Water Quality Factors Influencing Iron and Lead Corrosion in Drinking Water

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ABSTRACT

Corrosion is one of the most complicated and costly problems facing drinking water utilities. Corrosion of iron pipes can lead to economic losses and customer complaints, while lead corrosion poses a serious health risk.

This work first synthesizes nearly 100 years of iron corrosion research to provide the water industry with an updated understanding of factors that influence iron pipe corrosion including water quality and composition, flow conditions, biological activity, and corrosion inhibitors. Potential impacts of upcoming regulations on iron corrosion are also considered. Next, a four-year study is presented that evaluated the effect of water quality and phosphate inhibitors on the corrosion of iron pipes under extended stagnant water conditions. Surprisingly, many of the water quality parameters traditionally thought to influence iron corrosion were not controlling under these "worst case" stagnant conditions. Moreover, addition of phosphate inhibitors often had either no statistically significant effect or actually increased iron concentration, scale build-up and overall weight loss.

Temperature is often overlooked when corrosion of distribution systems pipes is considered. Temperature impacts many parameters that are critical to pipe corrosion including physical properties of the solution, thermodynamic and physical properties of corrosion scale, chemical rates, and biological activity. Moreover, variations in temperature and temperature gradients may give rise to new corrosion phenomena worthy of consideration by water treatment personnel. In laboratory experiments, cast iron samples at 5°C had 23% more weight loss, ten times higher iron release to water, and twice as much tuberculation compared to samples at 25°C.

For lead corrosion, hexametaphosphate inhibitors were proven to increase release of both particulate and soluble lead to drinking water by 200 – 3500% over a wide range of water qualities when compared to orthophosphate, effectively ending a long term debate as to their impacts. Utilities should consider these adverse effects whenever polyphosphate is used to prevent scaling or iron precipitation.

DEDICATION

This dissertation is dedicated to Kelly, who didn't have a chance to do his own Ph.D.

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Thanks for my parents for raising me right and always loving me.

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AUTHOR'S PREFACE

Each chapter of this dissertation is a separate manuscript that is formatted according to the specifications of the journal to which it was submitted. Chapter 1, "Review of Iron Pipe Corrosion in Drinking Water Distribution Systems," has been submitted to the *Journal of the American Water Works Association*. Chapter 2, "Phosphate Inhibitors and Red Water in Stagnant Iron Pipes," has been accepted for publication in the *Journal of Environmental Engineering*. Chapter 3, "The Importance of Temperature in Assessing Iron Pipe Corrosion in Water Distribution Systems," has been submitted to the *Environmental Monitoring and Assessment*. Chapter 4, "Temperature Effects on Iron Corrosion," will be submitted to *Corrosion*. Chapter 5, "Effect of Phosphate Inhibitors on Lead Release From Pipes," has been submitted to the *Journal of the American Water Works Association*.

Although each chapter is a separate manuscript, this dissertation is organized to explain several key phenomena related to the corrosion of iron and lead. Chapter 1 is a thorough review of the factors previously found to influence iron pipe corrosion in drinking water distribution systems. Chapter 2 presents the surprising experimental results that many of the factors reviewed in Chapter 1 did not control iron corrosion under stagnant water conditions. Because of these unexpected experimental results, a separate literature review is presented in Chapter 3 that investigates the role of temperature, an often-overlooked factor, on iron corrosion. This second review led to experiments on the effect of temperature on iron corrosion, the results of which are given in Chapter 4. Finally, Chapter 5 presents a parallel study on lead corrosion that demonstrates that a pipe study similar to the one in Chapter 2 can provide mechanistic insight to water quality effects on lead corrosion.