taken from
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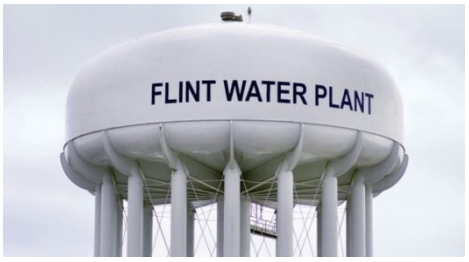
Corrosion Writing to Learn: Initial Draft

Objective:



The city of Flint needs to replace several pipes due to the recent Flint water crisis. You have been hired as a consultant by the city to advise them on the type of piping to use. Based upon your knowledge of corrosion and considering the galvanic series, write a memo to the government officials suggesting which metal or metal alloy they should use and why. Include a discussion of the relative reactivity of your chosen metal/alloy, the types of corrosion that are most likely to occur in this system, the relevant chemical reactions that could lead to such corrosion, and any preventative techniques the city should apply. In your memo, make sure to discuss the relative cost of the potential pipe materials.

References:

http://cen.acs.org/articles/94/i7/Lead-Ended-Flints-Tap-Water.html

https://www.scientificamerican.com/article/zapping-lead-pipes-with-electricity-could-make-them-safer-for-drinking-water/

https://players.brightcove.net/1399189305/370f2eae-5572-4746-8886-72790b360bff_default/index.html?videoId=4774241533001

Items to keep in mind:

- When we read your memo, we will play the role a government official with minimal scientific background who is trying to understand the materials science behind corrosion.
- Keep in mind that the pipes in Flint are currently made out of iron, lead, and copper.
- Consider environmental aspects that could damage the pipes, i.e. tree roots, freeze-thaw cycle.
- If external references are used, they should be cited using MLA citation style format.
- Since you are aiming to persuade potential donors of the viability of this idea, make sure to carefully edit and proofread your memo.
- Since you are aiming to persuade officials, while demonstrating your credibility as a consultant, make sure to carefully edit and proofread your memo.
- The memo should be 350-500 words in length, excluding references.

Corrosion Writing to Learn: Peer Review

Peer Review Guidelines:

- *Print* and read over your peer's memo to quickly get an overview of the piece.
- Then read over the rubric for the corrosion prompt.
- Read the memo again more slowly, keeping the rubric in mind.
- Highlight the pieces of texts that let you directly address the rubric prompts for the peer review online tool.
- For your online responses, focus on larger issues (higher order concerns) of content and argument rather than lower order concerns like grammar and spelling.
- Be ***specific*** in your responses, referring to your peer's actual language, mentioning terms and concepts that are either present or missing, and following the directions in the rubric.
- Use respectful language whether you are suggesting improvements to or commenting on your peer's work.

Rubric Prompts:

1. This memo should be understandable to someone with minimal scientific background. For a reader with minimal scientific background, which parts are difficult to understand? Which parts are easy to understand?
2. The memo should explain the chemical origins of corrosion, including the anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series. Is the explanation of corrosion origins complete and explained well? Is the role of the galvanic series in corrosion prevention discussed? Is there anything missing in the discussion of the galvanic series? How could these descriptions be improved?
3. The memo should detail the types of corrosion that are most likely to occur in the water system. For each type of corrosion, the relevant chemical reactions should be mentioned. Are the most likely corrosion mechanisms and their corresponding chemical reactions clearly described? How could these descriptions be improved?
4. The memo should provide a coherent argument for upgrades to the water system, including the specific metal/alloy to use for new pipes, and any additional preventative measures to be employed. The argument should be based upon both scientific reasoning and materials costs. Is the argument comprehensive, concise, and/or persuasive? How could the argument be more convincing?

Corrosion Writing to Learn: Revision

Revision Prompt:

Revising writing means re-seeing it, and the process of reading and commenting on the writing of others as well as receiving feedback from your peers gives you a way of seeing your own writing differently. Meaningful revision means changes at the sentence and paragraph level, usually involving a minimum of three sentences. ***In order to receive full credit for revision, meaningful revisions are required.***

Revision Guidelines:

- Re-read the prompt.
- Re-read the rubric and consider what a complete and effective response would include, noting what you do not fully address.
- Make a list of the content that you thought was effective while reviewing the drafts from your peers.
- Read and summarize the feedback you received from your peers.
- With these things in mind, re-read your draft and mark places where you can improve the content.
- Revise and submit your response.

Checklist from Corrosion Peer Review Rubric:

1. This memo should be understandable to someone with minimal scientific background.
2. The memo should explain the chemical origins of corrosion, including the anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series.
3. The memo should detail the types of corrosion that are most likely to occur in the water system. For each type of corrosion, the relevant chemical reactions should be mentioned.
4. The memo should provide a coherent argument for upgrades to the water system, including the specific metal/alloy to use for new pipes, and any additional preventative measures to be employed. The argument should be based upon both scientific reasoning and materials cost.

Corrosion Writing to Learn: Rubric Criteria

1. Would this memo be understandable to a person with a minimal scientific background.

Score	Description
0	No translation into their own words.
1	Translates into their own words or more accessible language.
2	Translates into their own words or more accessible language and attempts to explain the chemical principles behind corrosion. This must include reference to the galvanic series or chemical reactions, but with little background provided.
3	Translates problem into accessible and original language, providing a thorough and correct explanation of how metallic reactivity dictates corrosive behavior. Does not provide an in-depth or consistent solution to abating corrosion in Flint.
4	Translates problem into accessible and original language by providing a thorough explanation of how metallic reactivity dictates corrosive behavior. Relates this knowledge through a coherent and thoughtful plan for abating corrosion in Flint.

Exemplars:

1— The 316/304 Stainless steel is not very reactive. With this type of stainless steel it is considered "passive", all this means is that it has undergone a process where a protective film is added to the inward and outward facing steel piping.

2— The pipes used in Flint at the moment are made out of lead (Pb), copper (Cu), and galvanized steel. The pipes that are causing the most issues with water quality are lead pipes. Lead is a corrosive material. This means it undergoes a chemical reaction when it comes into contact with the dissolved oxygen (O_2) found in water and as a result breaks down.

4— *WHAT IS CORROSION & THE CHEMISTRY BEHIND THE ISSUE*

In many cities, molecules called orthophosphate are continuously usually added to the water supply. When Flint switched to using their river as a water supply, the city never added this chemical. Orthophosphates bond to lead pipes, creating a protective coating between the metal and the water, therefore, blocking corrosive chemicals like oxygen from interacting with the lead.

If oxygen comes in contact with lead on the pipe, it will oxidize the lead molecule by taking electrons from it ($Pb = Pb^{+2} + 2e^-$). In this transfer of electrons, the oxygen is reduced because it gains electrons and the lead is oxidized because it loses those same electrons. The oxygen then uses these electrons to bond and eventually form water with two hydrogen molecules ($O_2 + 4H^+ + 2e^- = 2H_2O$). The oxidized lead can then dissolve into the water flowing past it in the pipe.

Overtime, as more and more lead breaks off into the water, the concentration of lead builds up in the drinking water and the pipes begin to corrode and thin. The type of corrosion that occurred in Flint is called erosion-corrosion. It is due to the combination of chemical reactions and abrasion during fluid motion. The reason this catastrophe happened so quickly was due to the high levels of chlorine in the Flint water. Through various chemical reactions, chlorine has the power to increase the rate of lead corrosion in these pipes.

THE SOLUTION

The galvanic series shows rankings of different metals reactivities in seawater. The metals at the top are unreactive while those at the bottom are most reactive. The more reactive a metal, the more likely it is to corrode.

From this table you can see that iron is the most reactive, followed by lead, and then followed by copper. I believe that a switch to all copper piping is the best solution to your water pollution issue. Unlike lead and iron, copper is corrosion resistant in many conditions. You may believe it corrodes easily due to the familiar characteristic of turning green after some time. In fact, this change in color is the metals own effort to protect its self from corrosion. The thin green layer, called patina, prevents oxygen and other corroding elements from touching the remaining copper making it an efficient water proofing material. This is why copper corrodes so slowly when compared to iron and lead.

Obviously, a huge aspect of this issue has been the cost of a solution. The range of prices of copper lies within that of 304 and 316 stainless steel. Since Flint already as copper pipes, those that are damaged beyond repair should be replaced with new copper piping along with all of the lead and iron pipes. This would reduce the price of this project because not every pipe would need to be changed.

2. The memo should explain the chemical origins of corrosion, including the anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series. Is the explanation of corrosion origins complete and explained well? Is the role of the galvanic series in corrosion prevention discussed? Is there anything missing in the discussion of the galvanic series? How could these descriptions be improved?

Score	Description
0	No explanation to the chemical origins of corrosion, including the anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series.
1	Briefly discusses the chemical origins of corrosion. Does not include the anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series.
2	Discusses the chemical origins of corrosion **or** mentioned anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series. The connection between the placement of the metal on galvanic series and the origin of corrosion is either incorrect or incomplete.
3	Discusses the chemical origins of corrosion **and** mentioned anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series. The connection between the placement of the metal on galvanic series and the origin of corrosion is either incorrect or incomplete.
4	Discusses the chemical origins of corrosion. Mentions anticipated compatibility of metal/alloy joints based upon their relative placement in the galvanic series. The connection between the placement of the metal on galvanic series and the origin of corrosion is correct and complete.

Exemplars:

1— Overall, copper is incredibly resistant to corrosion from all materials it will come in contact with as it has a relatively low reactivity. Corrosion is defined as the failure or deterioration of a metal due to chemical reactions it undergoes. Although copper does react to water quite quickly, it is only a surface change and will not cause the metal to actually deteriorate as the layer formed does not dissolve into the water.

4— In solutions where two metals are present, the driving force that determines which metal will corrode is the electric potential (voltage) that exists between the cations and neutrally charged metals (Callister and Rethwisch 612). The electric potential, or voltage, can be thought of as the energy that is released when a reaction occurs. Since reactions that produce energy are more likely to occur than reactions that use energy, the overall reaction between the

metals that produces a positive voltage will be favored. The relative reactivities of metals and commercial alloys in their ability to undergo oxidation is represented in the galvanic series (Figure 1). The more reactive metals and alloys are placed at the bottom of the galvanic series, while the less reactive ones are at the top. Being more reactive means that the oxidation of those materials results in a more positive voltage, making corrosion more likely. Therefore, [the galvanic series] provides an estimation of how corrosive certain materials are...The proximity of metals and commercial alloys in the galvanic series with respect to each other represent the relative ability of the less reactive material to corrode the more reactive one.

3. The memo should detail the types of corrosion that are most likely to occur in the water system. For each type of corrosion, the relevant chemical reactions should be mentioned. Are the most likely corrosion mechanisms and their corresponding chemical reactions clearly described? How could these descriptions be improved?

Score	Description
0	No mentioning of corrosion mechanisms and their corresponding chemical reactions.
1	Describes the corrosion mechanisms and their corresponding chemical reactions, but is neither complete or correct.
2	Either (A.) describes all relevant correct corrosion mechanisms but does not provide the corresponding chemical reactions OR (B.) mentions some but not all contributing corrosion mechanisms and their corresponding chemical reactions. (reactions may be represented in words, diagrams, or equations)
3	Describes the correct corrosion mechanisms and corresponding chemical reactions with their own words. (reactions may be represented in words, diagrams, or equations)
4	Describes the correct corrosion mechanisms and corresponding chemical reactions with their own words and relates this to the main problem.

Exemplars:

1— The reason that Flint's water became contaminated was due to the corrosion of the iron, copper, and lead piping. Corrosion is the natural process of destroying a metal by chemical reactions.

3— The process by which corrosion occurs is an oxidation reduction reaction which produces hydroxides. These hydroxides combine with ferrous ions which become rust. Copper and iron are far enough apart on the galvanic series that when the two-different metals encounter corrosive water, they experience galvanic corrosion where the rate of corrosion will be increased. The metals have different affinities for electrons – the iron serving as the more anodic metal will attract electrons and the copper serving as the cathode will attract protons. This potential difference allows current to flow. This electrochemical cell can start the process of corrosion in pipes through the previously mentioned oxidation reduction reaction

4— Corrosion is an electrochemical attack on metal. On one end, oxidation occurs, which is when a metal loses an electron. For example:

$$M \rightarrow M^{n+} + ne^-$$

The place where oxidation happens is called the anode. On the flip side, whenever oxidation occurs, another reaction called reduction happens. This is when electrons are added to some chemical species. In the case of the flint water crisis, where neutral water with dissolved oxygen runs over the pipe[1], the following reaction occurs:

$$O_2 + 2H_2O + 4e^- \rightarrow 4(OH^-)$$

This galvanic component of reduction is known as the cathode. In the case of the flint water crisis, it is crucial to use a metal that is cathodic relative to the water. As a result, that metal will be less likely to oxidize and result in poisoning, because it will be less likely to release as a charged ion due to electron loss.

Such a ranking of reactivities is present when considering the galvanic series, which represents the relative reactivities of metals and commercial alloys in seawater. This series is shown in Figure 1. (Figure 1 is a galvanic series figure included in the submission. The figure is omitted due to copyright issues.)

4. The memo should provide a coherent argument for upgrades to the water system, Including the specific metal/alloy to use for new pipes, and any additional preventative measures to be employed. The argument should be based upon both scientific reasoning and materials costs. Is the argument comprehensive, concise, and/or persuasive? How could the argument be more convincing?

Score	Description
0	Does not propose an upgrade to the water system.
1	Proposes an upgrade to the water system, but lacks logical steps in reasoning.
2	Clearly proposes an upgrade to the water system based upon scientific reasoning. This solution is purely technical, lacking discussion of environmental and economic variables.
3	Clearly proposes a logical upgrade to the water system that demonstrates scientific reasoning as well as an awareness of environmental variables and materials costs. Considers making changes to either (A.) the pipe material OR (B.) water treatment.
4	Clearly proposes a logical upgrade to the water system. Provides a persuasive argument that combines scientific reasoning with an awareness of environmental variables and materials cost. Considers making changes to both pipe material **and** water treatment.

Exemplars:

1— Of the potential materials, the best long term choices would be aluminum, copper or stainless steel. An alloy such as brass would be the most, but the price makes this a less useful choice. Ultimately aluminum or an alloy of aluminum would be the best choice to maintain long term and is my recommendation to use in future piping endeavors.

3— Through some research, we have concluded that Schedule 10 stainless steel would be an ideal material to replace the current lead pipes. The materials used for pipes can range anywhere from metals to plastics. Given the high chloride levels in the current Flint water supply, the rate of corrosion of the pipes are accelerated. It is imperative to choose a material that is able to withstand this corrosion while staying cost effective. Plastic polymers are an adequate candidate for the pipes given their durability and low cost. Unfortunately, the harsh winters of Flint will lead to increased stress from freeze-thaw cycles. Most of these plastics are unable to handle this drastic change in temperature and will split when frozen. Copper is another common material with high durability and resistance to corrosion. However, copper, similar to polymers, is prone to splitting under low temperatures, and the cost of installation can be very high. Galvanized steel is also an option, but the corrosion/health risks and difficulty of implementation do not make it an ideal candidate. On the other hand, Schedule 10 stainless

has the durable characteristics of copper and the ability resist temperature changes similar to galvanized steel (Chen). In addition, the cost of implementation are lower than both copper and galvanized steel, making it a good choice for the replacement process.

4— The preferred pipe material should have the following characteristic:
Relatively corrosion resistant (this is the main focus, and the choices are located at the upper section of the galvanic series)
Affordable for township level pipe replacement (this rules out expensive and rare materials such as Gold and Platinum, even if they have excellent corrosion resistance)
High material strength or hardness (the pipe must be able to withstand large water pressure, and stresses from the environment. For example if the pipes are buried underground, they must be able to support pressure from the ground and potential earth quakes. This rules out "soft" materials such as Gold, Graphite and copper.)
Upon consideration the aforementioned criterions, stainless steel is the recommendation of candidate. It has excellent corrosion resistance, because Iron Oxide layer is formed on the materials surface that insulates oxygen from further corrosion. Stainless steel is also economically feasible ($280 per 10 ft. of pipe). It also has demanded material strength, as it has already been commonly used for architecture.

*Preventive measures for corrosion

Extra preventive measures can also greatly assist in the pipe safety and durability. To counter-act "erosion-corrosion", pipe elbow could be reinforced with metal oxide or Tin/Nickel coating. New pipes can also be built underground for cooler temperature, which slows down corrosion reaction. Lastly, monitor the pH level of water. Chlorine Ion creates acidic environment that speeds up corrosion. Monitoring and maintaining pH level at pH 7 helps control corrosion.