Assignment 7 (Extension: Flint Water Crisis)

Group Assignment

LEAD AND COPPER IN DRINKING WATER

The three articles below should be used as a resource to address and support your work.
Links are provided to the original papers.

7-A-1

Original Articles

The Flint, Michigan, Water Crisis: A Case Study in Regulatory Failure and Environmental Injustice

Lindsey J. Butler, Madeleine K. Scannell, and Eugene B. Benson

7-A-2

A Case Study of Environmental Injustice: The Failure in Flint

Carla Campbell, Rachael Greenberg, Deepa Mankikar, and Ronald D. Ross

7-A-3

Flint Water Crisis Caused By Interrupted Corrosion Control: Investigating “Ground Zero” Home

Kelsey J. Piiper, Mia Tang, and Marc A. Edwards

Virginia Tech, Civil and Environmental Engineering, 418 Durham Hall, Blacksburg, Virginia 24061, United States

Supporting Information
Many cities in the US have old infrastructure that includes lead in pipes; lead alloy pipes as well as copper and brass alloys containing lead. Different pipes are made from different alloys with different galvanic corrosion properties. Lead leaches into the water through several pathways. Corrosive products in the water such as acids eat away at the pipes and do so to older alloys more quickly. You also have selectively leaching where in one element within an alloy leaches out more than another element. The article above presents an overview of the issues related to the “flint Water Crisis”. In here you are asked to:

1. Present an overview of the issues relating to Pb leaching and the Lead and Copper Rule (LCR).


3. Present in detail the use of phosphate as corrosion inhibitor. Make sure you illustrate all the chemical reactions involved with relevant equilibrium constants. Make sure to use the solubility products of Me-phosphates to support your argument.

4. Use what you know from solubility, corrosion and redox couples to justify the following statements. Please make sure you include equilibrium constants to justify your answers.
   a. In pipes “Lead is more likely to leach out than copper but less likely than zinc” (use standard redox potentials to justify your answer)
   b. “Different pipes within the city's system can form galvanic cells if the water has ionic properties”
   c. “No exposed metal in pipes allows chlorine (Cl₂ ) levels to remain stable”
   d. “Phosphate in the water reduces the acidity of the water”

5. Present the different water chemistry qualities when they move from Detroit to Flint water.

6. The figure bellow is from another article published in Chemical and Engineering news (http://cen.acs.org/articles/94/i7/Lead-Ended-Flints-Tap-Water.html)
7. Explain how the chloride-to sulfate mass ratio (CSMR) can be used as a measure of water corrosivity for galvanic connections.

8. Flint is not the only case. Go online and search for other cases in which drinking water distribution systems where highly contaminated by lead. Prepare a 1-page description of the problem; be as specific as possible and try to write as many chemical reaction as possible that would allow to quantify the problem and postulate solutions!

9. Based on the papers provided, is there an evidence of environmental injustice at Flint? Justify your answer and indicate which indicators you would use.

Environmental justice and Metals in drinking water

The following sites provide general information related to Environmental Justice and metals in drinking water:

USEPA. Basic information about Lead in drinking water. Retrieved from: https://www.epa.gov/ground-water-and-drinking-water/basic-information-about-lead-drinking-water


7-B-1. DATA ANALYSIS

1. Dissolved metal data from the ICP results (Lab. 7) will be posted on ELMS. Obtain the data and conduct relevant statistical analysis on each measurement. Produce an average copper concentration for the replicate treatments and standard deviation, for each treatment.

2. Using statistical information, produce graphs of different treatments to visualize which treatments had the highest dissolved copper. Use standard deviation calculations to produce error bars for your graphs. Please organize and label the data by treatment chemistry and pH, not by treatment number. Check out Figure 4 in the paper Nguyen et al. (2011) “Acceleration of galvanic lead solder corrosion due to phosphate”. Corrosion Science, 53(4), 1515-1521 [http://www.sciencedirect.com/science/article/pii/S0010938X11000382] for ideas of how to present this type of data and use of photos to demonstrate corrosion!

3. Discuss soluble copper data, and photos for lab report.

4. Produce an average copper concentration and standard deviation with the data of the phosphate solutions. Compare soluble copper concentration among the student’s samples. Also compare the soluble copper concentration found in the phosphate solutions and synthetic treated water. Discuss the differences you observe. Where do you find more dissolved metal in general (phosphate solution or treated water)? Comment your answer.

5. Analyze student tap water data uploaded to ELMS. Graph the student data as stacked bar graphs of each metal, by student location.
7-B-2. DISCUSSION QUESTIONS

Using citations to strengthen your answers: if other material is cited to improve your answer, please use a government, academic, or university source. Pictures/structures do not have to be from a formal source however, but please note source in caption. Outside references are encouraged! Try https://scholar.google.com/ or the UMD libraries websites for academic, peer-reviewed references. Please provide an in-text citation after the sentence, such as (Andrade et al., 2017). Please provide the full reference in a final “References” section at the end of your lab report, as in this report. Hint: Google Scholar will format your citation automatically after the search, click “Cite” for options located under each search result Google Scholar returns.

1. Briefly state the role the different ions and chemicals used to model different treated drinking waters. They include FeCl₃, FeSO₄, Cl₂ (bleach), CaCO₃ (alkalinity), and Na₂HPO₄ (flocculation, pathogen destruction, corrosion agents, corrosion control, etc.). These salts are highly soluble.

2. Re-state your original hypothesis for the water treatments (see page 5 of this protocol). Did it hold true in testing? Was there as much variation in soluble metals between each water treatments, as expected?

3. How did pH seem to influence results? Why?

4. Look at the pictures uploaded in the collaboration file on ELMS. Can you see differences in the pipes exposed to different water treatments? Do they pipes look like you expected? Comment your answer.

5. The concentrations of chemicals for the different water treatments were based on actual drinking water treatment values. Consider the following two references used to design this experiment:
   b. Pieper et al. (2017), presenting Flint, MI levels after December 2014: http://pubs.acs.org/doi/abs/10.1021/acs.est.6b04034

Which waters represented Flint, MI after Dec. 2014, which waters represented UMD’s water (WSSC), and which waters represent neither source?

6. Another concern in drinking water treatment and in Flint, MI were trihalomethanes (THMs) (EPA Memo on Flint Crisis, 2015, introduction). What are THMs, why are they of concern, and how do trihalomethanes form in drinking water (use 1-2 citations)? Provide the pictures of possible reactants and products. (Does not have to be a formal, balanced reaction). Could trihalomethanes form in our experimental set-up? Did we test for this?

7. Class tap water: What metals were abundant in our tap water? Does this concern you? Was any lead or copper over EPA Action Levels (AL)?
8. Bonus question: You’ve learned about alkalinity. Alkalinity is another important drinking water quality measure. Given that that CO$_3^{2-}$ can complex with lead to form Lead (II) carbonate (PbCO$_3$), is alkalinity provided by the carbonate-bicarbonate system a good thing in drinking water? How would pH influence this? Some of the synthetic drinking waters you test in this laboratory have CaCO$_3$ (see table 2). Is the concentration of dissolved metals in these waters as you expected? Why?

9. Final Thoughts: As an environmental engineer, what would be your recommendation to remediate the pipe corrosion problem created by the water engineers in Flint, MI? (See EPA Memo and YouTube Videos to help form your opinion, in Background, page 2).

   c. Include recommendations such as chemical addition to water to stop the problem and recommendations to fix the network of corroded pipes (think about all three pillars of sustainability).