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Short report

Novel colour additive for bleach disinfectant wipes reduces corrosive damage on stainless steel

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SUMMARY

Bleach disinfectant wipes are corrosive to hospital surfaces and equipment. This study measured the effect of two widely used bleach wipes, with and without Highlight® colour additive, on stainless steel to quantify the rate of corrosion and to determine the effect of Highlight® on reducing surface damage caused by bleach wipes. The two bleach wipes alone caused severe corrosion [>5 mils per year (mpy), where 1 mil = 0.001 inch], while the addition of Highlight® reduced the rate of corrosion significantly (<2 mpy) and prevented discolouration of the metal. These results indicate that Highlight® reduces the deleterious corrosive effects of bleach wipes, thus improving their viability for cleaning healthcare surfaces.

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Introduction

Ready-to-use bleach disinfectant wipes are frequently used for hospital environmental cleaning, and their implementation has been associated with decreased surface contamination and reduced healthcare-associated infections [1]. However, improper usage of these wipes compromises their efficacy, with reports of personnel not wiping surfaces fully, using insufficient wipes per room, or drying off wiped surfaces before the requisite wet-contact time [2]. A novel attachment to bleach wipe containers, Highlight® Wipes Lid (Kinnos, Brooklyn, NY, USA), was developed to improve compliance and thoroughness of cleaning by imbuing blue colour on to dispensed bleach wipes

that visibly indicates coverage and fades away once a designated contact time has elapsed.

However, the corrosiveness of sodium hypochlorite remains a significant shortfall of bleach wipes. Bleach damages hospital furniture and equipment, especially stainless steel, resulting in increased costs due to repair and replacement [3–5]. This presents a challenge to the constant need to disinfect surfaces, as surface damage tends to attract additional soil and retain increased bacteria [6]. Although the corrosion of medical instruments by liquid bleach has been well documented, there is no extensive research on the surface corrosiveness of bleach disinfectant wipes [5].

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This study investigated the corrosive effects of commonly used bleach wipes on stainless steel, and the effect of the Highlight® colour additive on reducing bleach wipe corrosion.

Methods

Two bleach wipes were evaluated: Clorox Healthcare Bleach Germicidal Wipes (0.55% sodium hypochlorite; 12 in × 12 in; Clorox, Oakland, CA, USA) and PDI Sani-Cloth Bleach Germicidal Disposable Wipes (0.63% sodium hypochlorite; 7.5 in × 15 in; PDI, Orangeburg, NY, USA). To test the effect of the colour additive, Clorox and PDI bleach wipes were also dispensed through a Highlight® Wipes Lid.

The rate of corrosion caused by the bleach wipes was determined by a mass loss method adapted from American Society for Testing and Materials (ASTM) Standards G1 and G31 [7,8]. Stainless steel 316L coupons measuring 5 × 5 × 0.06 cm with #4 finish were used as the test surfaces (Stainless Supply, Monroe, NC, USA). Four types of bleach wipe were assessed: Clorox wipes, Clorox wipes + Highlight®, PDI wipes and PDI wipes + Highlight®. Each type of wipe was tested in triplicate, with a different coupon for each of the three trials. Three untreated coupons served as procedural controls. All coupons were rinsed in distilled water, degreased in acetone, oven dried at 50°C for 1 h, weighed, mounted on to a flat horizontal surface using double-sided tape, and photographed.

Coupons were wiped by placing a 1-kg cylindrical weight (Rice Lake Weighing Systems, Rice Lake, WI, USA) on top of a fresh wipe and pushing the weight across the coupon three times in the same direction. The weight of 1 kg was chosen to simulate real-life rubbing force, similar to the ~800 g of pressure established by ASTM E2967 for microbiological tests of pre-wetted wipes. The same operator conducted each test to ensure a consistent technique. One wipe treatment was conducted on each test coupon every 20 min for a total of 120 wipes. Coupons were then demounted and pickled in ASTM G1 C.7.5 solution (10% HNO₃ and 5% HF in ddH₂O) for 20 min at 23°C to remove surface corrosion products [7]. Coupons were oven dried at 50°C for 1 h, weighed to determine mass loss, and

photographed. Possible mass loss caused by rinsing and pickling procedures was corrected by subtracting the mean mass loss of the procedural control coupons from the mass loss of each test coupon. Corrosion rate, standardly expressed as mils (1 mil = 0.001 inch) per year (mpy), was calculated using the following equation [7]:

$$\text{Corrosion rate} = \frac{K \times W}{A \times T \times D}$$

where K is a constant (3.45×10^6), W is corrected weight loss (g), A is exposed area (25 cm^2), T is exposure time (40 h), and D is density (7.98 g/cm^3 for stainless steel 316L). Calculated corrosion rates were averaged across the triplicate samples. Student's t -test was used to compare corrosion rates between groups.

Results

Figure 1 shows the appearances of the stainless steel coupons before and after 120 bleach wipe treatments. Untreated control coupons remained visually unchanged. Coupons treated with Clorox wipes were significantly discoloured, with visible corrosion products in Trials 1 and 2. Coupons treated with Clorox wipes + Highlight® showed mild discolouration. One coupon treated with PDI wipes (Trial 2) exhibited slight discolouration. Coupons treated with PDI wipes + Highlight® did not exhibit visible discolouration or corrosion.

Figure 2 shows the percentage mass change and corrosion rate of the stainless steel coupons following bleach wipe treatments. For Clorox wipes, Clorox wipes + Highlight®, PDI wipes and PDI wipes + Highlight®, the calculated corrosion rates (mean ± standard deviation) were 6.24 ± 0.53 , 1.56 ± 0.24 , 9.79 ± 0.28 and 0.98 ± 0.66 mpy, respectively. There was a significant difference between the corrosion rates of the Clorox wipes vs Clorox wipes + Highlight® ($P = 0.0002$), and between the corrosion rates of the PDI wipes vs PDI wipes + Highlight® ($P < 0.0001$). There was no significant difference between the corrosion rates of the two Highlight®-treated bleach wipes ($P = 0.2259$).

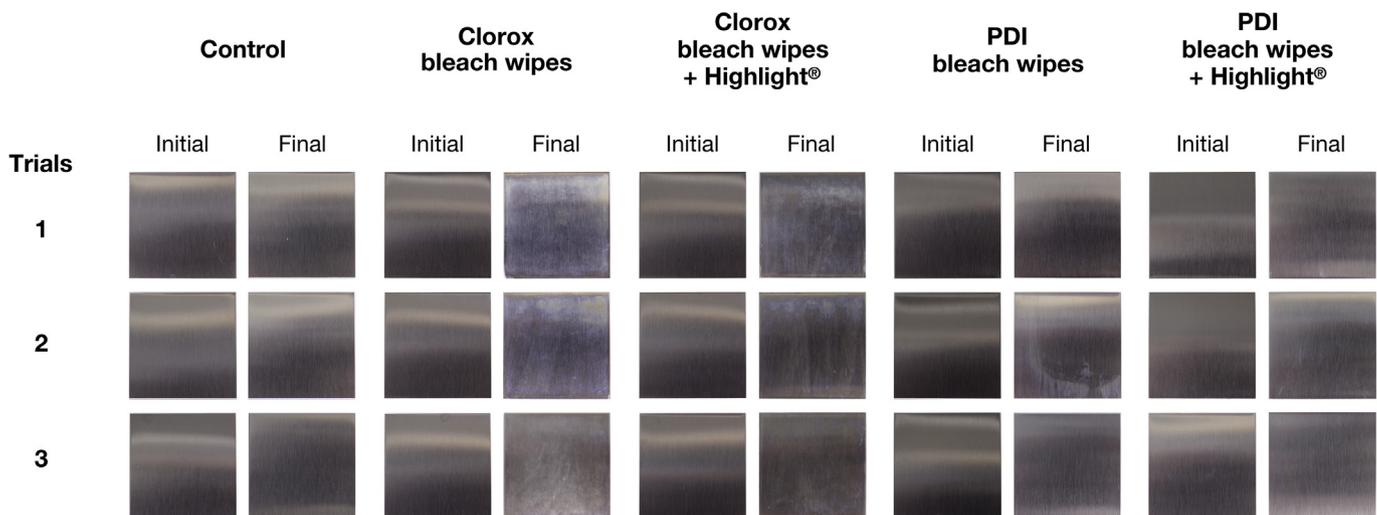


Figure 1. Visual appearance of stainless steel 316L coupons before and after 120 bleach wipe treatments. Procedural control coupons were untreated. Three trials were performed for each group, with each trial (1, 2, 3) corresponding to a single coupon treated 120 times by a type of wipe.

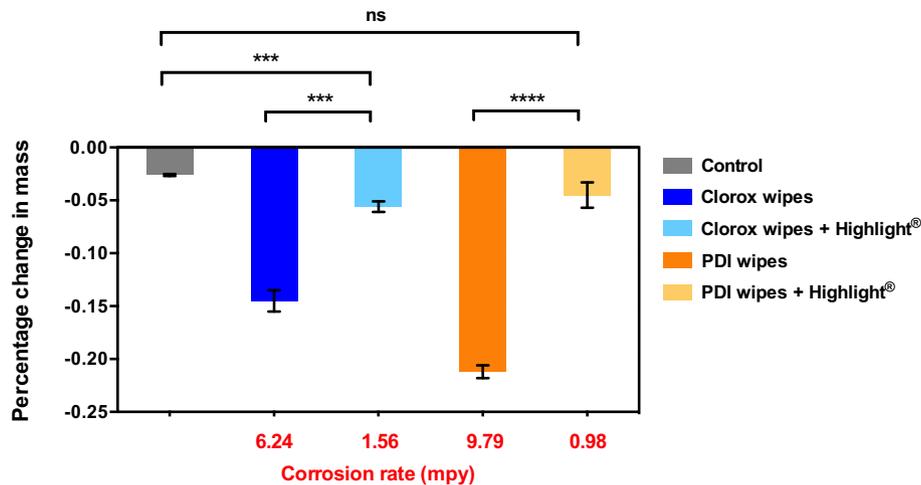


Figure 2. Comparison of percentage change in mass of stainless steel 316L coupons following 120 treatments with bleach wipes. Grey bar, control; dark blue bar, Clorox wipes; light blue bar, Clorox wipes + Highlight®; dark orange bar, PDI wipes; light orange bar, PDI wipes + Highlight®. Corrosion rate was calculated based on mass loss corrected by the control mass loss. Corrosion rate is expressed in the standard unit of mils per year (mpy), with 1 mil = 0.001 inch. Experiments were performed in triplicate for each group. Error bars show standard deviation. *** $P < 0.001$; **** $P < 0.0001$; ns, not significant.

Discussion

This study quantified the corrosive effect of bleach disinfectant wipes on stainless steel, a common material in hospitals. While bleach corrosiveness has been evaluated previously with traditional solution immersion tests, these methods do not accurately simulate how hospital surfaces are exposed to bleach disinfectant wipes [5]. To best observe the corrosive effect of mechanical wiping, this study combined a standardized wiping procedure with ASTM measurement methods. The results indicate that although commercially available bleach wipes are significantly corrosive to stainless steel, the addition of Highlight® ameliorates these corrosive effects.

Clorox wipes caused significant discolouration on stainless steel, with visible corrosion products. Relatively less discolouration appeared on coupons treated with Clorox wipes + Highlight®. Similarly, PDI bleach wipes caused slight discolouration in one coupon, whereas coupons treated with PDI wipes + Highlight® remained visually unchanged. The unchanged appearance of the control coupons indicates that rinsing and pickling procedures did not contribute to discolouration.

Although Clorox wipes caused more discolouration than PDI wipes, the calculated corrosion rate indicates that PDI wipes yielded greater mass loss. It is hypothesized that the increased chlorine content of PDI wipes (0.63%) compared with Clorox wipes (0.55%) contributed to increased corrosiveness, while discolouration may be a result of other ingredients specific to the Clorox wipes. Interestingly, the rate of corrosion was reduced when either bleach wipe was used with Highlight®. Mass loss caused by PDI wipes + Highlight® was statistically equivalent to mass loss of the untreated control coupons ($P = 0.062$). Based on ASTM guidelines, the corrosion rates caused by both bleach wipes alone are considered excessively high (>5 mpy), whereas the use of Highlight® reduced the corrosion rates to levels considered negligible to mild (<2 mpy) [9]. These results demonstrate that Highlight® improves the materials compatibility of bleach wipes by reducing their propensity to discolour and corrode stainless steel.

Despite improvements in environmental decontamination provided by bleach disinfectant wipes, the fact that <50% of surfaces in hospitals are cleaned properly indicates that there is a need for significant progress in ensuring compliance with proper cleaning practices [10]. Furthermore, despite evidence that demonstrates the effectiveness of bleach-based disinfectants against resilient pathogens such as *Clostridium difficile* [1], facilities still report reluctance to use such harsh chemicals due to concerns with surface compatibility and corrosion damage [4].

Implementing Highlight® with bleach wipes can address these problems. It is predicted that the colour-fading technology will enhance cleaning compliance through real-time monitoring of coverage and contact time. Indeed, a spray form of Highlight® improved worker ability to correctly identify hospital surfaces successfully treated with bleach, and Ebola treatment unit workers in Liberia and Guinea using Highlight® reported greater confidence and coverage in decontaminating personal protective equipment properly, thus emphasizing the importance of visual feedback during cleaning [11,12]. Further studies on the ability of Highlight® to improve the thoroughness of cleaning with bleach wipes are warranted, and tests on fluorescent marker removal, adenosine triphosphate level reduction, and patient outcomes based on *C. difficile* infection rates are currently in progress. This study demonstrated a significant reduction in discolouration and corrosion rate when using Highlight®, which may incentivise greater adoption of bleach wipes in facilities concerned about materials compatibility.

This study had some limitations. Only one material, stainless steel, was assessed, based on its widespread presence in hospital surfaces and the abundance of corrosion studies involving this metal. Bleach wipes from two manufacturers were tested, based on their prevalence in hospitals. Based on evidence of dye compounds as effective corrosion inhibitors [13], it is hypothesized that Highlight® inhibits corrosion through a chemisorption mechanism. Dye compounds in Highlight® may adsorb on to surfaces and function as a protective barrier from ion exchange,

thus limiting oxidative damage and dissolution of metal [14]. Nonetheless, the exact nature by which the Highlight® composition reduces the corrosiveness of bleach warrants further study.

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Conflict of interest statement

KT, KJ and JK are founders and shareholders of KinnoS Inc. and have patents pending on the Highlight technology.

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