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PIM #3

Determining the Problem, Cause and Solution
For Lead in Washington, DC Drinking Water

Introduction

Ever since the early 1990's, there has been reported problems of lead leaching into potable water sources from corrosion of plumbing materials. The Environmental Protection Agency (EPA) has been managing the lead problems in cities such as Washington, D.C.. Problems were discovered in 2001, in which high levels of lead were getting into homes ***after*** the water was being treated. Some water testing in D.C. had lead levels around 300 ppb, whereas the EPA's limit is 15 ppb *(1)*. A scandal ensued because the lead levels were not disclosed to the public until years later. The public received conflicting reports from the D.C. Water and Sewer Authority (DCWASA) who distributes the water and the Army Corps of Engineers who manages the water treatment facility on the Potomac River. Determining where the source of lead was coming from and why it was now soluble in potable water stirred an investigation which still continues to this day.

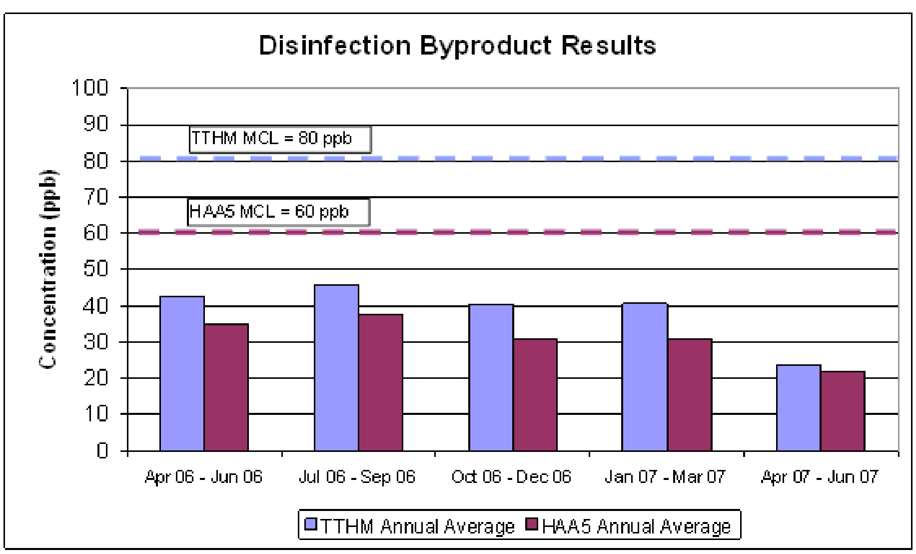
Background

Many scientists believe that the problem of increased lead in potable water started from the switch in disinfectants, from chlorine gas to monochloramine:

$$HOCl + NH_3 \rightarrow NH_2Cl \text{ (monochloramine)} + H_20$$

The change was made in 2001 to comply with a 1998 Disinfection Byproducts Rule, which restricts disinfection byproducts in water *(1)*. Although contact time for 99 percent of destruction of E. coli significantly decreases when switching from hypochlorous acid to monochloramine, DCWASA still determined to change the disinfectant.
Possible sources of lead were initially thought to be in old lead pipes. In November of 2001, DCWASA began delivering water with chloramines. As a result, disinfection byproducts, trihalomethanes (TTHM) and halo acetic acids (HAA5) decreased as shown in Figure 1 *(8)*.

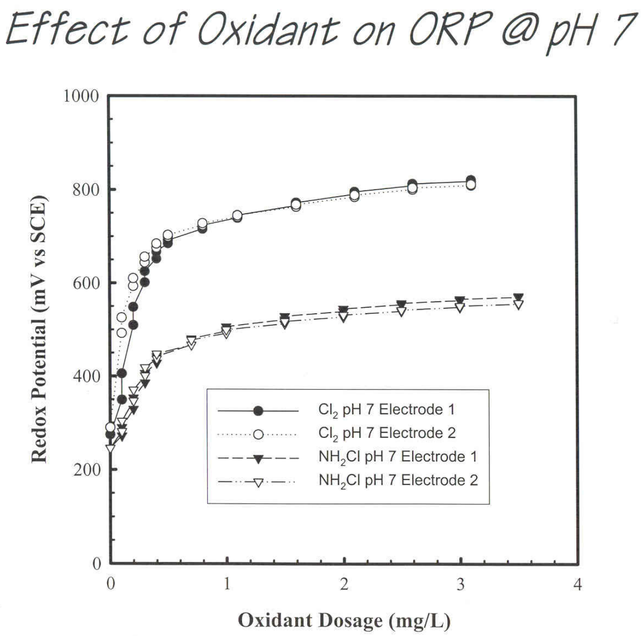
Figure 1



Consequences

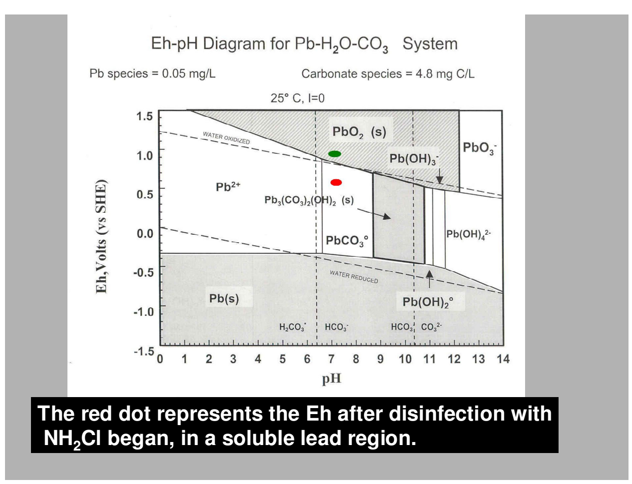
Despite the reduction in disinfection byproducts, there were many unwanted consequences from changing the disinfection process. The first big consequence, was that the oxidation reduction potential of the water was lowered several 0.2 V as shown in Figure 2 *(10).*

Figure 2



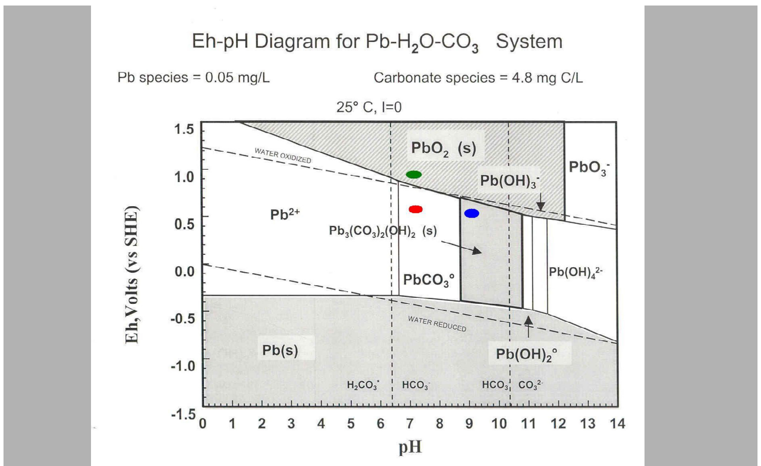
Furthermore, if the oxidation reduction potential is reduced by the addition of chloramines (as compared to HOCl and OCl^- produced from the disinfectant Cl_2), then insoluble Pb^{+4} could change to soluble Pb^{+2} as seen in the Figure 3 *(10)*. As a result, the solubility of lead, existing in old pipes, was changed. Conventionally, most environmental scientists thought that lead in old water pipes existed in a +2 oxidation state. However, Schock, from the USEPA discovered that in highly oxidizing drinking water, an oxidation state of +4 for lead is quite common *(1)*. Schock found PbO_2 scales in pipe scales when he examined Washington, D.C. service lines *(1)*.

Figure 3



DCWASA countered the multiple problems of insoluble lead in old pipes by raising the pH (as the arrow shows in Figure 3 above) so that the soluble Pb^{+2} was no longer soluble. To do this they decided to add orthophosphate to bind with the lead and enhance the "corrosion control treatment" of old lead pipes *(4)*. WASA set a range of 1.0 to 4.5 mg/L for the distribution of orthophosphate *(4)*. According to figure 22 in Hem, the form of PO_4^{3-} they likely added was HPO_4^{2-} *(10)*. The addition of orthophosphate would increase the pH of the water to 9, pushing the water into the zone in the stability field diagram where insoluble $Pb_3(CO_3)_2(OH)_2$ would form (See Figure 4) *(10)*.

Figure 4



The blue dot is where Washington wishes to get by adding PO_4^{3-}.

The problem of lead seemed to be fixed in the Washington, D.C. area. Nevertheless, adding phosphorus has many unwanted side effects. One side effect is the difficulty in removing phosphate from potable water that is returned for treatment. Metcalf and Eaddy note that aluminum sulfate (alum) and ferric chloride are typically used for the removal of phosphorus *(5)*. This increases the mass of sludge as compared with non-phosphorus treated water. Higher PO_4^{3-} content is also a problem because it is a nutrient for aquatic biota and a major cause of eutrophication in ecosystems *(10)*.

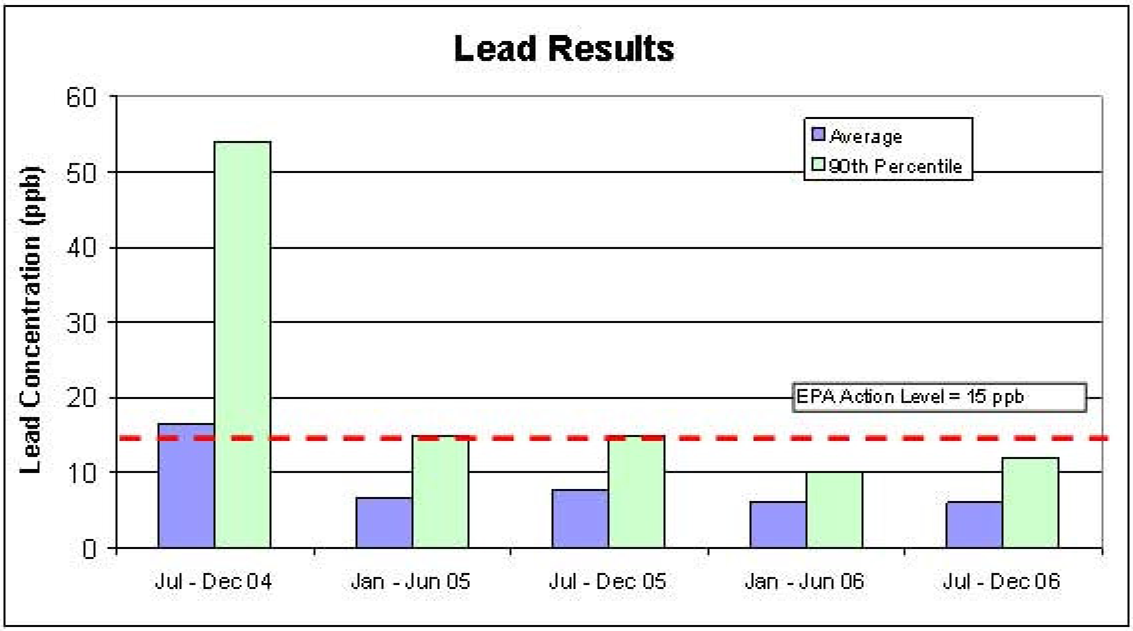
A further problem from adding phosphorous and chloramines was discovered by Edwards in an extensive study. Not only can lead come from service lines, but also from brass plumbing materials. In experimental waters at a pH of 8.5, adding phosphate with chloramines was discovered to cause accelerated galvanic corrosion in brass fixtures *(1)*. Brass fixtures are made from an alloy of copper, zinc, lead, and other trace constituents. Edwards found that if brass has stress cracks, ammonia in chloramines can attack brass, especially at higher pH levels *(8)*. Brass typically appeared to be the anode when connected to other metal plumbing with HOCl treatment. However, when chloramines was changed as a disinfectant brass also changed to the cathode, thus dissolving brass fixtures and releasing lead contaminants. In fact, brass fails three times faster in the presence of chloramines residue *(8)*.

Recent Developments

Beginning in 2006, DCWASA plans to spend in excess of $400 million to replace all of the district's 29,000 known lead service lines with copper pipes. All private home owners are being encouraged to pay WASA to replace their lead pipes as well *(7)*. Thus far 6,500 privately owned lead lines have been replaced. This accounts for approximately 25% of all the houses that have private lead pipes leading to their homes. Financing programs are available to help eligible customers replace lead service lines on private property *(7).*

Despite all the consequences from the change of disinfectants and the addition of phosphate, lead in potable water has been decreased. Figure 5 indicates lead concentrations of water after it has left the water treatment plant and has traveled through existing water pipes *(8)*.

Figure 5



More recently, parents of school children have been concerned of increased lead concentrations from public school drinking fountains. D.C. public schools found "isolated findings of increased lead levels" after using a private lab that followed EPA guidelines *(9).* One fountain had 1,200 ppb of lead. In response, Rick Rogers, an EPA official leading a federal team trying to reduce lead levels said recent efforts are working *(9).* Rogers noted that high lead levels in schools are just another example of an "elusive" lead problem in large buildings that the EPA can't explain. Rogers was also quoted in April of 2007 that "lead city wide is looking very low, very good" *(9).*

Conclusion

Officials from the EPA and DCWASA appear to be satisfied with the levels of lead in Washington, D.C. area potable water. They have a proposed solution of not only continuing to use phosphate with chloramines, but also replacing old lead pipes. The solution of changing the disinfectant has appeared to eliminate the illegal disinfectant byproducts but has caused other problems. For example, the use of lead-bearing brass plumbing fixtures in private homes has not been solved. As Edwards notes, one has to be very careful when changing the chemistry of water without examining of the possible consequences *(10).* The problem in Washington, D.C. has really opened the eyes of environmental chemists and water treatment officials of the potential dangers in changing water chemistry.

Literature Cited

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