Wiper Material Effect on Germicidal Efficacy of Disinfectant Solutions

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Abstract: The efficacy of germicidal agents is based upon a combination of contact time and active ingredient concentration. The manufacturer recommended contact times are based upon the efficacy of the material when the active ingredient is at end of shelf-life. What may be poorly understood in disinfection is that the method for disinfecting can have an impact on the active ingredient concentration. Depending on the germicidal agent's mechanism of action, certain environmental factors can effectively reduce or even neutralize the efficacy of the germicide. These environmental factors include reuse of solution and the materials the solution comes into contact with (including wipers). Oxidizing germicides, such as sodium hypochlorite, can be especially sensitive to organic material. Contamination of a bucket or tub with blood, such as occurs while cleaning up after a spill, can cause rapid degradation of the active ingredient. Use of organic-based wiper materials, such as cellulose towels (i.e. "paper" towels) can also cause the sodium hypochlorite concentration to degrade in minutes to levels that will be ineffective as a disinfectant.

Introduction: Healthcare today is facing serious challenges from pathogenic micro-organisms. Particularly contagious species that are a challenge to treat in the human body include methicillin-resistant *Staphylococcus aureus* (MRSA), Vancomycin- resistant *Enterococcus coli* (VRE), and the spore-forming *Clostridium difficile (C. diff.)*. While hand-hygiene practices remain important in reducing the cross-contamination of these organisms, environmental decontamination also plays a critical role[1]. The selection of appropriate disinfectants is a first step.

The CDC's 2008 Guideline for Healthcare Facilities[1] recommends disinfection in the hemodialysis unit with an EPA-registered disinfectant or a hypochlorite solution with 500-600 ppm free chlorine. For decontamination of rooms where *C. diff*. infected patients have stayed, the guideline[1] further recommends the use of hypochlorite of a minimum of 1,600 ppm free chlorine and cites efficacy of a 5000 ppm free chlorine solution with a contact time of up to 10 minutes to provide a 6-log reduction in *C. diff.* spores. OSHA regulations[2] on Blood-borne Pathogens specifies that "contaminated work surfaces shall be decontaminated with an appropriate disinfectant…" and letters of interpretation of this regulation[3,4] specify that an appropriate disinfectant would be one with tuberculocidal claims. EPA-registered disinfectants vary in their ability to achieve tuberculocidal efficacy. Low-level disinfectants are not generally tuberculocidal. Mid-to high level disinfectants will vary on the concentration and contact time required to achieve tuberculocidal efficacy. For example, an EPA-registered peracetic acid/hydrogen peroxide disinfectant[5] claims that 600 ppm peracetic acid for 10 minutes at room temperature will be effective, whereas EPA-registered sodium hypochlorite products[6,7,8,9] recommend a concentration of 10,000 ppm free chlorine for 5 minutes of contact time at room temperature.

Common hospital disinfectants include alcohols, quaternary ammonium compounds, phenols, chlorine compounds, peroxides, and

peroxy acids. While alcohols, quaternary ammonium compounds and phenols are relatively effective against vegetative bacteria (such as MRSA and VRE), they are ineffective against spore-forming bacteria, such as *C. diff.* Chlorines, peroxides, and peroxy acids are effective against spore-forming bacteria. Selection of a method to employ these disinfectants is a critical next step.

Sodium hypochlorite products with EPA-registered claims[6,7,8,9] for hard surface disinfection instruct the user to prepare a solution with 2700 ppm and ensure that the surface remains wet for 5 minutes. For tuberculocidal activity, the recommendation is 5000 ppm chlorine for 5 minutes. Typical germicidal or ultra bleaches are supplied as ~6% active chlorine. To obtain a level of 2700 ppm chlorine, a 4.5% commercial bleach solution is needed. To obtain a level of 5000 ppm chlorine, an 8% commercial bleach solution is needed. CDC recommends a minimum of a 1% commercial bleach solution, which would provide ~600 ppm chlorine. The CDC recommends using manufacturer's recommended contact times. EPA-registered sodium hypochlorite products[6,7,8,9] recommend contact times of 10 to 15 minutes at this level (500-600 ppm) to ensure disinfection of vegetative bacteria, such as *Staphylococcus aureus*. This indicates the critical connection between concentration of active ingredient and efficacy. As the concentration decreases, longer contact times are required for adequate disinfection. If staff do not have the time to ensure surfaces remain wet for 10-15 minutes, they need to be aware of the concentrations that they are using.

Sodium hypochlorite and hydrogen peroxide are both vulnerable to degradation by organic materials. These include complex carbohydrate materials, such as cellulose, and protein materials, such as blood proteins. EPA-registered sodium hypochlorite products instruct the user to pre-clean surfaces of all soil and organic material before disinfection. Reusing an open bucket of disinfectant may pose serious infection control problems. Even small levels of contamination can cause the breakdown of sodium hypochlorite. Using open buckets with paper towels or even higher level wiper materials containing cellulose will greatly affect the stability of the sodium hypochlorite within the bucket and the portion of the solution that is transferred to the surface that is to be disinfected.

Experiments in literature demonstrated a 5 log reduction in *Staphylococcus aureus* with 400 ppm sodium hypochlorite in suspension at 60 minutes of contact time[10]. This dropped to a 1 log reduction with 500 ppm sodium hypochlorite at 60 minutes of contact time in the presence of organic washcloths[10]. These experiments also demonstrated up to a 4-log reduction of organisms on cloth using a 2,400 ppm hypochlorite solution for at least 15 minutes of contact time[10]. Bloomfeld and Miller demonstrated the effect of plasma and blood on the efficacy of sodium hypochlorite[11], showing that as little as 10% blood could reduce the efficacy of a 10,000 ppm (~20% commercial bleach) from a 6-log reduction of *Staphylococcus aureus* in 5 minutes under clean conditions to barely a 3 log reduction of the organism in 10 minutes with as little as 10% blood contamination in the disinfectant solution.

Peroxy acids, such as peracetic acid, have an advantage in the form of equilibrium. The components of the solution, hydrogen peroxide, acetic acid, and peracetic acid, exist in a chemical equilibrium. Thus, as peracetic acid reacts with organic materials, it breaks down into acetic acid and hydrogen peroxide. The loss of the peracetic acid causes a shift in the equilibrium, leading to the reaction of the hydrogen peroxide and the acetic acid to form new peracetic acid. These reactions are constantly occurring in disinfectant solutions of this type. Eventually even these equilibrium solutions will be overwhelmed by large amounts of organic material, but they will remain stable for a much longer period of time relative to solutions containing only hydrogen peroxide or only sodium hypochlorite.

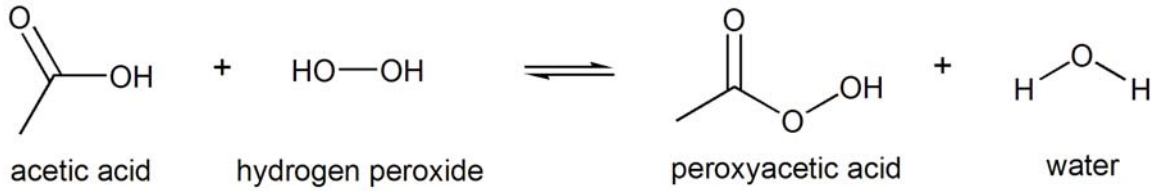

Figure 1: Equilibrium equation for peracetic acid

The reports on the cost of hospital acquired infections (HAIs) are astounding, both in terms of casualty and financial impact. CDC[12] reports in March of 2000 that nearly $5 billion are added to U.S. healthcare costs every year due to HAIs. CDC also estimates that close to 88,000 patients die as a direct or indirect cause of the infection. Prolonged bloodstream infections can cost more than $50,000 per patient episode[12]. The Boston Globe reported a cost to Massachusetts hospitals alone of $473 million annually due to HAIs[13] also citing that a single ventilator-associated pneumonia case can cost up to $30,000. Hollenbeak[14] reports estimates of up to 100,000 deaths a year and cites a study demonstrating a net loss of reimbursement margin due to HAIs of $286 million annually. The Association for Professionals in Infection Control and Epidemiology, Inc. (APIC) recently released the findings of a national survey dealing with just one type of HAI- specifically *C. diff.* infections[15]. This study revealed an estimated 300 person mortality per day for the United States and an average cost of $32.1 million per day with U.S. hospitals due to increased costs associated with *C. diff.* infections alone.

As cost-effective as the bucket and rag method appears to be at first, it leads to significant costs in treating hospital acquired infections (HAIs) when the efficacy of the disinfectant has dropped below effective levels. Because these solutions are not tested continuously, if at all, users are unaware of the risks.

Pre-moistened towelettes are convenient, though they are often much more expensive. The solution may lie between these extremes. Dry rolls of wiper materials that have been carefully selected for compatibility with disinfectants will allow flexibility of choice while providing ease of use and portability.

Experimental Design:

A series of experiments were designed to demonstrate the effect of wiper materials on disinfectants. Initial experiments focused on sodium hypochlorite, as this was deemed most vulnerable to organic load.

1. Wiper material effect on sodium hypochlorite concentration in small volumes

Disposable wipers of a variety of materials were selected. These included: Hydroknit (a polypropylene-cellulose blend), Spunlace (A Rayon-polyester blend), melt-blown polypropylene, and paper towels (cellulose). A stock solution was prepared by diluting commercial bleach with DI water to prepare a solution of ~1% bleach. This stock solution was analyzed by titration of the chlorine concentration before and after using it. The entire experiment took less than 2 hours. 10 ml of solution was added to one wipe of each material. The wipes were of approximately the same size. Immediately after adding the solution to the wipe, a liquid sample was manually extracted by the process of wringing the wiper material. The total contact time with the wipe was ≤ 10 seconds. The extracted solution was analyzed for chlorine concentration within 2 minutes. This was repeated three times per wiper material to calculate an average value of chlorine concentration after exposure to the wipe.

2. Wiper material effect on sodium hypochlorite concentration in large volumes

Due to the results of the previous experiment, the worst case wiper material was selected. This was also believed to be the

most common type of wiper material in use in healthcare facilities today. Soft 'N Fresh (bonded cellulose) wipers were used for this experiment, because they are a brand used in healthcare. Four 3L batches of 1% bleach were prepared using commercially available bleach and diluting with DI water. The chlorine content was analyzed by titration immediately after preparation. One batch was reserved as a control and stored at room temperature in an open bucket. To the other three batches were added 5, 10, and 15 wipers, respectively. The chlorine concentration was analyzed periodically throughout the experiment from samples removed from the solution in the bucket. This experiment was designed to mimic the working condition of a fresh solution prepared at the start of the day, with wipers added to the bucket. The results were charted to show degradation over time. The experiment was completed within 8 hours, or a typical working shift.

3. Wiper material with sodium hypochlorite compatibility

In order to demonstrate that not all wiper materials will cause active ingredient degradation in disinfectants, two experiments were conducted using two non-organic wiper materials. In one experiment rolls of polyester wipers measuring 7" by 10", 100 count were used. Early experiments showed that a quart of solution was sufficient to wet out the rolls. In a second experiment, rolls of wettable polypropylene wipers measuring 7" by 10", 150 count were used. Three disinfectant solutions were also used with each type of wiper material. Actril Cold Sterilant, a peracetic acid and hydrogen peroxide disinfectant with EPA approval; CleanCide, a citric acid based disinfectant with EPA approval; and Clorox bleach, a sodium hypochlorite based disinfectant prepared by label directions to a 1% solution using DI water. For each disinfectant, two rolls in dispensing canisters were used. To one roll,950 ml (~1 quart) of disinfectant use solution was added. To the second roll, 700 ml (worst case if customer adds less than one quart) was added. A small bottle of solution used to wet out the rolls was maintained in a closed container to serve as a control in the event that the solution may have become contaminated in some way that would cause degradation, even without the presence of the wipes. Immediately after adding solution to the roll and periodically over the next 14 days, wipes were removed from the canister dispenser and a liquid sample was mechanically extracted from the wipes. This liquid sample, as well as the reserved control, was analyzed for active ingredient concentration. Actril Cold Sterilant was analyzed for peracetic acid, CleanCide was analyzed for citric acid, and the bleach samples were analyzed for the active chlorine concentration. The samples were charted to show degradation over time of storage.

Results:

Experiment 1: A dramatic difference in the chlorine content of the liquid mechanically extracted from the wipers was observed between different materials; the larger the organic content of the wiper, the greater the effect on the concentration of a small volume of liquid. 10ml were used for each wipe and repeated three times for an average value. 10ml was more than sufficient to saturate the wiper. The contact with the wiper was less than 30 seconds. This would mimic the effect of dunking a dry wiper into a bucket of disinfectant, squeezing excess fluid from it, and then using the wiper to transport the disinfectant to a surface.

The chart below shows the chlorine content of the liquid extracted from the wipe, compared with the measured chlorine of the solution used to wet the wipes.

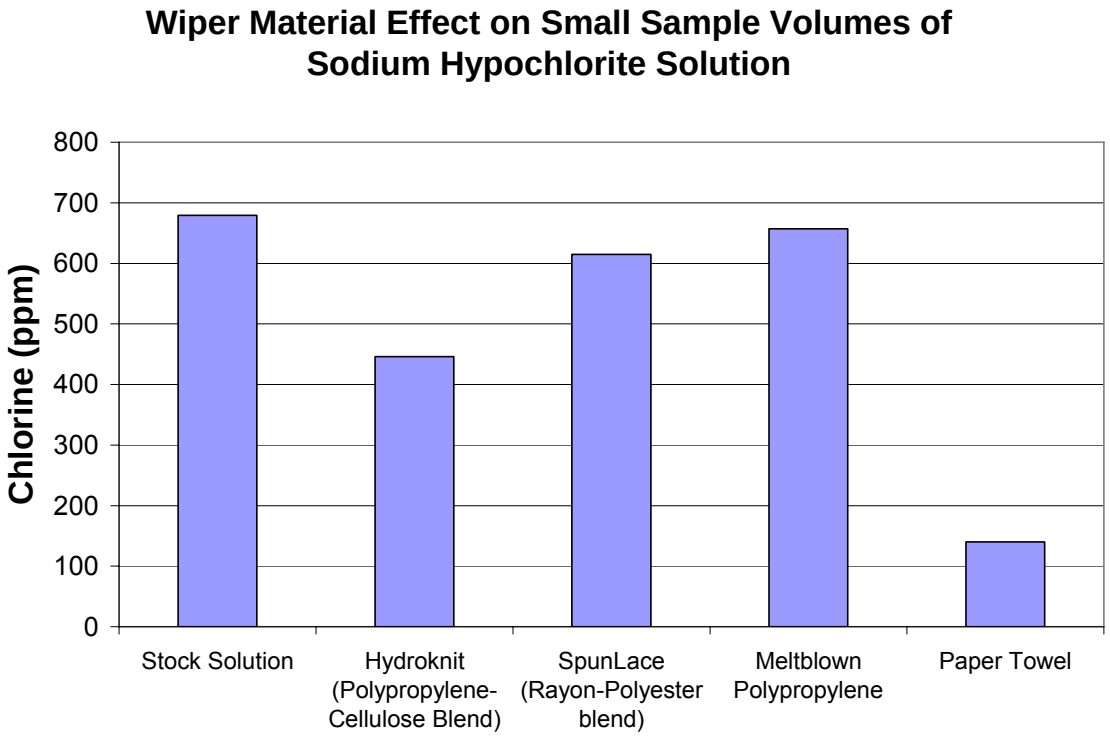

Chart 1

As noted in chart 1, above, the liquid in contact with paper towel only retained 20% of the concentration of active ingredient when it was extracted. The chlorine content was reduced by 80%, to a level unlikely to be effective as a disinfectant in normal use in less than 30 seconds of contact with the paper towel. In contrast, the meltblown polypropylene, a non-organic wiper material, retained 97% of the active ingredient concentration.

Experiment 2:
The number of wipers added to each 3L bucket dramatically affected the stability of the active ingredient within the bucket sample. Over the course of seven hours, less than one typical working shift, the chlorine concentration dropped noticeably with a correlation to the number of towels added to the volume. Chart 2 demonstrates the change in chlorine concentration over time in each of the samples.

Wiper Material Effect on Large Volumes of Sodium Hypochlorite Solution

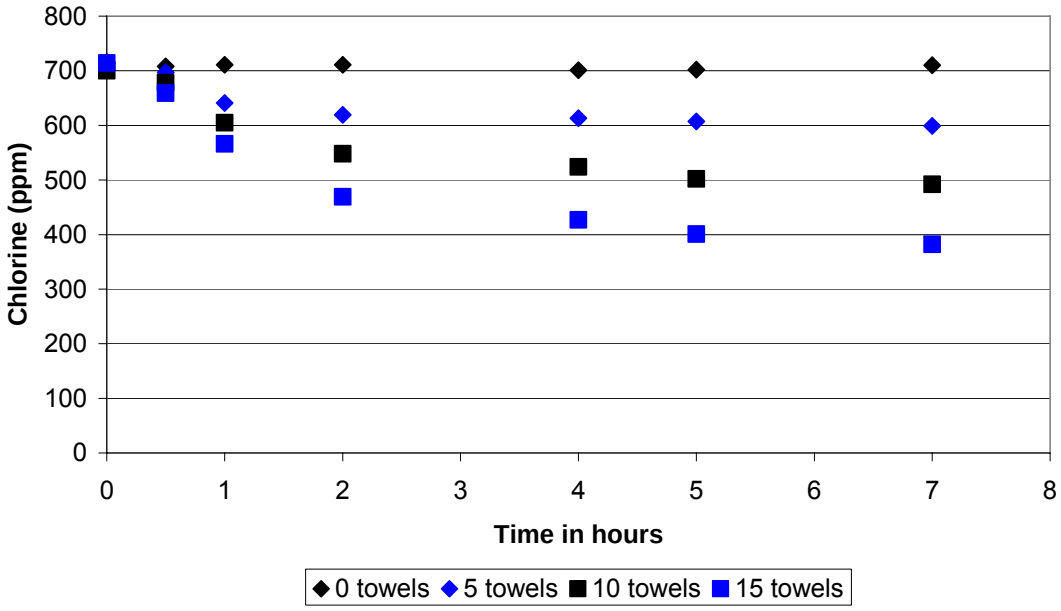

Chart 2

As noted in chart 2, samples with towels in the bucket began losing active ingredient almost immediately. By the end of 7 hours, the samples with 5, 10, and 15 towels lost 16%, 30%, and 47% of the active ingredient concentration, respectively. These results do not take into consideration any effect that might occur due to contamination of the solution through reuse of the wipers or dirty hands/gloves.

Experiment 3:
By contrast to the previous experiments, it is possible to store disinfectants with appropriately selected wiper material for up to a week or more without losing significant active ingredient. This experiment followed three types of disinfectant with both polyester and polypropylene wipers. The peracetic acid product had a minimum recommended concentration of 500 ppm. The citric acid product had a minimum recommended concentration of 0.6%. The bleach showed a maximum of 18% decrease in active ingredient concentration over 14 days of storage in contact with the wiper material.

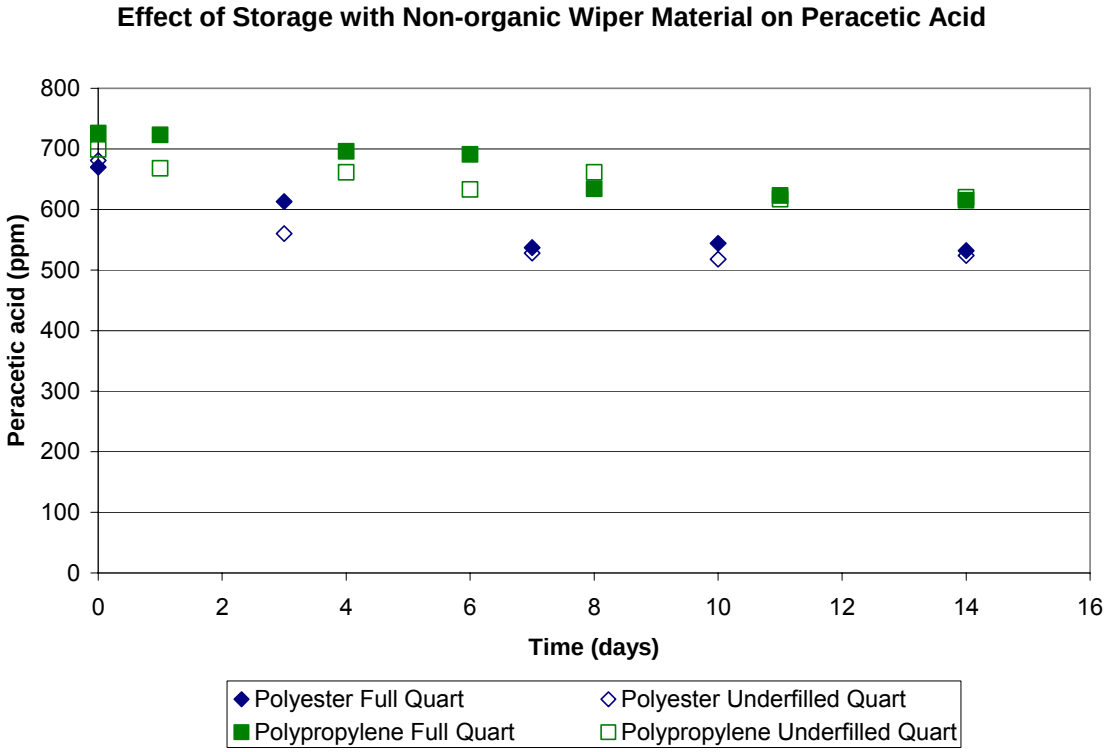

Chart 3

Chart 3 demonstrates that the peracetic acid concentration remained above the minimum recommended concentration (500 ppm) throughout the experiment. A user could load the roll of wipes and still be confident of the chemical efficacy after up to 2 weeks of storage.

Chart 4, below, demonstrates that the citric acid concentration remained above the minimum recommended concentration (0.6%) throughout the experiment. Again, a user could load the roll of wipes and be confident about the chemical efficacy for up to 2 weeks of storage.

Chart 5, below, demonstrates that the bleach concentration remained significantly more stable in contact with these non-organic wiper materials than with the organic-based wipers used in the previous experiments. In Chart 5, the worst drop was 18% of active ingredient over the course of 2 weeks. A user could load a roll of wipes and be confident in the efficacy of the active ingredient for a minimum of one week.

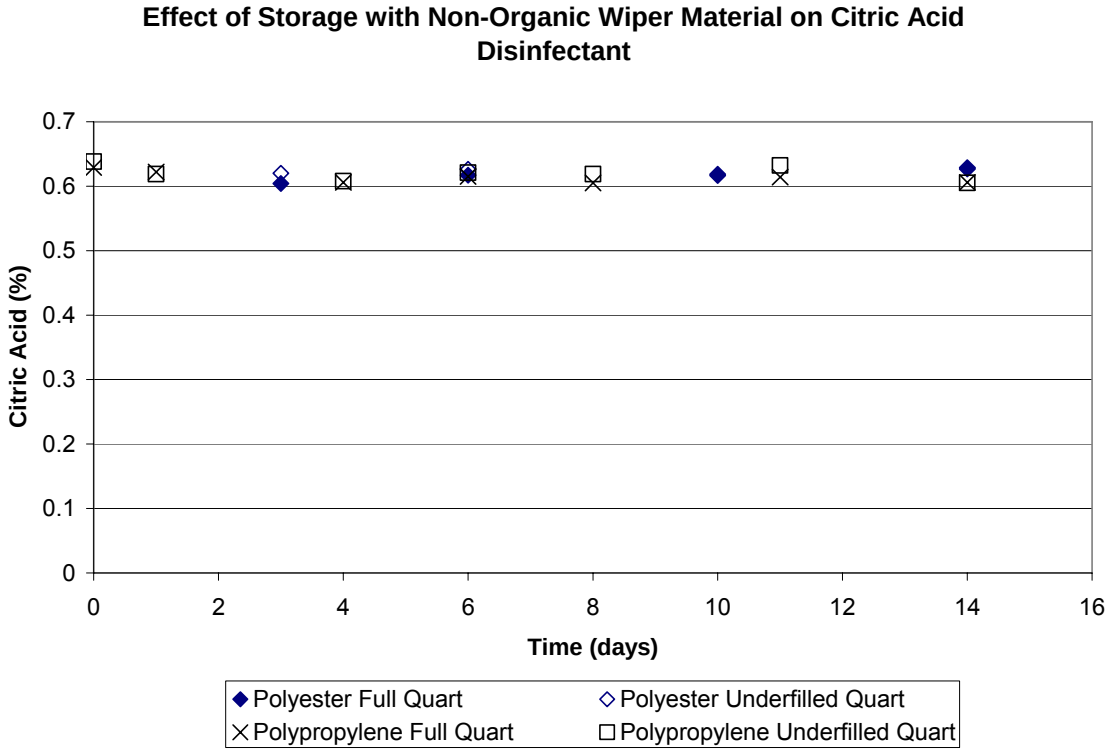

Chart 4

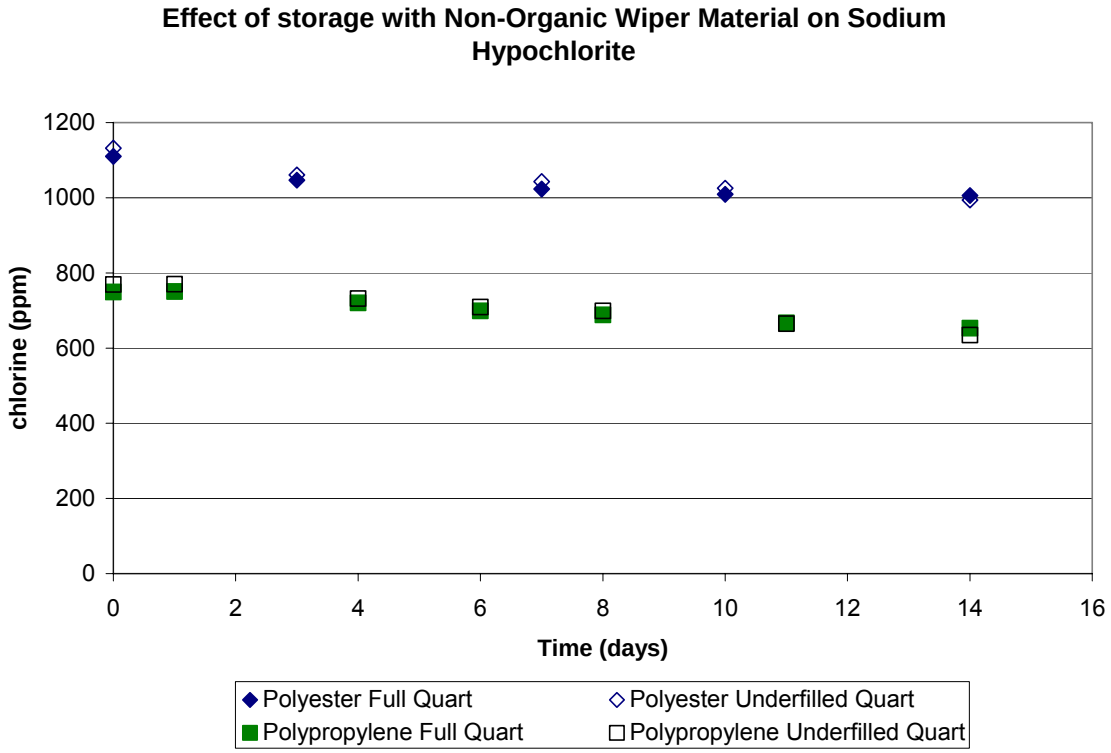

Chart 5

Discussion:

It is well known in the healthcare industry that chemical disinfectants need to have a minimum level of active ingredient to function effectively. It may be less obvious what factors can affect the concentration of that active ingredient. This principle seems simple until it is viewed with more detail. It is no longer acceptable to claim that "a chemical is a chemical, no matter how it is used." Disinfectant manufacturers expect users to employ their products in an effective manner. Users need to understand that choices, sometimes as simple as which wiper material to use, can dramatically affect the active ingredient, and by extension the disinfectant efficacy. If a disinfectant, such as sodium hypochlorite, can be expected to have a certain level of efficacy at 500-600 ppm, it cannot be held to the same standard at a fraction of that level. User awareness of these issues can help them make strong choices- choices that will contribute to effective cleaning and disinfection, rather than choices that diminish the value of the work they are already putting into their activities every day. It doesn't help the healthcare industry to save pennies per roll buying inexpensive wipers to apply disinfectant if it leads to having an ineffective level of disinfectant. Instead of being faced with the extra dollars in cleaning supplies, healthcare will be faced with the extra thousands of dollars treating infections that might otherwise be prevented.

References:

1. Rutala, W., Weber, D., and HICPAC, Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008, CDC
2. OSHA: Bloodborne Pathogens, 29CFR 1910.1030
3. OSHA: 01/26/1993: Registration of Sterilants, Tuberculocidal Disinfectants, and anti-microbial products
4. OSHA: 02/28/1997: EPA-Registered Disinfectants for HIV/HBV
5. EPA Approved Product Label Product Registration 52252-7
6. EPA Approved Product Label Product Registration 1672-65
7. EPA Approved Product Label Product Registration 5813-1
8. EPA Approved Product Label Product Registration 5813-50
9. EPA Approved Product Label Product Registration 9616-13
10. Kusumaningrum, H. D., Paltinaite, R., Koomen, A.J., Hazeleger, W. C., Rombouts, F. M., and Beumer, R. R., " Tolerance of *Salmonella* Enteritidis and *Staphyloccocus aureus* to Surface Cleaning and Household Bleach", *Journal of Food Protection* 2003; 66(12): 2289-2295.
11. Bloomfield, S. F. and Miller, E. A. "A Comparison of Hypochlorite and Phenolic Disinfectants for Disinfection of Clean and Soiled Surfaces and Blood Spillages," *Journal of Hospital Infection* 1989; 13: 231-239.
12. CDC Media Relations, "Hospital Infections Cost U. S. Billions of Dollars Annually," March 6, 2000, accessed by www.cdc.gov/od/oc/media/pressrel/r2k0306b.htm on February 10, 2009.
13. Smith, Stephen, "Hospital Infection May Cost $473M," *Boston Globe*, August 9, 2007, accessed by www.boston.com/news/local/articles/2007/08/09/hospital_infection_may_cost_473m/ accessed on February 10, 2009.
14. Hollenbeak, Christopher, "Dispelling the Myths: The True Cost of Healthcare-Associated Infections," *Healthcare Financial Management* March 2007, accessed by http://findarticles.com/p/articles/mi_m3257/is_3_61/ai_n18764839 Accessed on February 10, 2009.
15. The Association for Professionals in Infection Control and Epidemiology, Inc. (APIC) "National Prevalence Study of *Clostridium difficile* in U. S. Healthcare Facilities: Overview and Key Findings," Released November 11, 2008.