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R. A. Sims
University of Arkansas at Little Rock

R. W. Raible
University of Arkansas at Little Rock

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R. A. SIMS and R. W. RAIBLE

Department of Electronics and Instrumentation
University of Arkansas, Graduate Institute of Technology
Little Rock, Arkansas 72203

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Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

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R. A. Sims and R. W. Raible
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Arkansas Water Resources Research Center
University of Arkansas
223 Ozark Hall
Fayetteville, Arkansas 72701

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ABSTRACT

CAUSES OF LOCALIZED COPPER CORROSION IN
DRINKING WATER SUPPLIES

Excessive amounts of copper have been observed in drinking water at certain installations on Lake DeGray and at isolated locations in the Arkadelphia area of Arkansas. A study of these installations was conducted to determine the source of the copper contamination. The supply water was very low in copper and therefore dissolution of the copper plumbing caused by low water pH and long residence times was determined to be the most probable source.

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KEYWORDS -- *copper/ *corrosion/ *potable water/ *taste/ corrosion control/ water quality/ impaired water quality

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INTRODUCTION

The problem concerning a bad taste in drinking water in the Arkadelphia, Arkansas, area first came to the attention of the authors in a letter to WRRC from Dr. Joe Nix, Professor of Chemistry at Ouachita Baptist University (OBU). The problem was first exhibited in water from a drinking fountain in the library at Henderson State University (HSU). Dr. Nix found that this particular fountain had 2 ppm of copper in the existing water while the entering water contained less than 0.05 ppm. Additional inquiries by Dr. Nix revealed several other sites with similar taste problems.

Copper has been used extensively since World War II for potable water plumbing, principally because of its ease of installation and its relative freedom from corrosion. However, a review of the literature indicates that there are some instances of unusual corrosion of copper water tubing.[1] From this literature review, it appears that the causes of excessive corrosion are varied and are often unique to a locality.

In a general discussion, Carlton[2] indicated that corrosion might be produced in buried water pipes used for electrical grounds.

A unique form of copper corrosion in buried pipe was reported by Bennet, et.al.,[1] who found that corrosion in the Yukon Territory was caused by currents created by radio frequency pickup. Romanoff[14] gives a very complete treatise of the corrosion of most common piping materials when placed in the soil.

Many of the references were concerned with the fact that leaks were produced in a very short time. These studies focused on the mechanisms of this rapid penetration and the general cause for corrosion. Lucey[8] principally examined the electrochemical mechanics of pit formation while Obrecht and Pourbaix[10] investigated the electrochemical reaction mechanics and dynamics. Cruse and Pomeroy,[5] in investigating the rapid penetration of pipe in the Los Angeles area, concluded the water pH was the problem.

Other researchers have looked at pH as a possible cause. Studies by Hatch[6] involved electrochemistry but were very concerned with erosion or impingement attachment. Obercht and Quill[9] also were concerned with the kinetics of corrosion as related to velocity, but were looking at the corrosion in boiler tubes where temperature has a great effect.

Reinhart[13] gives a very good description of factors that should be included in the design of potable water systems to reduce the potential for corrosion. This publication by Reinhart and a very general article on corrosion by Holler,[7] provide a good guideline on factors to investigate in trying to determine the cause for rapid pipe penetration. None of these articles have broached the subject of taste of the water.

Rambow[11,12] mentions the effect of taste of limited copper corrosion due to low pH. He does not present any further investigations into this subject, but concentrates on tube failure due to rapid pitting.

In an Application Data Sheet,[4] the Copper Development Association does address the effects of copper in drinking water. This data sheet points out some interesting facts.

1. The limit set by HEW for copper content in drinking water is 1 ppm.

2. Only 5% of a test panel perceived a copper taste with distilled water containing 2.6 ppm, and 5 ppm in spring water.

3. At a rate of 5 ppm, copper is not considered to be hazardous to human health.

4. Copper should not be used for plumbing with acid waters.

5. If water is allowed to stand in copper for a sufficient time period, it will pick up a coppery taste but still not be considered a health hazard.

MATERIALS AND METHODS

The research effort reported here was conducted on three fronts.

1. Sites known to have water taste problems were studied to determine which, if any, of the factors reported in the literature are applicable.

2. A laboratory simulation of a copper plumbed water supply system with water from Lake DeGray was constructed. The purpose of these simulations was an attempt to accelerate dissolution of copper to determine the particular mechanism involved in the Lake DeGray copper plumbing water system. The water cooler from the Henderson State University Library was also thoroughly studied.

3. A survey was conducted of all the water systems in the state with more than 1000 customers.

Each of these phases will be discussed separately.

1. Site Studies

The U. S. Corps of Engineers was most helpful in this phase of the study. Problems of taste had been reported at two locations within the Corps eight separate water treatment systems operated by the Corps in the Lake DeGray region. The two systems known to have locations with a bad tasting water were the Corps' office drinking fountain and the shop drinking fountain (different water treatment systems). No reports had been received from other locations. Our investigations assumed the lack of reports were due to the type of usage. The drinking fountains were periodically used by Corps personnel who occasionally noted the bad taste and were around to report it. The other taps in those systems were in sinks, outside faucets, etc. and generally not used for drinking water. Drinking fountains located in the area of the other treatment systems are in camping/picnic areas generally used by a transient population so that many problems may have gone unreported or unnoticed.

With this in mind, samples were periodically drawn from taps throughout the Corps' water systems with particular attention to the taps in the office and shop. The samples were collected over a period of 13 months to detect seasonal and/or temperature related phenomena.

Following this period of analysis on all the samples, it was concluded that only the Corps' office and shop did indeed have problems.

The pH of the water in the Corps office was generally around 6.2, or too low to prevent corrosion. The copper content of the water from the sink tap was almost as high as that from the cold water fountain (approximately 1.5 ppm). The equality of the copper content at the two taps indicates a problem not specific to the drinking fountain but to the entire system. The pH was the only common factor detected and must be assumed to be the cause. This problem can be corrected only at the water treatment plant.

2. Laboratory Studies

The water of Lake DeGray was found to be free of copper and acidic with pH of about 6.5. With the known taste problems existing only in systems where electrical power was connected, it was decided to investigate the effect of the presence of electrical currents (both AC and DC) on the rate of copper dissolution and in water with various pH values.

A. pH Studies

The experimental setup for pH effects allowed agitation of water samples contained in copper pipe sections. The pipe sections were 2' long pieces of type K or L copper pipe with a copper cap on one end and fitted with a rubber septum on the other. The copper cap was attached by soldering in some systems and epoxyed in others. One sample of each tubing type and termination was loaded with water of pH values 4, 6, 8, and 10. As was expected, copper rapidly dissolved into the acid water, eventually reaching 10 ppm and slowly into basic water to only 0.7 ppm. This was in systems where there was no solder connection, only epoxy. When solder was used, the final copper concentration in the water was less than 0.5 ppm even though the pH became neutral, indicating that the lead and tin were preferentially dissolved.

B. Electrical Current Studies

The experimental setup for determination of the rate of copper dissolution in the presence of electrical current consisted of two identical stations, one for AC, the other for DC. R.F. measurements were not needed as there was no strong R.F. source located in the area.

The laboratory stations consisted of 3 sections of copper pipe, each with a sweat-soldered coupling near one end and terminated on both ends with rubber septums. These three sections were connected in series to ensure equal current through each. The rubber septums allowed the use of a hypodermic needle to sample the water near the joint and at the other end. Needle sampling minimized system disturbances.

C. Water Fountain Studies

The drinking fountain that was removed from the HSU Library was studied non-destructively to try to pinpoint possible causes of the copper taste. The fountain was manufactured by Halsey Taylor (Model WM-8-A).

The fountain was observed to contain a light blue powder on all visible water line internal surfaces. The blue sample gave a negative HACH test for sulfate. Solubility and gas evolution in concentrated HCl indicated carbonate, probably copper carbonate.

The fountain was thoroughly flushed with dilute HCl in an attempt to clean the system. The acid was allowed to stand overnight and the system was then flushed with sodium bicarbonate solution followed by an extensive water flush. After this treatment, the water from the fountain still had over 5 ppm/Cu. After allowing water from the Little Rock city system to trickle through the fountain for several days, the Cu level was not preceptibly higher than the background. This fountain was then placed into limited service at the Graduate Institute of Technology for a period of nine months during which there was no noticeable copper taste, except where it had stood without use for extended periods of time.

3. Survey of Water Systems

A survey of municipal water treatment plants having over 1,000 customers was conducted to determine the extent of the problems associated with copper. The specific questions asked of the plant managers or operators were:

1. Has your department received complaints of a "bad taste" or of green water by users?

2. Have your customers experienced corrosion failure of copper lines under slabs or buried runs of pipe?

Of the 209 inquiries mailed out, 100 were returned. Eighty-three of the returns indicated no to both questions. The remaining 17 yes answers were divided: 9 answered yes to question 1; 4 to question 2 and 4 to both questions. A review of the locations of the positive responses indicates no geographical significance to the responses. Analysis of the water chemistry reports showed no specific pattern as pH ranged from 6.5 to 8.8, most around 7.6 and total hardness was from 12 to 85.

It is interesting to note that the response from the Arkadelphia City Water Systems indicated no taste or corrosion problems.

RESULTS AND DISCUSSION

The copper taste problems encountered in the drinking fountains at the Henderson State University Library and the Corps of Engineers buildings at Lake DeGray appear to have two factors in common that could be responsible for the taste. The water for both is from the Caddo River Watershed and the resultant pH is on the acid side. This acid pH has been shown by our studies and the literature to accelerate copper dissolution.

From the available use history and location of the problem drinking fountains, the taste problem might be due to the long residence time occuring because of infrequent use.

Usage patterns can not be changed, but an increase in the pH of the water at the treatment plants might also alleviate the taste problems. Throughout this study no sample from the affliated fountains exceeded the 2.6 ppm level mentioned in the Copper Development Association application note.

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