Bleach is known to be corrosive to metals commonly found in pharmaceutical work environments. Two commonly used types of stainless steel coupons were exposed to household bleach and sodium dichloroisocyanurate solutions—the rate and degree of corrosion were compared.

Objective
The objective of this study is to compare the corrosion caused by bleach and NaDCC solutions at use concentrations on two common types of stainless steel surfaces and to demonstrate the advantages of using NaDCC over bleach as part of a disinfection program.

Procedure
For this study, 18 stainless steel 316 (316) and 18 stainless steel 304L (304L) 2” x 2” x 1/8” coupons were obtained from GlobePharma. Six solutions were prepared daily with deionized water (18 MΩ RODI) using commercially available Clorox® bleach and commercially available tablets containing NaDCC. The solution concentrations, formulations, and appearance are compiled in Table 1.

Three coupons were submerged in 400-mL beakers containing 250 milliliters of one solution listed above ensuring complete coverage of the coupons. The beakers were then covered with plastic wrap. The coupons were removed from the beakers daily and wiped dry for visual inspection. Any differences were documented and photographed, as noted in Figures 1-3. Noted differences include changes in color, rust and corrosion, pitting, gas evolution observed while submerged in solution, and metal deposition on the glass surface of the beaker.

After inspection, fresh solutions were prepared for each coupon-solution combination, and the coupons were placed back in their original beakers. The beakers were maintained in an ISO Class 7 environment. The study was conducted over eight weeks. However, the undiluted bleach samples were maintained an additional four weeks until metal was deposited on the glass beakers.

Results
After four days, the 304L coupons in the 1:10 bleach solution exhibited definite corrosion as shown in Figure 1. The 316 coupons in the 1:10 bleach solution also exhibited corrosion, but to a lesser extent. Pitting began in the first week for both 304L and 316 coupons in the same solution. After one week, the 1:10 bleach solution containing the 304L coupon was brown from rust floating in the solution. The 1:10 bleach solution containing the 316 coupons was gray. In contrast, the 1,000-ppm NaDCC solutions containing the 316 and 304L coupons remained clear.

By eleven days, the glass beaker sides containing the 304L coupon in the 1:10 bleach solution were contaminated with
At two weeks, there was pitting, corrosion, and staining of both 304L and 316 1:10 bleach solutions and full-strength bleach solutions. The 304L and 316 coupons were clean in the water, 200 ppm, and 1,000 ppm NaDCC solutions (Figure 2).

At three weeks, the 1:10 bleach solution containing the 304L coupons was colored black. Corrosion began to appear on one 304L coupon in the 1:50 bleach solution. By four weeks, the 304L coupons in undiluted bleach were evolving a gas as evidenced by bubbles rising in the solution from the coupon edges and faces, and, between observations (once), rust was splattered on the plastic wrap beaker cover. At six weeks, metal deposition began on the glass beaker wall for the 1:10 bleach solutions containing the 304L and 316 coupons. An example of metal deposition is shown in Figure 3. By eight weeks, gas was evolving from the 316 coupons in addition to the 304L coupons in the undiluted bleach solutions.

The observations summarized by week are compiled in Table 2.

In Figure 4, the photograph contrasts the impact of the bleach and NaDCC solutions to the stainless steel coupons when the solutions are at the commonly used concentrations. The 304L and 316 1:10 bleach solution coupons are discolored and corroded.

In Figure 5, the photograph contrasts the impact of the bleach and NaDCC solutions to the stainless steel coupons when the solutions are at similar active chlorine levels. The bleach solution, though diluted at 1:50, still affects the more corrosion resistant 316 stainless steel through discoloration.

### Discussion

**Stainless steel**

There are different types of stainless steel. The addition of differing levels of other elements, molybdenum, nickel, manganese, and chromium, to iron gives steel various properties—in this case, corrosion resistance. The 304L and 316 stainless steel grades used in this experiment are designed to be more corrosion resistant, but not corrosion-proof. The difference in the metals’ content gives 316-grade stainless steel its higher corrosion resistance when compared to the 304L-grade.

Many pieces of equipment found in pharmaceutical, bioprocessing, and medical device facilities are constructed of 304L and 316 grades of stainless steel. This equipment is easy to clean and is resistant to corrosion by common chemicals and cleaners. However, continual use of bleach solutions as part of a disinfection program promotes corrosion of the equipment requiring the equipment to be replaced periodically.

**Active ingredient**

The sodium hypochlorite found in bleach and NaDCC is the active antimicrobial ingredient belonging to the oxidizing group of disinfectants. They form hypochlorous acid (HOCl) in water which interacts with biomolecules found in microbes resulting in cell death.1-7

**Household bleach:** Bleach is composed of sodium hypochlorite (NaOCl), sodium hydroxide (NaOH), and sodium chloride

### Table 2. Physical changes observed summarized by week.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Coupon</th>
<th>Time (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>304L</td>
<td>1, 8</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td></td>
</tr>
<tr>
<td>Bleach 50,000 ppm</td>
<td>304L</td>
<td>CC,CC,P,R,G</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td>CC,CC,P,G</td>
</tr>
<tr>
<td>Bleach 1:10,500 ppm</td>
<td>304L</td>
<td>CC,CC,P,CC,P,R,M</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td>CC,CC,P,CC,P,M</td>
</tr>
<tr>
<td>Bleach 1:50,1000 ppm</td>
<td>304L</td>
<td>CC,CC,P,C</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td>C</td>
</tr>
<tr>
<td>NaDCC 1,000 ppm</td>
<td>304L</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td></td>
</tr>
<tr>
<td>NaDCC 200 ppm</td>
<td>304L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>316</td>
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</tr>
</tbody>
</table>
(NaCl). It is produced by passing chlorine gas through a dilute sodium hydroxide solution or by electrolysis of salt water. Sodium hypochlorite is reactive and may chlorinate organic compounds. This solution contains HOCl in equilibrium with the hypochlorite ion as shown by the equations below.

\[
\text{NaOCl} \rightarrow \text{Na}^+ + \text{OCl}^-
\]

\[
\text{OCl}^- + \text{H}^+ \rightleftharpoons \text{HOCl} (\text{hypochlorous acid})
\]

**Sodium Dichloroisocyanurate:** NaDCC is formed through the pyrolysis of urea which forms cyanuric acid. The cyanuric acid is reacted with chlorine and sodium hydroxide to form NaDCC. In water, the NaDCC forms HOCl in equilibrium with a complex mixture of various chlorinated cyanurate chemical species.

\[
\text{NaCl}_2(\text{NCO})_3 + \text{H}_2\text{O} \rightleftharpoons 2\text{HOCl} + \text{NaH}_2(\text{NCO})
\]

The NaDCC used in this experiment was supplied by Brulin & Company, Inc. (EPA Registration Number 71847-2-106). On the label, the use instructions indicate adding one tablet per gallon for 937 ppm active chlorine.

**Product use**

To make a 1:10 bleach solution (5,000-ppm active chlorine), 1¼ cup bleach is added to one gallon of water with mixing as described by the bleach EPA label. For the 1,000-ppm NaDCC solution, one tablet is added to one gallon of water and allowed to dissolve through the effervescence, a process that takes less than two minutes. Each product is to be used per EPA registration label guidelines on hard, nonporous, inanimate surfaces that have been pre-cleaned. The products are applied to the pre-cleaned surface. The surface must remain wet for the prescribed contact time of ten minutes. If the surface dries before ten minutes, the reapplication of more solution is required. After ten minutes, the product may be allowed to dry on the surface or be removed.

While bleach is used to disinfect hard, nonporous, inanimate surfaces, as found on the Clorox® Bleach label, it also includes the following instructions, not found in the NaDCC product label:

- “Do not use this product on steel, aluminum, silver, or chipped enamel.
- If used on metal, a solution of this product should be allowed to stand for no more than five minutes, and then rinsed off thoroughly with clean water; otherwise, it may slightly discolor and eventually corrode the metal.”

It is interesting to note that the second instruction for limiting exposure to five minutes is less than the prescribed contact time.

**Conclusion**

This study shows the corrosive effects of bleach solutions on 304L and 316 coupons at use levels typically employed for equipment disinfection in the pharmaceutical, bioprocessing, and medical device industries as part of their standard operating procedures. The NaDCC solutions did not show corrosive effects to the stainless steel coupons as shown in Figures 4 and 5.

Users of diluted bleach solutions on stainless steel must replace carts,
hoods, biological safety cabinets, filter dryers, and other equipment periodically due to corrosion following repeated exposure to bleach disinfectant solutions. Substituting NaDCC for bleach can reduce the frequency of replacement of expensive equipment incurring a cost savings while maintaining the disinfection level required for product manufacturing. This suggests using a NaDCC solution in place of bleach as part of a disinfectant rotation.

References

Jay C. Postlewaite, Ph.D., is the Senior Technical Advisor at Texwipe, an ITW Company. He has held technical positions in global regulatory service, research, manufacturing, and product development. His current research is focused in the cleanroom consumables and contamination control markets.

Wendy Hollands, MBA, is Business Development Manager at Texwipe, an ITW Company. She has managed multiple cleanroom consumable product lines and specializes in sterile product lines including wipers, pre-wetted wipers, swabs, and sterile alcohol. ©