![EPA logo] United States Environmental Protection Agency

RESEARCH PROJECT
National Risk Management Research Laboratory
Water Supply and Water Resources Division
Treatment Technology Evaluation Branch

THE EFFECT OF WATER CHEMISTRY ON THE RELEASE OF IRON FROM PIPE WALLS

4.0 mm   0.7 mm

IMPACT STATEMENT

Colored water problems originating from distribution system materials may be reduced by controlling corrosion, iron released from corrosion scales, and better understanding of the form and properties of the iron particles. The objective of this research was to evaluate the effects of a number of water quality parameters including sulfate, chloride, and orthophosphate, on the release of iron from an old cast iron pipe section removed from a drinking water distribution system, and to study the properties of the resulting suspensions. This project further developed the U.S. Environmental Protection Agency's (EPA) understanding of water quality parameters and their effect on metals release in distribution systems. These results further enable EPA to provide expertise and guidance to water utilities, engineers, the general public and other stakeholders.

BACKGROUND:

The release of iron from distribution system materials, such as cast iron water mains, is a complex process which involves mass transfer and many interactions. These include corrosion, reduction-oxidation (redox) reactions, precipitation, dissolution, solid phase reactions and microbiological activity. Water chemistry and the properties of the scale and corrosion deposits that cover the iron pipe wall are important factors that affect iron release from drinking water distribution systems. The structure and chemical composition of iron corrosion scales are particularly important in understanding iron release. Iron corrosion scales are complex structures that typically consist of layers of ferrous, ferric, and mixed (ferrous and ferric) oxides and oxy-hydroxides.

The presence of an oxidant at the scale surface has an important effect on the scale; under flowing conditions oxygen and disinfectants are continually supplied to the scale surface where oxidation of ferrous iron occurs. Ferric iron precipitates primarily within the scale, which reinforces the scale structure and reduces porosity. Ferric iron solubility is low at typical pH values and, thus, iron release is relatively small. Under stagnant conditions that follow flow, dissolved oxygen is reduced via reaction with ferrous iron. Diffusion of oxygen to the surface in response to the concentration gradient is slow relative to the Fe^{2+}-oxygen reaction and an anoxic zone is created at or near the scale surface. The rate of formation of this zone depends upon the nature of the scale and water chemistry. With prolonged periods of stagnation, ferrous iron is released from the scale causing dissolution of ferrous solids and reduction of ferric phases. As a result, the scale weakens and porosity increases, allowing more ferrous iron to diffuse into bulk water. The scale break-down process can be reversed by increasing the flow rate and the concentration of disinfectants at the surface.

Iron release is greatly affected by water chemistry including pH, alkalinity and corrosion inhibitors. The effects of sulfate, chloride, orthophosphate and other water quality parameters on iron release are of interest to many drinking water systems. Changes in chloride concentration, for example, may be an issue for water utilities that are considering ion exchange treatment, changing to a more saline source, or using a source that fluctuates in chloride content.

Orthophosphate corrosion inhibitors are widely used to reduce lead and copper solubility in drinking water distribution systems, but it is not widely recognized for iron release or red water control. Despite the interest, very little work has examined the effects of sulfate, chloride and orthophosphate on the release of iron from drinking water distribution system pipe materials.

DESCRIPTION:

This project was conducted to determine the chemistry and extent of iron release from aging water distribution pipes. Experiments were conducted using a section of a cast iron pipe (approximately ninety years old) that was removed from the drinking water distribution system in the City of Cincinnati, Ohio. Two liters of tap water was collected in glass beakers after flushing the laboratory faucet for five minutes. The remaining volume of test water was then pumped through a 6.4 millimeter (0.25 inch) plastic tubing into the pipe section. The pipe section was loosely covered with a glass plate to reduce interaction with the outside environment, and allowed to sit undisturbed during non-work periods. Following this process, the first measurements of ferrous iron are taken by drawing 20 milliliters of water from the center of the pipe section. Finally, samples were carefully taken to measure certain parameters (e.g. pH, redox potential, turbidity, color, total iron, etc.). An additional sample was taken for inductively coupled argon plasma (ICAP) analysis.

EPA GOAL: Goal #2 - *Clean & Safe Water*; Objective 2.1.1- *Water Safe to Drink*
ORD MULTI YEAR PLAN: Drinking Water (DW), Long Term Goal - DW-2 *Control, Manage, and Mitigate Health Risks*

EXPECTED OUTCOMES AND IMPACTS:

The project will help utilities, engineers and consultants understand how water quality impacts iron release from corroding iron pipes and establish effective strategies to reduce iron release. Current outputs consist of several presentations and a peer-reviewed journal article.

OUTPUTS:

An output of the project will consist of a journal article.

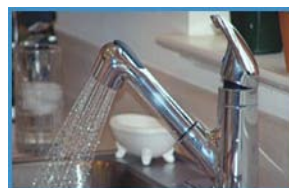## RESOURCES:

NRMRL Corrosion Research: http://www.epa.gov/nrmrl/wswrd/cr/index.html
NRMRL Treatment Technology Evaluation Branch: http://www.epa.gov/ORD/NRMRL/wswrd/tteb.htm

CONTACTS:

Darren Lytle, *Principal Investigator* - (513) 569-7432 or lytle.darren@epa.gov
Steven Doub, *Media Relations* - (513) 569-7503 or doub.steven@epa.gov
Michelle Latham, *Communications* - (513) 569-7601 or latham.michelle@epa.gov

Drinking Water