Lead Bioaccumulation

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Content Objectives

In teaching Environmental Science at Philadelphia High School for Girls one concept that students struggled with was the difference between bioaccumulation and biomagnification. In having a struggle with these two interconnected ideas, students have displayed a misunderstanding of how chemicals in the environment have an impact on organisms in the environment. Out of this struggle comes the key to my curriculum unit: to define how lead impacts at a bioaccumulation level and how this differs from the ability for biomagnfication. The bioaccumulation will be looked at in humans and center in on Philadelphia to connect this idea as close to home as possible. Biological affects at the macro and micro level will be examined to show a full breadth of concepts for high school students. There will be an examination of how biomagnification works for another pollutant and why it is not found in lead. The understanding of the actual biological effects of the bioaccumulation will allow students to have a deep grasp of how a chemical from the environment can impact them directly. The differentiation between this and biomagnficiation will spotlight the differences and similarities in concepts and show how what happens to humans can happen to other organisms as a focus will then go to other creatures and how lead can impact them. The deep understanding of how lead can impact humans and the environment will conclude in students considering an environmental justice project that can educate others in the community.

The following are the individual objectives for each piece of content for the whole lead unit.

1. Students will understand the chemistry and historical and present industrial value of lead.
2. Students will understand the human health impacts of exposure to lead.
3. Students will appreciate the environmental sustainability concerns regarding lead.
4. Students will discover the many community sources and commercial products that contain lead.

Lead in the Environment

In order to begin a discussion of lead with students, there needs to be an introduction to lead as a substance of concern. Chemistry concepts about its standing as a chemical and its value to being used in products like paint, pipes and gasoline would be discussed. Students would be engaged in discussions about why it could be more useful than other chemicals in certain products without thinking about health concerns. Then there would be the introduction of why health and sustainability concerns should be considered. Lead's appearance in the home and community would then be highlighted,

with students considering how it could get into the home and community. Students would learn what in the home from the past and present has lead. Using these examples, students will then learn about how this lead contamination can be removed. Articles like "Building the World that Kills Us: The Politics of Lead, Science and Polluted Homes, 1970 to 2000" and "Lead Exposure in Children: Prevention, Detection and Management" would provide background.

The exploration of lead will begin with its chemistry, occurrence and distribution, uses as a metal, compounds it forms and elemental properties. Symbol Pb with an atomic number of 82 and an atomic mass of 207.2 u, lead is a heavy metal. Despite its lack of abundance, it does have large deposits of commercial significance in places as diverse as the United States, Australia and Africa. Lead sulfide is the major source of lead production. To extract lead, smelting is most commonly used. It has been desirable for commercial uses because of its ductility, easy welding characteristics, low melting point, high density and ability to absorb both gamma and X-radiation. Lead monoxide protects metal from further corrosion and is also used for similar corrosion prevention in roofing, coverings for electric cables and linings for water pipes. Other major uses including in the production of storage batteries, ammunition, solder and protective shielding around X-ray equipment, among many other metal uses. In addition to lead oxide, lead dioxide and lead acetate are used. Lead carbonate, basic lead sulfate and basic lead silicate were used in white paints while tetraethyl lead was used in gasoline when it used to be "leaded." When considering lead elementally, it is toxic and can be retained by the body.

Lead use in the home and beyond can be very toxic to humans. One of the main ways this occurs is through interactions with lead paints. In the United States, 2/3 of all housing contains lead paint, with older homes, generally pre-1950's, containing the majority of this lead-based paint. In Philadelphia a large portion of homes were built before the 1950's, leaving residents likely to come into contact with peeling lead paint and paint dust, with children being most susceptible when eating the paint chips. The second major way lead is talked about hurting humans is through entry through water. This occurs when older lead piping still exists and municipal water systems are not making sure that corrosion will not occur that would release lead into the drinking water. This lack of care around corrosion control is what caused the Flint, MI problems.

Beyond paint and water, many other items can have lead contents that can harm humans. These include artificial turf, candy, folk medicine, sindoor, jewelry, toys, beverages, cosmetics and smoking, among others.

Objectives:

1. Students will develop an understanding of the chemistry of lead.
2. Students will understand why lead has been used in homes and industry.
3. Students will understand how lead can be managed in the home and industry, how it can be abated and overall possible solutions for the lead contamination problems.

Bioaccumulation

The concept of bioaccumulation will be defined and introduced with a secondary element – mercury – so it can be discussed later with biomagnification. Lead bioaccumulation will then be introduced to students with direct data. The biological implications of lead will also be covered in depth, to show how the bioaccumulation can actually affect the body. The interference with heme biosynthesis will be covered in depth, re-exposing students to enzymatic reactions and mitochondria (that they learned in biology) while digging deeper into blood biochemistry. The connection to kidneys and nerves, among other biological pieces of the human puzzle will show how one compound can do so much damage to a human, especially youth. Bioaccumulation in pets and other organisms would be examined too on a biological level to show the far-ranging impacts of lead and why students should be concerned about its occurrence anywhere in the biosphere.

Bioaccumulation is when a chemical toxin is taken into an organism and builds up in the organism's tissues. Lead is one toxin that can bioaccumulate in organisms, especially humans. Lead exposure that can lead to bioaccumulation depends on a variety of factors, including particulate size, route of exposure, nutritionals status, health and age of the individual. Blood is the first stop for absorbed lead, distributing it throughout the body. The majority of lead ends up in bones and teeth. It can become inert in the bones, but can be released back into the blood when bones break and advanced age occurs, among other occurrences. Most of the rest of lead goes to soft tissues, like the brain, liver, kidneys, lungs, spleen and heart.

One of the major biological effects of lead in the body is lead's interference with heme synthesis. Heme has an iron ion. It gives myoglobin and hemoglobin the ability to bind oxygen and contributes to the red color found in muscles and blood. When lead is present where heme is made, the lead can inhibit the production of heme. This occurs by inhibiting two of the eight enzymes necessary to make heme: d-aminolevulinic acid dehydratase and ferrochelatase. Therefore oxygen is not as easily bound in blood and anemia can occur.

Beyond the heme synthesis issue, many other problems can occur. In the nervous system, brain damage can be quite extensive, especially in children. Decreased IQ, lowered academic achievement and problems with thinking are the major effects. Kidney disease and impaired renal functions can be a result of lead poisoning. Other problems can occur in the endocrine, cardiovascular and reproductive systems as well.

Objectives:

1. Students will develop and understanding of bioaccumulation.
2. Students will appreciate the biological implications of bioaccumulation for humans and pets.

Biomagnification

To showcase the difference between bioaccumulation and biomagnficiation, students will investigate why PCBs, DDT and mercury are biomagnified. From this, there will be an introduction to chemical half-lives in organisms and what lead's half-life is. From this concept, students will investigate lead's half-life and the reason why this prevents biomagnification from occurring.

Biomagnification is when a chemical toxin is passed from one trophic level to the next in a food web and increases in concentration as it rises through tropic levels. To consider how biomagnification works, examples of PCBs, DDT and mercury will be useful. PCBs are chemicals that are used for coolants and insulating fluids as well part of plastics. In food webs, PCBs can first bioaccumulate in plankton and then when shellfish and larger organisms successively feed on one another, the concentration of PCBs grow in fatty tissue. This can go all the way up to humans who ingest seafood that can be contaminated with PCBs. The excess amounts of PCBs in humans can be cancer causing. Similarly, the insecticide DDT is biomagnified. Sprayed on crops and then getting into food webs on land and in water after runoff from land reaches water, DDT first bioaccumulates in insects and small sea creatures and biomagnifies as it moves up the trophic levels of the food webs its intertwined in. DDT's accumulation in humans could possibly lead to cancer, as the U.S. classifies it as a probable carcinogen. Mercury has a similar biomagnification fate, moving through aquatic food webs to emerge in seafood consumed by humans. The bioaccumulation of mercury in humans can deteriorate the nervous system and impair hearing, speech, vision and gait among other major impairments.

The big question then is can lead be biomagnified. No, it cannot be. The major reason is because of lead's short chemical half-life, preventing it from entering trophic level movement in food chains and food webs. With a half-life of 28-36 days, lead passes out of the body through the excretory system rather quickly. Also, since it does not usually become stored in fatty tissue, it does not stay around long enough in other animals to move through trophic levels and biomagnify.

By using the comparison of a substance that can only bioaccumulate and not biomagnify, it is hoped students will understand the connections and differences between the two terms of bioaccumulation and biomagnification and the damage biomagnified substances can cause versus one that is only bioaccumulated.

Objectives:

1. Students will understand the distinction between bioaccumulation and biomagnification.
2. Students will insight into environmental chemicals that biomagnify like PCBs, DDT and mercury.
3. Students will learn what a half-life is and how it relates to lead bioaccumulation and prevents leads from being biomagnified.

Lead in Philadelphia

By this point, students will have a concept of what lead can do to the human body. With this in mind, students will research where lead is found in Philadelphia. We would begin with a sampling of soil from student's homes, places around the school, other areas that could be checked for lead levels with UPENN's equipment. This data can then be checked against what the other data in points in Philly are as found on the interactive map website:https://www.arcgis.com/home/webmap/viewer.html?webmap=b1a0409f6d424e2cd98f5ac9ed33d8c26&extent=-76.2047,39.7073,-74.8575,40.1863. Students would do research on what could have historically caused lead levels in certain areas, with possible field trips to different parts of the city and interaction with environmental researchers/students/professors about their knowledge and the future of lead in the city.

Lead is found throughout Philadelphia, from the soil throughout the city to classrooms to homes. Students will be given the independence to research a site for lead and write a report about it. With a large portion of the city's properties being built before 1950, lead is most likely found in a large chunk of paint. With 80% of Philadelphia school district-run schools being in buildings built before 1978, which is when lead paint was banned, the possibility of lead paint flaking and human contact with lead is high. If students are interested in testing paint in school or at home, they will use 3M LeadCheck Swabs. They will mark the surface and if the color red appears, then lead is present.

Ground contamination with lead is very possible throughout Philadelphia. The history of smelting, the leaded paint on bridges and overpasses, not to mention in homes and the other industrial processes that can release lead are abundant. So students also have the choice of sampling soil from the school or home. Labelling it with the longitude and latitude, the soil would then be checked at University of Pennsylvania by an x-ray fluorescence monitor that checks for lead metal levels.

Students would then use this data to build a picture about what is going on at home or at school with lead. By analyzing it for a report and adding soil data to a citywide database of soil lead data, they are doing citizen science. This real-world scientist work will then empower them for the final section of the Lead Bioaccumulation unit.

Objectives:

1. Students will understand how ubiquitous lead is by sampling in their environments through, soil, paint and water testing.
2. Students will learn to research historical sources and learn why lead is so ubiquitous.

Environmental Justice

This final part of the unit would be a culminating project on environmental justice tied to lead. This would begin with research into what has occurred in Chester regarding environmental justice. Then students would be tasked with coming up with an action plan for lead in Philadelphia. Students could choose educating the community, talking to a representative in the city, or some other idea that gives them the voice to make change in

Philadelphia. Students would not have to see the whole project through, but rather plan it out as much as possible and present the project idea to their classmates.

Environmental justice is the fair and equal treatment and involvement of all people in the upkeep and enforcement of environmental laws. After getting through the rest of this unit, students have seen how Philadelphians have not been treated equally and now those students who have realized that can do something about it.

To be versed in environmental justice, an understanding of governance and policy development must occur. As the usage of economic, political and administrative authority to result in some end product, governance is a vital political tool. Governance is achieved by policy and policy guidelines. By considering how governance at levels like the executive branch, legislative branch, judiciary branch, advocacy groups, media and the citizens can help to shape policy guidelines, it can be understood how environmental justice policy can help solve the problems of lead contamination.

Before students can develop an environmental justice plan, they have to know how it has worked before. So students are introduced to the issues in Chester, Pennsylvania. The city is home to four hazardous and municipal waste treatment facilities. These incinerators release a lot of pollutants that have led to Chester residents having much higher chances of developing lung cancer, ovarian cancer, asthma, cardiovascular disease and heart disease, among many other conditions. The community joined together to file a lawsuit in 1994, asking the question of the permitting agency, the Department of Environmental Protection, "At what point has a city had more than their fair share of polluting industries permitted?" The courts found many great harms occurring. Ultimately the Supreme Court did not hear the case, so no ruling was ever made to improve environmental justice. The fight for environmental justice continues, despite governance and policy not helping the people.

Reading letters that have been written to politicians about the lead issues in Philadelphia and listening to public comments about lead issues at city hearings, students will then have a great background knowledge about how they would like to propose some environmental justice strategies in Philadelphia. They can write letters, make a video, create educational materials, make phone calls to representative and much more to help positively add to the Philadelphia community's response to the lead problem.

Objectives:

1. Students will understand the concept of environmental justice and how it applies to lead.
2. Students will understand the full range of actions that could be employed to tackle the lead problem and how citizens can participate in them.

Teaching Strategies

Lead in the Environment

This 2- to 3-day lesson will acclimate students with lead as an element and its history in products and how it has been reduced as a product and removed. There will be

a review of the periodic table and lead's placement on the table as a heavy metal with an atomic number of 82. There will be a jigsawed investigation where individual students in a group of four will research one of the following topics to share back with the group: lead's occurrence and distribution, uses as a metal, compounds it forms and elemental properties. Following the introductory look into lead, students will discuss its value to the home, commercial products and industry.

Then there will be an investigation into how lead used for the home and beyond can result in contamination. This will begin with a teacher-led presentation and discussion on two vital ways lead is encountered: paint and water. Power Points with guided questions will be used for these with paint focusing on the overall picture and water focusing more on what has happened in Flint, MI. For this, there are 2 solid resources than can be used together or piecemeal, depending on timing and class level (honors, non-honors). There is a look at 7 contamination source areas as found at the Centers for Disease Control (CDC): artificial turf, candy, folk medicine, sindoor alert, jewelry and toys. A much more expansive list than the CDC's is found at the Agency for Toxic Substances and Disease Registry (ATSDR), which includes the following sections of research: foods and beverages, commercial products, folk imported home remedies and cosmetics, environmental and industrial, smoking, occupation, secondary exposure and gasoline. With these research elements, students can delve into singular or small group research on topics to share out in a jigsaw with the class.

Using these concepts of lead's value and harmful nature to the home and community, the culminating assessment of this first lesson will be focused on students doing mini-presentations on information introduced in class (either paint or water) or independently researched for the jigsaw on lead contamination management, abatement and possible solutions for these problems.

Bioaccumulation

This 3- to 4-day lesson will cover the idea of bioaccumulation, how lead can bio-accumulate and how bioaccumulation can affect biological processes in humans. It will begin with students defining bioaccumulation for themselves, based on the word parts (bio and accumulation). Then students will learn about the actual definition as when a chemical toxin is taken into an organism and builds up in the organism's tissues. Students will consider what harm bioaccumulation can cause and share out. Then students in groups of 2-4 will do a bioaccumulation simulation lab to further explore the concepts of bioaccumulation.

The investigation of bioaccumulation will then extend to lead itself. There will be a review of what students already learned about lead and then a deeper dive into the concept of bioaccumulation of lead. The teacher will introduce this with an explanation of a decrease in heme synthesis, re-exposing students to enzymatic reactions and mitochondria (that they learned in biology) while digging deeper into blood biochemistry. Students will then research one body area and how lead bioaccumulation can affect it: nervous system, kidneys, blood, endocrine system, gastrointestinal area, cardiovascular system, reproductive system, development of body and other effects.

This research can be as in depth as a teacher wants it, as the ATSDR site for this has many effects listed that can be further researched. Students will share the researched information with the class so everyone will have information on all then be given notes on how the accumulation of lead affects the human body itself.

The cumulative assessment for this second part of the unit will be taking what has been learned about bioaccumulation to explain how a pet could bioaccumulate lead from the household and how the lead could affect its body as well as what solutions exist to prevent this lead bioaccumulation in the first place. There would be a "show and tell" of pets, symptoms and preventative measures.

Biomagnification

This 2- to 3-day lesson will cover what the idea of biomagnification is, how it occurs with PCBs, DDT and mercury and why it does not occur with lead. It will begin with students considering what the term means and coming up with their own definitions based on the word parts (bio and magnification). After a class discussion of these possible meanings, the meaning will be revealed to be when a chemical toxin is passed from one trophic level to the next in a food web and increases in concentration as it rises through tropic levels. Students will then be assembled into groups of 3 to 4 to examine some different examples of biomagnification: with PCBs, DDT and mercury. After completing the look at the PCBs, DDT and mercury, student groups will share out information about how they are each biomagnified so everyone understands.

Lead has a short half-life as a chemical in the body, preventing it from being biomagnified. Furthermore, it is not involved in trophic level movement in food chains. So, the concept of chemical half-lives must first be introduced in a lesson comparing them to the more familiar radioactive half-lives. With this information in hand, students will do some research on how long lead can stay in the body and what parts of the body it is locked into which would include looking at the blood, bones, teeth, liver, kidneys, lungs, brain, spleen and heart. This singular or group activity assignment would then be shared out as a whole so everyone will understand what parts of the body it can get locked into.

The assessment for this unit section would be making sure students understand the difference between the concepts of bioaccumulation and biomagnification as well as understanding how lead operates differently for the two concepts. This would best be served in a quiz-based format with an essay portion that would require students to compare lead to one of the other 3 biomagnified chemicals and justify why lead is not biomagnified while the other chemical is.

Lead in Philadelphia

This 4- to 5-day lesson will investigate where lead is found in Philadelphia using historical data, actual Earth samples and their results, and outside lecturers/scientists to engage in discussions about lead in Philadelphia past and present and what can be done in the future.

The lesson will begin with students thinking about where they would like to look for lead: in the classroom, in the school as a whole, outside in the ground, at home in the ground, at home inside, etc. Students will be assembled into groups of 2-4 for this purpose. Samples will be collected for analysis using the "How to Sample Soil" document for guidance, with soil samples being analyzed by PENN with an x-ray fluorescence monitor and indoor sampling done with lead sampling kit techniques via the 3M test swabs. Students will hypothesize what they think the data will reveal while also doing other qualitative and quantitative data collection at sites. Qualitatively they will describe the conditions in general and take photographs. Quantitatively they will measure the areas where the samples were taken from as well as latitude and longitudes of data collection.

While results are being waited for, students will get a chance to hear outside lecturers from PENN and the community about lead and/or watch some documentary and news clips about the lead issues affecting Philadelphia. There will also be readings of reports on lead in water and schools in Philly and Pennsylvania as a whole. Students will do this in groups and share the findings with the class.

When the data is collected, students will analyze it, contextualizing it within the scope of soil lead data as found at the Penn Medicine's CEET Lead Soil Sampling Results webpage and the Soil Lead Interpretation diagram. The cumulative assessment for this lesson will be a report typed up with the hypothesis, data, conclusions and further research information they would like to gather.

Environmental Justice

This 3- to 4-day lesson will begin with the meaning of the term environmental justice and the vital nature of other associated concepts. The will be followed with examples of how Chester environmental justice has worked and move into having students design their own environmental justice project around lead in Philadelphia.

The exploration of environmental justice will begin with students considering what the actual meaning could be for environmental justice. Students would discuss this in pairs and as a class. A joint guided note-taking session on governance and policy development would then occur so students can understand the points they can influence and what the least intrusive to most intrusive policy development actions can be. Student pairs will then brainstorm what actions can be done at a specific level of governance: executive, legislative, judiciary, advocacy groups, media and citizens. Students would then discuss their ideas as a class and record them.

With the background of governance and policy development, students would then encounter an example of environmental justice as occurred in Chester, PA. Using Power Point notes and independent research, students would construct their own explanation of why Chester needed environmental justice, what justice occurred, whether or not the justice solved the problem and, if not solved, what needs to still be done. Students would discuss their answers in small groups and then as a class talk about the successes and failures of the environmental justice in Chester.

To prep for the final assignment in the Lead Bioaccumulation unit, students will be given background information on how letters might be written about the lead issue from experts and how the public can voice its thoughts at a public hearing. With these examples of action and using their reports from the previous lesson as well as all the other information they have learned and/or other independent research on lead, students will determine what type of justice action they would like to take. This could include creating community educational materials and deciding what distribution they would like to do, communicating with a local political representative about their concerns, communicating with school officials their concerns, connecting their concerns to a national and/or international educational effort on lead, teaching other peers, younger students or adults about the lead concepts, etc.

Students will devise a plan for implementing this action and carry it out as much as possible. Their assessment in this unit is for the presentation to the class of the plan and the actual carrying out of the plan.

Classroom Activities

*Classroom Activity 1: Bioaccumulation

Lab Activity

In this activity, students will take what they know about the concept of bioaccumulation and add it to the idea of biological half-lives, which they will learn more about in the "Biomagnification" unit of learning. This should take 1 period.

ESSENTIAL IDEA:
*Bioaccumulation of lead is dictated by its half-life and environmental concentration.

STANDARDS:
*PA BIO.B.4.2.1 Describe how energy flows through an ecosystem.

*NGSS HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

PRE-LAB:

1. Students will look up the definition to half-life here: https://goldbook.iupac.org/html/B/B00658.html
2. Students will rewrite the definition of bioaccumulation.
3. How are half-lives and bioaccumulation linked?

4. What do you think happens if more of a chemical is taken in each day by the body than is expelled? What happens if less of a chemical is taken in each day by the body than is expelled?

LAB SET-UP:

Set up snack bags around a classroom that are labeled (put several of each at each spot):
+Peeling lead paint chips: 20 Blue M&Ms
+House dust from peeling paint: 10 Brown M&Ms
+Water: 3 Green M&Ms
+Eating soil: 7 Red M&Ms
+Putting hands in mouth: 10 Yellow M&Ms

PROCEDURE:

1. One student walks around the class and collects one bag of each of the 5 lead causes as a demonstration. The student will add them up to find 50 M&Ms in the bag.
2. Students in groups of 2-4 depending on the size of the class will then walk around and collect M&Ms from each bag type. At each bag type, they will roll a 6-sided die to determine how many M&Ms to take.
3. Students will record how many of each color they have.
4. Students will be told 5 days have elapsed and that they should remove half of all the M&Ms they have.
5. Students will repeat steps 2-4 2 more times.

ANALYSIS

1. What lead input did you end up with more than any other in the first round? Second round? Third round?
2. After all 3 rounds, did your group end up with more M&Ms than it had after the 5 day span in step 4?
3. Depending on your answer to #3, did your group bioaccumulate lead or did you reduce the amount of lead in your group's "body"?
4. How is the half-life of lead affecting its bioaccumulation?
5. What could be a reason that one could end up with more of the lead input in the first round that you ended up with than any other lead input? Think about human activities, environmental conditions and other factors.
6. The bioaccumulation of lead can lead to what physiological effects? Name at least 3 of them.

EVALUATION

Lab will be assessed based on completion and correct nature of PRE-LAB and ANALYSIS and completeness and correct nature of data recorded.

*Classroom Activity 2: Lead in Philadelphia

Cumulative Assessment Report

In this activity, students will use data from lead amounts in soil samples and/or lead presence or absence in paint to analyze the area in which the samples were taken from, determining how dangerous their areas are and what the next steps should be to make the areas as safe as possible. This should take 2 periods.

ESSENTIAL IDEA:
*Lead is a harmful substance that can be found in paint, soil and water.

STANDARDS:
*PA PA BIO.B.4.2.4 Describe how ecosystems change in response to natural and human disturbances.

*NGSS HS-LS2-7 Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

STARTER:
What kind of data did your group collect (soil sample, paint sample)? Were your results surprising or expected? Why do you say that? Discussion of answers in small groups and then as a class.

LAB REPORT:
Students will take data and use it to make a lab report that will stand as an assessment for this section of the unit. It will be typed and submitted as a Google Doc or Word document. The report will include the following sections:

+Introduction: This one paragraph section with introduce readers to the detrimental effects of lead in the environment and how prevalent lead has been historically in Philadelphia.

+Lead Sample: Students will describe where the lead sample was taken in from in as specific of terms as possible, like including latitude and longitude or the classroom number.

+Hypothesis: Students will share what they originally thought would be found in IF…THEN…BECAUSE format.

+Materials: Students will describe what materials were used to collect data and sample it.

+Procedure: Students will describe what the procedure was to collect the sample as well as to extrapolate data from the sample.

+Photos: Students will include images taken of the site the sample was taken at as well as any other supporting images that help to contextualize the sample further. These will be labeled in the report.

+Data: Students will make a data table and share data here, using proper units of measurement.

+Conclusion: Students will compare the data acquired to the hypothesis to determine if the hypothesis was supported or rejected. Students must discuss the actual data as specifically as possible.

+Future: Students will discuss what the data means in context with the rest of Philadelphia and what it means for the future of Philadelphia. Students will discuss two ways the situation with lead in Philadelphia can be improved and suggest ways to implement these improvements.

EVALUATION:
The assessment is the lab report, so students will be evaluated based on the correctness and thoughtfulness of each section.

*Classroom Activity 3: Environmental Justice

Environmental Justice

In this final assignment for the Lead Bioaccumulation unit, students will devise a plan for implementing some sort of action towards environmental justice with lead in Philadelphia. This should take 2 periods.

ESSENTIAL IDEA:
*Environmental justice is a valuable tool to enact change in a community dealing with an environmental problem like lead contamination.

STANDARDS:
*PA PA BIO.B.4.2.4 Describe how ecosystems change in response to natural and human disturbances.

*NGSS HS-LS2-7 Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

STARTER:
*What do you think will be the best way to address the lead issue in Philadelphia through environmental justice? Why do you think this? Students will share in their small groups and then as a class.

ENVIRONMENTAL JUSTICE PLAN:
*In small groups (2-3 students), students will first determine what aspect of the lead contamination issue they are most passionate about. They will then brainstorm 3 ways that address this through environmental justice from the following list:
+Letter writing to local politicians about fighting for the issue
+Teaching your community about the issue so they are informed and can act
+Teaching younger students about the issue so they are informed and can act
+Creating a pamphlet or poster to address the issue for education purposes
+Communicating with school officials about the issue so they are informed and can act
+Organizing a protest so the people can be informed and can act
+Connecting with a national or international organization about what is going on in Philadelphia
+Calling local representatives to address the issue so they are inform
+Make a video PSA
+Something else?!

*After brainstorming, each student will choose which way he or she wants to address the lead problem through environmental justice. Along with a 2-3 sentence description of their plan, they will share with their teacher for final approval or to be further edited and resubmitted for approval.

*Students will then individually work on crafting their environmental justice responses. Since there is a short amount of time allotted for the assignment, students are expected to only have a solid draft of what would be done and expectations of the response to what they do. This can take a form of a typed-out letter, a drawn poster, a typed-out possible phone conversation, etc. Students will receive 10% extra points if they actually carry out their plan, which would require evidence to back up carrying out the plan.

EVALUATION:
*Students will be evaluated on the completeness of the brainstorming session of three ideas, the proper execution of the approval of their final idea and the breadth, thoughtfulness, creativity and overall strength of argument that goes into their environmental justice response.

Resources

Bibliography for Teachers

*ATSDR, et al. *TOXICOLOGICAL PROFILE FOR LEAD*. 2019.

This draft of the most recent toxicology profile for lead provides vital information on lead's toxicity.

*Campbell, Carla et al. "A Case Study of Environmental Injustice: The Failure in Flint" *International journal of environmental research and public health* vol. 13,10 951. 27 Sep. 2016, doi:10.3390/ijerph13100951

This reading will provide vital background on lead contamination in Flint, MI.

* Eisler, Ronald, and Patuxent Research Center. *Lead Hazards to Fish, Wildlife, and Invertebrates*. U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 1988.

This reading provides vital background on lead hazards to non-human animals.

*Hornberg, Claudia, and Andrea Pauli. "Child Poverty and Environmental Justice." *International Journal of Hygiene and Environmental Health*, vol. 210, no. 5, 2007, pp. 571–580., doi:10.1016/j.ijheh.2007.07.006.

This article provides vital information about the linkage between child poverty and environmental justice.

* Needleman, Herbert. "Low Level Lead Exposure: History and Discovery." *Annals of Epidemiology*, vol. 19, no. 4, 2009, pp. 235–238., doi:10.1016/j.annepidem.2009.01.022.

This reading provides vital information on the history and discovery of lead exposure.

* Rosner, David, and Gerald Markowitz. "Building the World That Kills Us: The Politics of Lead, Science, and Polluted Homes, 1970 to 2000." *Journal of Urban History*, vol. 42, no. 2, Mar. 2016, pp. 323–345, doi:10.1177/0096144215623954.

This reading provides important background on pollution in homes and its connection to lead contamination.

* Rumpler, John, and Emma Dietz. *Get the Lead Out*. 2019, environmentamerica.org/feature/ame/get-lead-out-0.

This study reveals data on lead contamination in schools in the United States.

Reading List for Students

Lead in the Environment

*History, Written Article. "Lead | Definition, Uses, Properties, & Facts." *Encyclopedia B Britannica*, britannica.com/science/lead-chemical-element.

This provides the main information on lead chemistry for jigsaw activity.

*"It's Elemental - The Element Lead." *Jlab.Org*, 2019, education.jlab.org/itselemental/ele082.html.

This provides supplemental information on lead chemistry for jigsaw activity.

* Weis, C.P. & Casteel, S.W. & Brown, L.D.. (2016). Bioavailability of lead in paint. Toxicology Letters. 258. S234-S235. 10.1016/j.toxlet.2016.06.1837.

This provides information on lead in paint and the bioavailability of lead.

* "Protect Your Family from Exposures to Lead." *EPA*, Environmental Protection Agency, 26 Mar. 2019, www.epa.gov/lead/protect-your-family-exposures-lead#older.

This site provides information on lead in paint and other parts of older homes.

**CDC - Lead - Tips - Sources of Lead*. 2019, www.cdc.gov/nceh/lead/tips/sources.htm.

This provides information on sources of lead for research.

*"Lead (Pb) Toxicity: Where Is Lead Found? | ATSDR - Environmental Medicine & Environmental Health Education - CSEM." *Cdc.Gov*, 2017, www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=5.

This provides information on sources of lead for research.

* "Lead Exposure in Children: Prevention, Detection, and Management." *Pediatrics*, vol. 116, no. 4, 2005, pp. 1036–1046., doi:10.1542/peds.2005-1947.

This source provides information for lead management research.

*US EPA,OCSPP. “Lead Abatement, Inspection, and Risk Assessment | US EPA.” *US EPA*, 22 Aug. 2018, www.epa.gov/lead/lead-abatement-inspection-and-risk-assessment.

This is the source for lead abatement research.

Bioaccumulation

*Alexander, David E. “Bioaccumulation, Bioconcentration, Biomagnification.” *Encyclopedia of Earth Science*, 2019, pp. 43–44, link-https://doi-org.proxy.library.upenn.edu/10.1007/1-4020-4494-1_31.

Definition of bioaccumulation.

*Streit, B. “Bioaccumulation Processes in Ecosystems.” *Experientia*, vol. 48, no. 10, 1992, pp. 955–970., doi:10.1007/bf01919142.
This article reveals bioaccumulation processes in ecosystems.

*Czub, Gertje, and Michael S. Mclachlan. “Bioaccumulation Potential of Persistent Organic Chemicals in Humans.” *Environmental Science & Technology*, vol. 38, no. 8, 2004, pp. 2406–2412., doi:10.1021/es034871v.

This article shows what the bioaccumulation potential is in humans.

* Genuis, Stephen J., and Kasie L. Kelln. “Toxicant Exposure and Bioaccumulation: A Common and Potentially Reversible Cause of Cognitive Dysfunction and Dementia.” *Behavioural Neurology*, vol. 2015, 2015, pp. 1–10., doi:10.1155/2015/620143.

This article provides vital information on how lead and other substance bioaccumulate and how they can lead to cognitive issues.

* “Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations.” 1993, doi:10.17226/2232.

This article discusses lead amounts in infants, children and other populations.

*Cory-Slechta, and Deborah A. *Low Level Lead Exposure Harms Children: A Renewed*

Call for Primary Prevention Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention. 2012.

This article examines how low lead concentrations can harm children.

*Lubran, Michael. "Lead Toxicity and Heme Biosynthesis." *ANNALS OF CLINICAL AND LABORATORY SCIENCE,*vol. 10, no. 5.

This article discusses lead and heme synthesis.

*Chhabra, Namrata. "Effect of Lead Poisoning on Heme Biosynthetic Pathway." *Biochemistry for Medics - Clinical Cases*, 17 June 2018, usmle.biochemistryformedics.com/effect-of-lead-poisoning-on-heme-biosynthetic-pathway/.

This article discusses lead and heme synthesis.

*"Lead (Pb) Toxicity: What Are the Physiologic Effects of Lead Exposure? | ATSDR – Environmental Medicine & Environmental Health Education - CSEM." *Cdc.Gov*, 2017, www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=10.

This webpage discusses how lead toxicity is linked to health effects in humans.

*Langlois, Daniel K., et al. "Investigation of Blood Lead Concentrations in Dogs Living in Flint, Michigan." *Journal of the American Veterinary Medical Association*, vol. 251, no. 8, 15 Oct. 2017, pp. 912–921, 10.2460/javma.251.8.912.

This article examines lead toxicity in dogs in Flint, MI.

*Wismer, Tina. "Lead." *Small Animal Toxicology*, 2013, pp. 609–615, www-sciencedirectcom.proxy.library.upenn.edu/science/article/pii/B9781455707171000533, 10.1016/b978-1-4557-0717-1.00053-3.

This book chapter discusses lead's impact on pet health.

Biomagnification

*Alexander, David E. "Bioaccumulation, Bioconcentration, Biomagnification." *Encyclopedia of Earth Science*, 2019, pp. 43–44, link-https://doi-org.proxy.library.upenn.edu/10.1007/1-4020-4494-1_31.

The definition of biomagnification comes from here.

*Polak-Juszczak, Lucyna. “Distribution of Organic and Inorganic Mercury in the Tissues and Organs of Fish from the Southern Baltic Sea.” *Environmental Science and Pollution Research*, vol. 25, no. 34, 2018, pp. 34181–34189., doi:10.1007/s11356-018-3336-9.

This article discusses bioaccumulation and biomagnification of mercury.

* Griffin, T.B, et al. “Biological and Clinical Effects of Continuous Exposure to Airborne Particulate Lead.” *Archives of Industrial Hygiene and Toxicology*, vol. 26, no. Supplement, 2019, pp. 191–208, hrcak.srce.hr/167410?lang=en.

This article examines how lead levels decrease over time in animals.

* “Lead (Pb) Toxicity: What Is the Biological Fate of Lead in the Body? | ATSDR – Environmental Medicine & Environmental Health Education - CSEM.” *Cdc.Gov*, 2017, www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=9.

This webpage examines lead half-lives and the overall biological fate of lead.

Lead in Philadelphia

*Lusby, Gregory, et al. “Lead Contamination of Surface Soils in Philadelphia from Lead Smelters and Urbanization.” *Environmental Justice*, vol. 8, no. 1, 2015, pp. 6–14., doi:10.1089/env.2014.0008.

This article looks at data on lead contamination in Philadelphia.

* Laker, Barbara, et al. “Children Face Potential Poisoning from Lead, Mold, Asbestos in Philadelphia Schools, Investigation Shows.” *Philly.com*, 22 May 2018, media.inquirer.com/storage/special_projects/lead-paint-poison-children-asbestos-mold-schools-philadelphia-toxic-city.html.

This newspaper report looks at lead in Philadelphia schools.

* “Lead and Healthy Homes Program | Department of Public Health.” *City of Philadelphia*, 7 Nov. 2018, www.phila.gov/programs/lead-and-healthy-homes-program/.

This website has many resources about lead and the health of Philadelphians.

*Center for Excellence in Environmental Toxicology. “How to Collect Soil Samples for Lead Testing.” https://drive.google.com/file/d/1CLIe0Nz09UBKn-Wc5uuGiGzqPbRNrGKOa/view.

This document explains how to do the soil sampling properly.

* Center for Excellence in Environmental Toxicology. “Soil Lead Interpretive Graphic.” https://drive.google.com/file/d/1i1rYgmqA_FuZhs4uThS9GyCRBFUozswv/view

This graphic shows how to interpret soil lead data.

Environmental Justice

*“Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.” *EPA*, Environmental Protection Agency, 29 Mar. 2016, www.epa.gov/environmentaljustice/federal-actions-address-environmental-justice-minority-populations-and-low.

This is a primary source on federal actions on environmental justice.

* University of Michigan. “Environmental Justice Case Study: Toxic Waste in Chester, Pennsylvania,” www.umich.edu.proxy.library.upenn.edu/~snre492/polk.html.

This resource describes some of the history of the toxic waste in Chester, PA.

*Howarth, Marilyn. “Verbal Comments to Philadelphia City Council for Lead in Schools Legislation.”https://drive.google.com/file/d/1Bqyz7wd3KDQOEkKaAHXBRYZOS_kUZDeC/view

This resource will show how one can provide input to local representatives on the issue of lead.

* “COUNCILWOMAN REYNOLDS BROWN HOSTS HEARING ON BILLS TO PROTECT CHILDREN FROM LEAD EXPOSURE.” *Philadelphia City Council*, 20 Mar. 2019, phlcouncil.com/councilwoman-reynolds-brown-hosts-hearing-on-bills-to-protect-children-from-lead-exposure/.

This article includes comments both in print and in video format made by citizens about lead exposure to children in Philadelphia.

Materials for Classroom Use

Lead in the Environment

*Center of Excellence in Environmental Toxicology. "Lead and Health: Background and Context," https://drive.google.com/file/d/1J6zP8OuSyBaO7cJNt6R-fjTr4X_aDeSm/view

This presentation provides background information for notes for the Lead in the Environment section.

*Pepino, Richard. "Lead-laced Water in Flint, Michigan," https://drive.google.com/file/d/1yMkmRAdC5liMtepeaPVk7c9hLgr4WuWD/view

This presentation provides background information for notes for the Lead in the Environment section.

Bioaccumulation

* "Bioaccumulation and Half-Life Lead Lab." https://drive.google.com/file/d/1im_lIEYlcd_bu9VQsjWXefN5g3lJ8rqR/view?usp=sharing

This document is for a lab on bioaccumulation and half-lives of lead.

*Howarth, Marilyn. "Lead Concentration in Blood and Expected Effects." https://drive.google.com/file/d/1mI7_sjVxTKgiZdBUzpjIiy3ACsXxdwuR/view

This figure shows expected physiological effects that will result from certain lead blood concentration levels.

Biomagnification

* Vinzant, Alisa. "Bioaccumulation and Biomagnification: Increasingly Concentrated Problems! - CIMI School." *CIMI School*, 7 Feb. 2017, cimioutdoored.org/bioaccumulation/.

This provides information about PCB biomagnification.

* Amoeba Sisters. "YouTube." *YouTube*, 24 Sept. 2016, www.youtube.com/watch?v=TZk6vcmLcKw.

This video explains how biomagnification works with DDT.

* “Biomagnification.” *Noaa.Gov*, 2019,
oceanexplorer.noaa.gov/edu/learning/player/lesson13/l13la1.html.

This reading explains the connection between biomagnfiication and mercury.

*Nuc Med Tutorials, “Half Lives,”
https://nucmedtutorials.files.wordpress.com/2016/12/half-lives1.pdf.

This link explains the difference between physical and biological half-lives.

Lead in Philadelphia

* *Arcgis.com*,
www.arcgis.com/home/webmap/viewer.html?webmap=b1a0409f6d424e2d98f5ac9ed33d8c26&extent=-76.2047,39.7073,-74.8575,40.1863.

This shows lead soil sampling data in Philadelphia.

Environmental Justice

*Howarth, Marilyn. “Governance and Policy.” https://drive.google.com/file/d/1RJc-MIoMpvHUVjjgmcZ4hFCFYhkgIQSG/view.

These are notes for the lesson part on governance and policy.

*Howarth, Marilyn. “Environmental Justice Case Study: Chester.”
https://drive.google.com/file/d/1mvettID1mFeGdrAvdQCeReGbFHktbrY4/view

These are notes for the lesson part on environmental justice in Chester, PA.

*Center for Chemistry Education, “Environmental Justice in Chester, PA.,”
http://www.terrificscience.org/lessonpdfs/Environmental_Justice.pdf.

This is an alternative lesson plan on environmental justice in Chester, PA.

Appendix

When thinking about how the unit plan implements the Pennsylvania science standards, each of the following unit sections use the corresponding standard(s):

*Lead in the Environment:

+PA CHEM.A.2.3.2 Compare and/or predict the properties of selected elements by using their locations on the periodic table and known trends.

This standard is addressed since this unit section examines the chemistry properties of lead.

*Bioaccumulation:

+PA BIO.A.2.3.1 Describe the role of an enzyme as a catalyst in regulating a specific biochemical reaction.

This standard is addressed when considering the interference in heme synthesis.

+PA BIO.A.1.2.2 Describe and interpret relationships between structure and function at various levels of biological organization.

This standard is addressed when considering cellular parts like mitochondria and molecules like enzymes and how they work through the interaction of structure and function.

+PA BIO.B.4.2.1 Describe how energy flows through an ecosystem.

This standard is addressed through the movement of a chemical throughout a food chain that is biomagnified on its journey.

*Biomagnification

+PA BIO.B.4.2.1 Describe how energy flows through an ecosystem.

+NGSS HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

This standard is addressed through the movement of a chemical throughout a food chain that is biomagnified on its journey.

*Lead in Philadelphia & Environmental Justice

+PA BIO.B.4.2.4 Describe how ecosystems change in response to natural and human disturbances.

+NGSS HS-LS2-7 Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Both of these unit parts address how lead's introduction into the local ecosystem changes the ecosystem.