

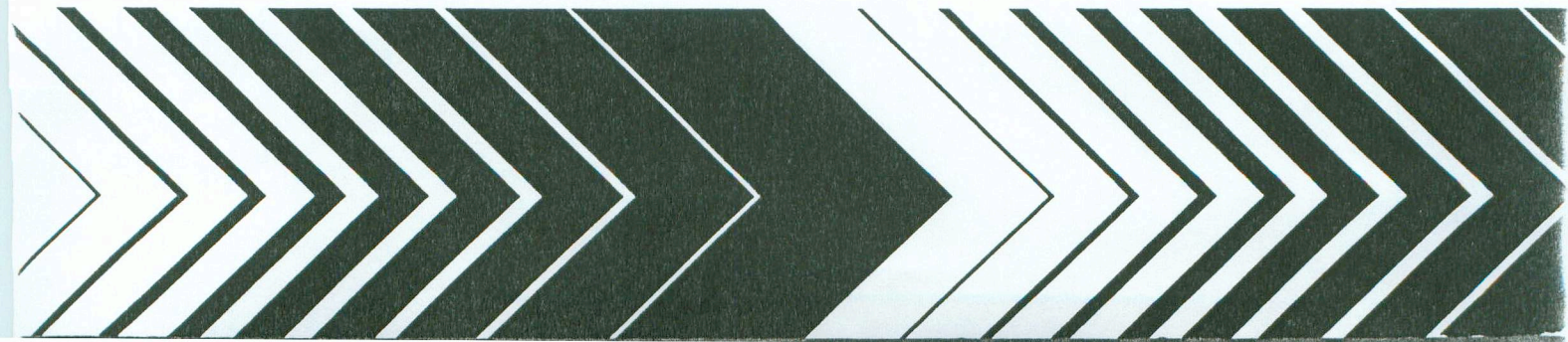
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Leaching of Metals from Household Plumbing Materials: Impact of Home Water Softeners



the softened water point fell on the upswing of the curves. The difference in profile shapes suggest that the difference in the hardness concentration may have had some indirect impact on the copper dissolved oxygen reaction that took place during the stagnation time. There is no physical evidence from the pipe surfaces, however, to confirm or reject such a hypothesis. These large fluctuations masked any differences that may be related to the differences in hardness of the two exposure waters.

The extremely high levels of copper in all the copper loops are mainly attributable to the water quality (pH, DIC, and DO). Although the sample standing time of 17 hours (that was about twice the standing time of the Phase I) plays some role, copper(II) solubility determined by pH and DIC is likely to be more significant. Based upon the Copper (II) equilibrium solubility diagram of Schock et al¹², copper(II) solubility of the Phase II water is about 3 mg/L in contrast to only about 0.02 mg/L for Phase I. The observed difference is of similar magnitude to that predicted based upon system chemistry differences, being approximately 3 mg/L compared to approximately 0.1 mg/L. Because of the highly non-equilibrium nature of the loop systems in this water, however, comparisons to theoretical models should not be taken very literally.

5. Discussion and Conclusions

Cyclical variations and the relatively short duration of the study prevented achieving constant metal levels, or reproducible cycling in response to background water chemistry changes. Physical differences in the initial pipe surfaces or exposed metal areas (e.g., solders) caused enough variability between loops that the duplicates could not be paired for statistical evaluations. Moreover, lead

leaching levels of the soldered copper loops and faucets were very low and therefore most of the test data did not lend itself to the statistical tests generally applied to the evaluation corrosion control test results. Consequently, the general conclusions drawn from the study were based primarily upon visual examination of the plotted test data.

5.1 Phase I

Visual examination of the Phase I data (Figures 4-8 to 4-14) suggests little difference in metal levels between the two systems and where differences were apparent, there was no pattern of the softened water metal levels being higher than the non-softened water levels. The only observed data to have consistent differences in metal levels throughout the study were the lead levels from the lead pipe loops where the levels of the non-softened water loops were always 0.05 to 0.06 mg/L higher than the softened levels.

The lead levels observed for the lead pipe are higher by a factor of three than would be expected for a water of the same pH and DIC.¹⁰⁻¹² Therefore, the behavior of lead in this study suggests the presence of an interferant to normal passivation film formation. X-ray diffraction analyses of pipe specimens showed almost no film formation, and no significant amounts of basic lead carbonate as would be expected. At this DIC/pH combination, the difference in lead solubility for the small pH difference between the softened and non-softened water should be minimal. Therefore, some surface reaction not directly resulting from hydroxide or carbonate ion probably occurred.

The lead levels from the faucets were observed to be slightly higher in the softened

water system, but the absolute levels were very low, less than 0.007 mg/L. The lead levels from the copper solder pipe were both near the detection limit of 0.002 mg/L except for several spikes during the last eight months of the study. This concentration range can be accounted for by differences in joint surface exposure as well as corrosivity, so it suggests little or no difference.

During the last six months of the study, the copper levels of the copper tubing loops were about 0.01 to 0.02 mg/L higher in the softened water loops while there was essentially no difference between the copper levels of copper pipes or faucets of the two systems. Additionally, copper levels from soft and hard copper pipe are higher than would be expected based on current experimental and theoretical work.^{6,7,13-16} X-ray diffraction analyses of pipe specimens from this project did not show normal film formation of Cu(II) solids, such as $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$, CuO_2 , or $\text{Cu}(\text{OH})_2$ under controlled conditions. Abnormally higher copper levels have been previously observed in presence of 60-120 mg/L sulfate at pH 8.1-8.8⁶. However, this study water also contains, in addition to significant sulfate, appreciable polyphosphate and polyphosphate is known to increase lead solubility at least at pH 8 and above.^{17,24-26} Similar effects on copper would be expected.

5.2 Phase II

Visual examination of the data (Figures 4-22 to 4-27) from Phase II reveals that the absolute metal levels from all of the plumbing materials to be significantly higher than the results of Phase I. The higher levels are attributed to several factors, but most importantly to the differences in water quality (pH, DIC and DO) and in some cases in standing times, 17 hours versus 7+ hours.

The general outcome of Phase II, however, was very similar to the overall results of Phase I where there was no pattern of the softened water metal levels being higher than the non-softened water levels.

The copper levels from the copper soldered pipes, the soft copper tubing and faucets show extreme variability and have a great dependency on the DO content of the water initially and at the time of sampling. Standing time tests conducted on the copper pipes showed copper levels differed over the course of stagnation. The rate of increase and subsequent decrease were in direct relationship to the DO level of the water and also differed between the copper pipes exposed to the non-softened and softened waters. All of these factors were observed to have such a great influence on the copper levels that any potential impact of hardness could not be measured on these test systems.

In summary, considering all of the lead, copper, and zinc leaching data from all loops and faucets from both studies, there is no clear evidence of a pattern that the ion exchange softened waters systematically produced higher metal levels than the non-softened waters under otherwise identical conditions. Copper (especially) and lead displayed relationships to water oxidant level that appeared to differ between non-softened and softened waters and, therefore, the effect of hardness could not be isolated.

Except for the decrease in calcium levels, the softened water did not change any of the significant water quality corrosion parameters that would cause a prediction of higher metals leaching in the softened water system. The ion exchange softening process increased the pH of the control waters by 0.2 to 0.3 units which could have a slight

beneficial effect on metal leaching.

Corrosion inhibitor anions, such as HPO_4^{-2} and PO_4^{-3} , can pass through the system, so ion exchange should not impact them adversely.

These studies involved only two water qualities and many chemical and physical characteristics can affect corrosiveness, so the results cannot be extrapolated to all water qualities. These results do indicate, however, that ion exchanged softened water will not necessarily produce higher metal levels.