

**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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TABLE OF CONTENTS

Chapter 1: Review of Iron Pipe Corrosion in Drinking Water Distribution Systems	1
Introduction	1
Factors Influencing Iron Corrosion	2
Implications of Upcoming Regulations.....	10
Summary.....	12
References	12
Chapter 2: Phosphate Inhibitors and Red Water in Stagnant Iron Pipes.....	26
Introduction	26
Experimental Methods	27
Results	29
Discussion	31
Conclusions	37
References	39
Chapter 3: The Importance of Temperature in Assessing Iron Pipe Corrosion in Water	
Distribution Systems.....	50
Introduction	50
Different Constant Temperatures	51
Temperature Variation	54
Recommendations.....	56
Conclusions	57
References	57
Chapter 4: Effects of Temperature on Iron Corrosion.....	66
Introduction	66
Materials and Methods.....	67
Results	68
Summary.....	71
References	72

Chapter 5: Complexation of Lead by Polyphosphate and Implications for Corrosion Control ...	77
Introduction	77
Experimental.....	79
Results and Discussion	80
Conclusions	88
References	89
Appendix A: Thermodynamic Calculations.....	103
Vita.....	104

LIST OF TABLES

Table 1-1: Summary of expected effects of various factors on iron corrosion	25
Table 1-2: Selected iron solids.....	25
Table 2-1: Water qualities for pipe experiments	43
Table 2-2: Pipe ages during experiments	43
Table 2-3: Comparison of scale build-up over four year life of pipes	43
Table 3-1: Activity coefficient (γ) variation with temperature	62
Table 3-2: Change in solubility product (K) with temperature	62
Table 3-3: Selected Pilling-Bedworth Ratio (PBR) values	63
Table 3-4: Selected coefficients of thermal expansion (α) values.....	63
Table 4-1: Mass composition of the soluble portion of the digested scale	73
Table 5-1: Typical Ionic Constituents in Base Water.....	91
Table 5-2: pH and Alkalinity Modifications	91
Table A-1: Coefficients “A” and “B” for Extended Debye-Hückel Equation	103
Table A-2: Parameter “a” for Extended Debye-Hückel Equation	103

LIST OF FIGURES

Figure 2-1: Total iron released during 72-hour stagnation experiments.....	44
Figure 2-2: Total iron released during 8-hour stagnation experiments.....	45
Figure 2-3: Percent change in total iron release compared to pipe with no inhibitor added	46
Figure 2-4: Percent change in weight loss over 4-year lifetime of a pipe.....	47
Figure 2-5: Total iron released as a function of residual phosphorus.....	48
Figure 2-6: Percentage of total iron released as soluble	48
Figure 2-7: Iron released during a cut pipe experiment.....	49
Figure 2-8: Total iron released with orthophosphate vs. zinc orthophosphate	49
Figure 3-1: Possible effects of different constant temperature on aspects of iron corrosion	64
Figure 3-2: Possible effects of varying temperature on iron corrosion.....	65
Figure 4-1: Representative total iron concentrations in water as a function of time.....	74
Figure 4-2: Iron coupons	74
Figure 4-3: Iron scale digestion	75
Figure 4-4: Scale build-up and overall weight loss	75
Figure 4-5: Apparent cycling of turbidity as temperature is cycled	76
Figure 4-6: Weight loss observed after 133 days of exposure.....	76
Figure 5-1: Simplistic conceptualization of factors influencing soluble lead concentrations	92
Figure 5-2: Total lead release from pipes after 72-hour stagnation.....	93
Figure 5-3: Effects of aging on lead release at constant DIC or pH	94
Figure 5-4: Total lead release during 72-hour sampling event.....	95
Figure 5-5: Total lead released during 8-hour sampling event.....	96
Figure 5-6: Relative impact of indicated inhibitor on total lead release	97
Figure 5-7: Lead release with time at pH 7.8, alkalinity 45 mg/L.....	98
Figure 5-8: Final pH after 72-hour stagnation for new pipes	99
Figure 5-9: Phosphate residuals	99
Figure 5-10: Soluble lead release in the 8-hour stagnation sampling event.....	100
Figure 5-11: Predicted soluble lead concentrations.....	101
Figure 5-12: Percentage increase in soluble lead due to use of hexametaphosphate	102
Figure 5-13: Excess soluble lead as a function of residual hexametaphosphate.....	102

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.