Water Pipe Corrosion Demo

Materials
- 0.75oz condiment containers with lids
- Salt packet (or pinches from dispenser)
- 3.25oz container 1/2 filled with water
- Vinegar (from store)
- Water
- Paper towel
- 3 Pennies
- 8oz Deli Container to hold all supplies

What To Do
Pre-measure 5-10 mL vinegar into condiment containers before activity
1. Observe appearance of 3 pennies
2. Add salt to vinegar in container with lid
3. Add one penny to the water (-control) and 2 pennies to the salt and vinegar
4. Swirl/shake the pennies in their liquids. Let sit for 5 minutes
5. Remove the penny from the water and dry with paper towel
6. Remove one penny from the salt and vinegar, dip corner of paper towel in water, clean this penny with paper towel, add to water. This control shows that the mixture removes CuO
7. Pour the salt and vinegar into the outer container (8oz) and keep the penny in the container. Place lid on container. Put to the side for 10-15 minutes
8. Make observations about the 2 control pennies that were removed from their containers
9. After 10-15 minutes have passed, observe the appearance of the penny that was in the salt and vinegar container and not rinsed
10. (optional) Take the penny in the condiment container home and observe the unrinsed penny after 24 hours. All remaining containers will be re-used.
11. Clean hands as the acidic solution can be irritating. All materials can be disposed of in the regular trash.

What's Happening
Concepts: dissolution, acid-base, redox, environmental, chemical reactions
The vinegar and salt react to form aqueous ions in solution. Notice that the ions can rearrange to form HCl.
\[ \text{CH}_3\text{COOH(aq)} + \text{NaCl(aq)} \rightarrow \text{H}^+(aq) + \text{Cl}^-(aq) + \text{CH}_3\text{COO}^-(aq) + \text{Na}^+(aq) \]
Dirty pennies often have a lot of dark copper oxide on them that can be cleaned off with acid in an acid base reaction:
\[ \text{CuO(s)} + 2\text{H}^+(aq) + 2\text{Cl}^-(aq) \rightarrow \text{CuCl}_2(aq) + \text{H}_2\text{O(l)} \]
However, copper itself is not soluble in acid. But, it can react with chloride ions in a redox reaction to become a soluble copper chloride (therefore, putting the metal ions in the liquid):
\[ \text{Cu(s)} + \text{Cl}^-(aq) \rightarrow \text{CuCl(aq) and CuCl}_2(aq) ; \text{CuCl}_2(aq) + \frac{1}{2}\text{O}_2 \rightarrow \text{CuO(s)} \]
When enough of the copper layer is gone, it reacts with chloride to re-make black CuO

How this relates to the lead getting in Flint’s water:
Lead metal itself is not soluble in water:
\[ \text{Pb(s)} = \text{insoluble} \]
Over time, lead that is wet and exposed to oxygen will convert to lead oxide, which is a little soluble in water and could get into water over time:

\[2\text{Pb}_{(s)} + \text{O}_2(g) + 2\text{H}_2\text{O}_{(l)} \rightarrow 2\ \text{Pb(OH)}_2_{(s)}\]

Therefore, phosphates (orthophosphate) are normally added to water to act as a corrosion inhibitor by creating a lead phosphate (mineral) passivation layer. The lead phosphate is not soluble in water and protects the lead underneath from getting into the water when exposed to oxygen. **This is comparable to the copper oxide originally covering the penny.** There are good pictures of this white lead phosphate on a pipe here: [http://michiganradio.org/post/heres-what-drinking-water-pipes-look-and-without-corrosion-control#stream/0](http://michiganradio.org/post/heres-what-drinking-water-pipes-look-and-without-corrosion-control#stream/0)

\[\text{Pb}_3(\text{PO}_4)_2 = \text{insoluble}\]

Flint originally got its water from Lake Huron via Detroit. Detroit had added orthophosphate to the water before it came to Flint. The Flint plant never had to add it before. When Flint switched to using river water instead of lake water, they recognized that the water chemistry was different. Rivers flow and lakes do not. This causes the rivers to have a lower pH (because rivers also have less buffers (carbonates and phosphates)).

When Flint switched to river water, it had more organic matter in it than what they used to have. They also added a lot of chloride to disinfect the water from *E. coli*. The organic matter reacted with the chlorine used to disinfect the water and made trihalomethanes. Trihalomethanes are bad and the public was outraged when they found out, so Flint immediately started adding ferric chloride to the water. The ferric chloride would react with the organic materials and cause them to flocculate (like precipitate) and makes it easier to filter out the organic material. This took the organic material out so that it could no longer make the trihalomethanes. But, it also added more chlorides and made the pH more acidic.

High chlorides and acid content ate away at the mineral passivation layer. **This is comparable to the acid reacting with the copper oxide layer on the penny and additional dissolving of the Cu by the chloride ions.** The quick reforming of the copper oxide when exposed to oxygen (dumping off the liquid) is proof of easily accessible copper ions. Without added orthophosphate, this layer was not rejuvenated as it was removed. This exposed the lead underneath. The lead underneath was then able to react with the high level of chlorides and produced lead chloride, which is very soluble in water:

\[\text{PbCl}_4^{2-} = \text{soluble}\]

This allowed the lead to dissolve in the water. **This is comparable to the exposed copper metal in the penny reacting with the chloride ions from the salt.** This same reaction happens with lead, copper, and iron. Both lead and iron will continue to come out of the pipes until the mineral passivation layer is completely reestablished, even though they have switched back to getting their water from Detroit.