How Safe is Your Soap?

Bacterial Contamination of Soap from Open Refillable Bulk Dispensers

Charles P. Gerba, PhD

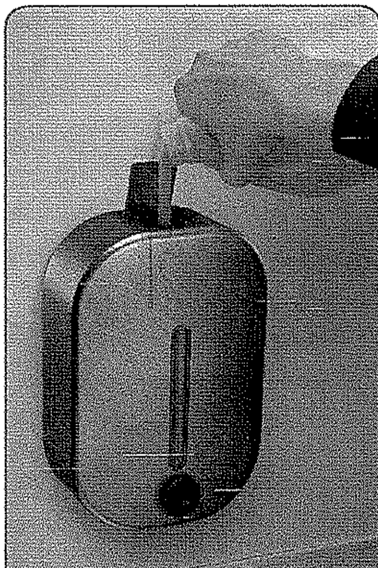
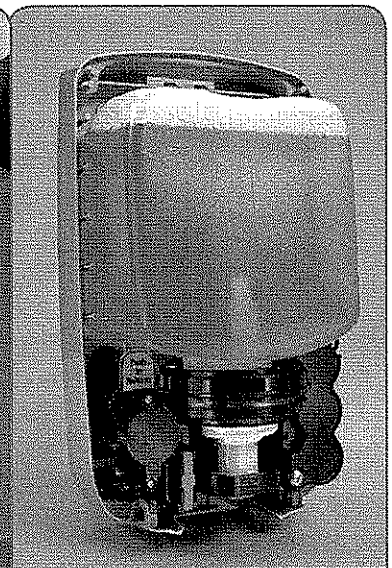
Marisa B. Chattman

Sheri L. Maxwell

An overview and summary of research studies conducted by The University of Arizona, Tucson, AZ, and presented to:

- The American Society for Microbiology 107th General Meeting
  Toronto, ON, Canada; May 21-25, 2007
- The National Environmental Health Association 71st Annual Educational Conference & Exhibition
  Atlantic City, NJ; June 18-21, 2007

Do you know the difference?

	Open Refillable Bulk Soap Dispenser	Sealed Soap Dispensing System
Design	• Open to the environment • Permanent nozzle is reused	• Factory sealed • New nozzle with each refill
Refilling Method	• Pour soap into dispenser from bottle	• Snap new cartridge into dispenser
Maintenance	• Labor intensive • Extensive cleaning and sanitizing required	• Labor-free • No need for cleaning and sanitizing
Contamination	• Prone to contamination	• Safe from contamination

Bacterial Contamination of Soap from Open Refillable Bulk Dispensers

Table of Contents

Bulk Soap Contamination Research Study Summary

Background

Several studies conducted during the last 25 years have demonstrated that liquid soaps can become contaminated with microorganisms and multiple instances of infections and nosocomial outbreaks associated with such contamination have been reported (1-4). Contamination often occurs after the product reaches the user (extrinsic contamination) (1;3;5) and has been observed in both nonmedicated (1) and antimicrobial products including those with the active ingredients Chloroxylenol (PCMX) (3), Benzalkonium chloride (5;6), Triclosan (4), and Chlorhexidine gluconate (2;5;7-10). All types of liquid soap, regardless of the active ingredient or preservative system, are susceptible to contamination when exposed to adverse circumstances. Soap dispensers with sealed disposable refills are an alternative to this contamination challenge. By contrast, open refillable ("bulk") soap dispensers continue to present significant risk of contamination during use. Because the addition of soap to a partially empty dispenser ("topping off") can lead to bacterial contamination in healthcare settings, the CDC recommends the use of soap dispensed from disposable containers or containers that are thoroughly washed and dried prior to refilling (11;12).

Recent studies conducted at the University of Arizona by prominent microbiologist, Dr. Charles P. Gerba, revealed that liquid hand soap collected from open refillable dispensers are a public health risk. Dr. Gerba determined the levels of bacteria in soap sampled from various types of dispensers. He found unsafe levels of bacterial contamination in soap from open refillable dispensers, whereas no bacterial contamination was found in soap from dispensers with sealed disposable refills. This research has been presented at two recent scientific conferences (13;14).

National Environmental Health Association 71st Annual Educational Conference & Exhibition
Atlantic City, NJ; June 18-21, 2007

Title: Bacterial Contamination of Liquid Hand Soaps Used in Public Restrooms

Authors: C. P. Gerba and S. Maxwell; University of Arizona, Tucson, AZ

Abstract

The objective of this study was to determine the occurrence of heterotrophic and coliform bacteria in liquid hand soaps collected from public restrooms across the United States. Sample locations included public restrooms in restaurants, health clubs, office buildings and retail stores. The liquid soap samples collected were from refillable dispensers (also referred to as "open systems" or "bulk soap" systems). Of 541 samples, 133 (25%) had bacterial numbers greater than 500 CFU/mL and 87 samples (16%) contained coliform bacteria. Approximately 65% of the bacteria isolated from the soap belonged to the coliform group. The average number of bacteria detected in the soap was 3.02×10^6 CFU/mL with a range of 590 to 5.3×10^7 CFU/mL. The average number of coliform bacteria was 3.94×10^6 CFU/mL with a range of <10 to 6.5×10^7 CFU/mL. Opportunistic pathogens identified in the liquid soap samples included *Klebsiella oxytoca, Klebsiella pneumoniae, Enterobacter aerogenes, Serratia marcescens, Pseudomonas aeruginosa* and *Enterobacter sakazakii.* No bacteria were detected in dispensers that required sealed soap replacements. All of the organisms detected in the soap samples were Gram-negative bacteria. This is most likely because of the presence of sodium lauryl sulfate in the soap, which inhibits the growth of Gram- positive bacteria. The results suggest that some liquid soap dispensers become colonized by Gram-negative bacteria over time, possibly because of the degradation of preservatives in the liquid soap.

American Society for Microbiology 107th General Meeting
Toronto, ON, Canada; May 21-25, 2007

Title: Bacterial Contamination of Liquid Hand Soaps

Authors: M. Chattman, S. Maxwell and C. P. Gerba; University of Arizona, Tucson, AZ

Abstract

The occurrence of heterotrophic bacteria (HPC) and coliform bacteria in liquid hand soap from 130 refillable unsealed (a.k.a. open or bulk) dispensers collected from employee break rooms, airplane restrooms, kitchens and public restrooms was determined. The percentage of samples that contained HPC numbers above 500 CFU/mL was 23%, averaging 4.5×10^6 CFU/mL. Total coliform bacteria were detected in 22% of the samples, averaging 2.2×10^6 CFU/mL. Bacterial species most frequently identified included *Serratia marcescens, Enterobacter aerogenes,* and *Klebsiella pneumoniae.* One of the soap dispensers containing contaminated soap was monitored over a three month period. Various levels and types of bacterial contamination were observed. When bacteria were added to uncontaminated, factory-sealed, liquid hand soap the bacteria quickly died. Liquid hand soap from a public restroom, that contained large numbers of bacteria was pasteurized

and inoculated with *K. pneumoniae.* Growth was observed, indicating that degradation of preservatives must occur in the soap dispenser over time, allowing for the growth of bacteria. These results demonstrate that bacteria growing in soap dispensers are not resistant to the preservatives and that preservative degradation takes place, likely after introduction of the soap in the dispensers.

Contaminated Bulk Soap is a Public Health Risk

Dr. Gerba's studies demonstrate that soap from open refillable dispensers in public restrooms in the US are routinely contaminated with opportunistic pathogens. Soap users are exposed to an average of over 1,000,000 of these bacteria approximately 1 in 4 times they wash with soap from an open refillable soap dispenser. This level of contamination is 1000 times greater than upper limit recommended by cosmetic industry standards (15) and presents a potential health risk to the soap users as well as to others they may have contact with. Hands are known to be a common transmission vector and it has been shown that bacteria remain on the hands after using contaminated soap (1). The risk of acquiring an infection is greatest for anyone who has a defect in their body's normal defense mechanisms. Up to 20% of the US general public have impaired immune function and this percentage is growing due to advances in medicine which are prolonging life as well as the increase in the proportion of elderly in the population (16-18). The immunocompromised population includes a diverse group with a wide variety of conditions ranging from the severely immunocompromised (HIV/AIDS, cancer, organ or bone marrow transplant recipients) to pregnant women, young children and the elderly which exhibit non-specific general reduced immune function (19;20). The fetus, neonate and young children have reduced immune function for the first few years of life until their immune systems mature (19). Over 12% of the US population is over the age of 65 and are at a greater risk of acquiring infections due to their age-related diminished immunity (16;21). In addition, many common chronic conditions weaken the immune system including diabetes (which affects 10% of the population) (18), cirrhosis/alcoholism, chemical dependency, nutritional deficiencies, and any defects resulting in skin barrier function loss (burns, ulcers, or dermatitis) (17;20).

Illnesses Caused by the Contaminating Bacteria

In the recent study by Dr. Gerba, several of the bacterial species isolated from the contaminated soap (e.g. *Klebsiella, Enterobacter, Citrobacter, Serratia,* and *Pseudomonas*) are medically important opportunistic pathogens. These organisms cause a variety of illnesses including respiratory tract infections, pneumonia, urinary tract infections, bloodstream infections, surgical site infections, meningitis, skin ulcers, gastroenteritis as well as wound and soft tissue infections (22-24). *Klebsiella pneumoniae,* for example, is responsible for 1-5% of community-acquired pneumonia (25). *Enterobacter sakazakii* causes neonatal meningitis (26). *Citrobacter* causes sepsis, meningitis and central nervous system abscesses in neonates and young infants (27) and there has been one report of *Citrobacter koseri* causing a central nervous system infection in a healthy person with a fully functional immune system (28). *Citrobacter freundii* was also implicated as a potential cause of an outbreak of diarrheal disease (24). *Pseudomonas aeruginosa* is a common nosocomial pathogen causing urinary tract infections, sinusitis, wound infections, and pneumonia. Occasionally it has been known to cause a rare form of community-acquired pneumonia with a 33% mortality rate that can affect persons with healthy immune systems (29). *Serratia* has been implicated in multiple outbreaks due to contaminated soaps in healthcare facilities (1;3;4). *Pantoea* is a rare pathogen that was reported to be responsible for 7 infant deaths in a neonatal outbreak (30). The frequent presence of such high numbers of organisms known to be medically significant both in the community and in healthcare settings is quite alarming.

Reducing the Risks of Bulk Soap Contamination

Unsafe levels of contamination were found in 23% – 25% of soap samples collected from open refillable dispensers. In contrast, no contamination was found in soap samples collected from dispensers containing sealed disposable refills. It is recommended that all open refillable dispensers should be switched to dispensers with sealed disposable refills, which are a safer alternative and avoid unnecessary health risk.

Bacterial Contamination of Liquid Hand Soaps

Introduction

Liquid hand soap is used daily by millions of people worldwide. Hand washing, with soap and water, is a universally accepted method to reduce the microbial load on the hands. People encounter situations in which they are exposed to a variety of bacteria that have the ability to cause infection. In response to these situations, many people wash their hands with soap and water. Society recognizes that good hygiene can reduce the risk of bacterial infection. Some public facilities have soap dispensers that require sealed bags or cartridges while others have dispensers that are refillable by using stock soap solutions that are often diluted with tap water. Bulk open refillable liquid soap dispensers in many public restrooms and restaurants, offer a suitable environment for the growth of potentially disease causing microorganisms.

Materials and Methods

Soap was collected into sterile 50mL centrifuge tubes through the dispenser mechanism. One mL of Dey-Enger (DE) neutralizing broth (Remel, Lenexa, KS) was added to each sample tube and shaken for 30 seconds. Heterotrophic plate counts (HPC) were obtained by spread plating 0.1mL onto duplicate petri dishes containing R2A media (Difco, Sparks, MD) and incubated at 30°C for 5 days.

Coliform enumeration was performed by spread plating on mEndo agar plates (Difco, Sparks, MD) and incubating at 37°C for 24 hours. Representatives of each colony type were streaked for isolation on petri dishes containing Tryptic Soy Agar (TSA) (Difco, Sparks, MD). Identification of bacteria was performed by using API20E strips (BioMerieux, Marcy-l'Etoile, France).

Results

Table 1: Occurrence of Bacteria in Liquid Hand Soap from Refillable Dispensers

Type of soap dispenser	Total number of liquid soap samples tested	Number >500 CFU/mL	Coliform bacteria	Average number HPC CFU/mL	Average number coliform bacteria CFU/mL
Refillable	132	30	29	4.5×10^6	2.2×10^6
Disposable bag	20	0	0	0	0

Figure 1: Frequency of Detection of Various Bacteria in Soap Samples

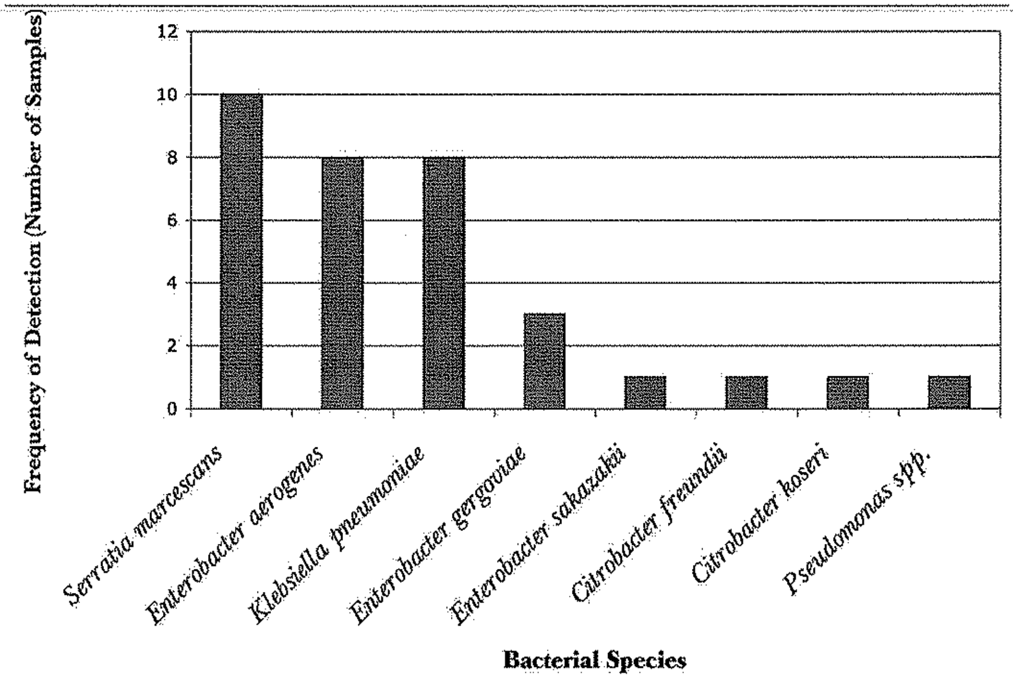


Table 2: Occurrence of HPC and Coliform Bacteria Over Time in a Restaurant Soap Dispenser

Date	HPC (CFU/mL)	Coliform bacteria (CFU/mL)
5/29	4.3×10^7	2.0×10^7
6/21	9.3×10^3	<1
7/17	1.9×10^7	8.2×10^6
7/31	9.5×10^6	7.3×10^6
8/14	1.2×10^7	9.0×10^6
8/28	<1	<1
9/12	3.2×10^7	2.6×10^7

Table 3: Growth of *Klebsiella pneumoniae* in Pasteurized Contaminated Soap (CFU/mL)

	Time (Days)			
Sample	0	1	4	8
9/12	6.3×10^2	3.4×10^4	5.9×10^5	2.5×10^6
Negative Control*	<1	<1	<1	<1

* Undiluted, pasteurized soap inoculated with same amount of bacteria as sample. Number of *Klebsiella pneumoniae* added to each soap sample was 5.6×10^3 (9.3×10^2 CFU/mL).

Table 4: Minimum Inhibitory Concentration of a Liquid Soap against *Klebsiella pneumoniae* (CFU/mL)

	Time (Days)				
Dilution	0	60 min	1	5	10
No Dilution	50	<1	<1	<1	<1
1:1	330	<1	<1	<1	<1
1:2	490	<1	<1	<1	<1
1:4	480	160	<1	<1	<1
1:10	410	320	<1	<1	<1
1:100	350	580	240	<1	<1
1:1000	410	550	240	1.5×10^4	1.5×10^5
Negative Control*	500	520	150	1.5×10^3	2.3×10^3

* No soap added.

Conclusions

- 22.7% of samples taken from refillable bulk dispensers contained >500 CFU/mL HPC, and 22% contained coliform bacteria, averaging 10^6 CFU/mL.
- Bacterial species identified were all opportunistic pathogens.
- No bacteria were found in sealed system soap dispensers.
- A soap dispenser monitored over a three-month period, demonstrated that bacterial contamination was prolonged although the levels and types of bacteria varied.
- Eight types of uncontaminated, factory-sealed, liquid hand soaps were inoculated with various species of bacteria. All of the bacteria quickly died in the soaps after addition, even when the soap was diluted.
- The minimum inhibitory concentration of a specific brand of soap used at a restaurant that had bacterial contamination in the soap indicated that it contained sufficient concentrations of preservatives to inhibit bacterial growth.
- Liquid soap from a public restroom, that contained large numbers of bacteria was pasteurized and inoculated with Klebsiella pneumoniae. Growth was observed, thus it appears that degradation of preservatives must occur in the soap dispenser, allowing for the growth of bacteria.
- Bacteria growing in the soap dispensers are not resistant to the preservatives and that preservative degradation takes place, likely after introduction of the soap into the dispensers.

Bacterial Contamination of Liquid Hand Soaps Used in Public Restrooms

Introduction

Washing hands with soap and water is a universally accepted method to reduce the microbial load on the hands and is used daily by millions of people worldwide. However, the majority of public facilities have soap dispensers that are refillable using a stock soap solution. The CDC recognized in 1975 that the use of these types of dispensers can result in a suitable environment for the growth of potentially disease causing microorganisms. Current health-care hand hygiene guidelines do not recommend the use of open refillable dispensers. The liquid soap used in these dispensers can become contaminated regardless of the preservative used when the microbial population exceeds the preservatives defenses. When product contamination has been reported, contamination was more likely to have occurred extrinsically (after product had been used) than intrinsically (during manufacturing). The likelihood of extrinsic contamination is greatest when the product is open to repeated exposure to bacteria from the user or the environment, hence, the packaging and the dispensing method plays a significant role in product safety.

Materials and Methods

Liquid soap samples were collected from public restrooms in five cities [Boston, MA (107), Atlanta, GA (120), Columbus, OH (109), Los Angeles, CA (94), and Dallas, TX (111)]. Samples were organized into 5 categories: office, health clubs, food service, retail locations and other (education, leisure, etc.). The total number of liquid soap samples analyzed in this report were 541, consisting of 428 soap samples from the sink area and 113 soap samples from the shower area at health clubs, 65 from men's showers and 48 from women's showers. A total of 428 liquid soap samples from the sink area, 226 from men's restroom sink areas and 202 from women's restroom sink areas, were analyzed for this report. Samples with <500 CFU/mL were not considered since industry standards allow for this amount of bacteria in liquid soap. All samples were confirmed to be from open refillable systems.

The samples were collected in sterile 50 mL conical tubes and shipped to the laboratory on ice. 1 mL of DE neutralizing broth (Remel, Lenexa, KS) was added to each sample tube and shaken vigorously for 60 seconds. Heterotrophic plate counts (HPC) were obtained by the spread plate method on R2A media (Difco, Sparks, MD). Plates were incubated at 30°C for 5 days. Any sample showing bacterial content was reexamined for Coliform bacteria.

Coliform analysis and enumeration was performed using the spread plate method on mEndo agar (Difco, Sparks, MD) and incubated at 35°C for 24 hours. Bacterial colonies were counted and recorded, representatives of all colony types were subcultured to TSA plates (Difco, Sparks, MD) for oxidase tests and identification. TSA plates were incubated at 35°C for 24 hours. Identification of bacteria was obtained using API20E strips (BioMerieux, Marcy-l'Etoile, France). *S. aureus* analysis was performed by using the spread plate method on TSA amended with 5% Sheep Blood (BA) (Hardy Diagnostics, Phoenix, AZ) to check for hemolysis. Plates were incubated for 24-48 hours at 35°C. Beta hemolytic isolates were enumerated and streaked onto a TSA plate and incubated for 24 hours at 35°C. Isolated colonies underwent further confirmation testing utilizing catalase production, microscopic morphology, coagulase production (tube and slide tests) and antibiotic (polymyxin) sensitivity.

Results

Figure 1: Locations Containing HCP and Percent of HCPs that were Coliforms

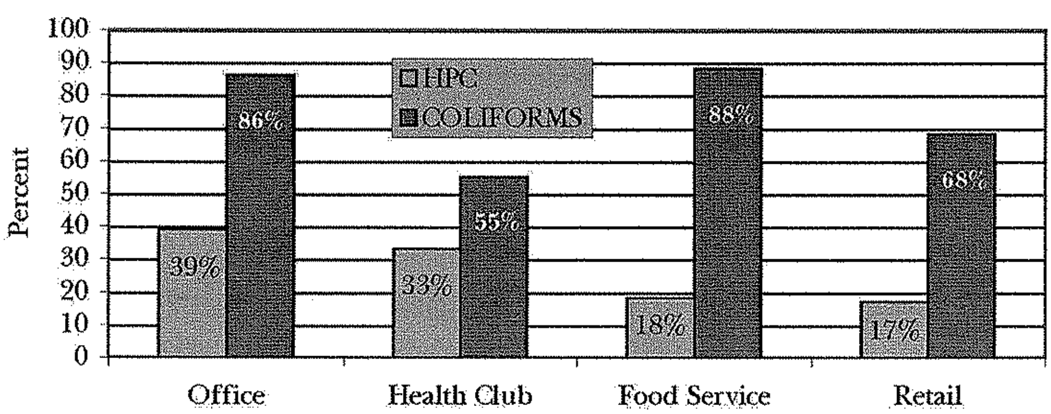


Figure 2: Frequency of Bacterial Species Isolated from Refillable Liquid Soap Dispensers

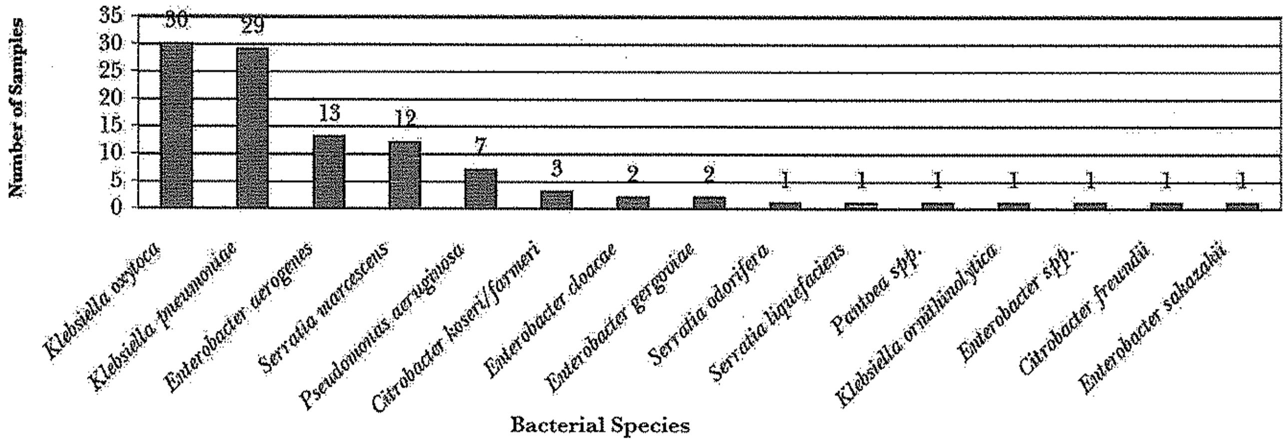
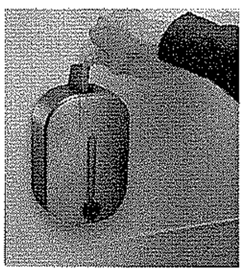


Figure 3:

Sealed System
0% Contaminated



Open Refillable Bulk Soap Dispenser Being Refilled
25% Contaminated

Table 1:

Total number of open refillable soap samples	Number of samples with bacteria	Number of samples with Coliforms
541	133 (25%)	87 (16%)

Summary

A total of 541 open refillable liquid soap samples were analyzed for bacteria, coliforms and Staphylococcus aureus. Of the 541 samples, 133 (25%) contained bacteria, 87 samples (16%) contained coliforms. The percent of bacteria isolated from open refillable liquid soap samples that were identified as coliforms was 65%. Heterotrophic bacterial numbers detected in the liquid soap samples ranged from 590 to 5.3 x 10^7 CFU/mL. The average number of bacteria found in one mL of soap was 3.02 x 10^6 CFU/mL. Coliform bacteria ranged from <10 to 6.5 x 10^7 CFU/mL, with an average of 3.94 x 10^6 per mL of soap. The frequency of contamination was similar for all cities tested, for both men and women's restrooms and for both wall mounted and counter-mounted dispensers. Klebsiella was the most frequently isolated genus of bacteria, followed by Enterobacter and Serratia. No Staphylococcus aureus were detected in any of the liquid soap samples analyzed.

Conclusions

High levels of bacterial contamination (average 3.02 x 10^6 CFU/mL) were found in 25% of the liquid soap samples in this study. Previous reports found no contamination in soap from sealed systems (figure 3). Since these samples represent a diverse cross section of geographical locales and individual sites, it is concluded that refillable open, or "bulk", liquid soap systems commonly found in the U.S. are routinely contaminated with bacteria. Many of the bacteria isolated are opportunistic pathogens which can cause a variety of health issues including respiratory infections, bloodstream infections, urinary tract infections and skin infections. The type and level of bacteria found in these systems represent a potential health risk to users, especially to any immunocompromised individuals.

Footnotes

(1) Sartor C, Jacomo V, Duvivier C et al. Nosocomial Serratia marcescens infections associated with extrinsic contamination of a liquid nonmedicated soap. Infect Control Hosp Epidemiol 2000 March;21(3):196-9.

(2) Vigeant P, Loo VG, Bertrand C et al. An outbreak of Serratia marcescens infections related to contaminated chlorhexidine. Infect Control Hosp Epidemiol 1998 October;19(10):791-4.

(3) Archibald LK, Corl A, Shah B et al. Serratia marcescens outbreak associated with extrinsic contamination of 1% chlorxylenol soap. Infect Control Hosp Epidemiol 1997 October;18(10):704-9.

(4) McNaughton M, Mazinke N, Thomas E. Newborn conjunctivitis associated with triclosan 0.5% antiseptic intrinsically contaminated with Serratia marcescens. Can J Infect Control 1995;10(1):7-8.

(5) Oie S, Kamiya A. Microbial contamination of antiseptics and disinfectants. Am J Infect Control 1996 October;24(5):389-95.

(6) Oie S, Kamiya A. Microbial contamination of benzalkonium chloride products. Am J Health Syst Pharm 1998 December 1;55(23):2534, 2537.

(7) Brooks SE, Walczak MA, Malcolm S, Hameed R. Intrinsic Klebsiella pneumoniae contamination of liquid germicidal hand soap containing chlorhexidine. Infect Control Hosp Epidemiol 2004 October;25(10):883-5.

(8) Kahan A, Philippon A, Paul G et al. Nosocomial infections by chlorhexidine solution contaminated with Pseudomonas pickettii (Biovar VA-I). J Infect 1983 November;7(3):256-63.

(9) McAllister TA, Lucas CE, Mocan H et al. Serratia marcescens outbreak in a paediatric oncology unit traced to contaminated chlorhexidine. Scott Med J 1989 October;34(5):525-8.

(10) Sobel JD, Hashman N, Reinherz G, Merzbach D. Nosocomial Pseudomonas cepacia infection associated with chlorhexidine contamination. Am J Med 1982 August;73(2):183-6.

(11) Boyce JM, Pittet D. Guideline for Hand Hygiene in Health-Care Settings. Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Society for Healthcare Epidemiology of America/Association for Professionals in Infection Control/Infectious Diseases Society of America. MMWR Recomm Rep 2002 October 25;51(RR-16):1-45, quiz.

(12) Department of Health and Human Services, Centers for Disease Control and Prevention. Guidelines for Infection Control in Dental Health-Care Settings-2003. Morbidity and Mortality Weekly Report 2003 December 19;52(No. RR-17):1-76.

(13) Chattman M, Maxwell S, Gerba CP. Bacterial Contamination of Liquid Hand Soaps. The American Society for Microbiology 107th General Meeting 2007 May 21.

(14) Gerba CP, Maxwell S. Bacterial Contamination of Liquid Hand Soaps Used in Public Restrooms. National Environmental Health Association 71st Annual Educational Conference & Exhibition 2007 June 18.

(15) CTFA. Technical Guidelines. Microbial Limits for Cosmetics and Toiletries. 2001. The Cosmetic,Toiletry,and Fragrance Association.

(16) Hetzel L, Smith A. Census 2000 Brief: The 65 Years and Over Population 2000. 2001 Oct.

(17) Association for Professionals in Infection Control and Epidemiology. APIC Text of Infection Control And Epidemiology. 2nd ed. 2005.

(18) National Center for Health Statistics: Health, United States, 2006. 2006 Nov. Report No.: DHHS Publication Number 2006-1232.

(19) Levy J. The Pediatric Patient. In: Wenzel RP, editor. Prevention and Control of Nosocomial Infections. 3rd ed. 1997. p. 1039.

(20) Risi GF, Tomascak V. Prevention of infection in the immunocompromised host. Am J Infect Control 1998 December;26(6):594-604.

(21) Gross PA, Levine JE, LoPresti A, Uraneta M. Infections in the Elderly. In: Wenzel RP, editor. Prevention and Control of Nosocomial Infections. 3rd ed. 1997. p. 1060-1.

(22) Murray PR, Rosenthal KS, Pfaller MA. Enterobacteriaceae. Medical Microbiology. 2005. p. 323-38.

(23) Abbott SL. Klebsiella, Enterobacter, Citrobacter, Serratia, Plesiomanas, and Other Enterobacteriaeceae. In: Murray PR, editor. Manual of Clinical Microbiology. 9th ed. 2007. p. 698.

(24) US FDA/CFSAN. FDA Foodborne Pathogenic Microorganisms and Natural Toxins Handbook. 2006.

(25) Bouza E, Cercenado E. Klebsiella and enterobacter: antibiotic resistance and treatment implications. Semin Respir Infect 2002 September;17(3):215-30.

(26) Gurtler JB, Kornacki JL, Beuchat LR. Enterobacter sakazakii: a coliform of increased concern to infant health. Int J Food Microbiol 2005 September 25;104(1):1-34.

(27) Doran TI. The role of Citrobacter in clinical disease of children: review. Clin Infect Dis 1999 February;28(2):384-94.

(28) Prais D, Nussinovitch M, Harel L, Amir J. Citrobacter koseri (diversus) meningitis in an otherwise healthy adolescent. Scand J Infect Dis 2003;35(3):202-4.

(29) Hatchette TF, Gupta R, Marrie TJ. Pseudomonas aeruginosa community-acquired pneumonia in previously healthy adults: case report and review of the literature. Clin Infect Dis 2000 December;31(6):1349-56.

(30) Van RH, Noraida R, Wan Pauzi WI et al. The clinical picture of neonatal infection with Pantoea species. Jpn J Infect Dis 2006 April;59(2):120-1.