Report for 2002NE12B: Assessment of Source of Variation in Copper Concentrations in Nebraska Drinking Water Systems

There are no reported publications resulting from this project.

Report Follows:

Title: **Assessment of Source of Variation in Copper Concentrations in Nebraska Drinking Water Systems**

RESEARCH

Problem and Research Objectives:

Copper is a commonly used material for water distribution piping. Although it is fairly resistant to corrosion, copper piping may corrode under some conditions, resulting in elevated copper concentrations in drinking water. In response to potential for adverse health effects at high concentrations, the EPA has established an action level of 1.3 mg/L for copper in drinking water (USEPA, 2000). The action level is the 90% percentile value for the samples collected. Because the primary source of copper in drinking water is corrosion of plumbing materials, the EPA requires treatment for corrosion control as a method for reducing copper concentrations. As of August 2001, a total of 49 drinking water systems in Nebraska exceeded the U.S. EPA's action level for copper in drinking water (NDHHS, 2001). A total of 19 of the systems in violation of the copper standard were below the copper action level in several rounds of samples between 1992 and 1999, but exceeded the action level in a round of testing in the past year. Implementation of the EPA-mandated corrosion control methods will be a significant financial impact on many of these communities.

Many of Nebraska water systems that have excessive copper levels utilize groundwater that has high alkalinity, neutral pH, and low dissolved oxygen. There is little scientific information concerning corrosion of copper by this type of water chemistry (Edwards, 2001; Schock, 2001).

For many waters, a protective scale will form on copper pipe (which significantly reduces copper corrosion) in between 1 day and 50 years, depending on a range of factors (water chemistry, temperature, water use pattern, etc.). In a few cases, a protective scale will never form. If a protective scale layer has not formed on the copper pipes, then a common method of reducing copper corrosion is to add food grade ortho- and polyphosphate inhibitors to the water at the water source. Past research has shown that orthophosphates will help form a protective $CuPO_4$ scale layer on the pipe. In all cases found in the literature, orthophosphates reduced copper dissolution. On the other hand, polyphosphates have been found to make copper corrosion worse.

The reason polyphosphates are often added to drinking waters is to sequester dissolved iron and manganese. In Nebraska this occurs with some high alkalinity, neutral pH, high TDS waters. Dissolved iron and manganese (in anoxic ground waters) can be oxidized in the home or distribution system by dissolved oxygen and/or chlorine and form precipitates that are observed a red or black water (and lead to staining of fixtures). The sequestering agents, such as ortho and polyphosphates, can change the iron and manganese precipitates so they form smaller, more stable particles, that result in less observed color and staining of fixtures. Past research has shown that polyphosphates are better sequestering agents than orthophosphates, but high orthophosphate concentrations can also be effective for sequestering. Also, polyphosphate will convert over time to orthophosphates in the water distribution system.

Edwards of Virginia Tech suggested in a 1999 publication a conceptual model of impact of polyphosphates on copper corrosion concentrations: Cu increase = [Poly PO_4] / ([total PO_4]) Too much polyphosphates in a phosphate blend negate ability of orthophosphates to form a protective $CuPO_4$ film.

Although some phosphate vendors are very knowledgeable, many vendors are not very knowledgeable and Nebraska communities have been sold phosphate blends that are not optimal for their water chemistry. This project is focused on providing scientific data and a conceptual model to help water utilities better select phosphate blends for copper corrosion control.

Based on the initial findings of this project related to scale layers and interactions with small community water suppliers, this study has slightly redirected focus toward impact of phosphate inhibitors on variations in copper concentrations.

This study is funded by funds from three sources: USGS 104 program, Nebraska Section of the American Water Works Association (AWWA), and the Nebraska Department of Health and Human Services System (NE HHSS). Not all of the non-USGS funds are listed as an official match to the USGS 104 grant. The USGS funds have been used to pay for the initial portions of the project and the AWWA and NE HHSS funds will be used to complete the project.

The basic research objectives are to:

1. Study a range of pipe scales from Nebraska public water supplies using a scanning electron microscope to characterize the copper corrosion phenomenon.
2. Identify the minimum ortho- and polyphosphate concentrations required to sequester iron and manganese in waters typically of Nebraska ground waters.
3. Examine the rate of polyphosphate conversion to orthophosphate in waters typically of Nebraska ground waters.
4. Study the impact of different mixtures of ortho- and polyphosphate concentration on copper dissolution in waters typically of Nebraska ground waters.
5. Develop a model to suggest the impact of ortho- and polyphosphate on copper corrosion in real drinking waters with high alkalinity and a neutral pH.

Methodology:

The basic methods for this project are listed below for the three portions.

Phase I. Understanding implications of different PO_4 mixtures on Fe and Mn sequestering.

Collect copper pipe samples from at least three public water supplies in Nebraska and study these using a scanning electron microscope.

Phase II. Understanding implications of different PO_4 mixtures on Fe and Mn sequestering.

Objective: perform "jar" tests to determine for three to four Nebraska waters the effect of different concentrations sequestering agents (different polyphosphates, orthophosphate, no treatment) on sequestering dissolved Fe & Mn. This information is useful to help utilities determine an approximate minimum polyphosphate dose required for sequestering.

Assumptions: Free Cl residual of 0.5 mg/L required at end of test period and test period of 24 hours.

Data collected: Basic water quality information, Fe, Mn (before and after sequestering agents), and free chlorine.

Values to Water Science: Information concerning reasonable trends concerning minimum sequestering agent concentrations for use in phosphate blends. Field confirmation of Darren Lytle's theoretical work related to phosphate concentrations required for sequestering

Phase III. Impact of different Phosphate blends on typical Nebraska water chemistries.

Objective: perform pipe rig study on two communities, each for three months, to test six different phosphate mixtures. These studies will test the blends only on new copper pipes. The results from Phase II were used to select the blend concentrations. Orthophosphate and polyphosphate chemicals were used that were purchased from chemical suppliers and are not proprietary blends.

Data collected: Basic water quality information, free chlorine, copper (both particulate and dissolved), PO_4 concentrations. Analysis of pipe scales at end of study.

Values to Water Science: Information concerning reasonable copper trends concerning results from typical phosphate blends. Field confirmation of Marc Edward's conceptual phosphate model and experimental work on synthetic waters.

Basic Work Plan:

1. A bench-scale apparatus has been constructed for the copper corrosion method testing. The apparatus allows six phosphate blends and the untreated water to be tested on a side-by-side basis. Chlorine was added to the water since state regulations require chlorination when phosphates are added to a drinking water since phosphates can accelerate microbial regrowth in a water distribution system. The concentrations are listed below; the phosphate concentrations are in mg/L as phosphate and the chlorine is mg/L total chlorine.

Pipe Number	Orthophosphate	Polyphosphate	Chlorine
1	0	0	0
2	2.0	0	0.6
3	0.7	0	0.6
4	0.3	0.3	0.6
5	0.7	0.7	0.6
6	1.3	0.3	0.6
7	1.3	0.7	0.6

For each corrosion control method, the drinking water has the corrosion control chemicals added to the water and then will flow through the apparatus (including the new copper pipe). Approximately 200 gallons of water will flow through each circuit each day. A flow rate of 1 gallon per minute will be passed through each pipe.

2. The apparatus is monitored for a total of 3 months for each of the two studies. The first study is occurring in Waverly, NE from May 6 to August 6, 2003. Negations are on-going to have the second study at Mahoney State Park in August through October 2003.

3. The source water for the apparatus is also monitoring and sampling on a regular basis. Water samples will be analyzed for copper and other common water quality parameters related to copper corrosion in order to determine the best method for copper corrosion control.

Proposed Project Timeline

Task	June	July	Aug.	Sept.	Oct.	Nov/Dec
Pipe Scale Analysis						
Analyze scale on pipes from other communities (Finished)						
Analyze scale on pipes from apparatus						
Jar Tests to evaluate Fe/Mn Sequestering Abilities						
Communities: Sequestering Study to determine reasonable min. Polyphosphate. Dose for Fe / Mn						
Copper Pipe Rig Studies at Two Communities near Lincoln						
Operate Pipe Rig Apparatus in Waverly for 3 months						
Operate Pipe Rig Apparatus on nearby water supply with higher Fe/Mn						
Analyze scale on pipes (before PO_4 used and 6 mo. after)						

Reporting and Dissemination of Information						
Data Analysis						
Final Report						

Principle Findings and Significance

This project is schedule to be completed in December of 2003. There are six preliminary findings at time are as follows.

1. Polyphosphates increase copper corrosion in high alkalinity, neutral pH water found in Nebraska. Polyphosphates are added to the water to sequester iron and manganese.
2. Polyphosphates aggressively remove existing scale layers and can actually increase copper corrosion.
3. Orthophosphates decrease copper corrosion in high alkalinity, neutral pH water found in Nebraska.
4. Orthophosphate concentrations often used for copper corrosion are sufficiently high to provide iron and manganese sequestering for the needs of many communities.
5. Polyphosphates convert to orthophosphates rapidly in high alkalinity, neutral pH water found in Nebraska.
6. Most communities will want to just use orthophosphates without polyphosphates to control copper corrosion.

Publications

None

Information Transfer Program

The results of this study will be disseminated three ways. The results of this work are scheduled to be presented at two regional conferences (Nebraska Section of the American Water Works Association and the Nebraska Rural Water Association). The result will be presented a National Conference (such as the 2004 American Water Works Association Annual Conference) and will be condensed into a journal article in order to include the results of this study in the archival literature.

Student Support

This project was an excellent opportunity for students with a technical background to expand their understanding of social and regulatory issues associated with the drinking water industry. In contrast to many research projects which provide students with an in-depth knowledge of an obscure technical process or model, this project required students to work with regulatory and community water system personnel, and to integrate their technical background into a broader experience with small communities. At the same time, the required data collection and analysis, and the laboratory work associated with the water analyses dictated that the student maintain and further develop strong technical and analytical skills.

Two students were employed on this project, a graduate research assistant (Ms. Junling Qiu) and an under-graduate research assistant (Ms. Gina Rust). Ms. Qiu was a graduate student in the

Environmental Engineering program and Ms. Rust was an undergraduate in Civil Engineering. This project was the basis of a Master of Science thesis for Ms. Qiu.

Section 104

	Base Grant	RCGP Awards	TOTAL
Undergrad	1		1
Masters	1		1
Total	2		2

Notable Achievements