

AN ACCELERATED HYDROGEN PEROXIDE (AHP)-BASED FAST-ACTING AND REUSABLE MICROBICIDE FOR MANUAL DISINFECTION OF HEAT-SENSITIVE SEMI-CRITICAL MEDICAL DEVICES

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ABSTRACT

Semi-critical and critical medical devices require high-level disinfection and sterilization. There are two main methods for reprocessing these devices: heat and chemical. While heat does not raise any toxicity issue associated with chemicals, it cannot be used on heat-sensitive instruments. Chemicals such as Ethylene oxide, formaldehyde, glutaraldehyde, orthophthalaldehyde, ozone, hydrogen peroxide, hydrogen peroxide plasma, and peracetic acid are currently used for this purpose, but they all have major disadvantages such as high toxicity, pungent and unpleasant smell, slow action, expensive machines requirement, special handling, storage, and usage requirements and corrosion. A new alternative to these chemicals is an accelerated H_2O_2 (AHP)-based formulation (ACCEL CS20) for manual disinfection of heat-sensitive devices. This new formulation addresses many concerns of the existing chemicals. It is a fast-acting sporicide, and takes only 20 minutes to inactivate bacterial spores at room temperature even after a simulated reuse period of 14 days. It does not smell pungent and does not require any specific ventilation system. It can be used as a cold soak in manual applications and is compatible with many materials such as different plastics and metals, and causes only slight corrosion on soft metals such as brass upon prolonged exposure.

INTRODUCTION

Based on the Spaulding classification¹, medical devices such as cardiac catheters, implants, or instruments

used for foot care procedures such as nail nipper, nail probe and callus parer may come into contact with blood-stream or sterile areas of the body and are defined as critical medical devices. Such items require sterilization between patients. There are two main methods for reprocessing these devices: heat and chemical. Examples of heat reprocessing include steam or dry heat, while ethylene oxide (ETO), formaldehyde gas, hydrogen peroxide (H_2O_2) vapor, ozone, chlorine dioxide gas, hydrogen peroxide gas plasma, H_2O_2 liquid, peracetic acid liquid, glutaraldehyde, ortho-phthalaldehyde (OPA), and accelerated H_2O_2 (AHP) are examples of chemical sterilization.

There are pros and cons for each of these methods. Physical methods such as moist or dry heat are environment-friendly; however, they cannot be used on heat-sensitive medical devices. For ETO, the turn-around time is relatively long (12 to 18 hours) due to its slow action and the aeration time needed to reduce the toxic residuals². ETO is listed as a mutagen and human carcinogen³. It has also been reported to accumulate in some materials⁴. Formaldehyde gas is flammable. In 2004, the U.S. Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) have declared formaldehyde as a carcinogen. Residual formaldehyde detected on materials that come into close contact with patients' mucous membranes may pose a health risk⁵. Formaldehyde is also thought to be genotoxic⁶. H_2O_2 vapor and gas plasma, ozone gas, chlorine dioxide gas, and mixed chemical/gas plasma have better toxicity

profiles than ETO and formaldehyde, but all need sophisticated and expensive sterilization devices for operating. H₂O₂ and/or peracetic acid-based liquid sterilants do not require machines to operate and they can be used as a cold soak for sterilizing devices. However, hydrogen peroxide solutions are slow sporicides⁷, and peracetic acid solutions are pungent and require ventilation in the use area.

Glutaraldehyde and OPA are also available commercially as cold soaks, and do not require a machine to operate. Additionally, their materials compatibility profile is more favourable. However, their sporicidal activity is very slow⁸. Further, Glutaraldehyde cannot be operated in open areas and requires the use of additional ventilation precautions such as fume hoods. Glutaraldehyde can cause irritation if inhaled or comes in contact with the skin^{9,10,11}. It is also reported to be mutagenic^{12,13}. OPA can sensitize some patients¹⁴. Additionally, several cases of allergic reactions to OPA have been recorded¹⁵. Based on the reported cases of sensitization, OPA has been contraindicated for use in reprocessing urological instruments for patients with a history of bladder cancer¹⁶.

As summarized above, the existing commercially available high-level

disinfectants and chemosterilants suffer from at least one of the following major drawbacks:

- High toxicity
- Slow sterilization time
- Need to use expensive sterilization equipment
- High corrosivity

Therefore, there is a need for a safer product that can decontaminate heat-sensitive medical devices faster and does not require any sophisticated machine.

In this paper, one such product is reported. Accel CS20, a 7% AHP-based solution is a rapid sporicide. It can inactivate spores on medical devices in 20 minutes at room temperature, and can be reused for 14 days. Accel CS20 is compatible with most medical devices, does not have any inhalation issues, and can be used in a simple cold soak application. The product is registered for sale as a 14-day reuse formulation in Canada.

MATERIALS & METHODS

Microbicidal tests Three lots (one being at the end of its recommended shelf-life) of the test formulation were placed in 20-L white plastic pails for simulated 14-day reuse at 20±1°C. The stressing of the solutions was as

detailed before.¹⁷ Briefly, each bath first received bovine serum to a final conc. of 2% and then, on a daily basis, the prescribed number of microbe-laden carriers and three cycles of respiratory therapy equipment. Samples from each reuse bath were withdrawn at the end of stressing and tested for sporicidal, mycobactericidal and fungicidal activities using glass vials (Galaxy, Newfield, NJ), as carriers in a quantitative carrier test (QCT).¹⁸

Pseudomonas aeruginosa (ATCC 15442), *Staphylococcus aureus* (ATCC 6538), *Salmonella choleraesuis* (ATCC 10708), and spores of *Bacillus subtilis* (ATCC 19659) and *Clostridium sporogenes* (ATCC 7955) were used to contaminate the carriers as bioburden for daily stressing. Glass beads of 6 mm in diam. (cat. #7268-6; Corning, NY) were soaked in separate suspensions of *S. choleraesuis*, *S. aureus*, and *P. aeruginosa*. Stainless steel penicylinders (8.0 mm outer diameter, 6 mm ID., 10 mm length; cat. #07-907-5; Fisher, Whitby, ON, Canada), were soaked separately in suspensions of *B. subtilis* and *C. sporogenes* spores. The contaminated bioburden carriers were held for 45 min at 37°C to dry the inocula.

Mycobacterium terrae (ATCC 15755), spores of *B. subtilis* and *C. sporogenes*, and the conidia of *Tricho-*

phyton mentagrophytes (ATCC 9533) were used in mycobactericidal, sporicidal, and fungicidal tests, respectively. The cultivation of these organisms and the contamination of the carriers as bioburden were as described before.¹⁷

In addition to the bioburden, the test solutions were also challenged with three daily cycles of inhalation therapy equipment consisting of (a) flexible, clear plastic CF cuffed tracheal tube 10.02 mm OD and 7.5 mm ID (cat. #5-10115; Kendal Sheridan, Mansfield, MA), (b) flexible tubing 1.83 m in length (cat. #301016, Respironics Inc, Murrysville, PA), (3) 2.0-L capacity breathing bag (cat. #5005; CH Medical, Exeter, England), (d) face mask (CH Medical); and (e) plastic, 22 mm bifurcator Y-connector (Intersurgical, Liverpool, NY). Each soak of the equipment lasted 30 min. Between soakings, the items were cleaned with a detergent (Sparkleen; Fisher, Ottawa, ON) and rinsed in sterile distilled water.

H₂O₂ in the test samples was measured by iodometric titration.¹⁹ High-range H₂O₂ test strips (Serim Research, Elkhart, IN) were also used once a day as an additional qualitative measure to confirm that the H₂O₂ conc. in the baths was above the minimum effective level. A pH meter (Accument; Fisher) was used daily to determine the pH of the test solution in each bath before the first challenge.

Control carriers in QCT were used in the same manner as test carriers except sterile saline was applied to the dried inoculum instead of the disinfectant. Lethen Broth (with 0.1% sodium thiosulphate) was used as the neutralizer.

In each QCT, 10 test and three control carriers were used and the results reported as log₁₀ reductions in viability in reference to the controls. For a product to be considered sporicidal or mycobactericidal, it was expected to reduce the viability titre of the test organisms by a minimum of 6 log₁₀. At least a 5-log₁₀ reduction was required for fungicidal activity.

In addition to the initial input of serum, every day each bath received

880 glass beads coated with each of the three types of vegetative bacteria and 200 penicylinders contaminated separately with one of the two types of spores. On the first day, each bath received the carriers contaminated with *S aureus* and *B subtilis*. The carriers used on the following day contained *P. aeruginosa* and *C. sporogenes*, and those for the third day were contaminated with *S. choleraesuis* and *B. subtilis*. The cycle was repeated for the remaining days of stress representing a daily input of a total of 1,080 bacteria- or spore-contaminated carriers. On average, each test solution received 8.95×10^3 and 9.48×10^3 CFU/mL of the bacteria and the spores, respectively, giving a cumulative daily bioburden of 1.84×10^4 CFU/mL of test solution.

The pH of the test solutions at the start ranged from 2.62 to 2.69 and it remained essentially unchanged even after 14 days of reuse. The H₂O₂ levels in the test solutions at the start of the experiment ranged from 6.25% to 6.39%; the levels dropped to 5.88% after 14 days of reuse. The test strips also showed the microbicide conc. to be in the acceptable range. As shown in Table 1, the tested formulation could reduce the titer of all the tested

organisms to undetectable levels in 20 min at 20°C.

Formulations derived from accelerated hydrogen peroxide (AHP), which is a patented technology, have demonstrated relatively rapid activity against all classes of human pathogens.^{20,21,22} In this study, ACCEL CS20, a 7% AHP-based solution was evaluated for 14-day reuse in the manual disinfection of medical devices. The product is registered with Health Canada as a medical device sterilant.

CORROSION TESTS AND DEVICE COMPATIBILITY STUDIES

The formulation's compatibility with metals (brass, copper, aluminum, mild steel and stainless steel) was assessed using coupons as given in ASTM International standards.^{23,24} In this method, the metal coupons were tested for the corrosion rate (miles per year). A 7% stabilized hydrogen peroxide solution (containing peroxide stabilizers and corrosion inhibitors) was tested as the control. Anodized aluminum parts were also soaked in the solution and were observed for the reaction of the solution with the coating. The samples were weighed before and after the exposure to the solution.

Table 1. Microbicidal activity of the stressed solution at 20°C.

Organism tested	CFU/control carrier	CFU/test carrier	Log10 reduction
20 minutes			
<i>B. subtilis</i> (spores)	1.12 x 10 ⁷	0	7.04
<i>C. sporogenes</i> (spores)	8.91 x 10 ⁶	0	6.94
<i>Mycobacterium terrae</i>	1.06 x 10 ⁶	0	6.03
<i>Trichophyton mentagrophytes</i> (conidia)	9.36 x 10 ⁵	0	5.97
10 minutes			
<i>Mycobacterium terrae</i>	4.50 x 10 ⁶	1	6.54
<i>Trichophyton mentagrophytes</i> (conidia)	1.02 x 10 ⁶	0	6.00
5 minutes			
<i>Mycobacterium terrae</i>	4.50 x 10 ⁶	1.96 x 10 ¹	5.40
<i>Trichophyton mentagrophytes</i> (conidia)	1.02 x 10 ⁶	0	6.00

Furthermore, materials compatibility test for plastics (high density polyethylene, low density poly ethylene, polypropylene, Teflon, acetal, polystyrene, polyacrylate, polycarbonate, acrylonitrile butadiene styrene, polyester, polyvinyl chloride, and polysulfone) was performed by immersing plastic panels in the test solution for one week. The weight change percent of each panel of the test solution was compared with that of the control (neutral detergent, a 0.05% of a non-ionic surfactant). Also, panels were checked for any visual damage. H₂O₂ levels and pH of the test solutions were also monitored during the test to

see whether peroxide reacts with the material.

PRODUCT STABILITY TESTING

Three lots of the product were tested for their stability at room temperature, for one-year period. The samples were tested for their peroxide concentration and pH before and after the test.

Results

Table 1 shows the microbicidal activity of Accel CS20 after 14 days of stressing.

These results show that Accel CS20 is a sporicide at 20 min contact time

at room temperature as a 14-day reuse solution.

Table 2 illustrates the compatibility of the test formulation against different metals. Based on these results, the test solution showed significantly less corrosion to soft metals than conventional H₂O₂ solutions with the same level of the active. Table 3 presents the weight loss for the plastics soaked in the test solution for one week at room temperature. No significant difference in the weight loss for the test solution and the control sample (soap solution) was observed.

Figure 1 and 2 show the H₂O₂ content and pH of the solution in a one-year period at room temperature. It is seen that peroxide content and pH of the solution remain almost unchanged.

DISCUSSION

The focus of this study was to assess the antimicrobial activity, stability and materials compatibility of a newly-developed AHP-based high-level disinfectant in simulated reuse conditions.

The test solution retained its sporicidal, mycobactericidal and fungicidal activities even after the 14-day simulated reuse period.

Of the 12 types of plastic tested, none was affected by a five-day exposure to the test formulation. No damage was caused to mild steel, stainless steel and anodized aluminum, with only a slight effect on aluminum, brass, and copper. We believe that such high materials' compatibility and the taming of corrosiveness of a strong oxidizer-based microbicide is a significant technological advance, which should allow its use with a variety of medical devices. The nearly 40 cycles of exposure of the respiratory therapy equipment to the test formulation during the 14-day stress did not result in any apparent damage.

The unique combination of ingredients not only accelerates the activity of H₂O₂, but also enhances its materials compatibility. The product is particularly suited for use on stainless steels, cold-rolled steels, aluminum, anodized aluminum, and even brass, copper or

chemically-resistant polymers or rubbers. Specific examples include medical and veterinary surgical tools (e.g., blades, pliers, or pins), certain rigid ophthalmologic and orthodontic instruments (e.g., tonometer tips, extraction tools, or drill bits), scissors, and respiratory accessories, such as respiratory masks, endotracheal tubes, tubing, and connectors. Non-clinical applications include soaking instruments used in tattoo parlors, medical spas, podiatry offices and home care services. Based on the oxidizing nature of H₂O₂, it is expected to be incompatible with some materials; although among tested items no compatibility issues were observed. Consequently, users are urged to investigate the composition of items to be disinfected in any peroxide-based formulation.

The AHP product tested in this study represents a recent development in the search for alternatives to aldehyde. Glutaraldehyde, OPA, traditional 7% H₂O₂ solutions and a combination of 7% H₂O₂ and 0.23% peracetic acid require contact times of 10, 32, 6 and 3 hours, respectively,⁷ while for sporicidal activity Accel CS20 requires only a contact time of 20 minutes. Accel CS20 contains only those ingredients that have a high safety and biodegradability profile and is also free from aquatic toxicants such as nonyl phenol ethoxylates (NPEs) or alkyl phenyl ethoxylates and does not contain volatile organic compounds. Based on its safe ingredients, it does not cause any environmental issues by entering into sewage or wastewater systems and easily breaks down into oxygen and water. Accel CS20 contains a combination of non-toxic and very effective surfactants, peroxide stabilizers, and corrosion inhibitors, which gives it both a remarkable cleaning activity and shelf-life stability. Also, as opposed to glutaraldehyde and OPA, Accel CS20 is not fixative.

In summary, the AHP-based formulation evaluated here remained a broad-spectrum and fast-acting microbicide even after 14 days of simulated reuse. Additionally, it also showed a high materials compatibility profile. Therefore, it represents a potential

alternative to currently used high-level disinfectants.

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Table 2. Metal corrosion rate at room temperature

Samples	Corrosion (Miles Per Year)			
	Brass	Aluminum	Mild steel	Copper
Accel CS20	6	4	0	13
Control solution*	208	5	0	156

*Control solution was a conventional 7% hydrogen peroxide solution containing corrosion inhibitors.

Table 3. Plastic corrosion test results

	Accel CS20	Neutral pH Soap
	Weight change%	Weight change%
LDPE	0.03%	0.26%
TEFLON	0.07%	0.16%
PP	0.04%	-0.07%
ACETAL	-0.40%	-0.37%
POLYSTYRENE	0.02%	-0.04%
POLY ACRYLATE	-0.60%	-0.63%
POLYCARBONATE	-0.17%	-0.23%
ABS	-0.26%	-0.38%
POLYESTER	-0.02%	-0.07%
PVC	0.03%	0.00%
POLYSULFONE	-0.38%	-0.43%

LDPE: Low density poly ethylene
 PP: Polypropylene
 ABS Acrylonitrile butadiene styrene
 PVC: Polyvinyl chloride

Figure 1. Hydrogen Peroxide stability of Accel CS20 samples at room temperature over one year

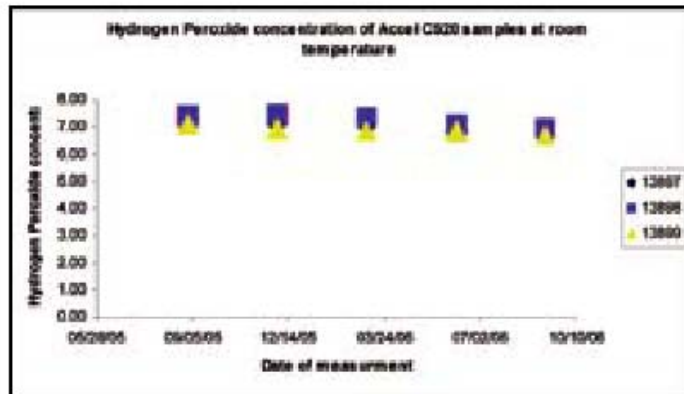
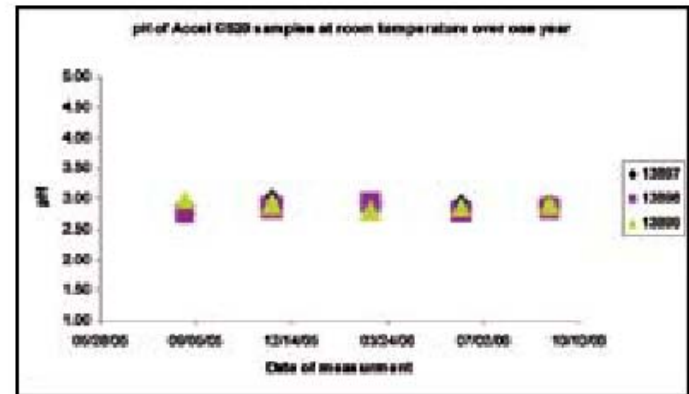


Figure 2. pH of Accel CS20 samples at room temperature over one year



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