Metal Corrosion by Dilute Aqueous Chlorine Solutions

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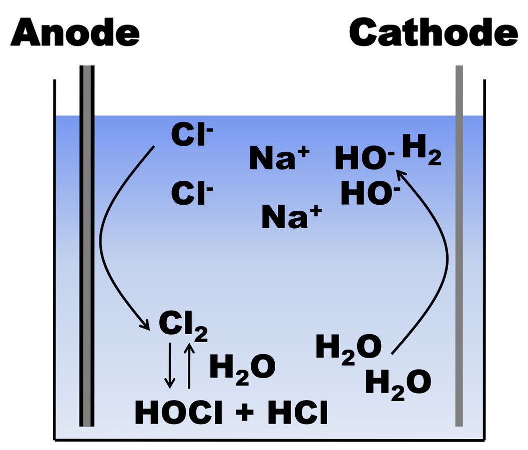
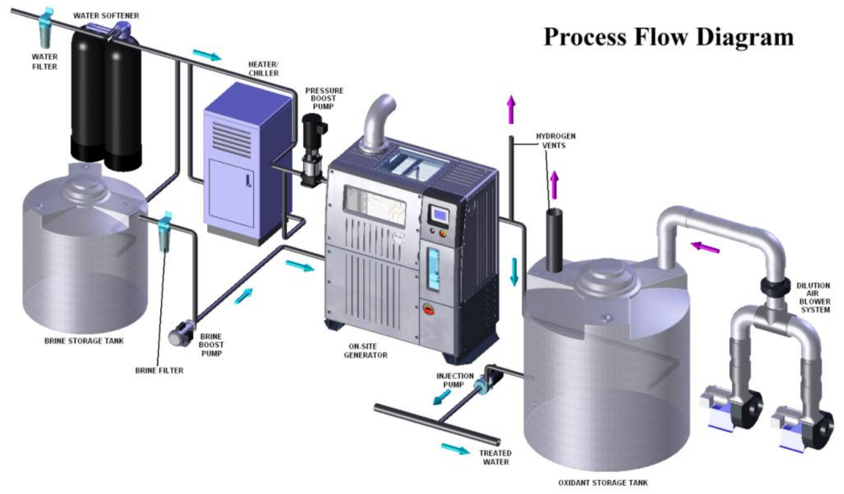
Introduction

- Aqueous chlorine has historically provided disinfection and oxidation chemistry in numerous industrial processes. Applications range from disinfection of cooling tower water to Clean-In-Place operations in beverage production facilities.
- Recently, on-site generation of aqueous chlorine solutions with enhanced disinfection capability has gained interest for industrial disinfection and cleaning applications. As corrosion is a consideration when using aqueous chlorine, understanding how aqueous chlorine solution composition impacts corrosion is critical for the implementation of on-site generation technology.
- On-site generation works through the electro-chemical oxidation of chloride ions to produce aqueous chlorine species (hypochlorous acid and hypochlorite ions).

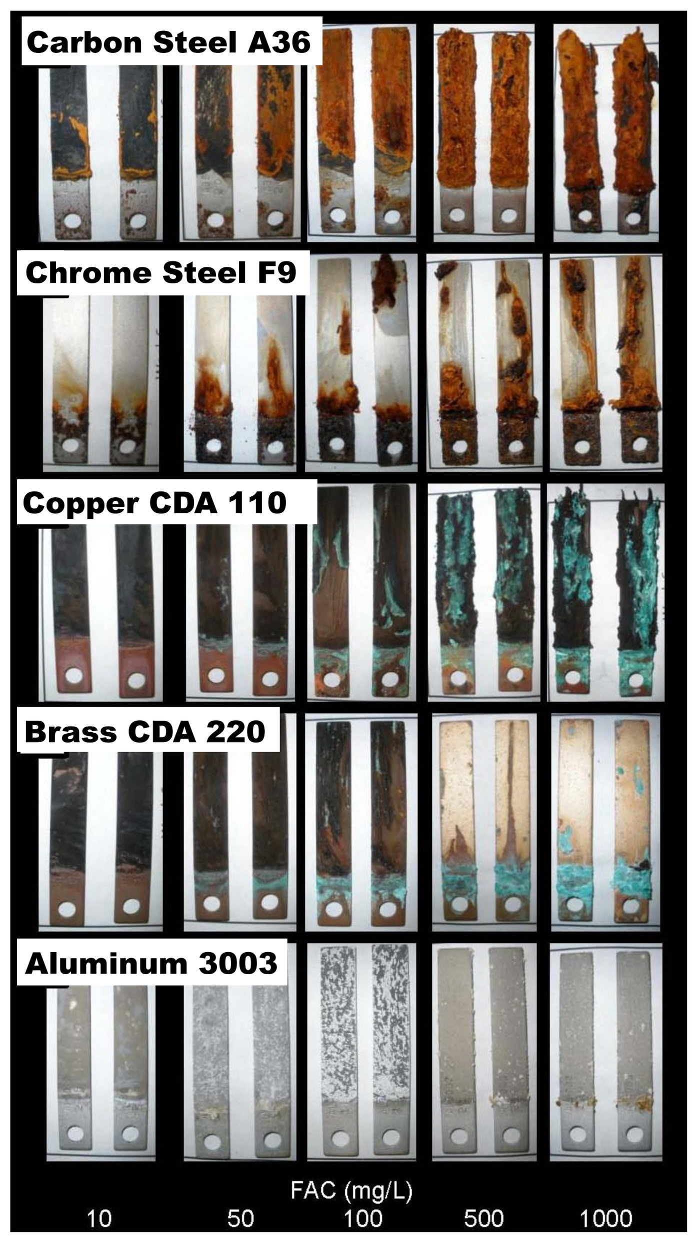




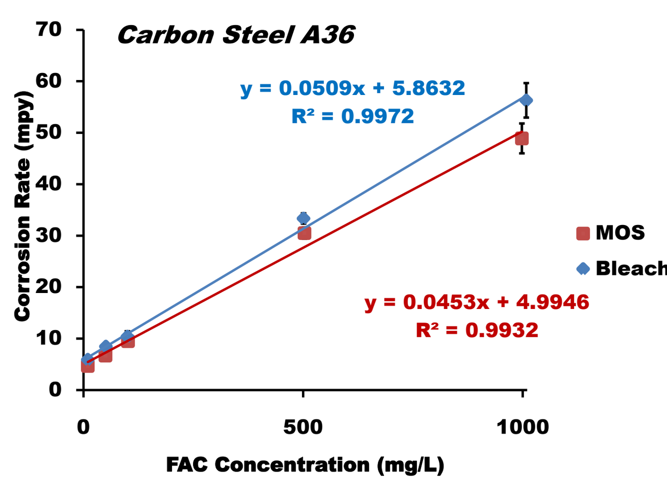
- MIOX is a company that focuses on technology integration and has developed a proprietary, scalable OSG technology that produces an aqueous chlorine based solution with enhanced microbial inactivation efficacy. The solution is known as Mixed Oxidant Solution (MOS).
- In this poster, we present an exhaustive study of the corrosion of common metals in dilute aqueous chlorine solutions as a function of chlorine source (MOS or commercial bleach), Free Available Chlorine (FAC) concentration, chloride ion concentration, and solution pH. To our knowledge, a systematic study comparing the corrosivity of on-site generates and bulk aqueous chlorine has not been previously reported.

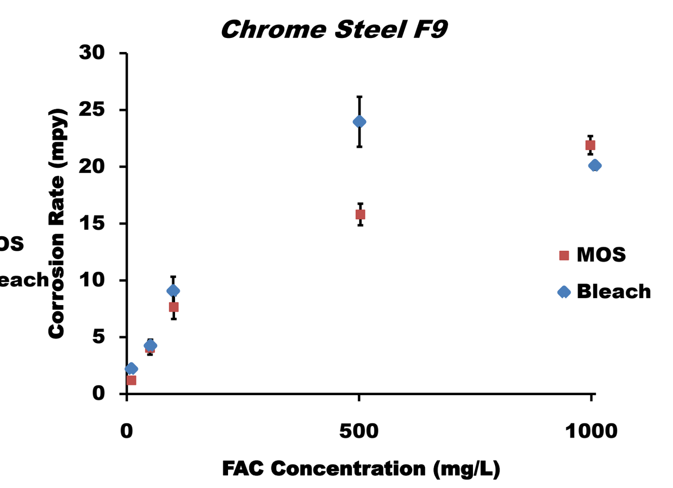
Corrosion in Variable FAC Chlorine Solutions

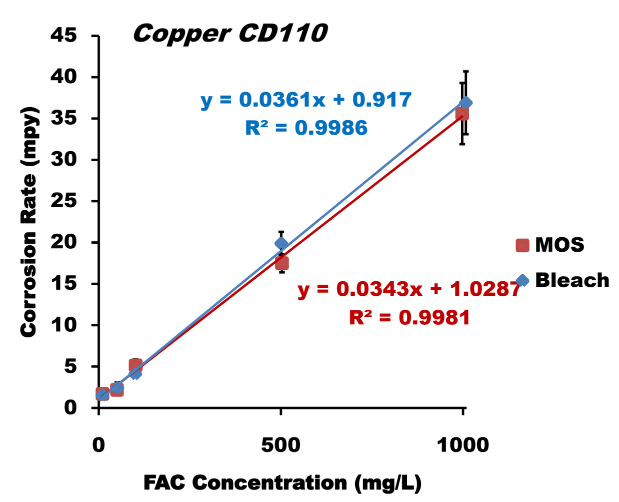
Here, solutions of MOS or bleach were prepared so as to have a FAC concentration of between 10 and 1000 mg/L. The pH and chloride ion contents of the solutions were not modified for these tests.

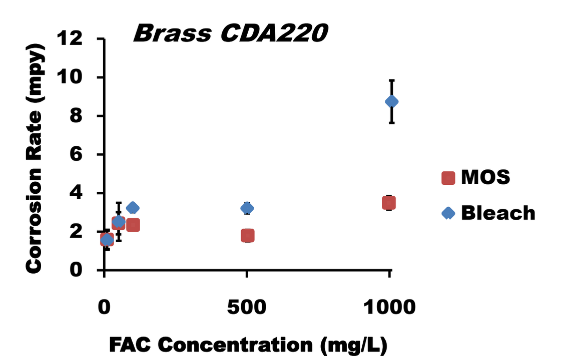


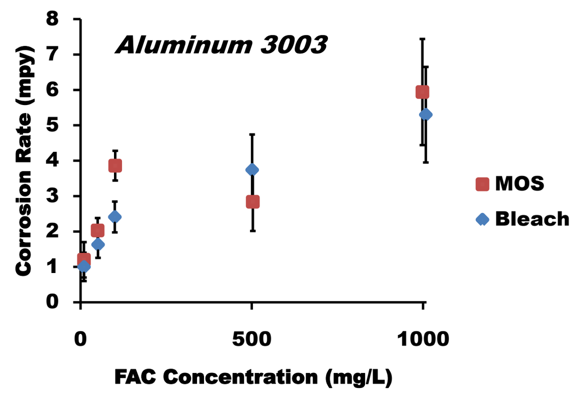
Photographs of coupons exposed to variable FAC MOS for six weeks. Coupons exposed to bleach solutions (not pictured) had similar visual appearances.











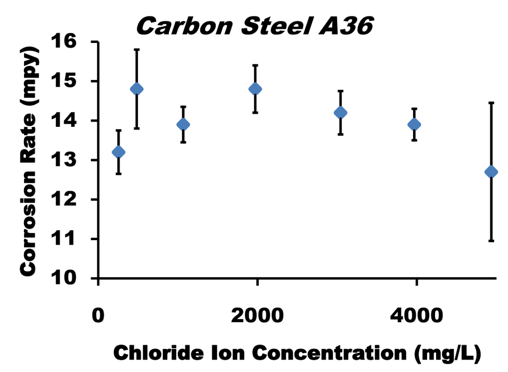
- Corrosion rates for all metals tested increased with increasing solution FAC concentration.
- Linear relationships between corrosion rates and FAC concentrations were observed for carbon steel and copper.
- MOS was less corrosive than bleach for carbon steel and brass.

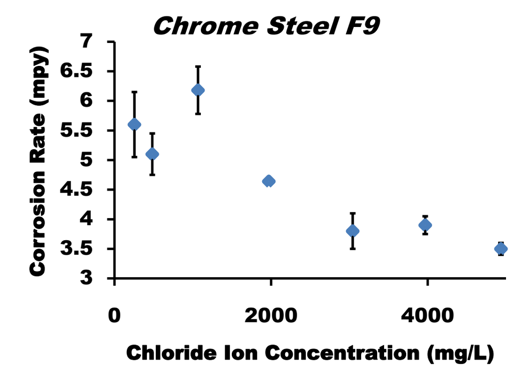
Experimental Methodology

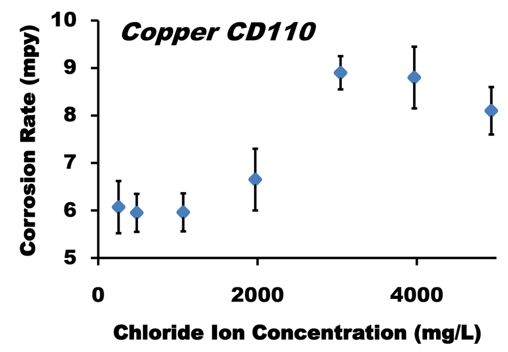
- Aqueous chlorine solutions were prepared by diluting either commercial bulk sodium hypochlorite or on-site generated Mixed Oxidant Solution (MOS) with deionized water to give the desired FAC concentration. HCl or NaOH were used to adjust pH while chloride ion concentrations were adjusted with NaCl.
- Solutions were exchanged every 72-96 hours and the FAC, chloride ion concentration, pH, and ORP of the solutions were monitored regularly.
- Coupons were periodically removed (duplicate samples) over the course of six weeks. After removal, coupons were photographed, cleaned, and weighed according to ASTM Method G31. Differences between initial and final weights were used to establish corrosion rates.

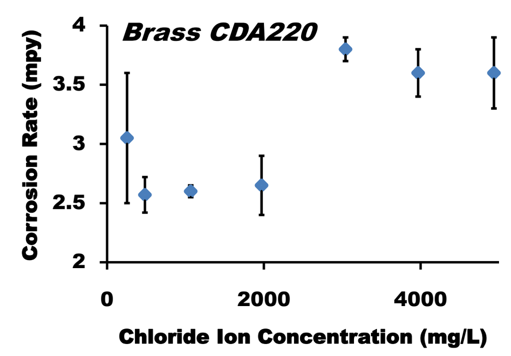
Impact of Chloride Ion and pH on Corrosion

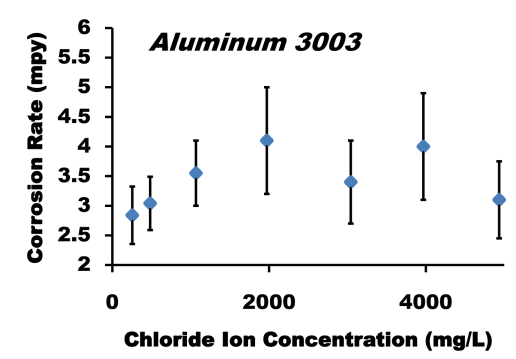
- In these studies, designed to better understand the interplay of pH and chloride ion content on corrosion, 100 mg/L FAC bleach solutions were prepared with adjusted pH or chloride ion concentration.



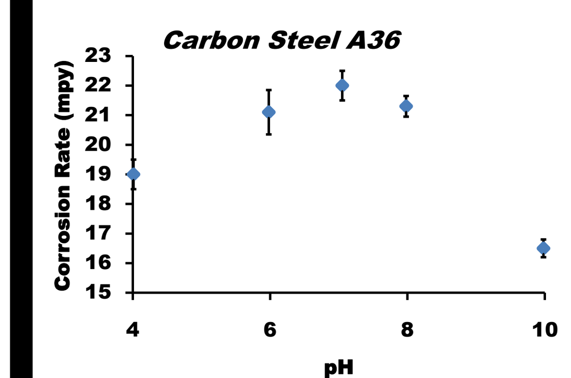


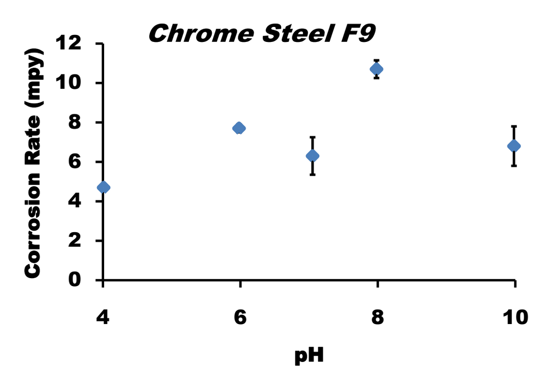


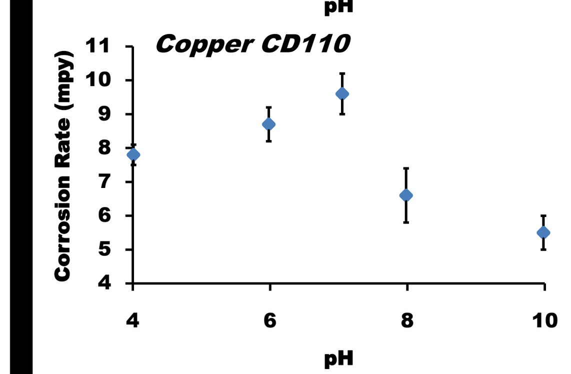


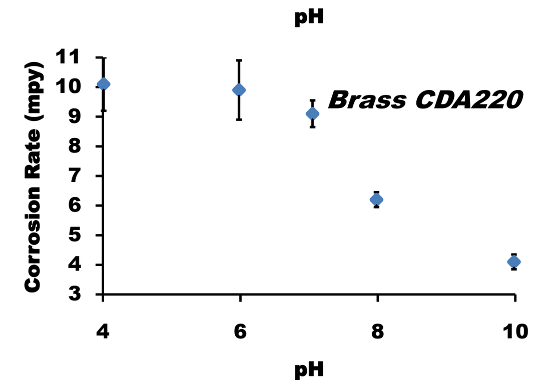


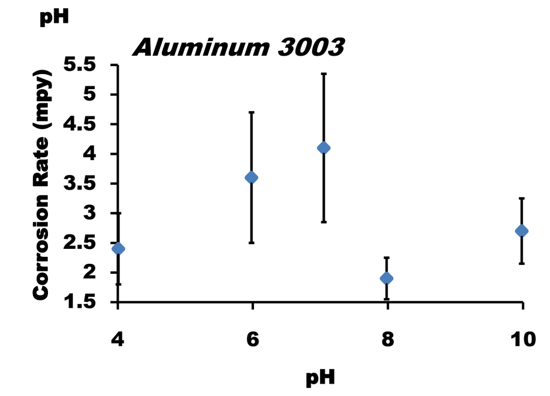
- Chloride ion content impacted the corrosion rates of chrome steel, copper, and brass.





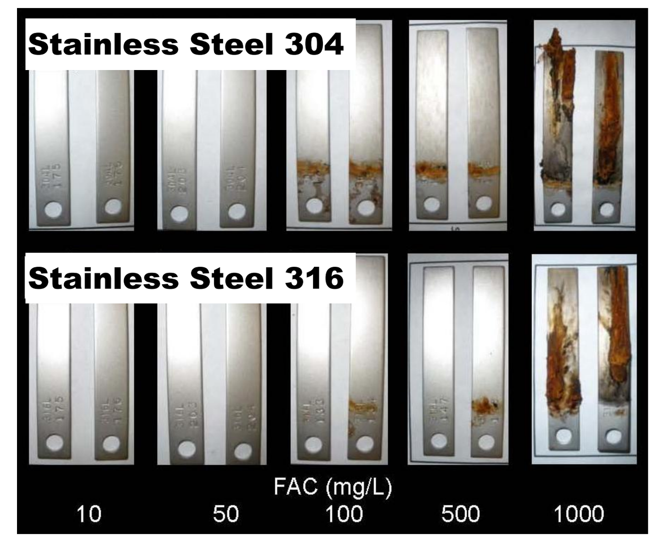






- Solution pH was a critical factor in determining the corrosion rates of all metals.

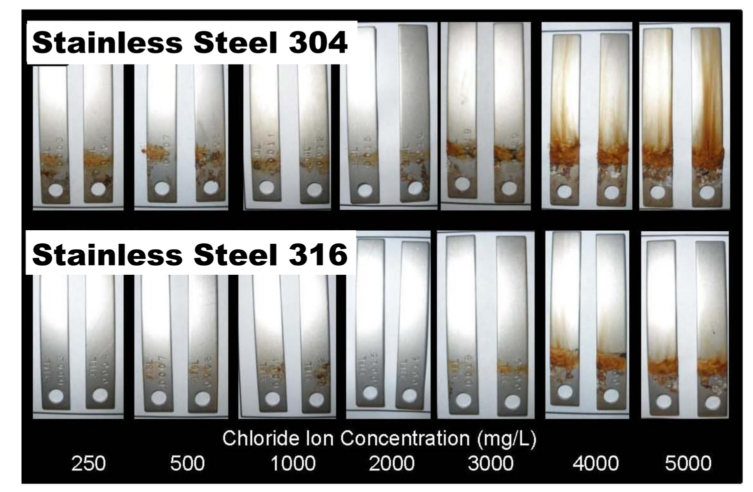
Pitting Corrosion of Stainless Steel



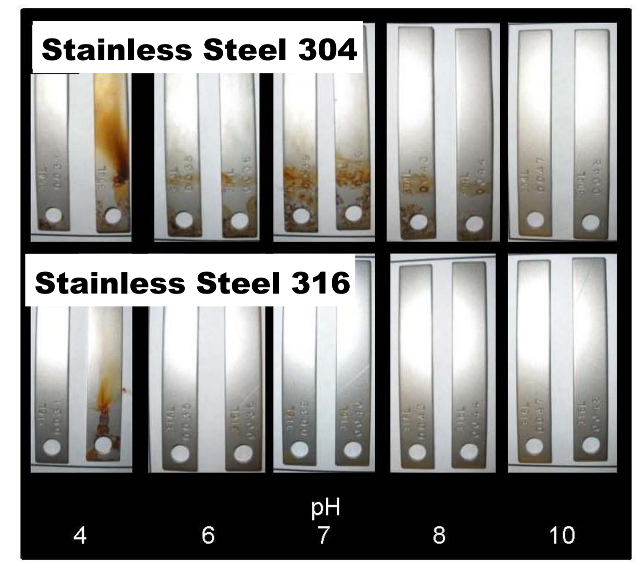
Photographs of coupons exposed to variable FAC MOS for six weeks

Photographs of coupons exposed to variable FAC bleach for six weeks

- For coupons immersed in variable FAC bleach solutions, only superficial corrosion was observed - no pitting occurred.
- When exposed to MOS, superficial corrosion was observed for both stainless steels when the FAC concentration was 100 mg/L or higher and pitting corrosion occurred when the FAC concentration was 1000 mg/L.



Photographs of coupons exposed to variable chloride ion content bleach for six weeks



Photographs of coupons exposed to variable pH bleach for six weeks

- For stainless steel 304, pitting corrosion was observed when the chloride ion concentration was 3000 mg/L or higher while the threshold for pitting corrosion of stainless steel 316 was 4000 mg/L.
- Pitting corrosion was observed in 100 mg/L FAC solutions for stainless steel 304 if the solution pH was 6 or less while for stainless steel 316, pitting corrosion was only observed in 100 mg/L FAC solutions with a pH of 4.

Summary and Conclusions

Metal corrosion processes induced by dilute aqueous chlorine solutions prepared from either commercial hypochlorite or on-site generated MOS were similar, with some notable exceptions.

- MOS was less corrosive than bleach for carbon steel and copper. However, at very high FAC concentrations, MOS induced pitting corrosion in stainless steels while similar FAC concentration bleach solutions did not.
- Differences in corrosion properties for the two chlorine sources tested typically only occurred at high FAC concentrations that are in far excess of any expected utilization strength.
- The origin of the different corrosion behaviors for the two chlorine sources tested likely arises from differing chloride ion content and pH of the solutions investigated.