COPPER LEVELS IN DRINKING WATER FROM PRIVATE HOUSEHOLD WELLS IN MAJOR PROVINCES OF GEORGIA

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Abstract. Copper is an essential element in human diet. However, too much copper in drinking water can cause flavor changes and health hazards. Thus, the U.S. Environmental Protection Agency (EPA) has set drinking water standards to regulate copper levels in the drinking water supply. Water test results obtained by the Agricultural and Environmental Services Laboratories (AESL) indicated that about 5.6% of the household well waters submitted for analysis contained copper at concentrations above EPA's primary maximum contaminant level (MCL) of 1.3 mg L-1. Most of these were detected in Sand Hills and Southern Piedmont provinces. Under Georgia conditions, copper occurs in drinking water primarily due to corrosive water and the dissolution of copper plumbing. These corrosive waters were characterized by being soft (hardness <50 ppm), slightly acidic (pH <6.5), and less buffered owing to low alkalinity (<50 ppm CaCO3).

INTRODUCTION

Copper (Cu) is an essential mineral in the human diet. It aids in the production of blood hemoglobin and thus is important for the individual's well-being. Excessive intake of copper, however, has adverse effects on human health such as stomach and intestinal distress, liver and kidney damage, and anemia.

In addition to food, drinking water is also an important source of Cu for humans (Zacarias et al., 2001). Although Cu concentrations in surface and groundwater are generally low, long term cumulative intake of the mineral poses a threat to human health. Thus, the U.S. Environmental Protection Agency (EPA) set a maximum contaminant level (MCL) for Cu of 1.3 mg L-1 in drinking water.

Elevated Cu level in drinking water is almost always caused by contamination in the water delivery system resulting from corrosion of pipes and fittings. Low pH and soft water running through Cu pipes and fittings cause gradual leaching of copper resulting in elevated levels in drinking waters. Also, residence time of water in pipes affects Cu level in household drinking water. A corrosive water that remains stagnant in the plumbing system for an extended period of time will likely increase the Cu level and could exceed EPA's primary and secondary limits. Therefore, it is recommended that the system should be flushed with cold water for a few minutes before water use, particularly in areas where low pH water is common.

Monitoring of Cu concentrations in drinking waters is important for prevention and correction purposes. One of the many services provided by the University of Georgia Agricultural and Environmental Services Laboratories (AESL) is to provide analytical services to the public through Cooperative Extension. Results of the analyses are interpreted and if necessary, AESL provides recommendations to the client.

This paper presents some Cu data of household drinking well waters from the major Georgia provinces including the Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain (Figure 1).

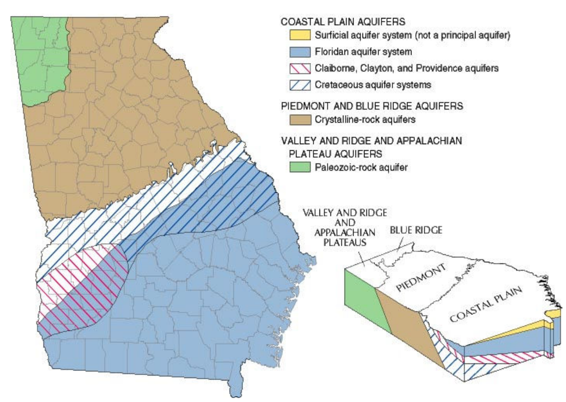

Figure 1. Major land resource areas or provinces of Georgia (source: U.S. Department of Agriculture).

METHODS

Water samples

Water samples collected from privately owned wells located in different Georgia provinces were submitted to the laboratory for mineral analysis. Well waters were primarily for domestic use by households, which included drinking. As indicated on the submission form, clients have their water tested because of quality concerns, which is oftentimes prompted by observance of unusual taste or appearance. The most common reasons indicated by homeowners for water testing could be broadly categorized into the following: taste (bitter, bad, odd, oily, funny, metallic, has after taste, tastes like cattle ammonia), smell (bad, smell of iron or sulfur, smells like urine, nausea, vomit, smells like fish, rankish, nasty), color (blue residues, green staining, hair green, blue water, teeth blackening, blue-green tub, rusty tub, sudden cloudiness), and others (gritty feeling, oily hair after shampoo, illness, stomach problem, dry skin and hair problems).

Sample Preservation

Water samples for metal analysis were first acidified to pH ~2.0 with HNO_3 prior to analysis. This step is being done to prevent adsorption of metal ions including Cu on the surface of sample containers (Standard Methods, 1995). Acidification also keeps metal ions from precipitating as hydroxides or form complexes with other constituents.

Sample Analysis

Copper concentrations were quantified using the Inductively Coupled Plasma Emission Spectrophotometer (ICPES, Thermo Jarrel-Ash 61E) and pH was measured using a pH electrode. References for the methodologies used by the AESL can be found on the web at *http://aesl.ces.uga.edu/methods/stl-water.html*.

RESULTS AND DISCUSSION

About 9,000 well water samples from various Georgia provinces were submitted to AESL for mineral analysis. Thirty percent of the water tested had low pH with 5.6% of the samples exceeding the EPA primary MCL of 1.3 mg Cu L^{-1}. Water samples coming from the Piedmont and the Sand Hills provinces were observed to be more acidic than those from other areas. As shown in Fig. 2, the most acidic (5.5 to 6.2) waters were from the Sand Hills province, which was accompanied by highest levels of Cu (Fig. 3). Also, these waters were soft (<30 mg $CaCO_3$ L^{-1} hardness) and may have caused some corrosion of the water line system. On the other hand, corrosion is not observed in pipes with running hard water as it may promote coating of carbonates on the inner lining of the pipes.

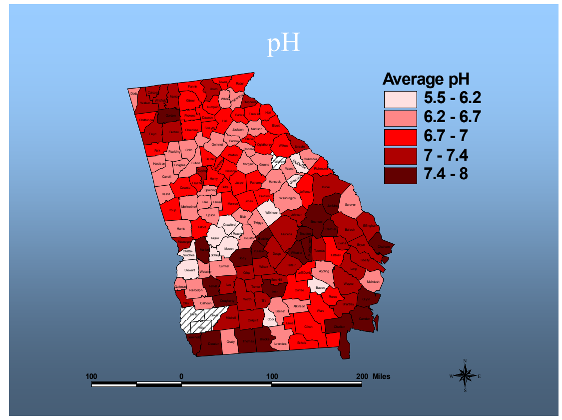

Figure 2. pH values of water samples from various provinces of Georgia

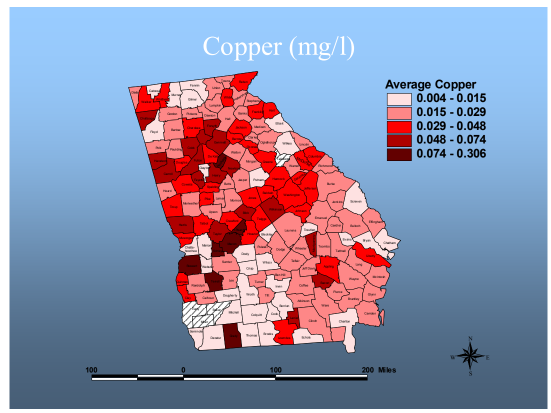

Figure 3. Copper concentrations in water samples from various provinces of Georgia

A plot of all the samples tested during the period of study indicates that most of the waters had a pH around 6.4 (Fig. 4). Water pH below 6.5 is indicative of corrosiveness. The ideal conditions to control corrosion include moderate alkalinity (30 to 70 mg/L) and a pH range of 7.9 to 8.2. Moderate alkalinity is beneficial since it is composed of carbonates that can react with calcium to form calcium carbonate. Calcium carbonate develops hard stable coatings inside pipes and helps control (inhibit) corrosion. However, these coatings must not be allowed to become thick because excessive calcium carbonate scale formation can eventually clog pipes.

Water acidity is attributed to several factors. Surface water or shallow well water acidity may come from runoff, mining spoils, decomposition of plant materials, and acid rainfall caused by atmospheric carbon dioxide and other airborne pollutants especially oxide gases of sulfur and nitrogen. In the case of groundwater, acidity is brought about usually by dissolved carbon dioxide, decaying organic matter, or acidic bedrock that has a close contact with the water. Most of the acidic waters presented in this report were observed to have come from shallow wells of the Sand Hills region. A report by Sonon et al. (2005) indicated that the occurrence of primary contaminants including Cu in groundwater was greater in shallow wells (<100 ft.) than in deep wells (>100 ft.). About 5 to 15% of the shallow

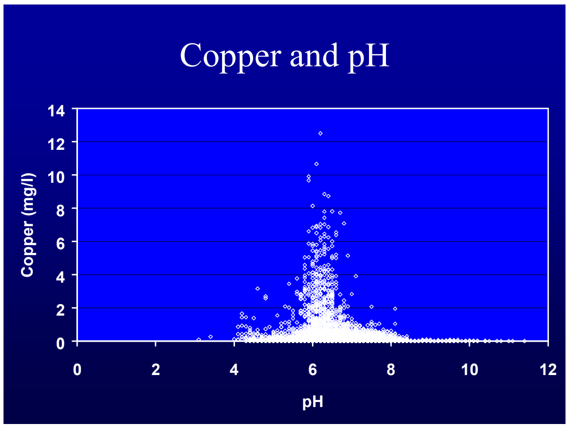

Figure 4. Relationship between pH and copper in water samples tested.

wells tested showed copper levels above the primary MCL. An earlier study also found greater contamination (nitrate-N) in shallow wells less than 100 ft deep in the Piedmont province (Bush et al., 1997).

RECOMMENDATION

The occurrence of Cu in drinking water above the primary MCL in 5.6% of the wells tested is likely due to corrosive water flowing through a copper-containing water delivery system. The Agricultural and Environmental Services Laboratories at the University of Georgia recommend mitigation practices to alleviate the above ground water quality problem. The laboratory recommends the best treatment methods with careful consideration of factors such as economics, water quality characteristics, and the limitations of the available treatment technology. Reducing corrosivity may be as simple as adjusting the pH and waiting for the water and pipes to reach a new balance, or it may be more complex. Unless the pH is again raised, the scale forming a protective coating inside the pipes is stripped away, exposing bare metal to the corrosive water. Mitigation options suggested by AESL include removal of the copper source, managing the water used by flushing water lines prior to water use, keep water cold as copper is more soluble at high temperature, and water treatment (reverse osmosis, distillation, ion exchange). Details of copper in water and its remediation can be found on the web at http://aesl.ces.uga.edu/publications/watercirc/index.html.

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