Products based on accelerated and stabilized hydrogen peroxide:

Evidence for cleaning and sanitizing efficiency, environmental and human safety and non-corrosiveness

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Abstract

Introduction: Chemical germicides based on accelerated and stabilized hydrogen peroxide (ASHP) have been designed to meet requirements for increased effectiveness in both cleaning and disinfecting while delivering improved safety to the user and the environment. One such product has already been shown to be a broad-spectrum germicide when used undiluted, while retaining good general disinfection at a 1/16 dilution. A similar ready-to-use product is also available. Reported here are their profiles for cleaning and decontaminating efficiency, volatile organic compound (VOC) release, skin and eye irritation and corrosiveness, acute oral toxicity and metal corrosion.

Objective: The objective was to evaluate the cleaning and decontaminating efficiency, volatile organic compound release, eye and skin irritation and corrosiveness, acute oral toxicity and corrosiveness to various metals of ASHP products, in comparison with other common germicidal cleaners.

Materials and Methods: The evaluations were conducted on multiple samples by independent testing laboratories using standard test procedures. The ASHP formulation, either concentrated or at the working dilution, or both as appropriate, were compared with some commonly used germicides.

Results: ASHP products exceeded the Canadian General Standards Board (CAN/CGSB-2.160-95 in accordance with CAN/CGSB 2.11 Method 20.3) cleaning efficiency requirements. They reduced the initial numbers of *Pseudomonas aeruginosa* (ATCC 15442) by 99.999%, in the presence of 5% bovine serum and 200 ppm synthetic hard water in 30 seconds (Germicidal and Detergent Sanitizing Action of Disinfectants, Final Action AOAC XV, 1995, part 6.3.03). VOC levels in headspace tests were below detection limits. The undiluted ASHP product showed low corrosion effects on metals tested. At the recommended dilutions for use, ASHP products were non-irritating and non-corrosive to skin and eyes and non-toxic by the acute oral route.

Conclusion: ASHP products can provide excellent hard surface cleaning prior to decontamination and efficient sanitizing for bacteria on environmental surfaces. They do not contribute to indoor air pollution and they also possess excellent health and safety profiles in comparison with other commonly used germicides. Moreover, lack of toxic residues should ensure their environmental safety. As they have already been demonstrated to possess broad-spectrum activity against a variety of microorganisms in contact times relevant to field situations, properly formulated ASHP products offer a range of germicides appropriate for a variety of uses.

Key words: Hydrogen Peroxide, cleaning efficiency, decontamination, VOCs, corrosion, irritant, germicides

Introduction

Chemical cleaners and germicides are regularly used for environmental cleaning and decontamination in hospitals and many other settings. Currently, the products most commonly used for these purposes are based on quarternary ammonium chloride, chlorine or phenols. Available formulations based on all these chemicals suffer from deficiencies such as poor cleaning ability, the release of volatile organic compounds (VOCs) into indoor air, irritation to skin and eyes, corrosion to metals, potential harm to the environment, and impractical contact times for decontamination and disinfection.

Hydrogen peroxide has long been known for its low toxicity to humans and safety to the environment. Until recently, however, its relative instability and slow germicidal action precluded its consideration as a viable alternative in infection control. Currently, technology is available not only to produce highly stabilized solutions of hydrogen peroxide but also to accelerate its germicidal action (1). Formulations based on such accelerated and stabilized hydrogen peroxide (ASHP) show strong germicidal activity against a variety of important human pathogens (2). While crucial to disinfectant performance, germicidal activity is only one of the factors to consider in selecting products for infection control. The present communication describes the findings on the cleaning activity, human and environmental safety, as well as materials compatibility of ASHP formulations in relation to others commonly used in hospitals and other health care settings.

Objective

The objective was to evaluate the cleaning and decontaminating efficiency, VOC release, eye and skin irritation, oral toxicity and corrosiveness to various metals of accelerated and stabilized hydrogen peroxide products, in comparison with other common germicidal cleaners.

Materials and methods

The Products: Accelerated and stabilized hydrogen peroxide products are all lightly coloured solutions and have a faint odour. They can have a variety of hydrogen peroxide contents and pH values ranging from 1.27 to 5.0; those tested here were an undiluted product containing 7% hydrogen peroxide which is normally diluted 1/16 for use, and a ready-to-use product at 0.5% hydrogen peroxide. In addition, a 1/70 dilution was tested as a sanitizer. In addition to hydrogen peroxide, ASHP products contain organic and food grade acids, detergents and corrosion inhibitors. The excellent cleaning action of these formulations is based on the judicious selection of synergistic detergents.

The products for comparison are regularly used for cleaning and sanitation. For the decontamination (sanitizer) test, three separate quaternary ammonium-based compounds (denoted A, B, and C) and two phenolic-based compounds (denoted products D and E) were used. The pH values of the quaternary ammonium based products were all in the neutral range, 7 to 8.5, upon dilution, whereas one of the phenolic compounds had a pH of 2 to 3, and the other had a pH of approximately 10. All of these products varied in colour and odour. The bleach used in the cleaning efficiency and metal corrosion tests was a standard household product from a local grocery store. This product was colourless, with a strong odour. Where dilution was required, all of the above products were diluted with water having a standard hardness of 200 parts per million (ppm) as calcium carbonate.

Cleaning Efficiency Tests: These tests were carried out by Dell Tech Laboratories Ltd. (London, Ontario) using Method 20.3 (cleaning efficiency) of the Canadian General Standards Board (CAN/CGSB – 2.11). In this procedure, a synthetic soil consisting of brown iron oxide pigment, kerosene, stoddard solvent, white petroleum jelly, lubricating oil and shortening, is applied to white vinyl tiles. Two sets of soiled panels are checked using a 1% w/v standard detergent and 125 ppm hard water solution. The cleaning efficiency using 1% standard detergent should exceed 70% cleaning efficiency, whereas the hard water should be less than 35% cleaning efficiency. If the criteria given are not met in at least two of the three panels, then the test lot is rejected. The remaining panels are cleaned with 50 mL of 1:20 dilutions (or as identified) of the samples using the Gardner straight-line washability apparatus, and the cleaned substrates are evaluated using reflectance measurements. The cleaning efficiency is defined as the ratio of the measured reflectance after cleaning to the original reflectance, multiplied by 100.

ASHP products containing 0.5 % and 7% hydrogen peroxide were tested using this test procedure. The concentrated 7% hydrogen peroxide product was diluted by 1/16 in standard hard water, thus having a final hydrogen peroxide concentrated of approximately 0.5%. The cleaning efficiencies of these products are determined by calculating an average of 12 readings in three panels for each of the products at their recommended dilutions. For comparison, a quat, a phenolic detergent, and bleach were tested at their recommended dilutions.

Decontamination Capability Tests: Nucro-Technics Inc. (Scarborough, Ontario) conducted these tests using the method 'Germicidal and Detergent Sanitizing Action of Disinfectants' (Final Action) of AOAC International (XV, part 6.3.03, 1995). In this procedure, the test microorganism used is *Pseudomonas aeruginosa* (ATCC 15442). 99 mL of the germicide sample, appropriately diluted with 200 ppm synthetic hard water, is measured into each of two sterile Erlenmyer flasks (A and B). The flasks were placed in a constant temperature waterbath at 25°C and allowed to stabilize for greater than 20 minutes. 1 mL of the standardized microorganism suspension with 5% fetal bovine serum is then added to flask A and swirled. Exactly 30 and 60 seconds after the addition of the culture suspension, a 1 mL portion of the exposed culture is transferred into 9 mL of neutralizer and shaken. This mixture (10^{-1}) is then serially diluted with phosphate buffer dilution water, to offer dilutions of 10^{-2}, 10^{-3}, and 10^{-4}. 1 mL of each dilution (10^{-1} – 10^{-4}) is then transferred to four individual sterile Petri dishes containing the recovery medium. The agar is allowed to solidify, and the plates are then inverted and incubated for 48 hours at 35 °C before counting. The above procedure is repeated in flask B for each sample. Negative and positive controls are also performed. Each of the four plates per dilution is counted and averaged, and then the counts of the dilutions are averaged to determine the reduction of the viable cells at 30 and 60 seconds. The minimum result for standard effectiveness is a 99.999% reduction in viability count of test microorganisms within 30 seconds. Using this procedure, the ASHP products tested were the ready to use product containing 0.5% hydrogen peroxide and the concentrated 7% hydrogen peroxide product after a dilution of approximately 1/70 in standard hard water, thus having a final hydrogen peroxide concentration of 0.1%. For comparison, three quaternary ammonium-based compounds and two phenolic-based compounds were tested at their dilutions recommended for low level disinfection.

VOC Release Tests (Headspace Tests): Ortech Corporation (Mississauga, Ontario) conducted these tests using the Headspace Test developed by the Ortech corporation to calculate the concentration of gases released from environmental surfaces. Aliquots of 100 mL of product are placed in 940 mL containers that are sealed and allowed to sit for 30 minutes at room temperature. The headspace gases are then sampled with collection on a charcoal tube and subsequently analyzed using gas chromatography with a flame ionization detector (GC/FID). In this experiment the use of a well-known volatile organic chemical such as toluene as an internal standard, provides evidence for the presence of VOCs in the product tested. This VOC content can be determined if the product sample chromatogram exhibits a peak at the same retention time as toluene. If a peak is observed then a quantitative measurement is determined in toluene equivalents. If the product sample does not produce a peak at this retention time then this provides sufficient evidence for the absence of VOCs. The concentrated ASHP product was tested in comparison with a concentrated and a diluted quaternary ammonium-based product and a phenolic-based product.

Skin/Eye Irritation and Acute Oral Toxicity Tests: Nucro-Technics Inc. (Scarborough, Ontario) also evaluated the ready to use product for its acute toxicity for eyes and skin using the Modified Draze methods as described in OECD Guidelines for the Testing of Chemicals (Section 404 and 405, 1992). The acute oral toxicity of the ready to use product was also evaluated using the Limit Test as described in OECD Guidelines for the Testing of Chemicals (Section 401, 1981).

InVitro International (Irvine, California) evaluated the potential corrosivity of the concentrated ASHP product using the Corrositex® test method. This test is performed by applying the test sample to a synthetic biobarrier. When the chemical permeates through or destroys the full thickness of this biobarrier, it comes into contact with a chemical detection system, which then undergoes a simple color change. This color change is visually observed and the time required for the color change to occur is recorded. The time required to destroy the biobarrier is recorded for four sample replicates and the mean of these replicates is utilized to designate the corrosivity of the test sample. Positive and negative controls are analyzed concurrently to confirm the test's validity.

Comparison testing was not performed on competitive products, since adequate information about the acute toxicity of many products is available in the literature (3,4,5).

Metal Corrosion Tests: This test was carried out by Dell Tech Laboratories Ltd. (London, Ontario) using the NACE Standard (TM0169-76) for Laboratory Corrosion Testing of metals for the Process Industries. Weighed metal specimens are immersed in sample solutions at room temperature for 120.5 hours. After immersion, the metal specimen is chemically cleaned to remove any corrosion products. The corrosion rate is calculated assuming that all weight loss is due to general corrosion and not to localized corrosion. The corrosion rate is expressed in millimeters per year (mmpy). The concentrated ASHP product containing 7% hydrogen peroxide was tested using this method. Bleach (undiluted) was also tested for comparison.

Results

Cleaning Efficiency: As shown in Table 1, the 7% (diluted by 1:16) and the ready-to-use ASHP products offered high cleaning efficiencies of approximately 86.5%. Under the test conditions used, other commonly used germicides showed lesser cleaning efficiencies of 12.6% (Quaternary Ammonium Compound, 1:250), 11.3% (Bleach, 1:20) and 5.6% (phenolic detergent, 1:250).

Decontamination Capability: As shown in Table 2, 7% ASHP product (~ 1/70 or 56mL: 4L) and 0.5% ASHP product (ready-to-use), reduced the viability of *P. aeruginosa* by 99.999% in 30 seconds. The three neutral quats and two phenolic-based compounds, diluted as recommended by the manufacturer, all failed to reduce *P. aeruginosa* viability by 99.999% in 30 seconds. The ASHP and the comparative products were able to reduce *Staphylococcus aureus* and *Salmonella choleraesuis* by 99.999% in 30 seconds.

VOC Release: As shown in Table 3, the concentrated ASHP product tested released volatile organic chemical levels below the detectable limits of the method, 0.03 mg/m^3 toluene equivalents. A quat in its concentrated form released 350 mg/m^3 toluene equivalents and in its diluted form released 9.89 mg/m^3 toluene equivalents. The concentrated phenolic compound tested released even more VOC; 6000 mg/m^3 toluene equivalents.

Skin/Eye Irritation and Acute Oral Toxicity: As shown in Table 4, the 0.5% ready to use ASHP product proved to be non-corrosive and non-irritant to the skin and the eyes. It was also proven to be non-toxic by the acute oral route. The concentrated ASHP product was proven to be mildly corrosive.

Metal Corrosion: As shown in Table 5, the undiluted 7% ASHP product had a very low corrosion rate; 1.24 mmpy on aluminum, 0.01 mmpy on mild steel, and 0.00 mmpy on stainless steel. While bleach had corrosion rates which were significantly higher; 4.23 mmpy on aluminum, 5.62 mmpy on mild steel, and 0.12 mmpy on stainless steel.

Discussion

We have developed a range of ASHP products that can be used for a variety of cleaning and sanitizing tasks. The results reported here for two such products show superior cleaning efficiency in comparison to the tested quaternary ammonium-, phenolic-, and chlorine-based compounds that are commonly used in infection control today. While the ASHP products exceeded the level of 70% set as the acceptable limit by a testing standard in Canada (CAN/CGSB-2.160 in accordance with CAN/CGSB-2.11 method 20.3), the other products tested fell below this standard. The quaternary ammonium-, phenolic-, and chlorine-based products tested here yielded cleaning efficiencies of less than 15% at recommended use dilutions. The 7% and 0.5% ASHP products also showed superior sanitizing abilities when results with all three test bacteria are taken into account; they were not compromised in the presence of hard water and soil loading. This is perhaps not surprising in view of the broad spectrum of germicidal activity previously demonstrated in relatively short contact times (2).

ASHP products also did not contain any detectable VOCs. In contrast, a quaternary ammonium- and a phenolic-based compound released significant amounts of VOCs. VOCs can adversely affect indoor air quality, and the inhalation of air containing such compounds released by cleaning and disinfecting agents has been associated with allergies and occupational asthma (5). This freedom from VOCs has led to the certification of ASHP products by the Envirodesic™ program, as suitable where maximum indoor air quality is desired. This program has been created to encourage the general use of products, which do not contribute to lowering the quality of indoor air.

ASHP products have also proven to be relatively non-toxic as evidenced by the fact that they are non-corrosive and non-irritating to the skin and eyes at use dilutions, and are only mildly corrosive in the concentrated form. They have calculated oral LD50s in rats that range from 4,213 mg/Kg in the concentrated form to 12,200 mg/Kg in the ready to use form. The OECD Guidelines have also classified the ready to use ASHP product as "a compound that does not present a significant acute toxic risk if swallowed". In contrast, concentrated chlorine compounds have acute oral LD50 levels in rats of 256 mg/Kg to 1,640 mg/Kg (3). Concentrated quaternary ammonium compounds have calculated oral LD50 levels in rats of 1700mg/Kg (neutral quat, to be used at a dilution of 1/250) and 1150 mg/Kg (dual quat, to be used at a dilution of 1/250). It has also been determined that a 0.1% solution of a quaternary ammonium compound is the maximum concentration that would not produce a primary irritation on intact skin or act as a sensitizer (4). These compounds are also corrosive in concentrated solutions of 10% or more (5). Chlorine compounds are also classified as corrosive, and have been reported to cause such ill health effects as allergic contact dermatitis (5). Metal corrosion produced by the ASHP products tested was also very low. On the other hand, the bleach product produced a significantly higher amount of corrosion and pitting of the same metals.

The findings summarized here show that ASHP technology offers enhanced safety to the user as well as to the environment. In addition, they offer superior cleaning efficiency and a broad spectrum of germicidal activity in short contact times (2). The comparative data presented here should assist infection control practitioners in making informed choices in the purchase and use of chemical cleaners and germicides.

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Table 1. The Cleaning Efficiency of ASHP Products, a Neutral Quat, Bleach, a Phenolic Detergent, and Distilled Water.

Product	Recommended Dilution	% cleaning Efficiency
7% Accelerated hydrogen peroxide product	1:16	86.5 ± 10.2
0.5% Accelerated hydrogen peroxide product	Ready-to-Use	86.5 ± 10.2
Neutral Quat	1:250	12.6 ± 2.2
Bleach	1:20	11.3 ± 0.7
Phenolic Detergent	1:250	5.6 ± 1.4
Distilled Water	-	8.0

Table 2. The Decontamination Capability against Pseudomonas aeruginosa (ATCC 15442) of ASHP Products, three Neutral Quats, and two Phenolic Compounds.

Product	Dilution Tested	Initial Number o Microorganisms (per mL)	Count after 30 seconds of contact (per mL)	% reduction in after 30 seconds
7% ASHP*	56mL:4L	94,500,000	None detected	>99.999%
0.5% ASHP	Ready-to-Use	94,500,000	None detected	>99.999%
A	Quat 4mL:1L	94,500,000	>3,000,000	<96.825%
B	Quat 4mL:1L	94,500,000	>3,000,000	<96.825
C	Quat 1mL:128mL	94,500,000	36,300	99.962%
D	Phenol 4mL:1L	253,000,000	>3,000,000	<98.814%
E	Phenol 4mL:1L	253,000,000	>3,000,000	<98.814%

*This product was also tested at a 1/16 dilution in the presence of 50% bovine serum and 200ppm hard water at 20 °C. The % reduction of the organism after 30 seconds was 99.999%.

Table 3. The Amount of Volatile Organic Chemicals Released by ASHP Products, a Quaternary Ammonium Compound, and a Phenolic Compound.

Product	VOC in Headspace
7% accelerated hydrogen peroxide product (Concentrated)	Below detectable limits
Quaternary Ammonium Compound (Concentrated)	350 mg/m^3 toluene equivalents
Quaternary Ammonium Compound (Diluted)	9.89 mg/m^3 toluene equivalents
Phenolic Compound (Concentrated)	6000 mg/m^3 toluene equivalents

Table 4. The Skin and Eye Irritation and Corrosiveness and Acute Oral Toxicity of a 0.5% and a 7% Accelerated Hydrogen Peroxide Virox Product, Quaternary Ammonium Compounds and Phenolics.

Product	Acute Eye Irritation/Corrosion	Acute Dermal Irritation/Corrosion	Acute Oral LD_{50} rat
7% Accelerated Hydrogen Peroxide Product	N/A	Mildly Corrosive	4,213 mg/Kg
0.5% Accelerated Hydrogen Peroxide Product	Non-Corrosive Non-irritant	Non-Corrosive Non-irritant	12, 200 mg/Kg
Quaternary ammonium compounds	N/A	Irritant at concentrations >0.1% (5) Corrosive at concentrations >10% (5)	1700 mg/Kg (concentrated neutral quat) 1150 mg/Kg (concentrated ('ual quat)
Chlorine Compounds (concentrate)	N/A	Corrosive (5)	490 – 1,300 mg/Kg (3)

Table 5. The Corrosion Rate of Certain Metals Exposed to the concentrated ASHP Product and Undiluted Bleach.

Product	Metal	Corrosion Rate (mmpy)
7% Accelerated Hydrogen Peroxide Product (Undiluted)	Aluminum	1.24
	Mild Steel	0.01
	Stainless Steel	0.00
Bleach (Undiluted)	Aluminum	4.23
	Mild Steel	5.62
	Stainless Steel	0.12