

Waterless (Towelette) Emergency Sanitation System for Food-Serving Utensils and Equipment

Edmund M. Powers¹, M. Cioffi², A. Hiokala³, and C. Lee¹

¹U.S. Army Natick Research, Development, and Engineering Center, Natick, MA 01760;

²Vicam, Watertown, MA 02172; ³OPTA Food Ingredients, Bedford, MA 01730

ABSTRACT

The feasibility and efficacy of a waterless sanitation system (WSS) for cleaning food service utensils and removing bacteria were demonstrated in the laboratory and tested in the field during U.S. Army training exercises with Mobile Kitchen Trailers (MKT). The WSS employed three wipes used in sequence: (1) a detergent/degreaser wipe; (2) a deionized water wipe to rinse the surface; (3) a quaternary ammonium disinfectant/sanitizer wipe. *Escherichia coli* and *Staphylococcus aureus* cells in biofilms produced on food-soiled, stainless steel surfaces were reduced by 99.999% to 100% at 5°C and 26°C by the WSS. The sanitizer dilution used reduced the numbers of planktonic cells of several food poisoning bacteria by more than 6 log units. In the field, all surfaces of food-serving utensils and equipment examined were monitored for bacterial contamination using Difco Hychek contact slides. Coliform bacteria were assessed using Millipore swab test kits. Total bacteria, coliforms, and molds on all utensils and equipment cleaned and sanitized by the WSS were reduced far below the Public Health Service limit for food-contact surfaces. Utensils and equipment were cleaned easily and effectively by the WSS. A waterless food-service sanitation capability will give the MKT an emergency backup cleaning

and sanitation system when either hot water or a potable water supply is unavailable.

Army mobile field feeding systems have a need for a field sanitation system that cleans and degreases food cooking and serving utensils without water. Because water may not be readily available in all theaters and scenarios, a waterless (towelette) food service sanitation capability will give the Mobile Kitchen Trailer (MKT) unprecedented range and independence and reduce its reliance on water. The towelettes also will serve as a backup sanitation system when either hot water or a potable water supply is unavailable or is being conserved for drinking.

Commercially available wipes previously tested were not suitable because they required water or the ingredients could not be used on food-contact surfaces (17). Although a premoistened disposable wipe was successfully used to improve the quality of raw milk by cleaning cow teats (2), the ingredients were also not suitable for food contact surfaces. More than 100 commercial cleaning/degreasing agents were investigated by Army scientists but all failed to remove grease from pots and pans at low temperatures (14). More recently, this laboratory demonstrated that pots and pans could be successfully cleaned, degreased, and sanitized in water at 15°C by hand scrubbing in a Vesta-Power (VP) detergent solution, (Calgon Corporation, Pitts-

burgh, PA) (11). The pots and pans were then rinsed in water at the same temperature and sanitized by immersing in an aqueous solution of Syn-Cide Plus, now called Process QDS, (Calgon Vestal Laboratory, St. Louis, MO), a quaternary ammonium disinfectant sanitizer. Aqueous solutions of VP and Syn-Cide Plus were also successfully employed at 20°C by soldiers during a field exercise (11).

The objective of this study was to develop and test a waterless sanitation system (WSS) that is effective in cold water by employing a combination of premoistened, disposable wipes used in sequence and incorporating the VP detergent/degreaser, deionized water, and the Process QDS sanitizer.

MATERIALS AND METHODS

Detergent/Degreaser

Vesta-Power is a detergent degreaser. It is authorized by the U.S. Department of Agriculture (USDA) for use in federally inspected meat and poultry plants. A 5% aqueous solution, pH 11, was used to saturate the wipes. Sodium metasilicate is the active ingredient incorporated to emulsify fat and grease.

Sanitizer

Process QDS (formerly Syn-cide Plus, Calgon Vestal Laboratory), (St. Louis, MO) is a blended quaternary ammonium compound (QAC) with organic tolerance. The active ingredi-

ents are alkyl (C₁₄, 50%; C₁₂, 40%; C₁₆, 10%); dimethylbenzylammonium chloride, 3%; octyldecyldimethylammonium chloride, 2.250%; didecyldimethylammonium chloride, 1.125%; and dioctyldimethylammoniumchloride, 1.125%. Process QDS was used to saturate the wipes at the recommended dilution of 1 fluid ounce in 4 gallons of water (1.92 ml/l). The concentration of active QAC was 150 ppm. No potable rinse is required. Process QDS is authorized by the USDA for use in Federally inspected meat and poultry plants.

Preparation of Sanitation Wipes (Towelettes)

Three wipes were prepared with commercially available towelettes (see table 5). Wipe #1 was soaked to saturation with 5% VP detergent/degreaser. Wipe #2 was saturated with deionized water to rinse the surface of VP detergent. Wipe #3 was saturated with Process QDS quaternary ammonium sanitizer at the recommended dilution to obtain 150 ppm of the active QAC. Excess liquid was removed by allowing the towels to dry on a line at equilibrating temperatures of 5°C and 26°C, only to the point when they no longer dripped. The wipes were used immediately.

Test Bacteria

Test bacteria included *Bacillus cereus*, Natick B6Ac; *Escherichia coli*, ATCC 11229 (1); *Klebsiella terrigena*, ATCC 33257; *Listeria monocytogenes*, Natick N2-1; *Pseudomonas aeruginosa*, Natick QM-3-1517; *Staphylococcus aureus*, ATCC 6538 (1); *Streptococcus faecalis*, ATCC 19433; and *Salmonella typhimurium*, ATCC 14028.

Soiling Surfaces with Spoiled Foods

Cleaned stainless steel frying pans were sterilized by flooding the surface with 100% ethyl alcohol and flaming three times until the alcohol was completely burned off. A mixed inoculum was prepared by mixing equal volumes of *E. coli* and *S. aureus* cultures. Then one ml of the mixed inoculum was blended with 100 grams of the food sample by

stomaching for one minute (22) to achieve approximately 10,000 bacteria per gram. The frying pans (12"×12") were soiled by spreading 100 g of the inoculated food over the bottom, inside surface of the pan. Pork chow mein was also inoculated with single cultures of *E. coli* and *S. aureus*. Soiled pans were incubated at 35°C for 24 hours to produce a biofilm. After gross residues of the spoiled food were removed from the pan by scraping and/or wiping with a dry paper towel, the surface was air dried at 5°C or at 26°C, for 1 to 3 h. When tests were conducted in skim milk inoculated with *E. coli*, 500 ml were added to the pans. The spoiled skim milk was poured off and the surface of the pan was dried only at 26°C. Bacteria were recovered from the pan by swabbing the surface (13,21). Total plate counts of the food before and after spoilage were conducted in plate count agar (PCA, Difco).

The bacteria inoculated into the foods were grown in trypticase soy broth (Difco, Detroit, MI) at 35°C for 22 to 24 h. Dilutions were made in Butterfields phosphate buffer (22) and the inoculum of each culture was adjusted turbidimetrically (Ratio/XR Turbidimeter, Model 43900, Hach Company, P.O.Box 389, Loveland, Colorado).

Cleaning and Sanitizing Surfaces

Gross food residues were first removed from the pans by scraping or wiping with a dry towel. The soiled surface was air dried at 5°C or 26°C, for 1 to 3 h and then cleaned with wipe #1 moistened with VP detergent until the surface appeared clean and greaseless. Residual detergent was removed by wiping the surface with wipe #2 moistened with deionized water. The surface was then sanitized by wiping for 1 min (wet contact time) with wipe #3 moistened with Process QDS sanitizer. All towelettes were equilibrated to the appropriate test temperature (5°C and 26°C) before application.

ENUMERATION METHODS

Inoculated and spoiled foods

Standard aerobic plate counts (22) in PCA were performed on

foods used to soil the surfaces before and after the foods were deliberately spoiled. Differential counts were conducted on Baird-Parker agar (Difco) for recovery of *S. aureus* (22), and on violet red bile agar (VRBA; Difco) for recovery of *E. coli* (22). All plates were incubated at 35°C for 48 h.

Swab Counts of Biofilms on Frying-Pans

Bacteria remaining on 40 in² of frying-pan surfaces preceding and following the application of each sanitation wipe (towelette) were determined by swabbing five, 8-square-inch areas with a single swab (21). The swabs were deposited into buffer containing neutralizing agents (Swab Buffer Sets, Millipore Corporation, Bedford, MA) to counteract the adverse affect of any residual quaternary ammonium compounds that may have been present on surfaces after sanitation. After manually shaking the swab in the neutralizing buffer for 2 min, appropriate dilutions were made in Butterfields phosphate buffer (22). One ml of each dilution was plated in duplicate and poured with PCA. Differential counts of injured as well as noninjured *S. aureus* cells, were made by spreading 1 ml of each dilution over 3 Baird-Parker agar (Difco) plates. Injured and noninjured *E. coli* were recovered on trypticase soy agar (TSA, Difco), incubated for 2 h at 35°C and then overlaid with VRBA. All plates were incubated at 35°C for 48 h (22).

Determining Efficacy of Sanitizers

A. Planktonic cells. Reagents, preparation of stock culture and operating technique were according to Association of Official Analytical Chemists (AOAC) Official Methods of Analysis, section 960.09, 1990 (1). All cultures were activated by three daily transfers on nutrient agar (Difco). One milliliter of a turbidimetrically standardized phosphate buffer suspension of planktonic cells (1×10^{10} /ml) was exposed to 99 ml Process QDS and Mandate (Klenzade, Division of Ecolab Incorporated, St. Paul, MN) sanitizers for 30 s (1, 3). At the

end of the time period one milliliter of the cell suspension was immediately transferred to 9 ml (1:10 dilution) of neutralizing buffers to inactivate the sanitizers. Dilutions were also made in neutralizing buffers (Difco) and plate counts were made in D/E neutralizing agar (Difco) and PCA pour plates. A numbers control in which cells were not exposed to the sanitizers was also employed (1).

B. Biofilm bacteria on stainless steel chips. *Staphylococcus aureus* was grown and cell suspensions were prepared as were the planktonic cells, above. However, the final dilution of the standardized cell suspension was made in 10% skim milk (Difco) to obtain 1×10^8 CFU's/ml for inoculation onto stainless steel chips ($2 \times 7/8$ in). Five chips were inoculated with 10^6 cells by evenly spreading 0.01 ml of the milk suspension on them with a calibrated loop. All chips were dried at room temperature for one hour. Three chips were immersed in 99 ml of the recommended dilution of the sanitizer (150 ppm QAC) and two chips were used as unexposed number controls. Biofilm cells on three stainless steel chips were exposed to the sanitizers for 10 min (1,3). *Staphylococcus aureus* was recovered by swabbing the entire surface of the chip (21). Swabs were deposited in the same neutralizing buffers used for planktonic cells. Dilutions were also made in the neutralizing buffers. Plate counts were made on D/E neutralizing agar and PCA pour plates. The unexposed number controls were diluted and plated in exactly the same manner.

Stainless Steel Chips

Stainless steel chips ($2 \times 7/8$ in) were fabricated from #304 steel. The chips were autoclaved in Alconox detergent, sonicated, brushed, rinsed in tap water, soaked in acetone, soaked in boiling distilled water, rinsed three times in tap water, rinsed 3 times in deionized water, soaked in absolute ethyl alcohol, and air dried. The chips were sterilized by autoclaving for 30 min at 121°C.

Inactivation of Sanitizers

To avoid bacteriostatic or bacte-

ricidal conditions in growth media, the QAC in Process QDS, in which planktonic cells were suspended, was inactivated by transferring 1 ml of the treated cell suspension to 9 ml of neutralizing buffer (Difco). Mandate, a fatty acid sanitizer (22.5% phosphoric acid, 20.0% citric acid, 6.0% octanoic acid, and 2.0% decanoic acid) was neutralized in Sorensens buffer (4). Residual sanitizers on swabs used to recover biofilm bacteria from stainless steel chips were likewise inactivated. Dilutions were also made in neutralizing buffer (Difco) and plate counts were made in D/E neutralizing agar (Difco) and PCA (Difco). In the field, residual sanitizers on surfaces of food serving utensils and equipment sampled were inactivated by the D/E neutralizing agar in the Hycheck contact slides (Difco) used to quantitate total bacteria. Millipore swab buffer sets (to inactivate QAC's or chlorine) and coli count water testers were used in the field to recover coliforms on food serving utensils.

Assessing the Microbiological Contamination on Food Contact Surfaces in the Field

All surfaces of food-serving utensils and equipment examined in the field were monitored for bacterial contamination by using Hycheck contact slides containing D/E neutralizing agar on both sides. Coliform bacteria were assessed by using Millipore swab test kits (13).

Determination of Concentration of Quarternary Ammonium Compound (QAC)

A. Bromophenol blue method. The concentration of QAC in Process QDS (Syncide Plus) was determined by a bromophenol blue method (1, 10): 25 ml of chloroform, 25 ml salt buffer solution (7 g sodium carbonate, 100 g sodium sulfate and 1000 ml distilled water, pH 10), and three drops of 0.1% bromophenol blue indicator to 50 ml of sample in a 250 ml flask. The flask was stoppered and shaken vigorously. The mixture was titrated with 0.003 N sodium lauryl sulfate (SLS) dropwise. The endpoint

was the first definite appearance of a violet color in the upper layer when viewed under direct light. The concentration of QAC was calculated by the following formula (10):

$$\text{QAC ppm} = \frac{\text{SLS ml} \times \text{N} \times \text{MW} \times 10^3}{\text{ml of sample}}$$

B. QT-30 test paper. The test kit is available through customer service, Calgon Vestal Laboratories, St. Louis, MO 63166.

RESULTS

Table 1 shows the efficacy of the three wipes (WSS), applied in sequence, on the reduction of bacteria in biofilms produced in food on stainless steel surfaces of an electric frying pan. The bacteria grew in the foods and milk to more than 10^9 colony forming units (CFU's)/gram or ml respectively. The wipes (WSS) were effective in cleaning and sanitizing the pan at both 5°C and 26°C. After application of all 3 wipes, bacterial reduction was slightly greater at 26°C, where it exceeded the required 5 logs (99.999%) in all trials. At 5°C the bacterial reduction was slightly less than 5 logs in biofilms produced in beef stew and corn beef hash in which reductions were 99.98% and 99.99%, respectively. However the average reduction at 5°C was approximately 5 logs. The percent reduction was determined by comparing counts obtained before and after application of the WSS wipes. The effectiveness of wipe #1 (VP detergent/degreaser) followed by the water rinse in wipe #2 in cleaning the surfaces undoubtedly contributed to the successful reductions by the sanitizing wipe #3.

Table 2 shows the efficacy of the WSS on naturally soiled surfaces in a bakery and military kitchen. Surfaces were swabbed with Millipore buffer sets and aerobic plate counts were made in PCA pour plates. Bacterial reduction on stainless steel counter-tops was greater than on wood countertops. As expected, the wood surface was more difficult to clean and sanitize than stainless steel, because of cracks and crevices and the porous nature of wood. How-

ever, the wiping regimen effectively reduced indigenous counts on the wood surface by more than 96% after the final application of Process QDS. Indigenous counts on stainless steel were reduced by 98 to 100%.

The sanitizing action of Process QDS was tested against planktonic cells of four gram-negative bacteria and four gram-positive bacteria including a spore former (*B. cereus*) and was compared to a fatty acid sanitizer called Mandate. Results are shown in Table 3. To meet effectiveness standards, (99.999%) (5-log units) reduction in count must be achieved within 30 s (1). Process QDS sanitizer achieved greater than a 6 log units (99.9999%) reduction of all 8 bacterial species within 30 s, except the sporeforming *B. cereus*. Mandate sanitizer was less effective than Process QDS against *K. terrigena* and *S. typhimurium*. Although Mandate met the standard for effectiveness (5 log reduction) for *K. terrigena*, it did not achieve the required reduction of *S. typhimurium*.

Table 4 shows the sanitizing effect of Process QDS and Mandate sanitizers on the reduction of biofilm

cells of *S. aureus* on stainless steel chips. Process QDS sanitizer reduced *S. aureus* by 99.999% and was more bactericidal than Mandate which only achieved a 98.31% reduction.

Trials with *E. coli* were unsuccessful on stainless steel chips because *E. coli* did not sufficiently survive the 1 h drying time performed at room temperature before cells were exposed to the sanitizers. Figure 1 shows that only 24% of the *E. coli* biofilm cells survived drying after 30 min and only 4% after 1 h. A different substrate other than milk may be required.

Table 5 shows that the selection of the proper towel material for the wipes is very important to avoid inactivating the QAC. Cellulose (paper and cotton) towels reduced the QAC in the Process QDS sanitizer by 53% to 95%. Polypropylene and polyester reduced the QAC by only 8% to 30%, respectively. Therefore, polypropylene or polyester material must be used for sanitizer wipes containing QACs. Since some inactivation of the QAC can be expected, the sanitizer must be formulated overstrength to achieve the desired concentration of

QAC in the wipe. The Process QDS wipe must contain 150 ppm QAC.

Foods served in the field at two breakfast and two dinner meals to soldiers during field maneuvers were as follows. Breakfasts: scrambled eggs, grits, potatoes, and Spam; and creamed ground beef (Traypack ration), egg and sausage omelet (Traypack), grits, and cake; dinners: beef stew, rice, green beans, and cake; and pork, mashed potatoes, gravy, corn, and peach cobbler. Utensils which were used to serve the food and which were cleaned and sanitized by the WSS in the field were: 3 cake cutters, 1 fork, 1 ice-cream scoop, 2 or 3 knives, 1 or 2 large thongs, and 1 whisk.

The WSS system reduced the total count of bacteria and mold on utensils previously sanitized by standard Army procedures (19, 20), from 9.2/in² to only 2/in² on average. This represents a reduction of total CFUs on 20 surface samples from 184/in² to 42/in². Molds were reduced from an average of 4 to 0.06 CFU's/in². Coliform bacteria were not detected before or after applying the WSS. Utensils cleaned by standard Army procedures before and after application of the WSS were acceptable and in compliance with U.S. Public Health Service (PHS) requirements of total counts not greater than 12.5 CFUs/in² (21).

Table 6 shows the bacterial and mold counts on soiled food service utensils used during breakfast and dinner meals in the field after applying the WSS. The surfaces were cleaned with only one of each wipe and all counts were far below the 12.5 CFUs/in² considered acceptable on sanitized surfaces (21). Molds recovered were less than 1/in² and coliforms were absent.

The WSS was also very effective in sanitizing food-service equipment in the field as shown in Table 7. Microbiological samples were taken from surfaces before and after wiping with the WSS. Counts on all equipment surfaces were reduced below the maximum of 12.5 CFUs/in² allowed, with one exception: a table top sampled after the first dinner may

TABLE 1. Removal of *E. coli* and *S. aureus* in biofilms produced in selected foods on stainless steel surfaces by wipes of the waterless sanitation system (WSS).

Food	Inoculum 10 ⁴ g	Average Reduction Bacterial Counts (%)			
		5°C		26°C	
		Wipes 1 (VP) & 2 (H ₂ O)	Wipe 3 (QDS)	Wipes 1 (VP) & 2 (H ₂ O)	Wipe 3 (QDS)
Pork chow mein	<i>E. coli</i> (EC)	99.98	99.99999	99.99995	99.99995
	<i>S. aureus</i> (SA)	99.59	99.999	-	-
	EC + SA	99.97	99.9993	99.987	100.00
Beef stew	EC + SA	81.7	99.98	98.4	100.0
Chicken a la king	EC + SA	99.92	99.999	99.98	99.9994
Chicken stew	EC + SA	99.7	100.0	99.78	99.999
Corn beef hash	EC + SA	99.75	99.99	99.999	100.0
Escal. potatoes	EC + SA	99.99	100.0	99.997	99.9993
Tuna and noodles	EC + SA	99.97	99.9998	99.999	100.0
Skim milk	<i>E. coli</i>	-	-	99.9984	99.99996
Average		97.84	99.996	99.793	>99.999

Note: VP, Vesta Power detergent; QDS, Process QDS Sanitizer; H₂O deionized.

have been inadequately cleaned and sanitized. The tent was poorly lighted, and it was too dark to see the surface clearly. More importantly, the soldier did not apply the sanitizing wipe for the required 30s. However, the reduction of the bacterial count after applying the WSS was still substantial, going from greater than 200 CFUs/in² to only 48 CFUs/in². The WSS was also very effective on the large cake pan and frying grill. The bacterial count per square inch on the grill was reduced from 20 to less than 1. The grease was completely removed and undiscernible to touch and sight.

DISCUSSION

Removal and penetration of biofilms on surfaces represent the worst possible challenge for cleaners

and sanitizers. In this study, biofilms were deliberately produced on stainless steel surfaces by growing *E. coli* and *S. aureus* in thermostabilized military rations to very high numbers. These biofilms are formed by the attachment of microorganisms to surfaces and the accumulation of layers of fat, protein, polysaccharides, and other materials produced by microorganisms, as well as food debris (5, 7, 8, 18). Biofilms provide attached pathogens protection against chemical sanitizers, and the attached cells are more resistant to chemicals (5).

The three-wipe WSS was devised to remove and inactivate adherent microorganisms from food-contact surfaces. To be most effective, sanitizing agents must be preceded by effective cleaners (7, 8, 16, 18) as in

the WSS. Detergents contain surfactants which reduce surface tension, thereby suspending and removing greasy soils. This enables the sanitizers which follow to inactivate microorganisms that remain behind. Rinsing the detergent residues from the food-contact surface before application of the sanitizer ensures that the detergent residue does not inactivate the sanitizer. The application of single wipes (12, 17), or cleaner only (8, 18) by other investigators was not effective.

Because the surface of bacteria is negatively charged and hydrophilic, QACs such as those found in Process QDS, adsorb to the cells, penetrate the cell wall and rupture the cytoplasmic membrane, thus killing the cell (5, 15). However, this action may not occur if cells are protected by a biofilm that prevents penetration of the sanitizer into the cell.

The WSS was effective because the protective biofilm on both stainless steel surfaces and cells was disrupted and removed by application of wipe #1, containing VP detergent. VP detergent contains sodium metasilicate, which mixes with and emulsifies fats and grease, allowing the sanitizer in wipe #3 to penetrate and remove the adherent cells that remained behind. It is also suspected that adherent cells are more sensitive to sanitizers after removal from surfaces by a detergent (5).

The WSS was also very effective under field conditions when used by soldiers to clean and sanitize surfaces of soiled food-service utensils and equipment. The total number of CFUs on all WSS sanitized utensils and equipment was less than the maximum PHS standard (21) of 12.5 CFUs/in². The detergent wipe was very effective in removing grease from the grill in the MKT as well as removing a mixture of fuel and grease on the stainless steel surface under the grill. Dried and burnt foods on surfaces were also effectively removed by the detergent wipe. Removal of such dried foods from surfaces can be expedited by first wetting the surface with the detergent wipe and then applying a dry scouring pad as one would do if water was used. A dry

TABLE 2. Bactericidal efficacy of wipes on counter tops in food preparation areas.^a

Wipe	Reduction Bacterial Counts on Countertops ^b (%)	
	Wood	Stainless Steel
None	0	0
Vesta Power detergent	>75	78 ->96
Process QDS sanitizer	>96	>98 - 100

^a Natick bakery and Headquarters Company dining hall kitchen.

^b 40 in² of Countertop (5 x 8 in² areas swabbed).

TABLE 3. Bactericidal efficacy of Process QDS and Mandate sanitizers on planktonic cells.

Bacteria (10 ¹⁰ cells/ml)	Average Log Cycle Reduction After 30 s	
	QDS	Mandate
<i>B. cereus</i> (sporeformer)	1.3	1.3
<i>E. coli</i>	>6	>6
<i>K. terrigena</i>	>6	5.3
<i>L. monocytogenes</i>	>6	>6
<i>P. aeruginosa</i>	>6	>6
<i>S. aureus</i>	>6	>6
<i>S. faecalis</i>	>6	>6
<i>S. typhimurium</i>	>6	4.6

paper towel was also used to remove gross food residues from all surfaces before using the WSS, in order to conserve the WSS wipes. In many cases, one wipe was used for several utensils, depending on the utensil's size and condition. Only one wipe of each type was required to clean and sanitize a table top (4 ft x 3 ft). However, if necessary, more than one rinse wipe can be used.

The sanitizer wipe, in addition to being biocidal, polished the utensils and surfaces in the MKT more than those sanitized by standard procedures. This was most likely due to the fact that the detergent water used in the standard Army field washing procedure (20) was too hot for hand washing. Hot water causes the proteins from food residues to "bake" on the utensil surface, producing a film that dulls the surface and is difficult to remove. Therefore, detergent water temperature for manual washing should be only as hot as the hands can stand, which ranges from 110°F to 125°F (6, 9). Wash temperatures specified by Army Field Manual 21-10-1 range from 120°F to 150°F (20). Thermometers should be provided to permit frequent checks of water temperature when water is used as the sanitizing agent (21). Another advantage of the WSS is that thermometers to check temperatures are not needed since the detergent and sanitizing wipes are effective even at low temperatures.

CONCLUSION

The feasibility and efficacy of the WSS developed were demonstrated in the laboratory and in the field during military exercises. The WSS exceeded the required reduction (99.999%) of test bacteria in biofilms produced on stainless steel surfaces. The Process QDS sanitizer, tested alone, effectively killed planktonic cells of seven food-borne bacterial pathogens and *K. terrigena* within 30 s. The WSS provides the MKT with an emergency backup system to clean and sanitize serving utensils

and equipment when water is not available or must be conserved. The WSS wipes could also be used in an abbreviated emergency mode to clean and sanitize essential food-contact surfaces and equipment in the MKT itself, until a water supply was restored,

thus allowing the MKT to complete its mission. The wipes could also be used for many surfaces in a traditional food-service facility, and certainly in a civilian application by campers when potable or hot water and detergents are unavailable.

TABLE 4. Reduction of *S. aureus* on stainless steel chips immersed in Process QDS and Mandate sanitizers for 10 min at 25 °C.

CFU	Inoculum per 0.01 ml	Numbers control/chip	CFU/chip after 10 min	
			QDS	Mandate
Maximum CFU	1.6×10^6	1.5×10^6	18	59,000
Minimum CFU	8.2×10^5	1.2×10^6	<18	420
Average CFU	1.1×10^6	1.2×10^6	<18	17,772
Ave % reduction	0	0	>99.999	98.31

^a Average of 10 trials.

TABLE 5. Inactivation of quaternary ammonium compound (QAC) in Process QDS by towel material.

Towel	Composition	Average ^a Reduction of QAC (%)
Kim towel	Cellulose	53
Sturdi-wipe	Cellulose	89
Webril towel	Cellulose	95
Texwipe 60/40	Polyester/cellulose	51
Army cloth	Polypropylene	8
Army cloth	Polyester	18
Texwipe	Polyester	20
Exsorbx 400	Polyester	30

^a Average of two to seven trials.

TABLE 6. Bacterial and mold counts on food-serving utensils after cleaning and sanitizing soiled utensils in the field with the WSS.

Meal	Utensils	Samples	Average CFU/in ²	
			Bacteria ^a	Molds
Breakfast	10	20	4.0	0.2
Breakfast	11	22	0.73	0
Dinner	11	22	3.6	0.2
Dinner	10	20	2.6	0.5

^aNo coliforms found

Figure 1. Rate of decrease of *Escherichia coli* in a skim milk biofilm on stainless steel air dried at 26°C.

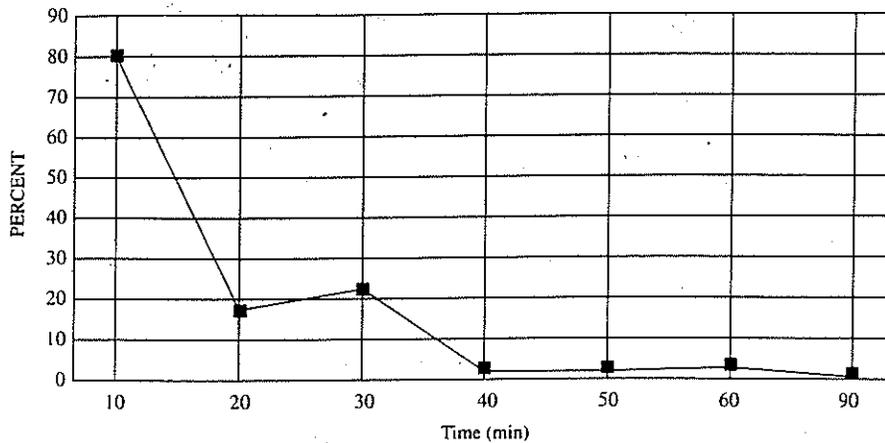


TABLE 7. Bioburden on soiled food service equipment and selected utensils in the field before and after application of the waterless sanitation system (wipes).

Equipment	Average CFU/in ²			
	Before WSS		After WSS	
	Bacteria	Molds	Bacteria	Molds
Cake Pan	47	0	8	1
Countertop	10	0	8	2
Grill	20	1	0.3	0
Pot (mashed potatoes)	—	—	3	0.5
Pot (rice)	—	—	6	0
Serving spoon (grits)	11	0	2	0.3
Table top	>200	0.25	2	0
Table top	>200	4	48	1

REFERENCES

1. Association of Official Analytical Chemists. 1990. Official methods of analysis, 15th ed., pp. 135 and 139. AOAC, Arlington, VA 22201.
2. Atkinson, R. W., R. H. Gough, and J. J. Ryan. 1991. Use of individual, premoistened, disposable wipes in preparing cow teats for milking and resultant raw milk quality and production. *J. Food Prot.* 54:957-959.
3. Block, S. S. 1983. Disinfection, sterilization, and preservation. Lea and Febiger, Philadelphia, PA.
4. Documenta Geigy. 1970. Scientific Tables. 7th ed. CIBA-Geigy Limited, Basle, Switzerland.
5. Frank, J. F. and R. A. Koffi. 1990. Surface adherent growth of *Listeria*

monocytogenes is associated with increased resistance to surfactant sanitizers and heat. *J. Food Prot.* 53:550-554.

6. Iowa State Department of Health and Economics Laboratory, Inc. 1962. Sanitation of food service establishments: a guide for on-the-job training of personnel. Economics Laboratory, 250 Park Avenue, New York, NY 10017.
7. Kramer, D. N. 1992. Myths cleaning, sanitation and disinfection. *Dairy, Food and Environ. Sanit.* 12:507-509.
8. Krysinski, E. P., L. J. Brown, and T. J. Marchisello. 1992. Effect of cleaners and sanitizers on *Listeria monocytogenes* attached to product contact surfaces. *J. Food Prot.* 55:246-251.

9. Longree, K. 1980. Quantity food sanitation. Interscience Publishers, John Wiley & Sons, New York.
10. Lonza Incorporated. 1993. Determination of concentration of Bardac® quaternaries, procedure LR-8. Lonza Incorporated, Fair Lawn, NJ.
11. McCormick, N. G. and R. G. Flaig. 1989. Cold water cleaning and sanitizing of kitchenware in the field. Technical Report Natick/TR-90/013. U.S. Army Natick Research, Development and Engineering Center, Natick, MA.
12. Meiseman, H. L. 1984. Ratings of the field wipe acceptability. Disposition Form to Morris Rogers, November 6. Science and Advanced Technology Laboratory, U.S. Army Natick Research, Development and Engineering Center, Natick, MA.
13. Millipore Corporation. 1975. Testing surface sanitation with the swab test kit. Bulletin PB 427, Millipore Corporation, Bedford, MA.
14. Muller, W. S., M. Rogers, D. Seekins, and R. Young. 1989. Chemical sanitation system for pots and pans in field operations. Technical Report Natick/TR-89/020. U.S. Army Natick Research, Development and Engineering Center, Natick, MA.
15. Petrocci, A. N. 1983. Surface active agents: quaternary ammonium compounds, p. 325. In S. S. Block (ed), Disinfection, Sterilization, and Preservation, 3rd ed. Lea and Febiger, Philadelphia, PA.
16. Reed, G. H., Jr. 1992. Sanitization in food service establishments. *Dairy, Food and Environ. Sanit.* 12:566-567.
17. Rogers, M. R. 1984. Individual eating utensil sanitation. Fiscal Year Progress, Report Form 1498. Soldier Science Directorate, U.S. Army Natick Research, Development and Engineering Center, Natick, MA.
18. Stone, L. S. and E. A. Zottola. 1985. Effect of cleaning and sanitizing on the attachment of *Pseudomonas fragi* to stainless steel. *J. Food Sci.* 50:951-956.
19. U. S. Department of the Army. 1978. Field sanitation team training. Training Circular TC 8-3. Headquarters, Department of the Army, Washington, D.C.
20. U.S. Department of the Army. 1989. Manual no. 21-10-1. Headquarters, D.C.
21. U.S. Public Health Service. 1967. Procedure for the bacteriological examination of food utensils and/or food equipment surfaces. Technical Information Bulletin no. 1. U.S. Department of Health, Education, and Welfare, Cincinnati, OH.
22. Vanderzant, C. and D. F. Splittstoesser (eds). 1992. Compendium of methods for the microbiological examination of foods. 3rd ed. American Public Health Association, Washington, D.C.