Teaching about Lead in Chemistry Class: Lead and Public Policy

Cristobal Carambo

Problem Statement:

Although there is overwhelming clinical evidence on the effects of lead on the neurological and emotional development of children the toxin continues to affect many of the most vulnerable within our inner-city communities (Braun et al., 2018). While the major sources of lead have been eliminated from our environment, vestiges of this powerful neurotoxin remain within the homes and schools of many poor urban communities.

> Although concentrations have decreased in all children, black children and poor children continue to have higher blood lead concentrations. Airborne lead should no longer be a source of community exposure in the United States, but individual counties sometimes still exceed airborne lead regulations, and continued vigilance is warranted (Pediatrics, 2005, p. 1046)

The elimination of lead in gasoline dramatically decreased concentrations of airborne lead, however cities with a history of lead-based industries (smelters, paint producers, radiator manufacturers, for example) have high levels of lead in the soils where the industries once stood. Although the smelters and other lead based industries are gone the residual lead particles continue to contaminate the earth, air and water of the homes and schools in these areas (Lusby, Hall, & Reiners, 2014). Many of Philadelphia's communities (Fish Town, Port Richmond, and the Kensington area) have high concentrations of lead in soils (Hilliker, Hall, & Srogi, 2015). In early June of this year, three playgrounds in Philadelphia; (Chew Park in Point Breeze: East Poplar in North Philadelphia, and Disston playground in Tacony) were closed as a result of high lead concentrations in the soil (Kummer, 2019).
Additionally, apartments and homes in most urban areas continue to have vestiges of lead-based paints within them. Although residential use of lead-based paint was banned in 1977, many residences in Philadelphia that were built prior to the ban are still contaminated. A recent report (The Assessment of Child Blood Lead Levels in a Philadelphia community (Dignama et al., 2018) found that children living in neighborhoods (mostly poor and urban communities) with a legacy of lead based industries were more likely to have elevated blood lead levels than those in areas without a history of lead manufacturing.

> We identified higher than anticipated lead soil and dust results likely due to a combination of pollution from suspected legacy lead emitting sites and deteriorating housing stock… [We] found higher geometric BLLs among children living in households with deteriorating interior and exterior paint and with recent home renovations (Dignama et al., 2018 p.36)

In addition to lead contaminants in the soil and air, lead can also find its way into a city's water supply. As the recent crisis in Flint Michigan showed, poor water management can allow lead (in water service lines, in fixtures and in the solder connecting the pipes) to leach into a city's drinking water. This is still a particularly dangerous situation in many of Philadelphia's homes and inner-city schools that have yet to properly address the issue of lead service lines that can potentially leach lead into the water that is made available to residents and our children. Efforts to enact legislation that would move us towards a lead-free environment lag far behind the suggestions of researchers and health officials as those with political and economic power have manipulated the debate over lead's health effects and have been able to slow the pace of responsible lead abatement policies. As a result, initiatives meant to address the issue have produced tepid public policies and laws that do not force those in power to adequately the ongoing "crisis".

It is important to note that there are various policies and initiatives within the city of Philadelphia that citizens can use to safeguard themselves from the dangers of lead exposure. It is vital that students and our community become aware of these measures and learn how to use them to safeguard their health.

An essential goal of this unit to help students become knowledgeable of existing lead policies and in so doing become advocates for responsible lead policies in their homes and in their school.

Rationale:

As science educator, I feel that it is vitally important that I create connections between the classroom content and my student's life experiences. This is especially necessary in the chemistry curriculum as many concepts are relatively abstract and difficult for students to conceptualize. Connecting the content to important real-world issues makes the learning relevant, engaging and illustrates how scientific knowledge helps us understand and improve our everyday lives. It is however equally important that my students understand that while science can be used for good, it can also be manipulated to benefit those with greater economic and political power. This is unfortunately part of the history of lead within inner city urban communities.

The unit will begin with a focus on the recent crisis in Flint Michigan as it demonstrates how misguided economic policies and poor application of water management procedures created the environmental and health catastrophe that shocked the nation. The Flint crisis will provide an opportunity to analyze the physical and chemical properties of lead, corrosion chemistry and water treatment methods. We will also analyze the causes of the crisis as well as the inadequacies in the federal and state responses that have yet to fully address the long-term effects of high blood lead levels.

This is an important expansion of my curriculum as it will give students in my chemistry class a comprehensive understanding of how political realities intersect with environmental policies. Lead continues to pose a risk to the children of Philadelphia as it remains an issue in our schools, in the soils of some communities, and in the lead water service lines in poorer communities throughout the city (Lebrón et al., 2019). For this reason, a major focus of the latter days of the unit will be to assess the City of Philadelphia's efforts to remediate the residues of lead in the city.

Given the importance of teaching students the need for responsible civic action, the major goal of the unit will be the creation of informational artifacts (posters, brochures, on line TED talks), that can educate our communities as to the dangers of lead, the measures to keep ourselves safe, and what local policies exist that will help lessen its effects on our lives.

Background: Content Knowledge

History of Toxicity:

Lead is one of the oldest and most widely used elements in the history of mankind. It's use predates the Iron and Bronze Ages because it is relatively abundant (it is the 38th most abundant element in the Earth's crust) and is easily mined and smelted. Lead mines that date back as far as 6,000 B.C. have been discovered in Turkey and throughout ancient Greece and Rome (Hernberg, 2000). Lead was used extensively in early societies because it has unique physical and chemical properties that make it suitable for a wide range of domestic and commercial applications. Greeks and Romans used lead in all manner of household items including cookware, toys, jewelry, in water pipes and to line the Roman aqueducts (H. Needleman, 1999). It is interesting to note that the word that describes those who work with water pipes (plumbers) comes from the Latin word for lead (Plumbum). Roman aristocracy sweetened their wine with lead and used a sweet syrup (Sapa) made by slowly heating and concentrating grape juice in lead lined vessels to further sweeten their foods and preserve fruits. It is believed that such constant exposure and ingestions of high amounts of lead caused a steep decline in fertility rates and increased infant mortality among Rome's upper classes (Gilfillan, 1965). Birthrates continued to decrease over the course of several generations (between the third and first centuries B.C.) leading to the near disappearance of the aristocracy. The loss of so many of Rome's leading citizens in such a short period of time, has led many historians to speculate that lead poisoning contributed to the decline of The Roman Empire (Hernberg, 2000).

During the late middle ages those who were regularly exposed to lead experienced a variety of illnesses and conditions (the "miner's disease", "lead gout", " the Devonshire colic", "dry gripes", wrist wrangles", "lead palsy", "crazy like a painter") that could not be explained using scientific methods of the time (H. Needleman, 1999). The first clinical descriptions of the symptoms directly attributed to lead were made during the 19th century when the ailments (encephalopathy, anemia, decreased fertility, and high death rates) of white lead workers and plumbers were attributed to the lead they were exposed to. The first "modern" clinical description of lead poisoning (plumbism) was published by Tanquerel de Planches in 1839 (Hernberg, 2000).

In subsequent years as the pace of industrialization increased demands for lead, large numbers of industrial lead workers, (smelters, printers, painters, battery makers, etc.) succumbed to an array of illnesses ending usually in acute encephalopathy or death. By the end of the 19th century, "plumbism" reached epidemic proportions throughout Europe and in the United States. Although countless numbers of adults were suffering little was known about the effects of lead on children's health or development. The first reported cases of childhood lead poisoning were reported in Brisbane Australia in 1892. Children playing around structures with peeling and cracked “white lead” paint became ill. Subsequent years of investigation found that lead in the paint was the cause of the epidemic.

As the effects of lead poisoning became more acute and certain, governments moved to address the increasingly severe and widespread harm caused by lead exposure. Particularly at risk were those who worked in paint manufacturing and the children who were exposed to lead paint. In 1921 the international Labor Conference met in Geneva to adopt the “White Lead Convention” to discuss responses to the growing health crises. As a result of the convention several nations Sweden & Czechoslovakia in1923; Austria, Poland, Spain-1924; Finland and Norway, 1929) banned the use of lead-based paints residential settings (Hernberg, 2000). Such was not the case in the United States as the political strength of the Lead Industries Association (LIA) of America, thwarted efforts to ban the use of lead paint. The industry would delay the decision until 1978 when the Consumer Product Safety Commission finally banned the use of lead based paints in residences (Campbell et al., 2013). The delay unnecessarily exposed millions of children to the toxin that covered the walls of their homes: “The consequences of this delay have been disastrous” (Hernberg, 2000, p.247). While the consequences of exposure to lead motivated many governments to ban its use in paint, the decision to put lead into gasoline would create a more powerful method of putting lead into our air and soil.

The lead in our environment has a variety of sources, however house paints, and leaded gasoline are considered the major sources (in the last 100 years). The gasoline additive known as Tetraethyl Lead (PbC_2H_5) developed in 1925 was developed as an anti- knock agent in automobiles. Many of the workers in the plants died of severe lead poisoning. In the ensuing years lead pollution for gasoline was responsible for an increase in blood lead levels throughout the country. It was not until 1975 that the catalytic converter was introduced which required the use of lead-free gasoline that blood lead levels began to decline. Lead in gasoline was not formally banned by the EPA until 1995.

Physiological Effects:

Lead is a divalent cation (Pb^{2+}) that can bind strongly with proteins and severely alter their interaction with enzymes and other biomolecules in the body. The effects of elevated blood levels are most dangerous in the nervous system where it acts as a neurotoxin that impedes brain development and normal neurological functions. It is particularly toxic to children given their rate of metabolism, immature excretory systems, and their lack of a fully formed blood / brain barrier.

Most of the neurotoxic effect is the result of lead’s ability to mimic or interfere with the normal functioning of calcium (which is also a divalent cation: Ca^{2+}). Calcium cations are central to the release of neurotransmitters at presynaptic nerve endings and within the CNS. At low blood level concentrations, lead can occasion the spontaneous release of neurotransmitters from presynaptic nerve endings. It is also able to block calcium channels thus inhibiting the release of transmitters (norepinephrine and epinephrine), normally produced at nerve endings. In the CNS lead can also stimulate the spontaneous release or blockage of neurotransmitters (dopamine, acetylcholine and γ-aminobutyric acid) (Bressler & Goldstein, 1991). The combined effects of the spontaneous release of (excess neurotransmitters) and blockage of requisite transmitters has a profound effect on the developmental processes in the immature brain.

> The precision of the relationship between experience and neuronal activity would be disrupted if lead increases basal neurotransmitter release and decreases the response of activity circuits in children. [Exposure] to lead in early life may have a lasting adverse effect on synaptic anatomy and brain function. Such changes may underlie the effect of low level lead exposure on learning skills and behavior of young children in the absence of overt pathological damage (Bressler & Goldstein, 1991,p.480)

In an 11-year longitudinal study (Needleman, Schell, Bellinger, Leviton, & Allred, 1990), found that the effects of elevated blood lead on a young child's cognitive abilities "persisted into young adulthood". They noted that the elevated levels resulted in a "significant impairment of academic success" as indicated by a higher than normal absenteeism, increased incidents of reading disability, poor motor skills, lower IQ scores, increased reaction time, and a greater chance of failing to graduate from high school. When socioeconomic status was factored into their analysis, the researchers found that "children from lower socioeconomic groups are more vulnerable to the effects of lead than children from more favored economic backgrounds" (Needleman, Schell, Bellinger, Leviton, & Allred, 1990, p. 87). The effects of elevated blood lead levels on the cognitive abilities and academic performance of children and the increased vulnerability of the poor have persisted to this day.

Water Chemistry

Water is delivered to homes and businesses through a series of underground lead, copper, and iron pipes. Oxidizing agents in the water (predominantly oxygen) can interact and break down the metals: in a process known as corrosion. Corrosion dissolves the metals which allows them to leach into the water supply. In order to halt this natural process, water managers add corrosion inhibitors (usually an organo-phosphate (PO_4^{3-}) to their water systems. These inhibitors react with oxidizing agents and form a protective insoluble chemical coating known as a passivation layer. This layer blocks oxidizing agents from corroding the pipes. When the city of Flint drew water from the Flint River, it failed to add sufficient inhibitors to the water supply. This led to a breakdown of the passivation layer and exposed the metals to the oxidants in the water. The first effects of rust colored water were the result of corroding iron pipes which resulted in the formation of iron oxide (rust) in the water. The exposed iron reacted with chloride ions in the water which diminished the amount of disinfectant in the water. As a result, colonies of pathogenic organisms (trihalomethanes and *Escherichia coli*) were detected in homes throughout the city. This led to the first citation of the city's water quality as it was now in violation of national water quality standards. By the spring of 2015 lead levels in the city's homes were beginning to exceed the EPA's (15 ppb) acceptable limits. In subsequent months elevated blood lead levels were detected in the city's children. The situation became a national crisis given city's slow and inadequate response to the possible long-term damage to its residents.

Flint Water Crisis

In 2013, in a supposed effort to save money, Flint water management officials decided to enter into an agreement with the Karegnondi Water Authority which was building its own pipes to Lake Huron. The pipes however, would not be completed for several years so the officials decided to use water from the nearby Flint River in the interim. The decision by the managers was made against the advice of water safety experts that warned that water from the river had the potential to be dangerously corrosive if not properly treated (Masten, Davies, & McElmurry, 2016). City officials ignored the warnings, and although the city had the option to continue their contract with the Detroit Water Authority, the state appointed emergency managers decided (on April 17, 2014) to end the contract and draw water from Flint River (Rothstein, 2016). The decision to expedite the change would lead to the indictment of emergency managers (Darnell Early and Gerald Ambrose) and two other officials (M. Kennedy, 2016) for misuse of funds, falsifying evidence, and failing to properly treat the water from the Flint River (Sanburn, 2016).

As early as May of 2014, residents began complaining of foul smelling, rust colored water in their homes. By late summer in response to increasing bacterial contamination two boil water orders were given to residents, then in October General Motors was granted permission to change its water source because the water from the river was corrosive to its auto parts (Torrice, 2016). It is interesting to note that the automaker was allowed to change its water source, but residents of the city were not given the same consideration. In February of 2015 lead levels of 104 μg /L (EPA limit is 15 μg /L) were found in residential tap water; then in late summer researchers from Virginia Tech, found elevated lead levels in samples from 120 homes (Masten et al., 2016). In September, Dr. Mona Hanna Attisha, published research showing an increase (from 2.4% to 4.9%) in the number of children with elevated blood lead levels (above 5 μg/ dL) (Hanna-Attisha, LaChance, Sadler, & Schnepp, 2016). In October after considerable national attention and public protests, the city reverted back to water from Lake Huron supplied by the Detroit Water Department. While this decision was a positive step to address the crisis, it is unfortunate that it took nearly 18 months to respond to the unnecessary exposure to toxic elements in the city's water supply.

> In Flint and the state capital, Lansing, the city and MDEQ [Michigan Department of Environmental Quality], discounted evidence of dangerous water quality problems, even manipulating sampling procedures mandated by the LCR [the Lead and Copper Rule]. The US Environmental Protection Agency (USEPA), on learning of these transgressions, waited months to act. The litany of poor decisions, dismissive responses, and failures to protect public health are a stain on the parties involved— and, as the FWATF [Flint Water Advisory Task Force], noted, signal a fundamental need for culture change, sensitivity to environmental injustice, and a review of Michigan's emergency manager law (Rothstein, 2016 p. 37).

By June of 2016 a total of nine state officials had been charged for negligent behavior (Haimeri & Goodnough, 2016) for distorting or hiding sampling data that limited the effects of lead contamination in poorer neighborhoods (Keller & Watkins, 2016). In the ensuing years a total of 15 officials would be charged, however in recent weeks the new state prosecutors (citing weaknesses in the investigations) have dropped charges in eight of those cases (Smith, 2016).

The new attorney general's office has promised the skeptical residents of Flint that they will continue their own investigations into the crisis.

Although testing has shown that the number of children with elevated blood lead levels decreased after the city reverted to water from Lake Huron, continual reassessment and testing of all children below six years of age is recommended (C. Kennedy et al., 2016).

In response to the crisis, the Centers for Disease control in coordination with various state and local agencies have funded a series of initiatives for the long-term recovery of Flint's Water system. In addition, President Obama signed the Water Infrastructure Improvements for the Nation Act in 2016 (Ruckart et al., 2019). These programs are a promising steps, however the effort to remove all residual lead service lines in order to eliminate the risk of contamination of our water supply (especially in the poorer communities) will necessitate the coordinated efforts of all members of the water management community (Rothstein, 2016).

Lead Health Policy in Philadelphia

Over the last fifty years, researchers and health officials have lowered the threshold of the "acceptable" blood lead level as data from numerous toxicological and epidemiological studies have suggested that even the smallest concentrations of lead in the blood is harmful. Recently the Advisory Committee on Childhood Lead Poisoning Prevention, (a subcommittee of the Centers for Disease Control and Prevention) proposed that clinicians should use BLL's of 5 μg/dl to identify children at risk for lead poisoning (CDC), 2012). Children with lead levels above this are at risk for the cognitive, emotional, and developmental risks posed by lead. Although many sources of lead have been limited (or eliminated), children (mostly in inner city environments) are still exposed to peeling, cracking lead-based paints, lead in dust and soil particles. The risk of exposure to lead in paint exists primarily in housing stock built before 1978 (when leaded paint was banned in the U.S.). Children in Philadelphia are at risk given that a majority of the houses (91.6% in 2009 (Campbell et al., 2013) were constructed before 1978. Compounding this is the fact that approximately 30% of Philadelphians live near or below the poverty level. This means that many of the city's poorer children live in deteriorating, poorly maintained homes and are therefore likely exposed to lead paint. Screening tests reported to the Philadelphia Public Health office shows that in 2011, 10.3% of children tested had BLL's above the 5 μg/dl level. While the overall trend has improved over the years, much remains to be done as there are still millions of children at risk (Presidential Task Force, 2000).

Philadelphia's Lead Court

The established protocol for children with elevated blood lead levels is to remove the child from the residence and have the owner remediate the property. However public records in 2002 showed that over 1400 property owners had failed to respond to remediation orders from the PDHD because city agencies had no formal authority to force compliance. The city's Childhood Lead Poisoning Prevention Program was the only agency tasked with remediation; however, it lacked the resources to adequately address the problem. The Lead Abatement Strike Team (LAST) was formed in response to the city's inability to address the issue. In 2002,the LAST group along with a number of community groups and the PDHD developed policies and the infrastructure for lead policy enforcement which became the Philadelphia Lead Court (Campbell et al., 2013). The court has been highly effective in increasing compliance of home that have failed initial inspections.

Additional initiatives are located in Appendix A

UNIT STRUCTURE

This unit will begin after the completion of the laboratory on the activity series lab which explores the reactivity of metal in single displacement reactions. Two reactions that will introduce the unit are the displacement of lead by more active metals, and the oxidation reduction reaction of metals with hydrogen (in hydrochloric acid). The first reaction will provide the introduction of how lead can get into our water supply, the latter will help in the analysis of the reactions that explain the corrosion of metals.

There are several fundamental questions and objectives that the unit will address:

- ◊ How does lead get into our water supply? What is corrosion?
- ◊ How safe is our water supply (at school and at home)?
- ◊ What policies (at that local and federal) level exist to keep us safe?
- ◊ What actions (effective) should we take to keep ourselves safe?

OBJECTIVES: By the end of the unit students should be able to:

- ◊ Analyze the process of corrosion of metals
- ◊ Explain how lead can get into our municipal water supply
- ◊ Analyze existing water quality initiatives at school and at home
- ◊ Promote healthy hydration habits at school and at home
- ◊ Prepare an informational brochure on lead policies and effective safeguards

STANDARDS USED IN THE UNIT

Common Core Literacy Standards

CCS-Ela-Literacy.Rst.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

CCS Ela-Literacy.Rst.11-12-9: Synthesize information from a range of sources into a coherent understanding of process, phenomenon, or concept, resolving conflicting information when possible.

Next Generation Science Standards

HS-PS1-1.Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-2 Matter and its Interactions: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS1-3 Matter and its Interactions: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles

HS-PS 6 Chemical Reactions Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

UNIT LESSON PLANS

Day 1 and 2: Flint Water Crisis

Objective: Students will analyze the processes of corrosion and how it contributed to the water crisis in Flint Michigan. Students will also explain the health effects of elevated blood lead levels on a child's health.

Students will be given two different articles on the Flint Michigan water crisis to analyze. The articles are similar in content but written at differing reading levels: this will allow for differentiated learning. Students will answer a set of (differentiated) analysis questions. Once finished the groups will engage in a whole class discussion to complete the assignment.

Following are the articles and their URLs.
Dogonews: The Water Crisis in Flint, Michigan: located at:
https://www.dogonews.com/2016/1/20/the-water-crisis-in-flint-michigan

Science and Technology: How lead ended up in Flint's water: located at:
https://cen.acs.org/articles/94/i7/Lead-Ended-Flints-Tap-Water.html

Analysis questions are located in Appendix A.

Day 3 and 4: Water Corrosion Laboratory

Objective: Students will differentiate oxidation and reduction and use experimental evidence to explain the process of corrosion.

The lab presented in the unit is adapted from the NSTA lab: *Corrosion in the Classroom* located at: https://www.jstor.org/stable/24142389

Materials, Procedure, and Conclusion questions are located in Appendix A

In this lab students will explore the oxidation of iron in three different environments. Iron alone, iron in contact with zinc and iron in contact with copper. Students will first make an agar suspension containing two indicators (phenolphthalein and potassium ferricyanide). The strips of iron will be submerged in petri dishes containing the agar suspension. One dish will hold the strip of iron, the other two strips will be placed in the second petri dish. Students will note the reactions of oxidation / reduction of the iron metal as evidenced by changes in the colors of the indicators.

In one the dish iron (alone) will be oxidized to Fe^{2+} at the anode (as indicated by the dark color of the ferricyanide indicator, while at the cathode reduction of Fe^{2+} reacts with hydroxide ions (which turns the phenolphthalein indicator pink). In the iron strip in contact with zinc, corrosion of iron occurs (but since Zn is more active than iron, it oxidizes quickly and reduces the iron ions back to iron): ferricyanide does not change color as no Fe^{2+} ions are formed. (For extension purposes this reaction is referred to as cathodic protection of iron by zinc). Evidence of corrosion is evident in the third in the strip (copper in contact with iron) as copper is less reactive than iron so it could not provide protection and halt the corrosion of iron: a noticeable change in the ferricyanide indicator is noted.

The lab provides practical experiences with the corrosion process. It can be used to analyze the corrosion of metals in Flint as both iron and lead water pipes in the water system corroded: the iron ions produced the rusty color that was immediately evident to residents, the lead ions (unfortunately) did not produce any evident products. Both corrosive processes are referred to in the article (How lead ended up in Flint's Water), which students analyzed at the start of this unit. The laboratory's conclusion questions can be assigned as homework for discussion on day following the lab.

Day 5 and 6: Lead Background Content: Collaborative WebQuest

Objective: Students will research the history of lead use, and its toxicology and engage in a collaborative analysis of lead public health policies.

At this point the class needs to assemble sufficient background knowledge about the history of lead, its usage, its toxicology and the health initiatives and public policies that exist to protect us. To accomplish this, students will engage in a two-day collaborative WebQuest on given topics. The WebQuests should take one class period to complete followed by a second collaborative session where information is shared. All students will be responsible for some information from all the quests: thus, providing background information for the final days of this unit. Students will work in groups of 4-5 per group. Students are able to edit topics or suggest additional research topics. Teacher will provide at least four websites for each topic. Students will be asked to complete a series of analysis questions for each topic. Group analysis questions and concluding analysis questions will developed during the unit as they depend on the websites used in the WebQuest.

WEB QUEST TOPICS:

- Physical and Chemical properties of lead: What makes lead so useful?
- Historic uses of lead: What are the important lead industries in society?
- What were the lead processing industries in Philadelphia? In what neighborhoods were they located?
- What are the health effects of lead: Why are the young especially at risk?
- What is the history of health lead policies: How has the government tried to protect us?
- What laws exist in Philadelphia to protect citizens?
- What are the sources of lead in our environment? Where are you most at risk?
- What policies do the schools have to protect you from exposure? Is the water in uour schools safe?

Day 7 - 9: Analysis of School lead safety policies: Healthy Schools Healthy Living Initiative: URLs for the initiatives are located in Appendix A.

Objective: To evaluate existing lead policy initiatives in public schools and to develop and promote an effective hydration program in our school.

To continue the discussion of the initiatives and policies that exist to keep us safe students will engage in an analysis of the school district's Green Futures Healthy Schools Healthy Living initiative: and assess the district's plans for protecting students:
The class will first review the Action Items with a focus on items 60 -64) to determine which are relevant to school environmental quality controls (and which relate specifically to lead exposure):
Class will then review the Drinking Water Quality, Access &. Appeal site and determine which parts of the initiative are at work in our school. Focus of the analysis are as follows:

Water Quality Data: Why there is no data for our school? We will request up to date accurate data on our school's water supply.

Hydration Station Information: Students will collaborate to promote information on hydration stations: Students will work to get hydration posters from school district. Students will create informational posters about the effectiveness of hydration stations. Part of the campaign will be to promote the use of reusable water bottles for water instead of purchasing bottled water.

Student-Led Healthy Hydration and Drinking Water Promotion Campaign: A major focus of this unit is to promote drinking of tap water at school (and eventually at home). Students will first complete a survey of their water drinking habits in school and at home.
Class will organize a campaign to promote drinking water (from hydration stations) at school. Class will promote the phrases:

- ◊ Clean, Cool, Refreshing:
- ◊ Your Body Needs Water: and
- ◊ Water is life as part of the campaign.

Day 10: Water Quality at Home

Objective: To create a presentation that informs relevant stakeholders of the Philadelphia Water Department's efforts to promote effective lead safety policies.

Students will be encouraged to view and analyze the City of Philadelphia's Water Quality Report with a focus on the following items:

- ◊ Daily Flushing Tips
- ◊ How to Check for Lead Pipes
- ◊ Presentations to City Council and testimony of city's Water Quality
- ◊ Checking your Home Plumbing for Lead
- ◊ What Can I Do If I Have Lead Pipes
- ◊ Programs for Lead Line Replacement
- ◊ Lead Testing in Philadelphia
- ◊ How Can I Get My Water Tested?

The goal of this day's work is to provide students and their families' information on water quality at home. The focus will be to answer any questions on the quality of water in the home and how to ensure that it is (and remains lead free). Students will be asked to create an informational brochure, poster, or TED Talk that provides all the needed information for their household.

BIBLIOGRAPHY

(CDC), C. for D. C. and P. (2012). *Low Level Lead Exposure Harms Children: A Renewed Call of Primary Prevention*. *Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the CDC*. Retrieved from http://www.cdc.gov/nceh/lead/ACCLPP/Final_Document_030712.pdf

Braun, J. M., Hornung, R., Chen, A., Dietrich, K. N., Jacobs, D. E., Jones, R., … Lanphear, B. P. (2018). Effect of Residential Lead-Hazard Interventions on Childhood Blood Lead Concentrations and Neurobehavioral Outcomes: A Randomized Clinical Trial. *JAMA Pediatrics*, *172*(10), 934–942. https://doi.org/10.1001/jamapediatrics.2018.2382

Bressler, J. P., & Goldstein, G. W. (1991). *Mechanisms of lead toxicity*. *Biochemical Pharmacology* (Vol. 41). Retrieved from https://pdf.sciencedirectassets.com/271311/1-s2.0-S0006295200X08623/1-s2.0-000629529190617E/main.pdf?x-amz-security-token=AgoJb3JpZ2luX2VjEAEaCXVzLWVhc3QtMSJHMEUCIARL5CVOjO9cgTJn99hl2Su8h%2BZh3aTNuhCYgmON7U2mAiEA53bg3nJWrPMEHKO1np5T6zD39cZANBSG1KTI%2BJEC6

Campbell, C., Gracely, E., Pan, S., Cummings, C., Palermo, P., & Gould, G. (2013). Public health and law collaboration: The Philadelphia lead court study. *American Journal of Public Health*, *103*(7), 1271–1277. https://doi.org/10.2105/AJPH.2012.301076

Dignama, T., Pomales, A., Werner, L., Newbern, C., Hodge, J., Nielsen, J., … Scruton, K. (2018). *Assessment of Child Blood Lead Levels in a Philadelphia Community , 2014*. Philadelphia. Retrieved from https://www.atsdr.cdc.gov/sites/jtlewis/docs/PHLchild_lead_assessment_2014-508.pdf

Gilfillan. (1965). Lead poisoning and the fall of rome. *Journal of Occupational Medicine*, *7*(2), 53–60. Retrieved from file:///Users/ccarambo/Desktop/lead and fall of roman empire .pdf

Haimerl, A., & Goodnough, A. (2016). 6 More State Workers Charged in Flint Water Crisis. *The New York Times*, 1–4. Retrieved from http://www.nytimes.com/2016/07/30/us/flint?michigan?water?crisis.html

Hanna-Attisha, M., LaChance, J., Sadler, R. C., & Schnepp, A. C. (2016). Elevated Blood Lead Levels in Children Associated with the Flint Water Crisis: A Spatial Analysis of Risk and Public Health Response. *American Journal of Public Health*, *106*, 283–290. https://doi.org/https://doi.org/10.2105/AJPH.2015.303003

Hernberg, S. (2000). *Lead Poisoning in a Historical Perspective*. *AMERICAN JOURNAL OF INDUSTRIAL MEDICINE* (Vol. 38). Retrieved from http://rachel.org/files/document/Lead_Poisoning_in_Historical_Perspective.pdf

Hilliker, J., Hall, C., & Srogi, L. (n.d.). Determining and Analyzing Lead Concentrations in Urban Areas with Philadelphia Based Soils. Retrieved from https://www.wcupa.edu/sciences-mathematics/earthSpaceSciences/documents/manuscriptExample1-17.pdf

Keller, J., & Watkins, D. (2016). How Officials Distorted Flint's Water Testing. *New York Times*. Retrieved from http://www.nytimes.com/interactive/2016/04/21/us/flint-lead-water-testing-distortions.html?_r=0

Kennedy, C., Yard, E., Dignam, T., Buchanan, S., Condon, S., Brown, M. J., … Breysse, P. (2016). Blood Lead Levels Among Children Aged <6 Years — Flint, Michigan, 2013–2016. *MMWR. Morbidity and Mortality Weekly Report*, *65*(25), 650–654. https://doi.org/10.15585/mmwr.mm6525e1

Kennedy, M. (2016, December). 2 Former Flint Emergency Managers, 2 Others Face Felony Charges Over Water Crisis. *The Two-Way*. Retrieved from https://www.npr.org/sections/thetwo-way/2016/12/20/506314203/2-former-flint-emergency-managers-face-felony-charges-over-water-crisis

Kummer, F. (2019, June 13). Athletic field at popular Point Breeze playground closed after lead found in soil. *Philadelphia Inquirer*. Retrieved from https://www.inquirer.com/health/philadelphia-lead-playground-east-poplar-disston-chew-20190613.html

Lebrón, A. M. W., Torres, I. R., Valencia, E., Dominguez, M. L., Garcia-Sanchez, D. G., Logue, M. D., & Wu, J. (2019). The state of public health lead policies: Implications for urban health inequities and recommendations for health equity. *International Journal of Environmental Research and Public Health*, *16*(6), 1–28. https://doi.org/10.3390/ijerph16061064

Lusby, G., Hall, C., & Reiners, J. (2014). Lead Contamination of Surface Soils in Philadelphia from Lead Smelters and Urbanization. *Environmental Justice*, *8*(1), 6–14. https://doi.org/10.1089/env.2014.0008

Masten, S. J., Davies, S. H., & McElmurry, S. P. (2016). Flint Water Crisis: What Happened and Why? *Journal - American Water Works Association*, *108*, 22–34. https://doi.org/10.5942/jawwa.2016.108.0195

Needleman, H. (1999). HISTORY OF LEAD POISONING IN THE WORLD. Retrieved April 13, 2019, from http://www.lead.org.au/history_of_lead_poisoning_in_the_world.htm

Needleman, H. L., Schell, A., Bellinger, D., Leviton, A., & Allred, E. N. (1990). The Long-Term Effects of Exposure to Low Doses of Lead in Childhood. *New England Journal of Medicine*, *322*(2), 83–88. https://doi.org/10.1056/NEJM199001113220203

Pediatrics, A. A. of. (2012). Lead Exposure in Children: Prevention, Detection and Management. *Pediatrics*, *116*(4), 1036–1046. https://doi.org/10.3329/jssmc.v3i1.12056

Presidential Task Force. (2000). *Eliminating Childhood Lead Poisoning: A Federal Strategy Targeting Lead Paint Hazards, February 2000*. Retrieved from https://www.cdc.gov/nceh/lead/about/fedstrategy2000.pdf

Rothstein, E. P. (2016). Why Flint Matters. *Journal - American Water Works Association*, *108*(July 2016), 36–42. https://doi.org/10.5942/jawwa.2016.108.0136

Ruckart, P. Z., Ettinger, A. S., Hanna-Attisha, M., Jones, N., Davis, S. I., & Breysse, P. N. (2019). The Flint Water Crisis: A Coordinated Public Health Emergency Response and Recovery Initiative. *Journal of Public Health Management and Practice*, *25*(1), S84–S90. https://doi.org/10.1097/PHH.0000000000000871

Sanburn, J. (2016). Flint Emergency Managers Criminally Charged in the City's Water Crisis. *Time Magazine*.

Smith, M. (2016). Flint Water Prosecutors Drop Criminal Charges, With Plans to Keep Investigating. *New York Times*. Retrieved from https://www.nytimes.com/2019/06/13/us/flint-water-crisis-charges-dropped.html

Torrice, M. (2016). How Lead Ended Up In Flint's Water. *C&EN Global Enterprise*, *94*(7), 26–29. https://doi.org/10.1021/cen-09407-scitech1

APPENDIX A

Flint River Analysis Questions:

Please read your assigned article and answer each of the following questions in complete sentences. If you cannot find a particular answer, then you may need to consult one of the other groups. Work collaboratively to complete this assignment. We will have a full class discussion tomorrow.

Key Questions: Where did the lead come from? How did it get into the water supply?

1. Why did the city of Flint stop using water from the Detroit River?
2. Why did they have to wait to get water from their new water management company?
   a. Why did they begin to draw water from the Flint River?
3. What did residents soon notice about their water?
   a. What were they told to do with their water? Why was this necessary?
4. What did local businesses notice about the water? What is corrosion?
5. What toxic element was discovered in the water supply? Where did it come from?
6. What metals are used in water pipes? Although lead has been banned for use in water pipes, some lead pipes still remain. Where are these pipes found? What do we call them?
7. What is the passivation layer? What is an anti-corrosive?
8. What causes the passivation layer to break down? What is the source of one of these chemicals?
   a. What happens when the passivation layer breaks down?
9. What does the term leaching mean? Explain how the lead (or iron got into the water).
   a. What is the result of iron leaching into the water?
   b. What is the result of lead leaching into the water?
10. Lead is known to be a neurotoxin. Define this term and explain why lead is so harmful? Who is especially at risk?
11. How do we measure the amount of lead in a child? What is the meaning of the term "elevated blood lead level"?
12. How could the city have avoided this crisis? What do most water management authorities do to control corrosion and limit leaching of metals into the water?
13. One article says that "People are wasting their time drinking bottled water because the water is fine". What do you think? If you were in Flint would you drink the tap water?
14. What about here in Philadelphia? Does your family drink tap water or bottled water? Tell us your opinion of Philadelphia's water.

Corrosion Laboratory Resources

The lab presented in the unit is adapted from the NSTA lab: *Corrosion in the Classroom* located at: https://www.jstor.org/stable/24142389

Materials

Two Petri dishes with covers
Powdered Agar
0.1M Potassium Ferricyanide
0.1 M Sodium Nitrate

Phenolphthalein Indicator
Copper Wire
Zinc Wire
Steel Wool
Iron strips

Procedure:

1. Heat 100mL of 0.1 M sodium nitrate to a boil. While stirring add 1.5 g powdered agar: heat solution until a suspension is formed.
2. Add 10 drops of 0.1 M potassium ferricyanide and10 drops phenolphthalein indicator to agar suspension.
3. Prepare three strips of iron by cleaning with steel wool
4. Place first iron strip into bottom of a petri dish
5. Wrap copper wire around second iron strip and place in second petri dish
6. Wrap zinc wire around third iron strip and place in petri dish with second strip (do not let strips touch each other)
7. Pour warm agar into each dish (approximately 1-2 mm deep). Cover dishes and let stand for 24 hours.

Data / Observations

Draw a sketch of each petri dish: Clearly label the metals in each dish. Note any color changes, or products formed at each end.
Repeat observations after 24 hours have elapsed.

Conclusion Questions:

1. What did you observe in each of the petri dishes that indicated a chemical reaction had occurred?
2. How did your observations change after 24 hours had elapsed?
3. At which end of the metal strip did reduction occur?
4. At which end did oxidation occur?
5. Which end is the anode? Which is the cathode? How do you know?
6. At which end did you observe an alkaline reaction? How do you know?
7. What causes phenolphthalein to change colors? What causes the potassium ferricyanide to change colors?
8. Explain the process of corrosion in your own words. Why did corrosion occur in the iron wrapped in zinc, but not in the iron wrapped in copper? (Remember the activity series of metals lab).
9. How does this lab illustrate the corrosion of iron in water? (Refer to the Flint water article from earlier in the unit).
10. How does this lab illustrate the corrosion of lead in water? (Refer to the Flint water article from earlier in the unit).

For more information on cathodic protection see: Cathodic protection at Chemistry Libre texts at:

https://chem.libretexts.org/Courses/Heartland_Community_College/HCC%3A_Chem_162/20%3A_Electrochemistry/20.8%3A_Corrosion

Three additional laboratory experiments are suggested as resources / extensions:

Rusting of metals lab: (http://www.corrosion-doctors.org/Training/HighSchool-rusting.htm) explains the acid base reactions that occur during the reduction /oxidation of metals.

The NACE Foundation cKit: The teacher's Guide to the Corrosion Toolkit
https://nace-foundation.org/wp-content/uploads/2017/07/cKit_2017_BOOKLET_FINAL.pdf
explains the fundamentals of the processes of corrosion: ACME: Anode: Cathode: Metal connector and Electrolyte: A good basic introduction to Corrosion with 4 experiments and real-world applications of corrosion.

Electrochemistry corrosion
https://www.usna.edu/ChemDept/_files/documents/manual/Exp%2021H%20s17v3.pdf
Explains the electrochemical reactions that occur during corrosion. A more detailed explanation than the NACE Foundation tool kit. Also explains how to use a multimeter to measure voltage during the redox reactions. Explains the difference between atmospheric and chemical corrosion.

The Corrosion Doctors
http://www.corrosion-doctors.org
Extensive information on corrosive processes in industry, the environment and in our homes; see: Home lead poisoning: http://www.corrosion-doctors.org/Pollution/lead.htm

Lead Public Health Policy Initiatives

Green Futures Healthy Schools, Healthy Living Initiative:
https://www.philasd.org/greenfutures/focus-areas/health-schools-healthy-living/

> **Drinking Water Quality Access and Appeal**
> https://www.philasd.org/greenfutures/focus-areas/health-schools-healthy-living/water/
>
> **Action Items:**
> https://docs.google.com/spreadsheets/d/1exQiuehnjQel1nloZjAHb6ve5wDpyeYlGvJnOf59GfU/edit#gid=823072182

City of Philadelphia's Water Department Lead in Water Website
https://www.phila.gov/water/wu/drinkingwater/lead/Pages/default.aspx

Additional Initiatives on Lead Exposure

Lead and Healthy Homes Program: funded by CDC to promote healthy homes and prevent lead poisoning. https://www.phila.gov/programs/lead-and-healthy-homes-program/

City of Philadelphia's Childhood Lead Poisoning Prevention Advisory Group:

https://www.phila.gov/documents/philadelphia-childhood-lead-poisoning-prevention-advisory-group/

Landlords and Tenants: Preventing Childhood Lead Poisoning
https://www.phila.gov/2018-11-16-landlords-and-tenants-preventing-childhood-lead-poisoning/

Lead Free Kids Initiative: https://www.phila.gov/departments/department-of-public-health/
Lead Paint Disclosure Law
https://www.phila.gov/media/20181108140841/Phila_Lead_Disclosure_and_Certification_Law_12_21_11.pdf

2015 Philadelphia Childhood Lead Poisoning Report
https://www.phila.gov/media/20161219112430/2015-Philadelphia-Childhood-Lead-Poisoning-Surveillance-Report_FINAL-1.pdf