. Soap was collected in the tube by catching the soap released when the dispenser lever was pressed. We used this method to ensure the soap collected was representative of what would be dispensed on to a customer's hands. Foaming soap was not sampled because bulk-refillable foam soap dispensers are uncommon, and challenges in collecting adequate mass of foaming soap made sampling impractical. Samples were sealed using parafilm (Bemis NA, Neenah, WI) and placed in an icepack chilled cooler after collection.

Microbiological analysis

Total heterotrophic viable bacteria were assayed on Reasoner's 2A agar (R2A, EMD, Gibbstown, NJ) using serial dilutions of 10^{-1} thru 10^{-3} of the soap samples, with colonies counted after 5 days incubation at $22 \pm 2^\circ\text{C}$. R2A agar was originally developed as a rapid method for fecal coliforms in water (28) but since its development has been used in a wide variety of applications including screening of bulk soap for contaminants (8) because it may be especially suitable for culturing slower growing organisms from stressed environments (36). Colonies of the three

most predominant morphologies were streaked to plates of Trypticase Soy Agar (TSA, EMB) for isolation and identification. R2A plates were also examined for the presence of *Pseudomonas*, isolated and confirmed.

Coliforms and *E. coli* were quantified using the IDEXX Quanti-tray Test®/2000 system (IDEXX Laboratories, Westbrook, MA). A 10-mL aliquot of the sample was added to 90 mL of sterile water containing the Quanti-tray reagent, poured into the Quanti-tray, sealed and incubated at 35°C for 24 h. Coliforms were identified by yellow pigmentation and *E. coli* by fluorescence under UV light. The number of positive yellow and fluorescing wells were quantified and the IDEXX most probable number (MPN) Generator Program was used for quantification.

Randomly selected coliform positive wells from IDEXX Colilert Quant-tray /2000 (IDEXX Laboratories, Westbrook, MW) were spread plated on MacConkey agar (EMD, Gibbstown, NJ) to select for lactose fermenters. These isolates were then spread plated to Trypticase Soy Agar (EMD) and subjected to an oxidase test (Becton Dickinson, Sparks, MD) and API20E identification biochemical test strips (BioMerieux, Durham, NC) to confirm as coliforms. Twenty-eight isolates were identified as coliforms and tested for antibiotic resistance by placing antibiotic disks for Vancomycin, Ampicillin, Gentamicin and Ciprofloxacin (Sigma Chemic, St. Louis, MO) onto bacterial lawns of the individual bacteria.

Salmonella pre-enrichment started by placing a 5-mL aliquot of the soap sample into a tube containing 10 mL of Tryptic Soy Broth (TSB, EMD) and incubating at 35 °C for 24 h. After 24 h, one mL of the TSB was transferred to a tube containing 10 mL of Rappaport-Vassildais Broth (Hardy Diagnostics, Santa Maria, CA) and incubated at

41.5 °C for 24 h. One mL of TSB was also added to a tube containing 10 mL of Selenite Cystine Broth (EMD) and incubated at 35.0 °C for 24 h. Each tube showing turbidity was streaked onto plates of Hektoen (EMD) and Xylose Lysine Desoxycholate (XLD, EMD) agars and incubated at 35 °C for 24 h. Presumptive *Salmonella* isolates were transferred to TSA for biochemical identification using the APIE20E (BioMerieux). If the isolate was presumptively identified as *Salmonella*, the isolated colonies were sent to National Veterinary Services Laboratories (Ames, IA) for serotyping.

pH and Water Activity

The pH of all samples was evaluated using a Thermo Orion 720A+ pH with the Thermo Scientific™ Orion™ ROSS™ Sure-Flow™ pH Electrode. Five g of each test sample was evaluated using the OHAUS™ Standard Moisture Analyzer (model MB45).

A water activity meter (Rotronic Instrument Corp., Hauppauge, NY) was used to measure the water activity of soap samples. Distilled water and glycerol solutions were used as standards. Each sample cup was filled with about 10 ml soap sample and after 4-5 min the temperature and water activity were recorded. The sample cup was rinsed using distilled water and dried completely using a Kimwipe (Kimberly-Clark, New York, NY) after each test.

Antimicrobial analysis

All samples were evaluated for the presence and quantity of triclosan using the Waters (Milford, MA) e2695 Alliance HPLC (High-Performance Liquid Chromatography) System with a UV/Visible Detector (Waters 2489) and a Waters

μ Bondapak C18, 125Å 10 μ m, 3.9 x 150mm (Waters No WAT086684) column. All samples that tested negative for the presence of Triclosan were evaluated for the presence and quantity of parachlorometaxyleneol (PCMX) using the same system, detector and column as used for triclosan.

RESULTS

Most of the soap samples tested (> 85%) contained no detectable microorganisms (10 CFU/ml detection limit). The distribution of microbial counts found in contaminated soap samples is shown in Figure 1. Samples containing detectable microorganisms were most often contaminated at a very high level (~7 log CFU/ml) with counts on the remaining samples ranging uniformly from 1 to 6 log CFU/ml. While not all bacteria recovered were identified, microorganisms detected in contaminated soap included *Klebsiella oxytoca*, *Serratia liquefaciens*, *Shigella sonnei*, *Enterobacter gergoviae*, *Serratia odorifera* and *Enterobacter cloacae*. Four of the soap samples were positive for *Salmonella* by APIE20E, but were not confirmed as *Salmonella* by National Veterinary Services Laboratories. Twenty-three samples contained Vancomycin resistant organisms. Seven of these were also resistant to Ampicillin, and two of those in turn resistant to Gentamicin. One sample contained an organism resistant to Vancomycin, Ampicillin, Gentamicin and Ciprofloxacin (antibiotic resistance data not shown).

When a sample contained detectable coliforms, similarly, the population was likely to be high, as shown in Figure 2. The distribution of coliforms is likely higher than what is shown in Figure 2, as the two highest populations were at the upper limit of quantification (i.e. >241,960 MPN/ml or >24,196 MPN/ml).

Figure 3 shows that higher coliform counts tended to be associated with samples containing higher bacterial counts overall. Coliform counts at the upper limits of the MPN method are especially associated with high total bacterial counts.

Figure 4 shows the relationship between sample pH, and the population of detectable microorganisms. Eighteen (18) percent of samples with a pH less than 7.0 had detectable contamination, while only 10% of samples with a pH of 7 and above had detectable contamination. It is interesting to note however, that contaminated soap samples with a pH ≥ 7.0 are more likely to result in contamination at a relatively higher level (i.e. $>1,000$ CFU/ml) perhaps because pH influences bacterial growth or survival.

Figure 5 shows the relationship between the measured percent solids (top panel) or water activity (bottom panel) of a sample and the bacterial count. Note that every sample containing less than 4% solids had some detectable level of bacteria, while only two samples with greater than 14% solids had detectable bacteria. A similar pattern is shown with water activity (Fig 5, bottom panel), and samples with water activities between 0.99 and 1.0 were associated with a range of bacterial populations, including the highest populations observed. As the measured water activity decreased, the occurrence of higher bacterial populations declined, although there was a low population of bacteria in the lowest water activity soap measured. There was no clear relationship between the solids content and the water activity (data not shown).

Figure 6 expands upon the analysis of the relationships between percent solids (top panel) or water activity (bottom panel) and bacterial count. As percent solids

increases, the fraction of samples with a bacterial count above the detection limit (10 CFU/ml) decreases (Fig 6, top panel). It should be noted that the two leftmost bars in the figure are associated with very few observations (three and six observations respectively), while all other points are always associated with 30 or more observations. The bottom panel of figure 6 shows the number of samples associated with different water activities, with the number of samples generally decreasing as water activities increases. The number of contaminated (grey) vs. uncontaminated (black) samples are shown by shading on the bars. Clearly the greatest number as well as the greatest fraction of samples containing detectable bacteria is associated with higher (0.99 to 1.00) water activities, although even lower water activity soaps can also contain detectable bacteria.

Figure 7 shows the relationship between the measured population of antimicrobial agent in the soap, and the bacterial count. Samples containing no detected antimicrobial agent have widely distributed contamination levels. Samples containing triclosan were contaminated regardless of the triclosan level (~0.15-0.65%), whereas only one sample containing PCMX was contaminated, and at a relatively low level (0.15%).

Table 1 shows a summary of these antimicrobial data in tabular form. Most of the samples tested contained no detected antimicrobial, and these samples contained the greatest fraction with countable microorganisms, almost 17%. There was a statistically significant difference between the fraction of bacteria positive samples with no detected antimicrobial and those containing an antimicrobial ($p=0.0035$).

There was not a statistically significant difference between the fractions of bacteria

positive samples for the two types of antimicrobial ($p=0.1022$). The fraction contaminated in total for all soap samples collected was 12.5%.

The relationship between the type of location sampled and the fraction of the time samples contained detectable microorganisms is shown in Table 2. Grocery stores and fast food operations each had more than 10 percent bulk soap samples positive. Grocery stores, fast food restaurants and sit down restaurants did not have a significantly different fraction of contaminated samples from one another ($p > 0.05$), but grocery stores and fast food restaurants had significantly more ($p < 0.05$) contaminated bulk soap samples than convenience stores.

The breakdown of bulk soap samples in Table 3 shows that both men's and women's bathrooms have contaminated soap >10% of the time. Although samples collected from men's restrooms have a slightly higher frequency of detectable bacteria, the difference was not significant ($p= 0.29$).

The relationship between soap color and the presence of detectable bacteria is shown in Table 4. There are differences in the fraction of samples containing detectable bacteria, by soap color. However, given the wide array of soap colors observed, and the small number of samples containing detectable microorganisms, no differences were statistically significant.

Table 5 shows the fraction of samples containing detectable microorganisms by state, with all three states have >10% of soap contaminated. There were not statistically significant differences between the three states where soap samples were collected ($p>0.05$).

DISCUSSION

This study identified Gram-negative organisms as the primary organisms that colonize bulk soap dispensers, consistent with past outbreaks (1, 2, 24, 38) and screening studies (8, 25). We identified Gram-negative organisms at a broad range of populations (1-7 log CFU/mL) as reported by Momeni et al. (25), (2-9 log CFU/mL). While Momeni et al. found detectable bacteria in ~60% of their samples, we found detectable bacteria in 15% of samples. This may be due to differences in sample size (our 296 vs. their 14), locations (3 states vs. 2 institutes) and type of facility (food service vs. dental institute). Chattman et al (8) collected 541 bulk soap samples from five U.S. cities (Boston, Atlanta, Columbus, Los Angeles, Dallas), from liquid soap dispensers in a wide variety of public settings: offices, health clubs, restaurants, and retail stores. These authors found heterotrophic and coliform populations greater than ~ 2 log CFU/mL in ~19% of the sink area dispensers, similar to what we found (> 2 log CFU/ mL in ~15% of dispensers).

Specifically, relevant to the food industry was the identification of *Shigella sonnei* from a contaminated soap dispenser in Arizona. According to the CDC, *Shigella sonnei* is the predominant cause of shigellosis in industrialized countries (and is the most common species in the US). Eating contaminated foods, such as after handling of ready to eat food from an infected worker, can be a significant contributor to the spread of *Shigella sonnei* (4).

The published literature reports that bacteria are more commonly isolated from plain soaps (1, 5, 27, 30), and less frequently isolated from antimicrobial soaps (1, 2, 24), which is consistent with the findings from our study. Although fewer bacteria are generally isolated from antimicrobial soaps (as they were in our study),

maintaining the activity of active ingredients like triclosan, such that they are not bound by the surfactant micelles is a major technical challenge (11, 34). Our research clearly shows that the presence of an antimicrobial agent is not a safeguard against the colonization of bulk soap by bacteria. This is consistent with Archibald et al. (1) who detected *S. marcescens* in 1% chloroxylenol soap (PCMX), and Barry et al. (2) and McNaughton et al. (24) who isolated bacteria from soap containing triclosan. It is well understood by chemists that formulation matters in the performance of hand hygiene products (10, 23). Our study is a reminder that quality also matters in soap development. For example, high water/low solids formulations may be less expensive to manufacture, but are more likely to be contaminated. Soap delivery systems designed to allow mixing (or dilution of soaps to save money) promote colonization and lead to less stable formulations. The differences between types of food establishments we observed is also interesting. One explanation could be that fast food and grocery stores are more likely contaminated due to less maintenance and management oversight of the bathrooms, relative to convenience stations which typically have small bathrooms that are cleaned frequently. Fast food restaurants should be of greatest concern because food handlers often use the bathrooms we sampled from in the “front of house” and often go directly from the bathroom back into the kitchen. This finding warrants strong consideration of Food Code restrictions of bulk soap in restaurants, analogous to rules that discourage their use in healthcare (3, 31, 39).

We believe this work is generalizable across the US, since samples were obtained in three states spread across the US with a wide range of weather (temperature and

humidity) and food handling environments, with no significant differences in level of microbial contamination between states. Our findings show the design of open refillable systems for dispensing bulk soap is fundamentally flawed, and creates opportunities for contamination and biofilm development, independent of geographic location. Future needs and opportunities include better understanding the relationship of bathroom design (e.g. toilet proximity to the soap dispenser, size of bathroom, etc.) and further assessment of the risk of antibiotic resistant bacteria in bulk soaps. Alternative approaches to achieve a lower/acceptable cost to the foodservice provider are also important, since low cost is the primary attraction to bulk soap systems. Changing this practice will require good policy development, analogous to what happened in healthcare (3).

Use of refillable-bulk soap dispensers is a clear public health concern as they provide an environment for bacteria to grow, often to high populations (8, 21, 25, 30, 40) and have led to non-foodborne disease outbreaks (1, 2, 5, 24, 27, 30, 38). In our study, most soap samples had no detectable bacteria, however those soap samples that did have detectable bacteria (12.5%) had populations that would be considered highly risky if the bacteria present were pathogenic (~ 7 log CFU /ml). While the CDC recommends that bulk liquid soap dispensers be thoroughly cleaned before adding fresh soap (3, 8, 14), cleanings in between soap re-fills might not prevent re-contamination (21), and difficult to clean biofilms may develop. Bulk soap has been proven to cause infection outbreaks in health-care settings. It has been difficult to document outbreaks in food service settings to date, however our findings show use of bulk soap presents a clear risk in food service facilities.

Acknowledgments: We would like to thank the technicians that visited food handling establishments and collected soap samples, including Robyn Miranda and Brandon Arbogast.

References

1. Archibald, L. K., A. Corl, B. Shah, M. Schulte, M. J. Arduino, S. Agüero, D. J. Fisher, B. W. Stechenberg, S. N. Banerjee, and W. R. Jarvis. 1997. *Serratia marcescens* outbreak associated with extrinsic contamination of 1% chlorxylenol soap. *Infect. Cont. Hosp. Epidemiol.* 18:704-709.
2. Barry, M. A., D. E. Craven, T. A. Goularte, and D. A. Lichtenberg. 1984. *Serratia marcescens* contamination of antiseptic soap containing triclosan implications for nosocomial infection. *Infect. Cont.* 5:427-430.
3. Boyce, J. M., and D. Pittet. 2002. Guideline for hand hygiene in health-care settings. *Morbid. Mortal. Week. Rep.* 51:1-56.
4. Brunette G. W. 2017. CDC Yellow Book 2018: Health Information for International Travel. Oxford University Press, New York, NY.
5. Buffet-Bataillon, S., V. Rabier, P. Bétrémieux, A. Beuchee, M. Bauer, P. Pladys, E. Le Gall, M. Cormier, and A. Jolivet-Gougeon. 2009. Outbreak of *Serratia marcescens* in a neonatal intensive care unit: contaminated unmedicated liquid soap and risk factors. *J. Hosp. Inf.* 72:17-22.

6. Bures, S., J. T. Fishbain, C. F. Uyehara, J. M. Parker, and B. W. Berg. 2000. Computer keyboards and faucet handles as reservoirs of nosocomial pathogens in the intensive care unit. *Am. J. Infect. Control.* 28:465-471.
7. Casewell, M., and I. Phillips. 1977. Hands as a route of transmission for *Klebsiella* species. *Brit. Med. J.* 1315-1317.
8. Chattman, M., S. L. Gerba, and C. P. Maxwell. 2011. Occurrence of heterotrophic and coliform bacteria in liquid hand soaps from bulk refillable dispensers in public facilities. *J. Environ. Health.* 73:26-29.
9. Chen, Y., K. M. Jackson, F. P. Chea, and D. W. Schaffner. 2001. Quantification and variability analysis of bacterial cross-contamination rates in common food service tasks. *J. Food Prot.* 64:72-80.
10. Edmonds, S. L., D. R. Macinga, P. Mays-Suko, C. Duley, J. Rutter, W. R. Jarvis, and J. W. Arbogast. 2012. Comparative efficacy of commercially available alcohol-based hand rubs and World Health Organization-recommended hand rubs: formulation matters. *Am. J. Infect. Control.* 40:521-525.
11. Edmonds, S. L., C. Zapka, D. Kasper, R. Gerber, R. McCormack, D. Macinga, S. Johnson, S. Sambol, C. Fricker, J. Arbogast, and D. N. Gerding. 2013. Effectiveness of hand hygiene for removal of *Clostridium difficile* spores from hands. *Infect. Control. Hosp. Epidemiol.* 34:302-305.
12. Fendler, E. J., and M. J. Dolan. 1998. Handwashing and gloving for food protection I: examination of the evidence. *Dairy Food Env. San.* 18:824-829.
13. Fuls, J. L., N. D. Rodgers, G. E. Fischler, J. M. Howard, M. Patel, P. L. Weidner, and M. H. Duran. 2008. Alternative hand contamination technique to compare the

activities of antimicrobial and nonantimicrobial soaps under different test conditions. *Appl. Environ. Microbiol.* 74:3739-3744.

14. Garner, J. S., and M. S. Favero. 1986. CDC guidelines for the prevention and control of nosocomial infections. Guideline for handwashing and hospital environmental control, 1985. Supersedes guideline for hospital environmental control published in 1981. *Am. J. Infect. Control.* 14:110-126.

15. Gräf, W., D. Kersch, and G. Scherzer. 1988. Microbial contamination of liquid-soap wall dispensers with one-way bottles. *Zentralbl. Bakteriol. Mikrobiol. Hyg. B.* 186:166-179.

16. Guzewich, J. J., and M. P. Ross. 1999. White paper, Section two: Interventions to prevent or minimize risks associated with bare-hand contact with ready-to-eat foods.

<http://www.fda.gov/Food/FoodSafety/RetailFoodProtection/ucm210138.htm>.

Accessed May 4, 2012.

17. Jensen, D. A., L. M. Friedrich, L. J. Harris, M. D. Danyluk, and D. W. Schaffner. 2013. Quantifying transfer rates of *Salmonella* and *Escherichia coli* O157:H7 between fresh-cut produce and common kitchen surfaces. *J. Food Prot.* 76:1530-1538.

18. Jensen, D. A., L. M. Friedrich, L. J. Harris, M. D. Danyluk, and D. W. Schaffner. 2015. Cross contamination of *Escherichia coli* O157:H7 between lettuce and wash water during home-scale washing. *Food Microbiol.* 46:428-433.

19. Jumaa, P. A. 2005. Hand hygiene: simple and complex. *Int. J. Infect. Dis.* 9:3-14.

20. LeBaron, C. W., N. P. Furutan, J. F. Lew, J. R. Allen, V. Gouvea, C. Moe, and S. S. Monroe. 1990. Viral agents of gastroenteritis. Public health importance and outbreak management. *MMWR. Recomm. Rep.* 39:1-24.
21. Lorenz, L. A., B. D. Ramsay, D. M. Goeres, M. W. Fields, C. A. Zapka, and D. R. Macinga. 2012. Evaluation and remediation of bulk soap dispensers for biofilm. *Biofouling.* 28:99-109.
22. Lubber, P., S. Brynstad, D. Topsch, K. Scherer, and E. Bartelt. 2006. Quantification of *Campylobacter* species cross-contamination during handling of contaminated fresh chicken parts in kitchens. *Appl. Environ. Microbiol.* 72:66-70.
23. Macinga, D. R., D. J. Shumaker, H. P. Werner, S. L. Edmonds, R. A. Leslie, A. E. Parker, and J. W. Arbogast. 2014. The relative influences of product volume, delivery format and alcohol concentration on dry-time and efficacy of alcohol-based hand rubs. *BMC. Infect. Dis.* 14:511.
24. McNaughton, M., N. Mazinke, and E. Thomas. 1995. Newborn conjunctivitis associated with triclosan 0.5% antiseptic intrinsically contaminated with *Serratia marcescens*. *Can. J. Infect. Control.* 10:7-8.
25. Momeni, S. S., N. Tomlin, and J. D. Ruby. 2015. Isolation of *Raoultella planticola* from refillable antimicrobial liquid soap dispensers in a dental setting. *J. Amer. Dent. Assoc.* 146:241-245.
26. Montville, R., Y. Chen, and D. W. Schaffner. 2002. Risk assessment of hand washing efficacy using literature and experimental data. *Int. J. Food Microbiol.* 73:305-313.

27. Rabier, V., S. Bataillon, A. Jolivet-Gougeon, J. M. Chapplain, A. Beuchée, and P. Bétrémieux. 2008. Hand washing soap as a source of neonatal *Serratia marcescens* outbreak. *Acta. Paediatr.* 97:1381-1385.
28. Reasoner, D. J., J. C. Blannon, and E. E. Geldreich. 1979. Rapid seven-hour fecal coliform test. *Appl. Environ. Microbiol.* 38:229-236.
29. Reij, M. W., and E. D. DenAantrekker. 2004. Recontamination as a source of pathogens in processed foods. *Int. J. Food Microbiol.* 91:1-11.
30. Sartor, C., V. Jacomo, C. Duvivier, H. Tissot-Dupont, R. Sambuc, and M. Drancourt. 2000. Nosocomial *Serratia marcescens* infections associated with extrinsic contamination of a liquid nonmedicated soap. *Infect. Cont. Hosp. Epidemiol.* 21:196-199.
31. Sax, H., B. Allegranzi, I. Uckay, E. Larson, J. Boyce, and D. Pittet. 2007. My five moments for hand hygiene: a user-centred design approach to understand, train, monitor and report hand hygiene. *J. Hosp. Inf.* 67:9-21.
32. Steinberg, D. C. 2006. Preservatives for cosmetics. Allured Publishing Corporation, Carol Stream, IL.
33. Strohbahn, C., J. Sneed, P. Paez, and J. Meyer. 2008. Hand washing frequencies and procedures used in retail food services. *J. Food Prot.* 71:1641-1650.
34. Taylor, T. J., E. P. Seitz, P. Fox, G. E. Fischler, J. L. Fuls, and P. L. Weidner. 2004. Physicochemical factors affecting the rapid bactericidal efficacy of the phenolic antibacterial triclosan. *Int. J. Cosmet. Sci.* 26:111-116.
35. United States Department of Health and Human Services, Public Health Service, Food and Drug Administration. 2013. Food Code.

<http://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM374510.pdf>. Accessed 06 December 2016.

36. van der Linde, K., B. T. Lim, J. M. Rondeel, L. P. Antonissen, and G. M. de Jong.

1999. Improved bacteriological surveillance of haemodialysis fluids: a comparison between Tryptic soy agar and Reasoner's 2A media. *Nephrol. Dial. Transplant.* 14:2433-2437.

37. Vigeant, P., V. G. Loo, C. Bertrand, C. Dixon, R. Hollis, M. A. Pfaller, A. P. McLean, D.

J. Briedis, T. M. Perl, and H. G. Robson. 1998. An outbreak of *Serratia marcescens* infections related to contaminated chlorhexidine. *Infect. Cont. Hosp. Epidemiol.* 19:791-794.

38. Weber, D. J., W. A. Rutala, and E. E. Sickbert-Bennett. 2007. Outbreaks associated with contaminated antiseptics and disinfectants. *Antimicrob. Agents. Chemother.* 51:4217-4224.

39. World Health Organization. 2009. WHO Guidelines on hand hygiene in health care. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf. Accessed December 22, 2014.

40. Zapka, C. A., E. J. Campbell, S. L. Maxwell, C. P. Gerba, M. J. Dolan, J. W. Arbogast, and D. R. Macinga. 2011. Bacterial hand contamination and transfer after use of contaminated bulk-soap-refillable dispensers. *Appl. Environ. Microbiol.* 77:2898-2904.

Figure legends

Figure 1: The distribution of microbial counts in contaminated soap samples.

Figure 2: The distribution of coliform counts in contaminated soap samples.

Figure 3: Relationship between coliform counts and total plate counts in contaminated soap samples. Coliform counts above 4.4 log MPN or above 5.4 log MPN are shown using open squares and open triangles, respectively. Counts below the detection limit (10 CFU/ml) are plotted as 0 log CFU or MPN.

Figure 4: Relationship between sample pH, and the population of detectable microorganisms. Counts below the detection limit (10 CFU/ml) are plotted as 0 log CFU.

Figure 5: Relationship between soap sample percent solids (top panel) or water activity (bottom panel) and bacterial count. Counts below the detection limit (10 CFU/ml) are plotted as 0 log CFU.

Figure 6: Relationship between fraction of soap samples with bacterial counts above the detection limit (10 CFU/ml) and percent solids (top panel) or number of soap samples contaminated (grey) or uncontaminated (black) and soap water activity (bottom panel).

Figure 7. Relationship between the measured concentration the antimicrobial agent triclosan (black triangle) or parachlorometaxyleneol (grey downward triangle) or no detectible antimicrobial agent (open circles) and total bacterial count. Counts below the detection limit (10 CFU/ml) are plotted as 0 log CFU.

Table 1. Comparison of the fraction of samples containing detectable bacteria for soap samples with detectable antimicrobial agents

	N sampled	number countable	Percent total Samples (%)	Percent countable (%)
None	166	28	56.1	16.9 ^a
Triclosan	97	8	32.8	8.2 ^b
Parachlorometaxlenol	33	1	11.1	3.0 ^b
Total	296	37	100.0	12.5

Percent countable values with a different superscript are significantly different ($p < 0.05$)

Table 2. Fraction of samples containing detectable bacteria by store type

Type	N sampled	Times bacteria detected	Percent Detected (%)
Grocery	30	5	16.7 ^a
Fast food	122	19	15.6 ^a
Sit down	113	11	9.7 ^{ab}
Convenience	28	1	3.6 ^b

Percent detected values with a different superscript are significantly different ($p < 0.05$)

Table 3. Fraction of samples containing detectable bacteria by restroom gender type

Type	N sampled	Times bacteria detected	Percent detected (%)
Men	169	23	13.6
Women	114	13	11.4
Other*	13	1	7.7

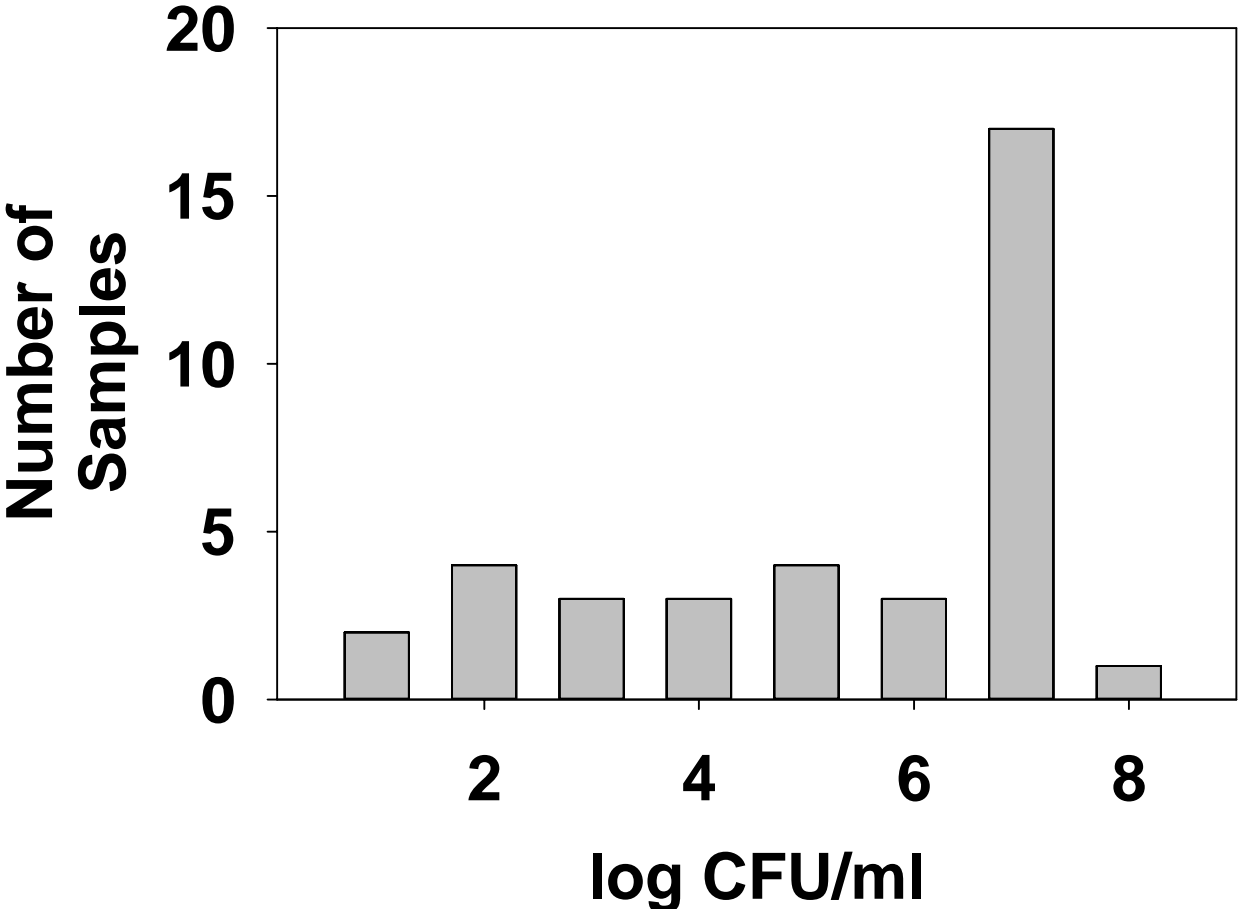
* includes unknown, not recorded and unisex bathrooms

Table 4. Fraction of samples containing detectable bacteria by soap color

Color	N sampled	Times bacteria detected	Percent detected (%)
Green	11	5	45.5
Clear	24	7	29.2
Orange	37	8	21.6
Pink	120	12	10.0
White	41	3	7.3
Blue	42	3	7.1
Yellow	16	0	0.0
Unknown	6	0	0.0

Table 5. Fraction of samples containing detectable bacteria by state

State	N samples	Times bacteria detected	Percent detected (%)
AZ	100	14	14.0
NJ	100	11	11.0
OH	96	12	12.5



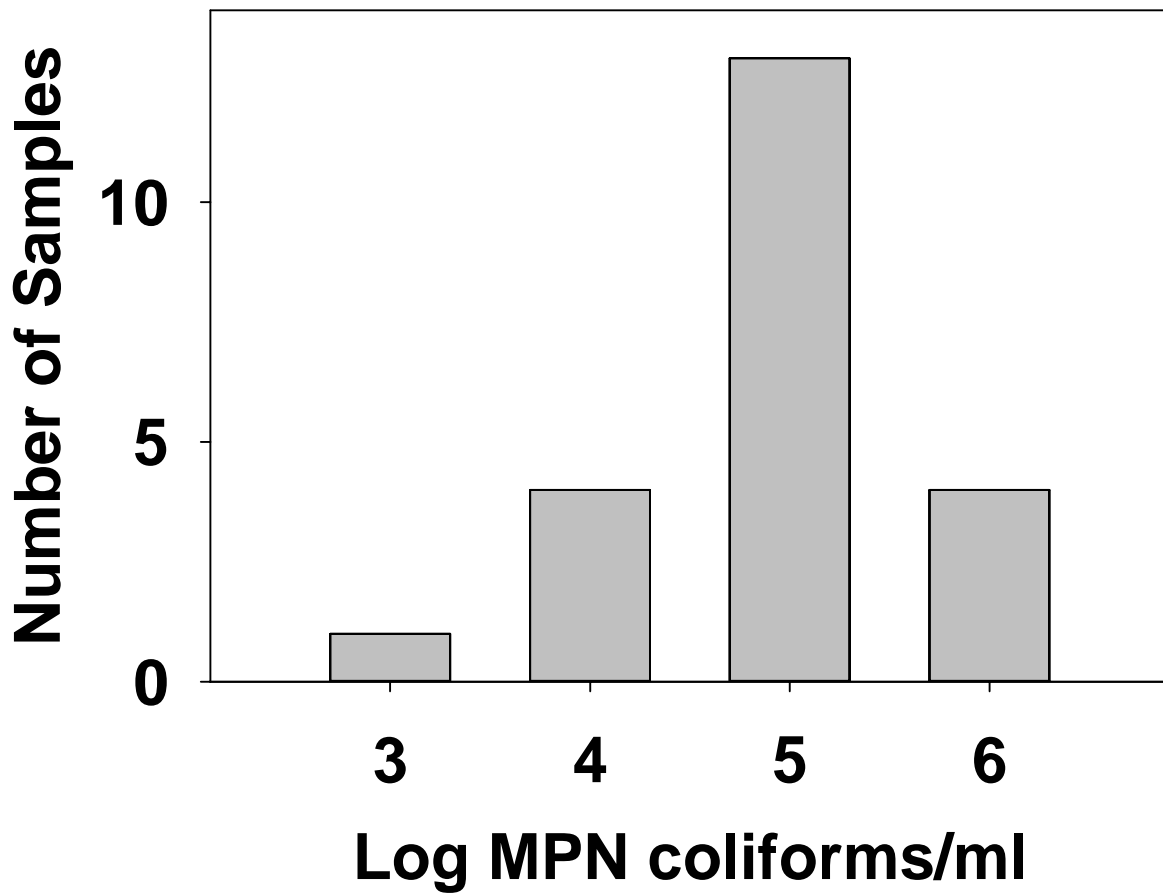


Fig 3

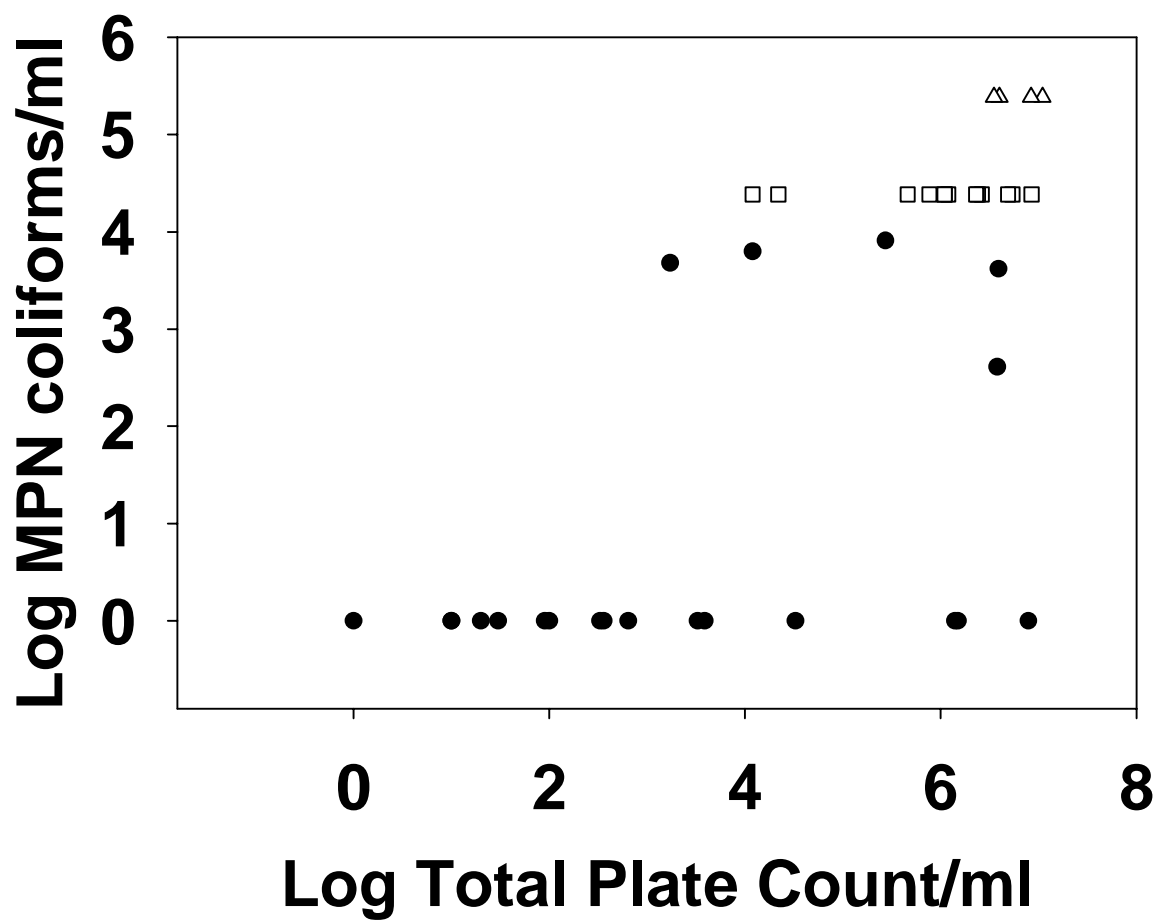
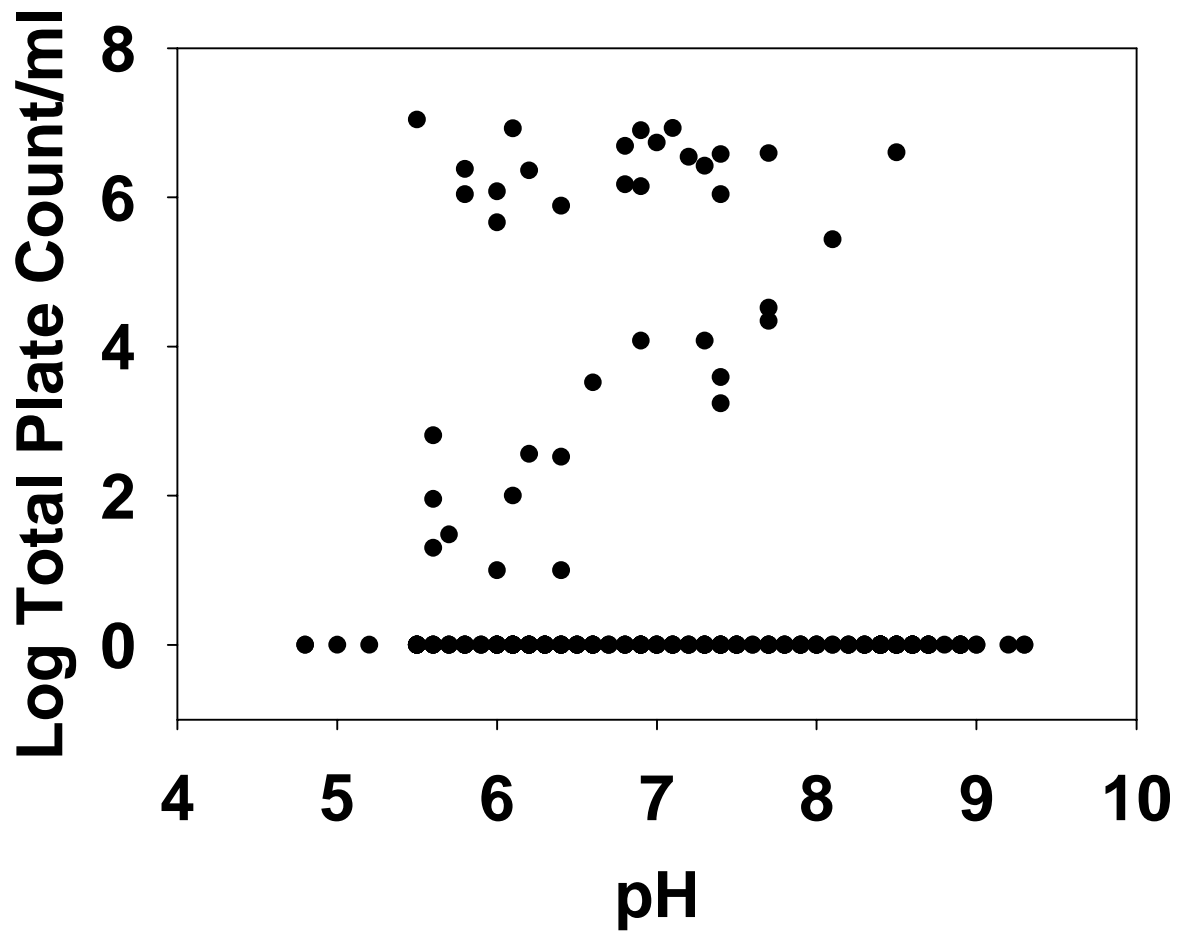


Fig 4



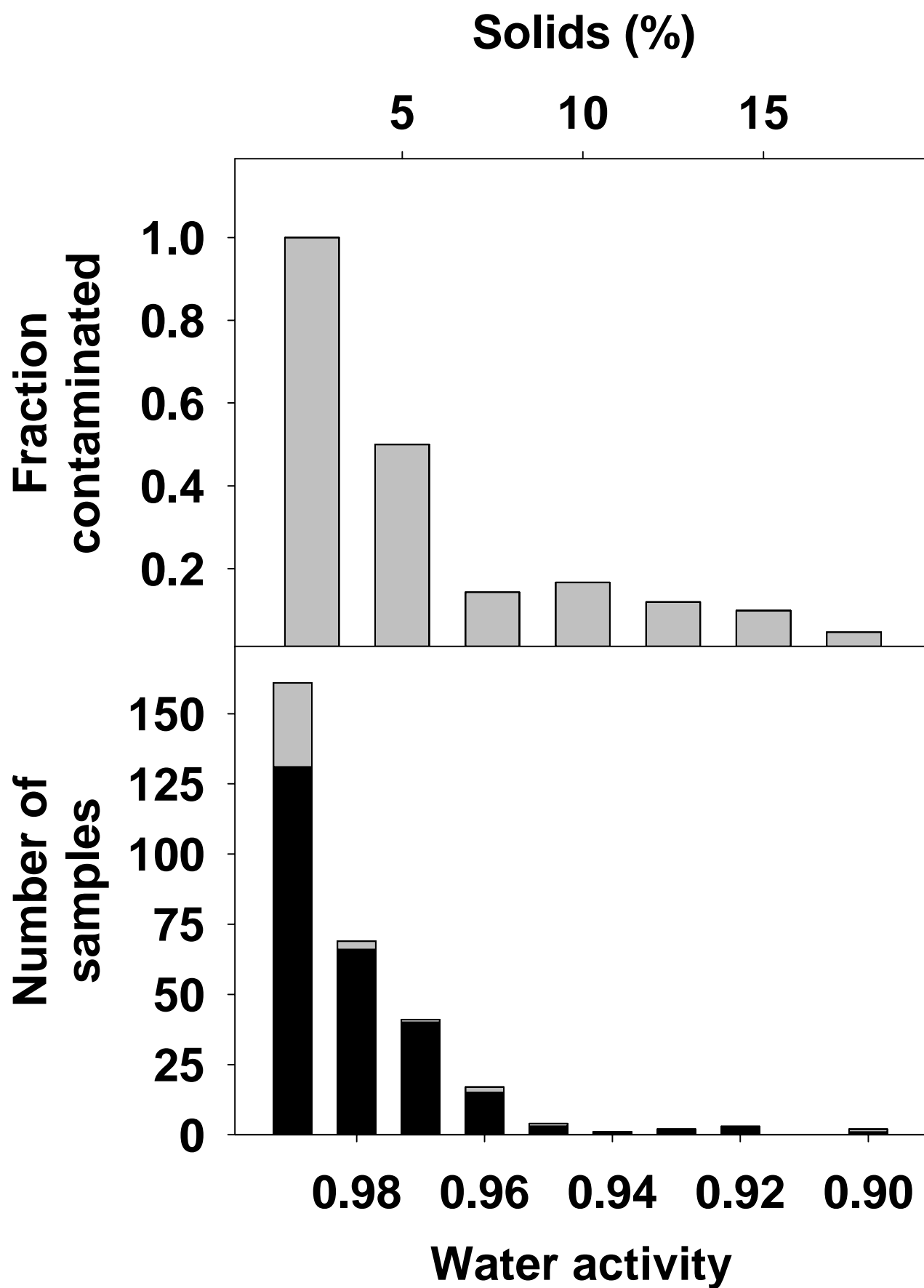


Fig 7

