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Brief Report

Novel color additive for chlorine disinfectants corrects deficiencies in spray surface coverage and wet-contact time and checks for correct chlorine concentration

Kevin Tyan BA [a,*], Katherine Jin BA [a], Jason Kang BSc [a], Aaron M. Kyle PhD [b]

[a] Kinnos Inc., Brooklyn, NY
[b] Department of Biomedical Engineering, Columbia University, New York, NY

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Bleach sprays suffer from poor surface coverage, dry out before reaching proper contact time, and can be inadvertently over-diluted to ineffective concentrations. Highlight®, a novel color additive for bleach that fades to indicate elapsed contact time, maintained >99.9% surface coverage over full contact time and checked for correct chlorine concentration.

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BACKGROUND

To be fully effective for surface decontamination, liquid disinfectants such as bleach must be used in accordance with label claims and instructions.[1,2] For example, to achieve high-level disinfection against common nosocomial pathogens, 0.5% sodium hypochlorite must fully cover a surface and maintain wet contact for 2-10 minutes, depending on the target pathogen.[1] In practice, however, inherent flaws and human error prevent disinfectants from being used effectively.[3] Bleach solutions form small droplets and cannot spread uniformly across hydrophobic surfaces; consequently, they may not come into contact with target microorganisms.[4,5] This is exacerbated on vertical surfaces where sprayed bleach runs off or evaporates without maintaining full coverage or contact time. Furthermore, liquid disinfectants may dry on surfaces in 1.5-2 minutes, falling short of recommended contact times.[2] Finally, routinely diluting bleach from concentrate introduces the potential for over-dilution.[3,6] A recent disinfectant study found that deviating below either label use contact times or concentrations resulted in significantly reduced bactericidal efficacy.[7]

A novel chemical additive, Highlight® (Kinnos, Brooklyn, New York), colorizes chlorine disinfectants blue to visualize sprayed regions, reduces droplet formation and surface tension to maintain full surface coverage over time, and fades to transparency to indicate when contact time has been met. One Highlight® formula designed for 0.5% sodium hypochlorite bleach is stably colored blue in containment for 5-6 hours and fades in precisely 5 minutes when sprayed on a surface. This precise fading time of Highlight® additionally serves to calibrate the bleach solution, since a deviation from the expected fading time indicates that an incorrect concentration of sodium hypochlorite was used.[3]

Few studies have quantified the surface area covered by a sprayed disinfectant and whether wet-contact time is properly maintained. In this study, we compared the spray coverage over time of standard bleach to Highlight®-enhanced bleach and characterized how the fading time of Highlight® changes based on chlorine concentration.

MATERIALS AND METHODS

To quantify surface coverage over time of bleach (CONTROL) versus Highlight®-enhanced bleach (HLT), we sprayed a vertical surface and performed image analysis over a 15-minute period. The density, surface tension, and wetting properties of water and 0.5% sodium hypochlorite bleach are nearly identical.[8,9] Therefore, water was used as the proxy diluent for both CONTROL and HLT, since the presence of chlorine initiates the color-fading reaction in Highlight® and interferes with image analysis. Squares of polypropylene Tychem QC material (DuPont, Wilmington, Delaware) measuring

* Address correspondence to Kevin Tyan, BA, Kinnos Inc., 760 Parkside Ave, Suite 215, Brooklyn, NY 11226.
E-mail address: kevin@kinnos.us (K. Tyan).

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Conflicts of interest: KT, KJ, and JK are founders and shareholders of Kinnos Inc. and have patents pending on the Highlight® technology. AMK declares no conflicts of interest relevant to this article.

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20 cm x 20 cm were mounted on a flat vertical surface. One-percent indigo carmine dye (VWR, Radnor, Pennsylvania) diluted in distilled water was prepared as CONTROL. Highlight® was dissolved in distilled water to create HLT. Forty mL of HLT or CONTROL was sprayed from a 10 cm distance at a rate of 4 mL/sec onto the Tychem square, from top to bottom. Based on the contact time of 10 minutes typically being the longest prescribed for bleach disinfection, we chose a testing time of 15 minutes to provide a suitable buffer and videorecorded each test.[1] Pixel analysis was performed on images from each minute using MATLAB R2015a software. Blue color intensity of each pixel in the sprayed Tychem square was measured, and pixels were defined as "covered" if blue intensity was greater than unsprayed Tychem baseline color intensity. Percentage of surface area coverage was calculated by the number of covered pixels divided by the total number of pixels. To verify results of the water proxy for standard bleach, we repeated this experiment with 1% indigo carmine dye in 40 mL of "Regular Bleach" and "Germicidal Bleach" (Clorox, Oakland, California) diluted to 0.5% hypochlorite concentration. We additionally tested 2 hospital-grade, ready-to-use (RTU) sprays not requiring dilution: Clorox "Healthcare Bleach Germicidal Cleaner" and "Bleach-Rite Disinfecting Spray" (Current Technologies, Crawfordsville, Indiana). A shorter observation period of 5 minutes was chosen to prevent interference of image analysis due to the dye-fading reaction.

Highlight® formula designed to fade in 5 minutes in 0.5% sodium hypochlorite bleach was tested in varying concentrations of sodium hypochlorite (0.05%, 0.25%, 0.4%, 0.6%, 1%, and 5%) to simulate incorrect dilution by an end-user. Two hundred mL of each solution was prepared by diluting "Regular-Bleach" in distilled water and adding Highlight®. Forty mL of each solution was sprayed from a distance of 10 cm and at a rate of 4 mL/sec onto 20 cm x 20 cm Tychem QC squares mounted on a flat vertical surface, using a top-to-bottom spray pattern. The time elapsed for sprayed surfaces to fully fade from blue to colorless was visually assessed.

All experiments were performed in triplicate. Student's t-test was used to analyze coverage data, and a 1-way analysis of variance test was used to compare fading times.

RESULTS

Figure 1 shows a comparison between the spray coverages of CONTROL and HLT over 15 minutes. Surface coverage of CONTROL significantly decreased over time ($P = .0003$), covering (mean ± standard error [SE]) 32.61% ± 4.32% of the surface area on initial spray before decreasing to 14.80% ± 1.85% after 15 minutes. For HLT, no statistically significant change ($P > .1$) was observed in surface coverage after 15 minutes, with initial coverage of 99.97% ± 0.02% and final coverage of 99.95% ± 0.03%. Figure 2 shows the initial and 5-minute spray coverages of 4 commercial bleach products. The initial spray coverages of "Regular Bleach" and "Germicidal Bleach" were 35.02% ± 1.51% and 33.78% ± 0.64%, respectively, and were not significantly different compared to CONTROL ($P > .5$). Of the RTU bleach products tested, "Bleach-Rite Disinfecting Spray" initially covered 38.11% ± 3.06% of the surface, whereas Clorox "Healthcare Bleach Germicidal Cleaner" demonstrated 99.98% ± 0.02% initial spray coverage.

Figure 3 shows the fading times of Highlight® at different concentrations of bleach. In 0.25%, 0.4%, 0.6%, 1%, and 5% sodium hypochlorite, color faded in (mean ± SE) 16.17 ± 0.60 minutes, 9.42 ± 0.36 minutes, 4.17 ± 0.13 minutes, 2.44 ± 0.06 minutes, and 1.00 ± 0.04 minutes, respectively. In 0.05% sodium hypochlorite, color did not fully fade before the solution dried. In 0.5% sodium hypochlorite, color faded in 5.05 ± 0.10 minutes. A significant difference was observed in fading times across all concentrations of bleach ($P < .0001$).

DISCUSSION

Inadequate application of disinfectants is a major problem in healthcare, biosafety, and epidemic response. While surface cleaning has been shown to reduce healthcare-associated infections, studies have revealed that <50% of near-patient surfaces are cleaned effectively.[10,11] Liquid disinfectants such as bleach sprays are flawed and prone to user error, preventing effective usage.

Using a proxy solution, we demonstrated that typical bleach sprays initially cover <33% of the surface before falling to <15% after 15 minutes, because of run-off and evaporation. Poor spray coverage was likely due to the lack of surfactants that results in uneven spreading and droplet formation.[4,5] We observed similarly poor initial spray coverage for "Regular Bleach" and "Germicidal Bleach," thus verifying the proxy solution results. Even a hospital-grade RTU cleaner, "Bleach-Rite," only covered <40% of the surface. This performance is concerning, given that bleach is considered one of the most viable options for resilient pathogens like *Clostridium difficile*.[4]

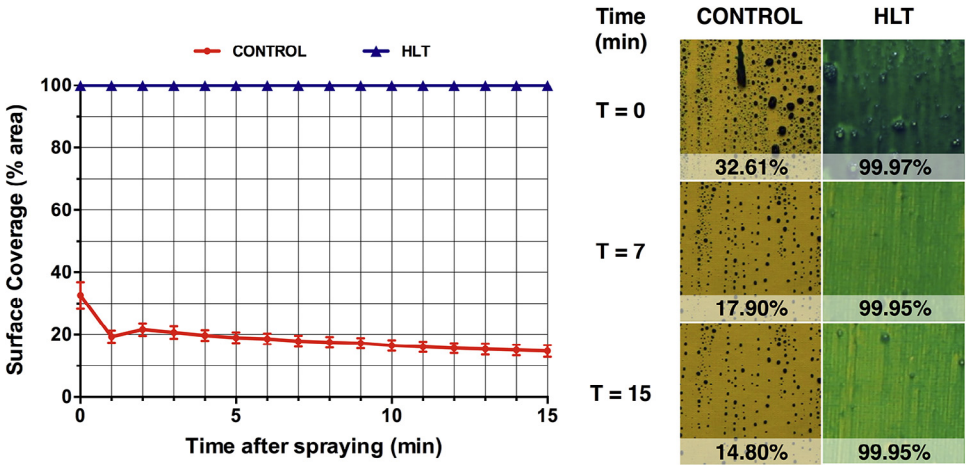

Fig 1. Percentage of surface area covered by CONTROL versus HLT solutions when sprayed on Tychem QC and left for 15 minutes. Error bars show standard error. Error bars for all HLT data points are too small to represent on the graph. Tests were performed in triplicate. Representative images of CONTROL versus HLT sprayed on surfaces at 0, 7, and 15 minutes are shown to the right, with corresponding surface area coverage values. The images of 0, 7, and 15 minutes were chosen to show the surface coverage appearance at the beginning, midpoint, and endpoint of the tests.

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