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Review

Outbreaks Where Food Workers Have Been Implicated in the Spread of Foodborne Disease. Part 10. Alcohol-Based Antiseptics for Hand Disinfection and a Comparison of Their Effectiveness with Soaps

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ABSTRACT

Alcohol compounds are increasingly used as a substitute for hand washing in health care environments and some public places because these compounds are easy to use and do not require water or hand drying materials. However, the effectiveness of these compounds depends on how much soil (bioburden) is present on the hands. Workers in health care environments and other public places must wash their hands before using antiseptics and/or wearing gloves. However, alcohol-based antiseptics, also called rubs and sanitizers, can be very effective for rapidly destroying some pathogens by the action of the aqueous alcohol solution without the need for water or drying with towels. Alcohol-based compounds seem to be the most effective treatment against gram-negative bacteria on lightly soiled hands, but antimicrobial soaps are as good or better when hands are more heavily contaminated. Instant sanitizers have no residual effect, unlike some antimicrobial soaps that retain antimicrobial activity after the hygienic action has been completed, e.g., after hand washing. Many alcohol-based hand rubs have antimicrobial agents added to them, but each formulation must be evaluated against the target pathogens in the environment of concern before being considered for use. Wipes also are widely used for quick cleanups of hands, other body parts, and surfaces. These wipes often contain alcohol and/or antimicrobial compounds and are used for personal hygiene where water is limited. However, antiseptics and wipes are not panaceas for every situation and are less effective in the presence of more than a light soil load and against most enteric viruses.

This is the 10th article in a series on food workers and foodborne illness. In the first three articles, the authors described the types of outbreaks identified during a review of 816 published and unpublished reports and how workers contributed to these outbreaks *(49, 130, 131),* and the next three articles provided information on infective doses, pathogen carriage, sources of contamination, pathogen excretion by infected persons, and transmission and survival of pathogens in food environments *(132–134).* In the seventh and eighth papers, the authors discussed physical barriers to contamination and the pros and cons of glove use *(136, 137).* In the ninth article, hand hygiene for removing as much soil (bioburden) from fingers and other parts of hands as possible, the effectiveness of various soaps (with and without antimicrobial compounds), and the need for drying hands to remove loose microorganisms from the skin surface were discussed *(138).* The present article provides a discussion of the increasing use of antiseptics and sanitary wipes in the health care and food industries and the effectiveness of various soaps and antiseptics or sanitizers under different conditions.

DEFINITIONS

Weber et al. *(147)* defined germicides as biocidal agents, such as antiseptics, disinfectants, and preservatives, that inactivate microorganisms. Antiseptics are antimicrobial substances that are applied to the skin or mucous membranes to reduce the microbial flora. Disinfectants are substances that are applied to inanimate objects to destroy harmful microorganisms, although disinfectants may not kill bacterial spores. Preservatives (antimicrobials) are incorporated into soaps and other antiseptics to prevent microbial growth.

Hand disinfection can be defined as the application of a chemical agent with antimicrobial activity to the hands. Reduction of the resident flora depends on the ability of the topical antimicrobial product to produce an immediate and persistent residual effect *(104).* The terms ''hand antiseptic'' or ''alcohol-based hand rub'' (ABHR) are more often used than ''hand sanitizer,'' especially in Europe *(121, 145).* In

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the 2005 version of the U.S. Food and Drug Administration (FDA) Food Code *(144),* the term ''hand sanitizer'' was changed to ''hand antiseptic'' to eliminate confusion with the term ''sanitizer'' (a defined term in the Food Code) and to more closely reflect the terminology used in the FDA monograph for health care concerning antiseptic drug products for over-the-counter human use *(143)*.

The term ''sanitizer'' is typically used to describe a substance used to control bacterial contamination of inert objects or articles, equipment and utensils, and other food contact surfaces, usually a strong chemical solution such as sodium hypochlorite or a quaternary ammonium compound. The Food Code definition of ''sanitizer'' requires a minimum microbial reduction of 5 log units, which is equal to a 99.999% reduction. Most antimicrobial hand agents typically achieve a much smaller reduction and so are not consistent with the definition of ''sanitizer'' in the Food Code.

A hand antiseptic solution used as a hand dip should be kept clean and at a strength equivalent to at least 100 mg/liter chlorine. An antimicrobial soap with an E2 designation requires activity equivalent to 50 ppm of chlorine. However, because ''sanitizer'' and ''antiseptic'' are used interchangeably in the literature with possibly different meanings it is not always easy to separate the two, and both are used in this article.

Four types of hand disinfection were described by Smith *(121)* based on hospital requirements. Hygienic hand disinfectants are alcohol-based agents used to rapidly kill transient organisms on the hands (i.e., within 15 to 30 s) but may have an additional antimicrobial effect on resident microflora. Hygienic hand disinfectants with residual activity differ from alcohol-based agents because repeated use of hexachlorophene, iodophors, alcoholic chlorhexidine, and chlorhexidine leads to longer residual activity. These agents can destroy both the existing transient bacteria and other bacteria (e.g., *Staphylococcus aureus*) that may subsequently contaminate the hands. Surgical hand disinfectants are agents that remain active against both transient and resident organisms for 2 to 4 h (e.g., povidone-iodine and chlorhexidine) and are less commonly used in food facilities.

Basic hand disinfection includes use of the agents described below, which are designed to continually reduce the density of resident organisms and are particularly useful for food, pharmaceutical, and health care workers. The effectiveness of these agents is based on application frequency, with repeated use giving a greater reduction in hand flora than that obtained with a single treatment. Hand disinfection agents approved for use in the food industry are limited because compounds that are potentially toxic to consumers or affect the taste or appearance of the food are not permitted. However, these agents must have sufficient activity against a wide range of microorganisms. Most of the compounds that meet these criteria are liquid soaps. Powdered soaps containing borax (sodium borate decahydrate) are available for heavy duty hand cleaning, to use as laundry detergents, or to remove grease under cold washing conditions and may be effective in hard water but are rarely used in the food industry for hand washing. Some of the agents most frequently used are listed below and mentioned briefly elsewhere in this article, especially when they are used in combination with alcohol. Alcohol-based compounds used as antiseptics are discussed in more detail in the following sections.

Chlorhexidine. This hand disinfectant is effective against gram-positive cocci and to a lesser extent gram-negative bacteria and fungi at 4% concentrations or at 0.5 to 2% (wt/vol) alcohol, e.g., 0.5% in 70% isopropanol. Chlorhexidine gluconate (CHG) is commonly used in health care facilities.

Quaternary ammonium compounds (''quats''). These products, typically used for cleaning equipment in food operations, are bacteriostatic and fungistatic. Benzalkonium chloride (BAC) is the quaternary ammonium compound most often used in health care settings.

Iodophors. These compounds (e.g., 7.5 to 10% povidone) are effective against both gram-positive and gram-negative bacteria and some spore-forming bacteria.

Triclosan. Triclosan is widely used at concentrations of 0.2 to 2% and exhibits bacteriostatic activity against gram-positive bacteria and to a lesser extent on other bacteria and fungi.

Ozone. The use of 4 ppm of ozonated water in combination with 0.2% BAC and 83% ethanol is an effective method of hand disinfection. However, Michaels and coworkers *(85, 86)* found that there was no significant difference between hands washed with water containing 3 ppm of ozone combined with bland soap (without antimicrobial compounds) or soap containing 0.2% BAC and hands washed with nonozonated water. Therefore, the combination of ozone and alcohol appears to be more important for disinfection than combination of soap with ozonated water.

ALCOHOL INSTANT HAND ANTISEPTICS, SANITIZERS, AND RUBS

Effectiveness of alcohol for disinfecting hands. Although alcohol has been used as an antiseptic since ancient times, the first systematic in vitro studies of the germicidal activity of ethyl alcohol against pure cultures of bacteria were performed by Koch in the early 1880s, and in the 1890s and early 1900s alcohol was proposed for use as a skin antiseptic *(22)*. Early investigators discovered that preparations containing 50 to 70% alcohol were more effective than those containing 95% alcohol, and isopropyl alcohol reduced bacterial counts on contaminated hands when used as a hand rub *(22)*. Using more quantitative methods, Price *(112)* found that 65.5% alcohol was effective for reducing the number of bacteria on the skin. He subsequently recommended the use of a 3-min wash with 70% alcohol as a preoperative hand scrub and that

70% alcohol should be used for disinfecting contaminated hands.

ABHRs have become commercially available and have been in common use since the 1970s; they appear to be more effective than many nonalcoholic products when hands are relatively clean *(106)*. ABHRs were more widely used in Europe than in North America until the early 2000s. Despite the proven efficacy of alcohol-based products, delayed acceptance of ABHRs by some hospitals was attributed to a concern that repeated use would lead to excessive drying of the skin, but with the addition of 1 to 3% glycerol or other emollients skin drying has not been a problem *(22)*, and most antiseptic brands contain a moisturizer to minimize irritation to the skin. Most alcohol-based antiseptics contain ethanol and/or isopropanol. The alcohol strips away oils on the skin and works immediately to kill bacteria and most viruses by modifying their protein structure, but the alcohol should remain on the skin for at least 30 s. Unfortunately, proteins and fats on soiled hands, often encountered in food production and preparation scenarios, decrease the effectiveness of alcohol as an antiseptic.

In health care settings, ABHRs are much more efficient for reducing the bacterial load on hands than is washing with antiseptic soap. Girou et al. *(48)* found that after hand rubbing, the median percent reduction in bacterial contamination was significantly higher than that achieved with hand washing in 23 health care workers in intensive care units (83 versus 58%, $P = 0.012$). In another study, Karabay et al. *(65)* found that rubbing with ABHRs was more efficient than washing with an antimicrobial soap for 35 nurses (54 and 27%, respectively; $P < 0.01$); compliance also was better in the hand rubbing group than in the hand washing group (72.5 and 15.4%, respectively; $P < 0.001$). Ehrenkranz and Alfonso *(41)* found that transmission of gram-negative bacteria can occur from patients to catheters unless an alcohol rinse is used with soap and water. Mackintosh and Hoffman *(77)* found that when hands contaminated with *Escherichia coli, Streptococcus pyogenes, Staphylococcus saprophyticus, Pseudomonas aeruginosa, Klebsiella aerogenes,* and *Serratia marcescens* were exposed to 0.3 ml of alcohol sanitizer containing either 80% ethanol or 70% isopropanol, bacterial transfer to fabric was slightly lower than that after a soap-and-water wash. However, when the volume of the alcohol in the rubs was raised to 0.5 ml with 70% isopropanol, a 14,000-fold reduction in transfer occurred compared with a 9,800-fold reduction after using a thorough soap-and-water wash, which is a nonsignificant difference.

Antiseptic effectiveness will differ based on (i) alcohol type, (ii) alcohol concentration, (iii) quantity used on hands, and (iv) exposure period. Use of small amounts of antiseptic containing low alcohol concentrations combined with short drying times will markedly decrease efficacy, especially when organic matter (dirt, grease, or food) and/or viruses are present. Differences in procedures, levels of grease or food debris, and specific requirements must be noted when comparing the requirements between food service and health care settings. Alcohol-based antiseptics should be combined with regular hand washing regimens and should not replace hand washing and drying or use of fingernail brushes *(71, 74, 87, 88, 145)*.

Types of alcohol-based agents. The majority of alcohol-based hand antiseptics or sanitizers contain isopropanol, ethanol, n-propanol, or a combination of two of these *(23)*. Those containing 60 to 95% alcohol denature proteins most effectively because water is needed for the process. These agents are effective against enveloped viruses but not against spores, oocysts, and nonenveloped viruses, e.g., norovirus, rotavirus, hepatitis A virus, and poliovirus. The alcohol-based gels or liquids can cause a 3.5-log reduction of bacteria on hands after a 30-s application and a 4- to 5-log reduction after 1 min; however, the time required for virus inactivation often is longer than the alcohol remains active on the hands. There is no residual effect with these products compared with CHG, quaternary ammonium compounds, octenidine, or triclosan, which are often added to the alcohols *(23, 88, 111)*. However, the use of alcohol hand antiseptics with and without antimicrobial additives was equally effective for reducing hospital-associated infections *(62, 87)*. Thus, the incorporation of antimicrobials with residual activity, such as CHG, into gels is considered unnecessary for health care workers and has been viewed with caution and concern because of the potential for development of antimicrobial resistance and dermatitis and the unknown long-term effects of residual biocides on skin flora. There is also the possibility of a false sense of security for users who believe that a ''long lasting'' formula offers ongoing barrier protection *(83, 111)*; antibiotic-resistant bacteria have been isolated from the surfaces of dispensers of soap containing CHG *(25)*.

Newer formulations with combinations of alcohols and other agents are being developed against pathogens resistant to disinfection. A formulation containing less ethanol (55%) in combination with 10% propan-1-ol, 5.9% propan-1.2-diol, 5.7% butan-1.3-diol, and 0.7% phosphoric acid has a broad spectrum of virucidal activity *(67)*. In quantitative suspension tests, with and without protein load, this formulation reduced the infectivity titer of nine enveloped viruses (influenza A and B viruses, herpes simplex 1 and 2 viruses, bovine coronavirus, respiratory syncytial virus, vaccinia virus, hepatitis B virus, and bovine viral diarrhea virus) and four nonenveloped viruses (hepatitis A virus, poliovirus, rotavirus, and feline calicivirus) by $>10^3$ units within 30 s. In comparative testing, only 95% ethanol had similar levels of activity. In fingerpad tests, the poliovirus type 1 (Sabin) titer decreased 3.04 log units after 30 s compared with 1.32 log units with 60% propan-2-ol. Testing against feline calicivirus produced a 2.38-log reduction with the test formulation, whereas 70% ethanol and 70% propan-1-ol produced 0.68- and 0.70-log reductions, respectively. In a recent WHO study *(124)*, two formulations, one based on ethanol and the other based on isopropyl alcohol, were compared for their activity against both enveloped and nonenveloped viruses. Formulation I contained 80% (vol/vol) ethanol, 1.45% (vol/vol) glycerol, and 0.125% (vol/vol) hydrogen peroxide, whereas formulation II contained 75% (vol/vol) isopropyl alcohol, 1.45% (vol/vol) glycerol, and 0.125% (vol/vol) hydrogen peroxide. Both formulations had activity against enveloped viruses. Formulation I also reduced the titers of adenovirus and murine norovirus (a surrogate for human norovirus) by >4 log units within 30 s but failed to inactivate poliovirus by 4 log units within short exposure times, indicating insufficient activity against enteroviruses. Steinmann et al. *(124)* strongly recommended formulation I rather than products with recognized microbiological activity for settings with frequent nosocomial viral infections. Because of its broader spectrum against viral pathogens, formulation I also should be used in outbreak situations involving known and unknown viruses.

Recently introduced alcohol foam antiseptics that can be spread over the surface of the hand are better than gel products and have been associated with higher compliance and increased efficacy as compared with gels in health care settings in the United States and the United Kingdom *(8, 82)*. In comparative studies with standard test methods (European Standard EN 1500), both alcohol liquid and alcohol foam products had significantly higher efficacy (>1 log) than did gel products *(37, 68, 82, 110)*. Gel and foam products are now used in remote high-traffic areas away from hand washing sinks, e.g., at bed sides, in food service facilities, at deli counters, in areas catering to at-risk patients, and at grocery store check-out counters. However, Boyce and Pittet *(23)* revealed the economic implications associated with extensive use of these products; the total budget for hand hygiene supplies in a hospital was about $1 per patient-day, but costs for alcohol-based products and foam products were 1.6 to 2.0 times higher and 4.5 times higher, respectively, than those for soap.

ANTIMICROBIAL WIPES

Moistened wipes. Before the widespread use of alcohol gels and foams, disinfectant wipes were popular for removing transient organisms from hands. Premoistened cleansing tissues are still used as baby wipes, adult incontinence wipes, hand and face wipes, feminine wipes, cosmetic wipes, and household cleaning wipes. Antiseptic wipes are available for general hand and face cleansing and specific uses such as antiacne treatment. These products can loosen soil, facilitating the removal of dirt, grease, and microorganisms from skin.

One recent concern is that sporadic cases of *Campylobacter* infection in infants have been linked to grocery store shopping carts. Infections have been acquired by infants who have either touched the contaminated shopping cart or been touched by the contaminated hands of caretakers who have handled packaged retail meats, which are known to harbor external contamination *(45)*. Thus, wipes have been advocated for removal of pathogens and are widely available to customers for in-stores use, but no peer-reviewed studies have been published addressing wipe effectiveness on carts.

The use of wipes in the food industry is more questionable. Smith *(121)* argued that wipe use may increase the risk of foreign body contamination of food from wipes themselves (or pieces of them); unless wipes are needed to remove visible dirt, alcohol gels and foams were suggested as better alternatives. In the past, wipes were most often treated with aqueous alcohol solutions containing surface-active detergents, fragrance, and humectants to maintain a moist state. Because of the lotions present in these wipes, friction is reduced, which is beneficial when wiping sensitive or irritated skin. However, because finger and palm friction is important for reducing microbial loads, these wipes also must include antimicrobial compounds. Alcohol-impregnated paper hand wipes were effective for surface sanitization *(63, 127)*, and have been advocated as an alternative to hand washing in hospitals in place of or as an alternative to soap and water *(29)*. Various alcohol concentrations have been studied for their effectiveness in wipes, e.g., 80% ethanol and 15% glycerol for removal of *P. aeruginosa* and *S. aureus* from the hands of nurses on ward rounds *(126)* and 70% isopropyl alcohol for removal of *Campylobacter* spp. on hands *(32)*. Larson et al. *(73)* advocated a minimum of 60% alcohol, whereas Butz et al. *(29)* reported that alcoholic wipes with 30% alcohol could reduce viable counts comparable to those achieved with nonmedicated soap after repeated use. This lower alcohol concentration may be an advantage because wipes containing 30% alcohol are less irritating to skin than are those with triclosan and chlorhexidine. However, because of skin irritation and dryness *(19, 57, 104)* newer hand antiseptics and moist wipe products are being formulated as alcohol-free *(39, 84)*. Antimicrobial moist wipes typically contain quaternary ammonium compounds such as BAC and benzethonium chloride and povidone iodine and triclosan products; most produce immediate effects through contact but some have cumulative and residual effects *(10, 34, 39, 84, 95)*. Inactive ingredients found in wipes include moisturizers, wetting agents, surfactants, detergents, emulsifiers, and emollients. Examples of prework creams, moisturizers, emollients, and conditioning creams were provided by Smith *(121)*.

In special cases in which hand washing sinks are not available, such as catering in remote locations, workers may use chemically treated towelettes for hand washing, but little work has been done to determine their efficacy. Butz et al. *(29)* and Ayliffe *(10)* found that dry tissue wiping combined with an antimicrobial moist wipe without rinsing is at least equivalent to or better than a soap-and-water wash and rinse. Michaels et al. *(84)* conducted an experiment in which hands contaminated with 10^8 CFU/ml *E. coli* in tryptone soya broth were wiped with dry tissue paper after a 2-min drying period and then wiped with a moist tissue containing 0.1% BAC. When the hands were exposed to a series of 10 contamination and wipe cycles, the residual effect of the BAC was noticeable; reductions increased from the 1st to the 10th decontamination step (1.09- to 1.4-log reduction per hand), equivalent to 96.1% decontamination. Edmonds et al. *(40)* evaluated the SaniTwice three-step process, which comprises a sanitizer hand wipe followed by paper towel drying and reapplication of the sanitizer. In a comparison study, the SaniTwice wipe and a nonantimicrobial hand washing procedure both achieved microbial reductions of about 2.6 to 2.9 log units when hands were contaminated with 10^9 CFU of *E. coli* in beef broth. Based on limited experimental work, the SaniTwice alcohol-based method seems to be more effective than the BAC wipe. However, the need for two stages (dry wipe and moist wipe) or three stages (moist wipe or alcohol alone, dry paper, and moist wipe or alcohol alone) may inhibit the use of these methods, or some of the stages may be ignored. Nevertheless, because wipe methods tested have been more effective than soap and water, they should be considered feasible, practical hand hygiene interventions for remote food service situations or where water availability is limited.

COMPARISON OF THE EFFECTIVENESS OF SOAPS AND ALCOHOL-BASED ANTISEPTICS AND SANITIZERS

A telephone survey of 40 consumers in Colorado revealed that in the home most people (78%) used a liquid hand cleaner typically containing an antibacterial ingredient (63%), but these respondents did not know the identity of the active agent *(26)*. A written survey of 60 students yielded similar results (73 and 67%, respectively). In general, these students thought that regular hand soaps and even ABHRs were not as effective as antibacterial soaps in removing bacteria from the hands, and only 2% of the telephone survey respondents had gel rubs in their homes compared with 15% of the students. At the same time that this survey was conducted, 90 students in food preparation classes were volunteers in an experiment to estimate the bacterial load on hands before and after cleaning by different methods *(26)*. Regular, antibacterial, and alcohol gel hand cleaners reduced bacterial populations by means of 0.4, 0.7, and 1.4 log units, respectively, indicating that alcohol gels significantly reduced bacteria on hands compared with liquid hand soap and antibacterial soap ($P \leq 0.05$). Gruendemann and Bjerke *(53)* published a full discussion on the value of alcohol gels in health care settings. However, it is not always clear from the literature whether experimental results are applicable to resident species of skin flora and/or transients, and caution should be used when comparing efficacy data.

Montville et al. *(96)* compared interventions by considering the results as distributions. Data from other publications and from their own experiments were translated into appropriate discrete or probability distribution functions. Soap with an antimicrobial agent was more effective than regular soap. Hot air drying increased the amount of bacterial contamination on hands, whereas paper towel drying slightly decreased contamination. There was little difference in efficacy between alcohol and alcohol-free antiseptics. Ring wearing slightly decreased the efficacy of hand washing. The experimental data validated the simulated combined effect of certain hand washing procedures based on distributions derived from reported studies. The conventional hand washing system caused a small increase in contamination on hands compared with the touch-free system, i.e., where faucets are operated by elbows, feet, or automatic movement sensors. Sensitivity analysis revealed that the primary factors influencing final bacterial counts on the hand were sanitizer, soap, and drying method.

We evaluated 38 separate studies of hand hygiene interventions for their effectiveness for removal of various microorganisms, mainly members of the *Enterobacteriaceae* and *S. aureus* combined with soils and applied to hands *(7, 11, 12, 16, 31, 32, 36, 76, 78, 86, 89–91, 94, 101, 102, 105, 107, 109, 115, 122, 125)* and enteric viruses, such as rotavirus, adenovirus, rhinovirus, poliovirus, and hepatitis A virus *(7, 20, 80, 119, 120)*. Most of the interventions in these studies used standard methods of 15 to 20 s of washing and 10 s of rinsing. Hand hygiene experiments in the health care field have mostly used light soil conditions, such as tryptone soy broth with or without 5% serum and phosphate-buffered saline, because they are standard laboratory materials easily applied to skin, but these conditions do not accurately represent conditions encountered in many settings in clinical practice and almost all food preparation environments. In these studies, the overall efficacy of hand hygiene methods depended on many factors such as soil type, antimicrobial soap strength, e.g., bland (no antimicrobial compound), E1 (low strength antimicrobial compound), or E2 (strong antimicrobial compound at 50 ppm), and the type of alcohol antiseptic (sanitizer). For information on bland, E1, and E2 soaps, see Todd et al. *(138)*. As expected, light soil was more easily removed than were heavy soils (ground beef, chicken juice, fecal material, and organic soils), and the contaminating organisms on lightly soiled hands were inactivated by antimicrobials at significantly higher levels. Enteric bacteria were fairly easy to remove (1.1- to 3.5-log reduction for light soil and 0.7- to 2.4-log reduction for heavy soil), but viruses were more difficult to remove because they are more resistant to physiochemical inactivation than are most non–spore-forming bacteria. Alcohol-based compounds were most effective against gram-negative bacteria on lightly soiled hands, but a soap with an antimicrobial agent seemed to be as effective, if not more so, when hands were more heavily soiled. Unfortunately, there is very little published work available on alcohol antiseptic efficacy against bacteria or viruses embedded in heavy soils, conditions more likely to be encountered by food workers.

Enteric bacterial loads on hands can be high when toilet paper is improperly used or not used at all after defecation, and hand washing will not remove all of the enteric organisms present. A combination of hand washing with plain soap and rubbing with an ABHR will enhance the hygiene process, making the procedure more effective than either approach alone, unless larger quantities of antiseptic (up to 6 ml) are employed *(87)*. Larmer et al. *(69)* evaluated the effectiveness of different types of soaps in 24 separate hand hygiene studies. These authors concluded that there were no significant differences in effectiveness between ABHRs and medicated and/or plain soap. However, greater efficiency was achieved with hand rubs with 70% alcohol or 70% alcohol with CHG than with rubs with 30% alcohol. Larmer et al. also noted that all of the studies had some methodological limitations, e.g., no assessor blinding or difficulty creating experimental conditions in institutions. However, they recommended that hands be washed with soap and water when visibly soiled, and when soap is used regularly hand moisturizers should be used liberally. All ABHRs used should contain an emollient and 0.5% CHG. The U.S. Food Code *(145)* specified that food workers must maintain clean hands by washing with an appropriate cleaning compound, e.g., soap and water. Ojajarvi *(101)* tested five types of liquid soap for 1 year and found little difference in their effectiveness. However, the type of antiseptic did affect the preference for the cleaning agent, especially among workers with dermatological problems who do not like alcohol or emulsion-type soaps and may prefer plain water.

In Europe, hygienic hand washing (biocidal) soaps are evaluated based on EN 1499 *(43)* and hand rubs are evaluated based on EN 1500 *(44)*. In both of these methods, the soap or hand rub being tested is compared with a reference product using 15 volunteers per test. The reference soap for EN 1499 is a defined nonbiocidal product, and the reference rub for EN 1500 is isopropan-2-ol. In these tests, hygienic hand washing soaps are approved when they perform significantly better than the nonbiocidal soap, and hand rubs are approved when they perform the same as or better than isopropan-2-ol. Testing at Campden BRI (Chipping Campden, UK) involved assessing six hygienic hand washing soaps and six hand rubs according to EN 1499 and EN 1500, respectively. All hygienic hand washing soaps passed the EN 1499 tests, with an overall mean 3.18-log reduction compared with a 2.79-log reduction for the nonbiocidal soap. However, only two of the six hand rubs passed the EN 1500 tests, with an overall 3.19-log reduction compared with a 3.81-log reduction for the isopropan-2-ol. Approval of hand rub agents in the European Union is thus more difficult to obtain than approval of biocidal soaps.

Five to 6 ml of alcohol antiseptic will reduce viral loads by 2.4 log units in the presence of light soil and by 1.1 log units in the presence of heavy soil *(20, 22, 80)*. However, this amount of alcohol is not practical to use in food worker environments; it is two to six times the amount commonly utilized by workers using alcohol antiseptics. Viruses are most practically removed by the vigorous friction that occurs during hand washing and drying *(120)*. A typical example is norovirus, which requires aggressive hand washing and sodium hypochlorite solutions (1,000 ppm) for surface sanitizing *(54)*. Rinsing hands under running water (2.0-log reduction) and use of alcohol antiseptic followed by vigorous wiping with a paper towel provide the necessary conditions for virus removal *(120)*. In recognition of this problem of cleaning before use of an alcohol antiseptic, the U.S. Food Code *(145)* requires that hands of food workers be washed before use of ABHRs.

In fingernail studies, overall lower levels of *E. coli* were removed from artificial versus natural nails, and a significant improvement ($P \leq 0.05$) over all other methods, including a soap wash followed by an alcohol hand sanitizer, was achieved when a fingernail brush was used *(87)*. Courtenay et al. *(33)* argued that the National Restaurant Association ServSafe program hand washing methods are more effective than a warm water or cold water rinse (<1 versus 1.4 and 2.1 log CFU/ml *E. coli* on hands, respectively, from 3.6 log CFU/ml on unwashed hands) and more effective than the use of an ethanol-based sanitizer alone (2.9 to 3.4 log CFU/ml remained on hands when ethanol-based sanitizers were used instead of hand washing). The ServSafe procedure calls for wetting hands in warm water, soaping to a good lather, scrubbing hands and arms, cleaning fingernails, and then rinsing and drying with a single-use paper towel. When vinyl food service gloves were worn during the hand washing treatments, gloves retained more bacteria than when only hands were rinsed or washed.

CONTAMINATION OF ANTISEPTICS

Contamination from bar soaps, soap dispensers, and reservoirs. Studies performed by soap manufacturers have indicated that bar soaps do not easily transmit bacteria to users *(14, 59)*; however, there is considerable evidence that soap bars stored in wet dishes are easily and commonly contaminated during use *(24, 27, 64, 81)*. In survey studies of bar soap contamination compared with liquid soaps, *S. aureus* and *Enterobacteriaceae* of human origin typically have been isolated in >96% of samples tested *(24, 60, 64, 81)*. This is one reason why bar soaps are not mentioned for hand washing in food operations in the 2005 and 2009 U.S. FDA Food Code editions in contrast to the 2001 version *(142, 144, 145)*, and liquid soaps are the current standard for soaps used in health care and food environments *(116)*. However, bar soaps still are used in many other settings, including the home, and these bars should be replaced frequently.

Contamination also can occur at hand washing stations that dispense liquid soaps *(92)*. More than 40 outbreaks or infections have been documented as associated with contaminated antiseptics *(147)*, resulting in systemic infections, skin abscesses, and conjunctivitis in patients and workers. The most frequently implicated soaps were those containing chlorhexidine and BAC. Both outbreaks and sporadic failures of antiseptics are typically due to user error rather than microbial contamination during production. Common errors include the use of overdiluted solutions, the use of outdated products, the use of tap water to dilute the germicide, the refilling of small-volume dispensers from large-volume stock containers, and use of an inappropriate product. Prior cleaning is necessary to remove proteinaceous material and biofilms so that the germicide can achieve adequate microbial inactivation. In a case-control study to determine the source of *S. marcescens* in a hospital, hands of health care workers were 54 times more likely to be contaminated with the organisms after hand washing with an *S. marcescens*–contaminated soap pump ($P <$ 0.001) *(118)*. In hospital environments, patients have been infected through handling of contaminated soap, resulting in eye damage, bacteremia, and even death *(51, 79, 117, 139)*. The most frequent contaminating microorganisms were *Pseudomonas* and/or *Burkholderia* spp., although *S. aureus,* *S. marcescens,* and other opportunistic pathogens have been isolated from these soaps. Soaps causing such infections range from bland soaps to those containing antimicrobial ingredients such as CHG, hexachlorophene, polyvinylpyrrolidone-iodine, and triclosan.

Soaps can become contaminated either before or during use. Intrinsic sources are production and packaging areas, where contaminated raw ingredients or the manufacturing process itself leads to bacteria being present in the soaps *(1, 17, 35, 61, 92, 128).* Contamination of ingredients or water used in processing can lead to formation of biofilms in distribution pipes, and these biofilms can be difficult to eradicate *(1, 92).* In a manufacturing plant producing iodophor products *(1),* the antiseptic became contaminated with a variety of gram-negative water bacteria, which colonized product distribution lines, affecting the manufacture and quality of the formulated iodophors and causing infections in several patients who used the antiseptic. *Pseudomonas* (*Burkholderia*) *cepacia* was able to survive for 68 weeks in a 1% iodine solution. Biofilm formation occurred in the distribution lines, and periodically the organisms would slough off into the product.

Manufacturers of iodophors and other health care professionals should be aware that pipes or other surfaces colonized with bacteria may be a source of contamination. Anderson et al. *(2)* recommended scheduled bacteriologic quality control checks of process water and finished product, maintenance of resin beds and filters, and sanitization of water and product distribution pipes (e.g., 60°C water for 1 h). Risk of contamination is minimized when manufacturing is configured around well-designed proprietary production processes and risk management protocols are incorporated within quality control and quality assurance programs (e.g., ISO 9001). Good manufacturing practices and hazard analysis critical control point plans should be considered when designing soap production systems, and assumptions should not be made that a few bacteria are of no consequence.

Extrinsic contamination occurs when contaminating microorganisms are introduced into soap containers during use by individuals with soiled hands. Design and function of soap and antiseptic dispensers, such as pump-top bottles and wall-mounted self-contained delivery mechanisms, are critical to reducing cross-contamination and infection rates. Devices delivering drugs or simple soap can be contaminated by hand contact, leading to infections in health care environments *(9, 47, 66, 97, 141).* In these scenarios, pseudomonads and other gram-negative bacteria can metabolize ingredients in soaps or lotions and predominate over staphylococci, yeasts, and molds *(128).* However, the outer surfaces of soap containers can easily be contaminated by hands before and after washing *(25, 81),* and the potential for cross-contamination between users should be considered another risk factor. Dispensers can be either open or closed. Reservoir systems fall into the open category, where soap is either poured into a reservoir or a bottle is positioned in a fixed reservoir. Bag-in-the-box or sealed cartridge systems have soap fully enclosed within the cabinet. Piston pump-top bottles are another form of an open system metering device. These pump-top bottle systems allow air ingress through the neck of the pump plunger and are thus considered open systems in the soap industry *(92).* McBride *(81)* and Brooks et al. *(25)* described how dispensers become contaminated with opportunistic pathogens. Soap residues were found on the underside of the dispenser, near the dispenser orifice, and in crevices around the dispensing button, which were heavily contaminated *(25).* The soap within the prefilled disposable bags appeared to be uncontaminated, but the dispensers were covered with *Klebsiella pneumoniae, Acinetobacter* spp., *Pseudomonas* spp., and methicillin-resistant *S. aureus* (MRSA). The nozzles and pumps on many collapsible bag systems do not work well, which leads to leaking soap. Sticky soap bottle surfaces attract organic soil and can become reservoirs for microbes capable of growing on and in soap films *(13, 25, 128).* Thus, hand washing stations must be monitored for proper settings and maintenance of soap dispensers and the amount of time simple soaps are used.

In addition to dispenser mechanism cross-contamination, soap reservoir systems have caused outbreaks in health care setting after dispensers have been refilled *(15).* After discovering that these reservoirs were problematic, health care regulatory agencies requested that the reservoir and dispenser nozzles be sanitized before refilling *(46, 75, 123).* These strict directives were seemingly forgotten or ignored, resulting in recent hospital-associated outbreaks *(52, 139).* One of these outbreaks involved an antimicrobial soap from a reservoir-type dispenser that staff refilled or topped off without sanitizing the reservoir *(52).* Reservoir systems situated in locations with possibly high insect populations, such as around food processing facilities, can become contaminated through contact by these pests *(83).* Weber et al. *(147)* recommend the following practices (germicides include both antiseptics and disinfectants): (i) use only approved antiseptics and disinfectants; (ii) use all germicides at their recommended use dilution and do not overdilute products; (iii) use sterile water to dilute antiseptics; (iv) use all germicides for the recommended contact times; (v) do not use germicides labeled only as antiseptics for the disinfection of medical devices or surface disinfection; (vi) follow the recommended procedures in the preparation of products to prevent extrinsic contamination; (vii) continue to use small-volume dispensers that are refilled from large-volume stock containers until they are entirely empty and then rinse dispensers with tap water and air dry before refilling; and (viii) store stock solutions of germicides as indicated on the product label.

Theft also may be an important risk factor in the contamination of reservoirs and dispensers, although this factor is not widely documented or discussed. Pilfering of product, i.e., taking small quantities out of a large container for personal use, can introduce contaminants into that container, and other soap product tampering situations have been identified in various food environments *(83, 113).* Thus, soap dispenser design should include a locking mechanism and reserves should be kept in sealed cabinets to prevent pilfering and/or intentional product contamination. Most standard soap and paper towel dispensers available through hygiene equipment suppliers include standard locking security devices, and these must be sophisticated enough to prevent tampering but not so complex as to be a barrier to restocking or to limit the availability of soaps for hand washing.

Contamination of hands and clothing at hygiene stations and automated hand washing machines. Michaels et al. *(93)* surveyed microbial contamination on contact surfaces associated with hand washing stations in restrooms and processing areas. Indicator organisms (coliforms, *E. coli,* and *S. aureus*) were found on many of the sampled surfaces, revealing that an individual can be contaminated from organisms deposited by a previous user on hygiene contact surfaces, e.g., water faucet handles, sink counter tops, door handles, and soap dispenser buttons (zigzag cross-contamination). An ideal hand washing station includes faucets that operate automatically or through use of a knee, foot, or elbow. In restrooms and many food preparation facilities, these types of faucets are not available, increasing the risk of cross-contamination through use of contaminated faucet handles. When a wet hand turns the faucet off, contamination deposited by one user is picked up by the next user. Paper towels for turning off faucets and opening restroom doors is a little-used option that can prevent recontamination of hands after washing. In health care facilities, surfaces contacted during hand drying have led to cross-contamination *(50, 55, 56, 58).* Another issue is the risk from sprays. During both manual and automated hand washing, users may become contaminated from water droplets dispersed from the water flow of taps or nozzles and the action of the hands during hand washing (J. Holah, personal observation). Such droplets can be described as either ballistic, i.e., they travel in the direction of the originating motive force (e.g., the bounceback of large water droplets from the sink surfaces) or aerosol (smaller droplets), whose movement is directed by local air currents. The degree of cross-contamination to the clothing and skin of the user from this transfer vector is unknown but is likely to be affected by the water pressure at the taps, the shallowness of the sink, the vigorousness of the hand rubbing, and the degree of contamination picked up from the hand or sink surface. Transfer of contamination to uniforms or clothing of food workers at a height on the uniform that may come into contact with foodstuffs during food preparation (e.g., around the waist and stomach area) would be of most concern. Managers of food preparation operations should be encouraged to check for water droplet transfer, i.e., how wet the uniform is in this area, and modify the hand washing station accordingly.

In the 13th century, Muslim engineer Al-Jazari in northern Mesopotamia (present-day Iraq) designed an automated hand washing device with humanoid servants *(150).* By pulling a plug on the tail of an artificial peacock, water was released from the bird's beak. As the wash water accumulated in a basin below the rinsed hands, a float rose and actuated a servant to appear from behind a door under the peacock and offer soap. When more water was used, a second float at a higher level was activated and a second servant appeared with a towel. When the base valve was released and the water drained away, the servants disappeared and the doors closed. Actual use of this device was not recorded, but a long time elapsed before automated hand washing machines were considered for industrial use.

In the 20th century, hand washing machines and automatic sinks were investigated as a way to improve hand washing effectiveness and compliance, but deficiencies were found *(146, 149).* Reports from users of early hand washing machines indicated contaminated water was a problem *(100),* and features of a then-available unit included a ''self-cleaning monitor to eliminate bacterial colonization during operation,'' indicating a possible problem. Negative attitudes concerning the use of these machines have been reported *(70),* and manual hand washing was noted to be superior in many instances *(140, 149).* In one case, hands were more effectively washed with an automatic sink, but this sink was used less often than a regular sink for hand washing, therefore decreasing compliance *(70).* In one instance, cross-contamination of the hands after the use of a hand washing machine resulted in an outbreak, and an observational study revealed that hand washing compliance improved from 22 to 38% when the hand washing machines were in use *(149).* However, 4 months after the hand washing machines were installed, an outbreak of MRSA infection occurred in the intensive care unit. As part of evaluating the outbreak, the machines were found to be positive for cultures of methicillin-resistant *Staphylococcus epidermidis, Achromobacter* spp., and *Streptococcus viridans*. The design of the hand washing machines made contamination of sleeves and already washed hands possible. The effectiveness of these devices also is dependent on water pressure *(146)* or use of alcoholic disinfectants *(98, 99).* Some units are designed for glove washing. These devices have been useful as compliance intervention devices *(72, 149).* Some automated cleansing systems have been associated with reducing variability in hand washing effectiveness *(103)* and therefore suited for the testing of antimicrobial soap products *(98, 148).*

Recent changes have made hand washing machines more sophisticated. One model is available in three different versions: countertop, wall mounted, and free standing but portable *(5, 18).* When washing hands, the user wearing a radio frequency identification badge is identified by the machine's reader, which scans that person's unique tag number that is associated with a name in a back-end database. The device records the date, time, and beginning and end of the wash cycle and then sends that information to the database. The touchless wash cycle automatically starts when the hands are inserted into two rotating cylinders, which deliver a fully automated 10- to 12-s cycle of hand washing, sanitizing, and rinsing designed to clean the hands from fingertips to wrists. The claim is that by using a CHG sanitizing solution the single cycle is able to remove >99.98% of pathogens and can continue to kill bacteria for up to 6 h. When the automated hand cleansing system was set for a total cycle length of 15 s using 5 ml of 2% CHG against feline calicivirus on hands (Standard Test Method for Determining the Virus-Eliminating Effectiveness of

Liquid Hygienic Handwash and Handrub Agents Using the Fingerpads of Adult Volunteers, ASTM E 1838.02), a mean 3.97-log reduction (99.99%) and as high as a 4.25-log reduction (99.994%) was achieved *(4)*. The system uses up to 75% less water than manual hand washing and discharges 75% less wastewater. The use of this system also further boosts compliance by ensuring a pleasant, uniform hand washing from fingertip to wrist with 20 to 40 high-pressure, low-volume water jets in a consistent wash-and-sanitize cycle. Time will tell whether this type of hand washing device will become sufficiently widespread to become the norm.

For food workers, boots also must be cleaned or disposable overshoes must be worn. As for automatic hand washing devices, boot washers tend not to be used. Unless these washers are well designed and maintained, the disinfectant quality is not sufficient to inactivate contaminants, as occurred in Wales in 2005 when a meat processing establishment was responsible for 157 cases of *E. coli* O157:H7 infection *(108)*.

NONDISINFECTION ISSUES ASSOCIATED WITH ALCOHOL-BASED COMPOUNDS

Flammability. Alcohols are flammable, and flash points of alcohol-based hand rubs range from 21 to 24°C, depending on the type and concentration of alcohol present *(114)*. Thus, ABHRs should be stored away from high temperatures or flames. Even removal of a polyester gown can create enough static electricity to generate an audible static spark, which can be sufficient to ignite unevaporated alcohol on the hands of a health care worker *(28)*. Queensland Health provided details on how alcohol-based products should be displayed and stored, e.g., in small quantities, not near any electrical outlet, and out of reach of children *(114)*.

Abuse of the alcohol content. Another issue for alcohol-based antiseptics is they could be consumed to access the alcohol, and ethanol-based hand antiseptics are considered a safety issue in prison communities *(38)* or hospital and/or health care settings where alcohol-addicted individuals are confined. In one anecdotal report from the United Kingdom (Campden BRI), the alcohol was removed from alcohol-based products and then mixed with orange juice before consumption. One individual was admitted to a hospital after consuming rubbing alcohol but then ingested ethanol-based hand antiseptic while in the hospital *(42, 129)*. The media have reported accidental and intentional consumption of alcohol-based antiseptics by children and teens, highlighting public awareness of the alcohol content of these products and the potential for misuse *(3)*. Blanchet et al. *(21)* reported intoxication of a hospitalized patient who on two separate days ingested two 100-ml bottles of a topical antiseptic solution containing isopropyl alcohol and propanol-1. This case points out the need to limit access to alcohol-containing antiseptic solutions in wards where alcoholic and psychotic patients are hospitalized. In 2009, Health Canada delayed the delivery of ABHRs to some First Nations communities affected by H1N1 influenza virus because of concerns that these products might be consumed for their alcohol content *(30)*. Thefts of ABHRs had been reported previously in some of these communities, where large numbers of people suffer from alcohol addiction.

Religious concerns. Another issue associated with these alcohol-based gels is the potential conflict with religious beliefs. In the United Kingdom, town councils, schools, and businesses have been purchasing alcohol-based gels to reduce the spread of the H1N1 influenza virus, but some Muslims are refusing to use these gels because the Koran forbids the use of alcohol *(6)*. To accommodate these individuals, some council chiefs issued nonalcohol gels, which have little effect on the virus *(121)*. However, the Muslim Council of Britain stated that people should follow medical advice and use the alcohol-based hand gels, pointing out that Islamic teachings allow Muslims to use alcohol for medicinal purposes. The Muslim Council of Britain stated that

> consumption of all intoxicants including alcohol is totally forbidden in Islam, and according to some Schools, alcohol itself is considered impure. External application of synthetic alcohol gel, however is considered permissible within the remit of infection control because (a) it is not an intoxicant and (b) the alcohol used in the gels is synthetic, i.e. not derived from fermented fruit. Alcohol gel is widely used throughout Islamic countries in health care settings. Any controversy, therefore, is likely to be in perception rather than principle within Islam. Any confusion in this respect may be avoided if references to and labelling of alcohol gel bottles emphasized the disinfection properties rather than its alcohol content—use of the term ethanol to describe the contents was to be encouraged.

CONCLUSION

In previous articles, a composite list of problems uncovered during investigations of foodborne disease outbreaks involving food workers and potential interventions to improve hygiene and prevent spread of foodborne disease from food workers were provided *(49, 130–134)*. The major concerns identified included (i) hand washing, (ii) sanitation of food contact surfaces, (iii) facility-wide hygiene education and training, (iv) incentives for workers to report their illnesses, (v) surveillance of the work force by management, and (vi) regular professional screening of employees for illness, including nasal and stool samples obtained from staff returning from overseas travel.

Hand hygiene is a key factor in the transmission of foodborne disease and one of the least costly interventions to implement. Use of hand antiseptics and/or sanitizers, including ABHRs, has been increasing in recent years, especially during the 2009 H1N1 pandemic. Public health messaging focused on hand washing or the use of antiseptics as a major method to control the spread of the virus when combined with vaccination, resulting in record sales for manufacturers of these hand hygiene products. The risk of cross-contamination from person-to-person and from hands to food or vice versa can be reduced by using wash stations with hands-free faucets and easy-to-use paper towel dispensing systems.

Alcohol instant hand antiseptic use has been advocated in conjunction with hand washing and drying, although experimental data indicate no significant increase in efficacy when both hand washing and alcohol antiseptics are used sequentially *(87)*. Most of these recommendations are incorporated into Chapter 2 and Annex 3 of the 2009 U.S. FDA Food Code *(145)*. Although alcohol-based antiseptics are convenient and can be installed at many locations where hand hygiene is required, these agents have their limitations when heavy soil is involved, and they must be combined with a hand washing regimen. They are effective against some but not all viruses, and the type of alcohol preparation used makes a difference, e.g., ethanol versus isopropyl alcohol at different concentrations *(124)*. The correct amount of antiseptic with an effective level of alcohol, e.g., 70%, must be used followed by an appropriate drying time. Alcohol-based antiseptics should be combined with regular hand washing schedules and should not replace hand washing and drying or the use of fingernail brushes.

Economic implications may play a role in the use of alcohol-based products because the daily cost can be up to 4.5 times higher than that of soap and water. ABHRs can be flammable and may be abused for their alcohol content. Religious prohibitions and social customs also can complicate hand hygiene practices, but every society recognizes the need for clean hands when preparing food.

Training alone will not improve hand hygiene and other important food safety practices substantially; manager commitment is required, and programs should be designed to encourage compliance through rewards and penalties. Employees come from diverse cultural backgrounds, sometimes with different concepts of the principles of contamination and sanitation. The issue of hand hygiene compliance is addressed in a subsequent article *(135)*.

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