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Mercury: An assessment of its life

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Objectives

Mercury is as ubiquitous as it is toxic, but people don't know where it is, what it is, or what we can do to change levels of it in the world around us. To a great extent, we also may not know how to regulate our exposure. The purpose of this unit is to teach learners about the natural and anthropogenic ways that mercury cycles through our environment, to teach about the different types of mercury, and to teach about the different impacts that mercury in the environment has; on top predators in a food chain, on the ecosystem as a whole, and on human health. Additionally, the unit examines that mercury is a known pollutant with health risks, yet is still is widely used to make energy efficient and electronic devices. The final outcome of the unit of study will be an action plan- learners will be active in changing the status of mercury in the environment by building a recycling plan than allows the community to recycle electronics in our school. Additionally, learners will understand that individual choices balance risk, and that to navigate decision making, the risk involved in all factors must be known and assessed.

Mercury is a commonly known heavy metal. It is element number 80 on the periodic table, and it has the unusual property of being a liquid at room temperature. Its chemical symbol is Hg, which hearkens back to its Latin name, *hydrargyrum*. Mercury is a metal in the d-block of the periodic table. The periodic table is designed in such a way that groups elements with similar properties together, and the elements in the d block have their valence electrons in the d orbitals.

Mercury is a metal whose uses have been known for hundreds of years, and has been prepared from cinnabar for medicinal and ceremonial purposes since at least the fifteenth or sixteenth century. Mercury is now known as a human toxin, and is used widely in industrial applications, weapons manufacturing, mining and smelting, and is used as a preservative. [1] Mercury nitrate also has a history of use in hat, fur, and felt industries, where mercury inhalation was an occupational hazard; leading to mercury poisoning that manifested such consequences as gingivitis, excitability, memory loss, and tremors. (Industrial mercury poisoning is the origin of the phrase "mad as a hatter.") Mercury is also in the atmosphere as a result of natural outgassing of the earth's crust, remains in the air for relatively long periods of time, and is frequently deposited on land through precipitation. [2]

Generally speaking, I believe that many people know that mercury is bad for you, that it is toxic, but I think

that people lack certain knowledge about the dangers of mercury poisoning. Specifically, I think many people can't answer the following questions: Where is mercury? How is mercury released? Where does it go when it is released? How does it move through the food chain? Who is most at risk?

Where is mercury?

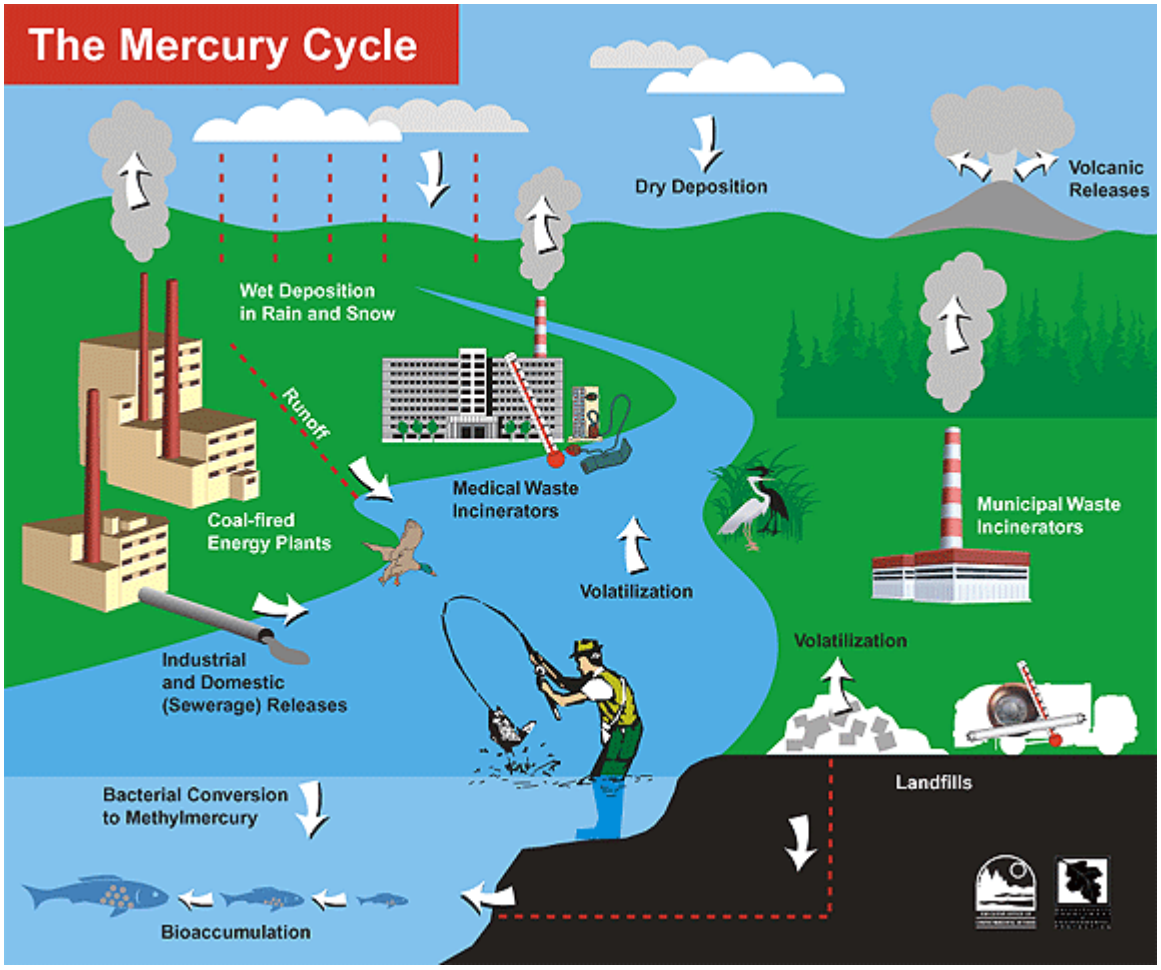
The answer to this question actually is twofold. On the first hand, where is mercury in the environment, both naturally and anthropogenically? On the other hand, where is mercury in the products we purchase and use each day? The answer to both these questions is also qualified by the types of mercury that are available in the world. For example, what are the different sources and location of elemental mercury and methyl mercury? Are there other forms of mercury that are prevalent, and what type of dangers do they pose?

Natural mercury

Mercury is found naturally in the land, in mineral deposits around the world. Mercury is a mineral that is found in soils and stones, and is especially concentrated in cinnabar, a mineral with the chemical structure HgS. Cinnabar has been used for centuries for things like paint, in medicinal applications (including to treat syphilis), and in religious ceremonies. As time went on, new uses were found for mercury, and its use increased especially during the industrial revolution. Mercury's properties made it especially suited for thermometers and barometers, and for amalgamation of precious metals like silver and gold. This amalgamation helps to extract the precious metals during mining, and then the amalgam is heated, driving the mercury vapor into the air. [3]

Human uses

Since the 1900s, there have also been many industrial applications- batteries, in the chemical creation of chlorine, and in the chemical creation of a substance referred to as caustic soda. Caustic soda is better known as lye or sodium hydroxide. The lye is used widely in labs, in soap making, and as desiccants. Mercury has been used in light switches, household thermostats, pesticides, in dental repair, and in paints as a preservative. [4] Importantly, mercury is also naturally found in fossil fuels. This means that as fossil fuels are burned, the mercury is released in the air. Since it can remain aloft for a year, it has the opportunity to travel wide distances. [5] This challenges the idea of point source and non point source pollution. Though the power plant can be said to be a point source of mercury pollution, the widespread nature of the mercury deposition is more of a nonpoint source type of consequence.



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After realizing the detrimental health benefits of mercury, the United States began to remove mercury from many products, including paint, thermostats, pesticides and thermometers. Even mercury containing batteries have recently declined in production. However, mercury has not been removed from every common product, and the mercury that remains poses several health and safety risks. For example, compact fluorescent lights are the wave of the future with regard to US lighting. Each light bulb contains a tiny amount of mercury, about 4-5 mg. [7]

Fluorescent lights contain, in the white powder lining the glass, a compound called a phosphor. The phosphor can absorb ultraviolet radiation and re-radiate it as visible light. This reaction requires very little energy, and typically the energy lost is also very little. However, that means that somehow, the electricity used to power the bulb must be converted into ultraviolet radiation; hence the function of mercury. The mercury atom, when ionized, releases energy in the ultraviolet spectrum, at 254 and 185 nm. (In the electromagnetic spectrum the ultraviolet range is roughly 10 nm to about 400 nm.) The phosphor in the light bulb absorbs that energy, and re-emits it in the visible light spectrum. [8] A little tiny bit of mercury is all that is needed for this reaction to occur- 4 or 5 mg, which is about as small as the tip of a ball point pen. [9]

However, the fact that mercury is in compact fluorescent light bulbs does raise a few salient points. What happens if the bulb breaks? What type of mercury is released into the indoor air? How dangerous is it? Moreover, the mercury means that the compact fluorescent light bulb is not able to be thrown away; it must be treated as household hazardous waste (HHW) and collected separately or recycled. Given the dismal rates

of curbside recycling in the US, the possibility that people will travel to recycle a light bulb when it burns out seems unlikely. On the other hand, stores such as IKEA and Home Depot have made headlines recently by instituting return policies in all their stores for compact fluorescent light bulbs. Lastly, what happens when mercury is thrown away with trash- whether incinerated or landfilled, the mercury will contribute to pollution. While there is a tiny amount of mercury in each compact fluorescent light bulb, the cumulative effect is bound to be large; the recently passed Energy Independence and Security Act has the goal of phasing out the incandescent light bulb in the next ten years. [10]

Electronics is facing a similar issue. Mercury (as well as other heavy metals known to be toxic to the environments and humans) is found inside electronic devices. [11] As our use and subsequent disposal of these items increases, 4-5 mg of mercury are added to our environment hundreds of thousands of times. If each light bulb has 4 mg of mercury, and each American throws one compact fluorescent light bulb away per year, that's over 12 million grams of mercury being landfilled or incinerated. [12] Landfills do little more than concentrate our toxic pollutants, and incinerators release them to the air. Though the EPA says electronic waste is 1-4% of our municipal solid waste, [13] this accounts for 70% of the overall toxic waste in landfills. [14] And while we can reuse or recycle- when it comes to electronics, even these options are fraught with concerns about negative social and environmental outcomes, as well as concerns about human health. One report estimates that as much as three quarters of "reusable" electronics shipped from the US to Africa are broken. The broken electronics are discarded on the sides of roads, where they're burned (releasing toxins into the atmosphere), picked over by people scavenging parts that are able to be sold on the black market (exposing both the individual and the environment to the toxic metals), [15] or recycled in a low-tech environment that exposes women and infants to extremely high levels of dioxin, another toxin. [16]

Elemental mercury

The pure element mercury is most dangerous when it is breathed as a vapor. Though toxic, it is less so than organic mercury compounds. It can cause tremors, mood swings, insomnia, muscle damage, headaches and more. Very high exposure can cause death. These effects are exacerbated in poorly ventilated rooms and vary with temperature. [17] Your age and previous health when exposed can also affect the amount of damage that elemental mercury will have when inhaled. Interestingly, ingesting the metal is rarely dangerous; what makes the body able to absorb mercury is biomethylation. Inorganic mercury typically stays suspended in red blood cells or plasma, and will typically leave the body in 30 - 60 days. [18] The EPA maintains a list of objects in your home that may contain mercury, and what to do if there is a spill. [19]

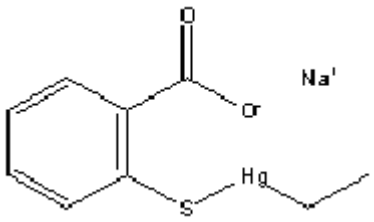
Inorganic compounds with mercury

Skin rashes, mood swings, memory impairment and other mental disturbances, and muscle weakness are attributed to exposure to inorganic compounds that contain mercury. Inorganic mercury can be absorbed by the gastrointestinal tract, but less so than organic mercury. It can damage the gastrointestinal tract, the nervous system, and the kidneys. [20] Inorganic mercury is commonly found in mercury salts, which are largely not used in the world today following the discovery in the 1970s that inorganic mercury, when dumped in open waters can be methylated by bacteria and returned to the food chain. Even more surprising was the discovery that the mercury could travel far distances away from its source. [21]

Organic compounds with mercury

It is generally accepted that not only is this the most harmful type of exposure, it is also the most frequent. Elemental mercury can be changed by aquatic bacteria into methyl mercury, CH_3Hg. Methyl mercury builds up in the tissue of aquatic organisms, and tends to bioaccumulate- in other words, animals higher on the food chain have higher concentrations of mercury than do animals lower on the food chain. This means that the top predators like the largest fish, eagles, owls, and hawks are exposed the most. [22] The other top predator is, of course, humans. People who eat fish and shellfish are exposed to mercury through the food chain. This means that dosages can't be exactly measured- different people eat different amounts of fish, differences in individuals can cause a range of exposures, and dosage will be different if the person eats a lot of fish or shellfish in a short amount time vs. over a greater period of time. Additionally, outside effects may be in play as well- acid rain can increase mercury's methylation, thus detrimentally impacting the food chain in areas prone to acid rain. [23]

Even when the dangers of organic mercury were well known, some substances were available on the commercial market that contained organic forms of mercury. The FDA maintains a list of products that contain mercury, both in organic and inorganic forms. [24] Recently, there has been much public debate about the mercury-containing thimerosal used as a preservative in multi-dose vaccines. Thimerosal is an organic mercury whose structure is shown.



As you can see, the thimerosal has mercury in it. Phenyl compounds (with a benzene ring) are converted to inorganic mercury rapidly, and inorganic mercury is oxidized to divalent mercury (Hg^{2+}). [25] Many people in the autism advocacy and awareness leadership now claim a link between thimerosal-containing vaccines and the rise in the incidences of autism in America. [26] The FDA claims just as strongly that there is no link, but most childhood vaccines (except flu vaccines) have removed thimerosal anyway. [27] Though the risks may be small, using alternative preservatives may eliminate any risk. What's more, the medical community was concerned that people may avoid vaccinating children- leading to a health crisis of a different type. This example is not one I'd use with children, but I include it here to illustrate the point that there is wide disagreement about the relative risk and safety of different types of mercury exposures.

How is mercury released?

Some mercury is naturally cycled through the world via the natural biogeochemical cycles that move all substances on Earth. Volcanoes, for example, can spew elemental or inorganic mercury into the atmosphere. On the other hand, the methods by which humans put mercury in our environment are known as anthropogenic sources. These sources contribute to pollution.

Mercury is released by burning coal, which tends to have high mercury content, by incinerating waste, and

through a variety of industrial & mining uses. [28] When electronic equipment like cell phones, computing devices, and televisions are thrown away, they can be incinerated. Along with a whole host of other vile pollutants, mercury is spewed into the atmosphere. Alternately, if the electronics are landfilled, the mercury and other toxic metals will build up in the landfill, and will likely pollute the groundwater! The other problems with mercury in municipal solid waste have already been described, so I won't repeat them here. Mercury is also released when weapons explode. This means that on islands like Vieques and the Bikini Atoll, where the US has run long-term weapons testing campaigns, among the litany of environmental devastations that were caused was elevated mercury levels among the island dweller, who fished for their food or are fish eaters. [29]

In some respects, mercury is a success story, in that the amount of mercury released by humans has decreased over the past two or three decades. In the past, inorganic mercury salts were converted to methyl mercury and dumped into open waters. In the bay in Minamata, Japan, 27 tons of mercury dumped over 36 years caused mercury poisoning in over 3,000 individuals. [30,31] The US government now regulates how much mercury is dumped into our waterways, and when concerns about vaccines are raised, industry and the government work together to remove the mercury-containing agent. On the other hand, mercury is found in a light bulb that is being touted all over the US and beyond as part of the solution to our energy crisis. When concerns are raised, the EPA issues warnings on how to clean up after a broken compact fluorescent light bulb, and pushes forward. It seems that indoor air quality is an issue that gathers little merit. The EPA's directions state that if a compact fluorescent light bulb breaks, the windows should be opened and the area should be vented for about 15 minutes. [32] (Remember that with elemental metal, like is found in compact fluorescent light bulbs, the largest danger to humans is in inhalation of volatile vapors.) Additionally, mercury is still in schools homes and businesses across America from the products and applications that were (or are) ubiquitous- from mirrors to thermostats & thermometers, to even our dental amalgam.

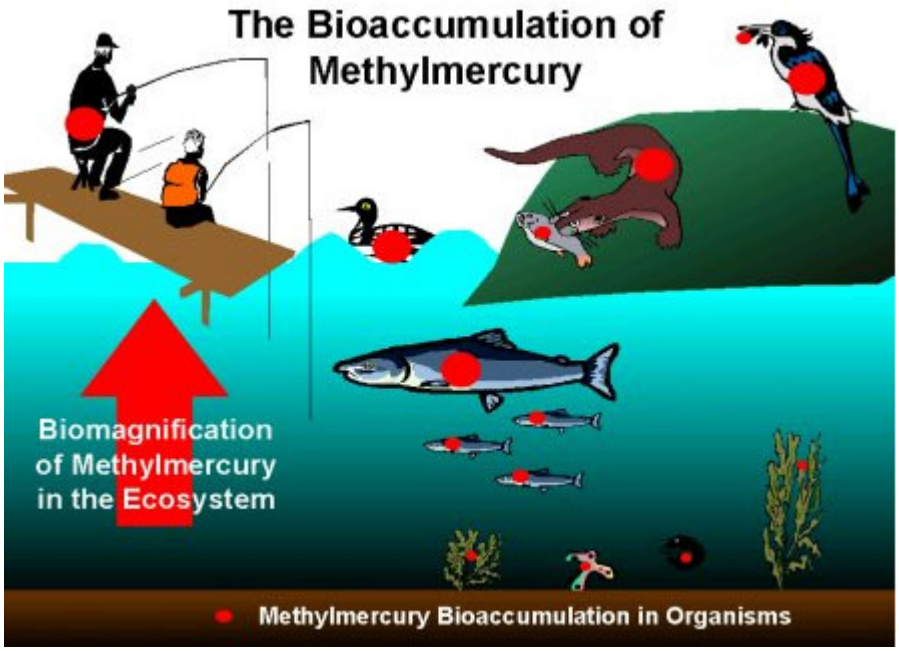
Where does it go when it is released?

Mercury is released into the atmosphere and can travel for hundreds of miles before it lands. [33] In fact, scientists were initially surprised at how far mercury can travel, and have found fish with elevated levels of methyl mercury far from any natural or anthropogenic source of mercury. [34] Penguins have been found to have elevated levels of mercury, thousands of miles from any anthropogenic sources. [35]

Again, the main concern about mercury in the environment is about mercury in the food chain. Mercury that is released into the air, for example when coal is combusted in a power plant, can travel far distances, and follows weather patterns. The mercury is deposited by either dry or wet deposition. In other words, it either finally settles out of the atmosphere as dry deposition, where it lands on whatever surface is below, or falls with rain. Even when it is deposited via dry deposition, mercury can percolate into ground water or run off to the nearest surface waters, depending on the nature of the landscape. Mercury in water is dangerous not because it pollutes the water, but because it pollutes the food chain.

How does it move through the food chain?

When mercury is in your food chain, bioaccumulation and biomagnification are the greatest concerns. Microscopic bacteria methylate the mercury, and tiny tadpoles or fish eat them. The mercury is water-soluble and protein-bound, and found in muscle and other fish tissue. [36] As you move up the food chain, remember that each carnivore must eat more of the fish in front of it. Consequently, the animal at the top of the food chain, the large bass, the loon, the eagle, is the animal most at risk. This is especially true when the top predator doesn't eat many different types of food. Humans who eat fish are also at risk, and this risk increases with an increase in amount of fish you eat. In aquatic ecosystems, the biomagnification can occur at a factor of more than 10 million. [37] The EPA and FDA advise against women and children eating any swordfish, shark, king mackerel, or tilefish, and they recommend portions not more than 12 ounces per week of "low mercury" seafood, such as shrimp, light tuna, salmon, pollock, and catfish. Albacore, or white tuna, is higher in mercury content than light, and should be limited to 6 ounces per week. [38] Since the mercury is protein-bound, rather than found in fat, it does not decrease when the fish is cooked. [39]



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Who is most at risk?

Unfortunately, the people most at risk for mercury poisoning are the least likely to be able to control their risk factors. Villages located along waterways where people fish for daily food and native populations whose diet is based mostly on fish are especially at risk. Generally speaking, these are people who have little money or few options to eat anything else.

Within populations some are more susceptible to health loss than others. Fetuses are extremely sensitive to

mercury poisoning, and women who are or may be pregnant are frequently encouraged to limit fish intake, or stop its consumption altogether. Women who have had no or few symptoms have had babies who were severely damaged by mercury poisoning. [41] Mercury is also excreted in breast milk, and infants and children are at risk of ingesting it, and are highly susceptible to its toxic nature. In some communities, for example among the small scale gold miners in the Brazilian rain forest, the men are more likely than the women to be exposed to mercury poisoning. [42] In these examples, people are not able to control their risk factors; fetuses, and infants can't change their own diet, for example.

When we average risk exposure over a whole population, we can often miss pockets of increased risk. When we average fish consumption of all Americans, we may think that no American is at risk of mercury poisoning. But when you check the individual risk of the fetus or newborn infant in a community which relies on fish for food, you may see entirely different risk factors for mercury poisoning. The same is true for compact fluorescent light bulbs. A family with compact fluorescent light bulbs in every lamp, lots of young kids, and a new-construction energy-efficient air-tight house may be saving money on the electric bill, reducing air pollution in their town, and increasing their kids' risk of exposure to toxic mercury vapor. Another household, in a drafty older home, with no children and compact fluorescent light bulbs only in overhead lamps unlikely to break, may have a wholly different risk/benefit analysis when it comes to compact fluorescent light bulbs.

Another concern is toxic doses. In the past, it was fairly well accepted that high exposures to toxins lead to high risk of adverse consequences. Recently, however, scientists are finding that this adage does not always hold true. Tyrone Hayes, for example, found that extremely small doses of atrazine, a common herbicide, caused reproductive abnormalities in frogs. [43] This turns the "less exposure is less dangerous" idea on its head. The recommendation by the EPA to vent the area for about 15 minutes if a compact fluorescent light bulb is broken may not be enough to limit the risk of exposure to mercury for every person. The point is that the answers are not simple.

The mercury story, though successful in some ways, illustrates some of the challenges of sustainable living. We have a powerful neurotoxin that is widely used in our society. Some people get sick and even die from it, but not everyone. There is no standard dose; because fish feeding grounds may vary; because acid rain or the lack thereof can affect mercury methylation; because lakes are different ecosystems than rivers; because coal-burning power plants are efficient at distributing mercury over a wide area; because deposition may differ based on presence or absence of prevailing winds and rain storms; because different members of the population are at different risks; because native or indigenous populations may have diets significantly higher in fish, and may not have any other options; because poor people are concentrated in certain areas and constricted to certain diets; because individuals' body weights and intakes differ; because organic mercury has a different path to neurotoxicity than inorganic or elemental mercury... the list goes on. As I said before, in some ways, the mercury story is a success story. However, there is still a lot that must be done.

Strategies

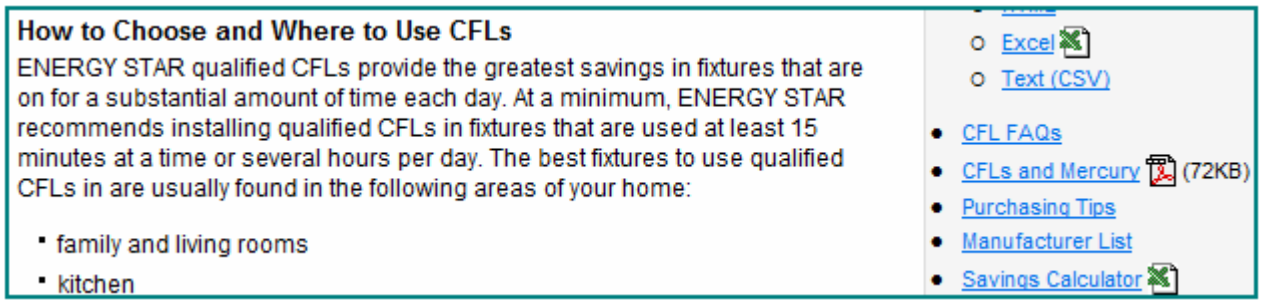
Products with a positive growth market in the US that contain mercury are electronic devices and compact fluorescent light bulbs. The sale of compact fluorescent light bulbs was about 75 million units last year, up from about 50 million in 2006. [44] One of my strategies is to have kids design a community recycling center in

the school, where community members can come and drop off cell phones and batteries. I choose cell phones to the exclusion of other electronic devices for three reasons; cell phones are small, and we can collect many in a small space; the Philadelphia Zoo also collects cell phones, and we are a partner of theirs, so we can bring the cell phones there; and because of the ever-present nature of cell phones in our lives. I don't know a person who doesn't have an old cell phone in a drawer somewhere that they didn't know how to return or recycle. Part of this community plan is going to be distributing information pamphlets to the community-though the stores nearby and through the East Park Community Corps.

Before starting the recycling plan, we'll need to examine the waste stream. When people throw things away, they don't know where the waste goes. In order to facilitate the understanding of why cell phones should be recycled rather than discarded, learners will have to learn about where our waste goes. They'll do a school waste audit to learn the types of waste the school creates. They'll also learn about the parts of a landfill, and the challenges that face them. They'll use Movie Maker to make a movie that illustrates the waste stream in our school, which we can show on the front screen of the school as visitors enter. This will also encourage them to recycle, because they'll need to know that the recycling is collected on a different day, and undergoes a different path.

The next activity will expose them to some of the issues in a spam e-mail. There are a lot of outrageous claims online, about haz-mat teams invading the homes of people who broke a compact fluorescent light bulb, or the federal government claiming that it cost thousands of dollars to clean up one broken compact fluorescent light bulb. My kids are extremely internet savvy, and are extremely familiar with spam e-mails. They'll find these claims as they do the research for the above activity. To open up the teaching of bias and point of view, I will circulate a "spam e-mail" to the class. The e-mail will make some of the outrageous claims about compact fluorescent light bulbs. I will then introduce the kids to the website, snopes.com [45] At snopes, urban legends are reviewed and debunked. They're able to trace the history of the claims, they check with manufacturers, and they post common variances of the e-mail. Then they give each legend a status: true, false, or unverified. We'll use this same format on a class wiki. A wiki is an online resource that allows users to add and edit content. In this wiki, the kids will post a resource page for the "spam e-mail" I sent them. For research resources, I'll limit them to about six different on-line sources. I'll create the format of the wiki to be similar to a debate. Learners will state their position, and use facts from the resources that support their opinion. Learners will then state the opposite position, and try to anticipate facts from the resources that will support the opposite position. Learners will rebut the "opposition" and then state their conclusion. When their snopes.com article is written, they'll post it on the wiki that is available to the class. If possible, I'll design the wiki so that learners can vote for the best answer.

Before the snopes activity, they'll do some discussion and research. This issue is two-fold; understanding that decisions involve risk, and learning to find bias in data and in information. To build up to the compact fluorescent light bulb recycling ideas, I'll start with energystar's information about compact fluorescent light bulbs. My learners all have laptop computers, so I'll have the learners read the website at http://www.energystar.gov/index.cfm?C=compact fluorescent light bulbs.pr_compact fluorescent light bulbs and list five things they learned about why Americans should change to compact fluorescent light bulbs. Then, I'll ask if anyone saw any reason NOT to purchase compact fluorescent light bulbs. I'll instruct kids to look at the website more carefully and see if they see any links that give more information. On the right hand side, there is a link to compact fluorescent light bulbs and mercury, and I'll instruct my learners to go to that page. Given how small the link is, my learners may not even see it.



The link is in the tiny compact fluorescent light bulbs and Mercury on the right hand side above. Then I'll have the learners read that web site. (http://www.energystar.gov/ia/partners/promotions/change_light/downloads/Fact_Sheet_Mercury.pdf). After reading this information, I'll ask them to list 5 reasons why they may not want to purchase compact fluorescent light bulbs. What I'm hoping to inspire is a conversation about WHY the first website may not have included information about mercury in the light bulbs, including why it was so hard to find the data that it may be dangerous. In fact, the energystar website makes the mercury dangers seem minimal.

The next step will be to have the learners research the issue online. They'll be able to find different websites with differing opinions, which can lead us to the topic of bias. Learners will have to give the website, their perspective, and write about what the site claims with regard to compact fluorescent light bulbs. They'll be able to rate the website on a scale from 1 to 10, on whether they think it is trustworthy or not.

I'll give them information about mercury poisoning, which I doubt they'll find on their own, and about lethal doses, and about methods of exposure. The goal here is to balance the different information they get. I predict that some learners will still think it is a good idea to change light bulbs, and some will think it is a bad idea. That's what I'm counting on. After the research, I'll do an activity in which kids can go to different corners to show how they feel about the topic. The corners will be: "They're safe, we should use them." "They're somewhat unsafe, we should still use them." "They're somewhat unsafe, we shouldn't use them until we know more," and "They're dangerous, we shouldn't use them." Once they're in their corners, they can defend their positions using the research they found in class. The group will meet and make a two-fact position statement that supports WHY they're in the corner they chose. If they're evenly dispersed, that will be their position for the snopes.com wiki activity. If not, I'll have to assign them positions.

Recently a Lowe's was built just down the road from my school. The kids will contact the Lowe's and find out what type of movement the organization is making towards collecting and recycling compact fluorescent light bulbs. If there is a plan in the future, I would like to be innovative about how we can partner with them. I think it is a poor idea to collect light bulbs at the school, because they're fragile and contain mercury. However, I think my kids can come up with some way that we can partner with organizations to encourage the recycling of compact fluorescent light bulbs.

Another local issue that may have applicability is the dredging of the Delaware River. The Delaware River has a highly industrialized history [46] and there is a history of mercury pollution in the water. [47] Because of our coal mining history, we also have some of the worst air pollution, with PA leading the nation in estimated mercury air pollution. [48] In order to deepen the shipping channel, PA wants to dredge the Delaware River. New Jersey, on the other hand does not. Could there be mercury in the dredge spoils? This brings forth another issue that is not clear-cut. PA is pushing the dredging for the benefit of the jobs it will bring. NJ is pushing against the dredging for the environmental consequences it could bring. Who is right? Who is wrong? What is the right

thing to do? In this case, I'd like to have kids investigate the history of the Schuylkill and Delaware Rivers and contrast them. Though both were polluted, the Schuylkill River was one that the city of Philadelphia has worked very hard to preserve. Is that in line with what PA is proposing for the Delaware? Where does the mayor stand? Where does the average Philadelphian stand? What are the issues, and how does mercury come into play? At the end of this unit, I'd have the learners write an opinion piece about what they found and what they think.

Finally, I want to make the connection between the largest producer of mercury in the environment and daily activities. The largest producer of mercury in the atmosphere is coal-burning power plants. Pennsylvania is a coal-producing and coal-burning state. When we waste electricity, we are causing mercury pollution to enter the air. We are polluting ourselves, but we are also polluting lands and animals and people very far from us. After we do an energy survey, learners can identify the ways in which they use energy wastefully, and learn that they're contributing to the reduction of pollution when they make different choices about energy.

This will also be supported with data analysis. The data table in the appendices section is data about the mercury deposition in the Philadelphia area in the year 2007. That data is from http://nadp.sws.uiuc.edu/mdn/, and I can send that to my learners. Then, I'll have them go to the NOAA web site and research climate data for the same time period. They'll use http://cdo.ncdc.noaa.gov/CDO/cdo to gather that data. Since the climate data is reported by day, and the mercury deposition data is reported by week, they'll use Excel to sum the precipitation for each week. Then, I'll have them graph two data sets: The total precipitation for the week, and the mercury deposition for the week. Finally, they'll examine the data to see if there is any correlation between rain events and mercury deposition. This will, hopefully, have the dual effect of teaching them about wet deposition and that in order to decrease mercury deposition (since we can't decrease rain) we'll have to decrease mercury in the air. The only way to do that is to reduce our wasteful use of energy.

Hopefully through all these activities, learners will learn to look at different types of pollutions and green technologies as systems of decisions and actions. By balancing themselves and their decisions within those systems, they can learn to make decisions that are more positive for the environment, and they can learn to share that information with the greater community, further solidifying their roles as active participants in society. Furthermore, they'll realize that each decision has a risk/benefit analysis which is never simple. When you realize the complexity of the decisions involved, you're able to make informed decisions because you're able to look at both sides of an issue. This lofty goal is one that I hope to achieve using this unit.

Endnotes

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Appendices

PA State Assessment Anchors which would be served with this project:

S11.C.1.1.1 Explain that matter is made of particles called atoms and that atoms are composed of even smaller particles (e.g., proton, neutrons, electrons).

S11.C.1.1.2 Explain the relationship between the physical properties of a substance and its molecular or atomic structure.

S11.C.1.1.3 Explain the formation of compounds and their resulting properties using bonding theories (ionic and covalent).

S11.C.1.1.4 Explain how the relationships of chemical properties of elements are represented in the repeating patterns within the periodic table.

S11.C.1.1.5 Predict the behavior of gases though the application of laws (i.e., Boyle's law, Charles' law, or ideal gas law).

S11.C.1.1.6 Describe factors that influence the frequency of collisions during chemical reactions that might affect the reaction rates (e.g., surface area, concentration, catalyst, temperature, agitation).

Mercury deposition Data for 2007 at a location near Philadelphia:

Date On	Date Off	HgConc ng/L	HgDep ng/m^2	Sample Type	YrMonth	DateMod
1/2/2007 13:40	1/9/2007 12:50	8.61	308.68	W	200701	6/20/2007
1/9/2007 12:50	1/16/2007 12:50	—	—	W	200701	6/29/2007
1/16/2007 12:50	1/23/2007 12:50	—	—	W	200701	6/25/2007
1/23/2007 12:50	1/30/2007 12:45	—	—	W	200701	6/25/2007
1/30/2007 12:45	2/6/2007 12:50	5.05	123.86	W	200702	8/3/2007
2/6/2007 12:50	2/13/2007 12:50	—	0	D	200702	8/3/2007
2/13/2007 12:50	2/20/2007 12:30	12.15	98.11	W	200702	8/3/2007
2/20/2007 12:30	2/27/2007 12:50	7.38	271.5	W	200702	8/3/2007
2/28/2007 12:50	3/6/2007 12:50	9.56	58.29	W	200703	8/3/2007
3/6/2007 12:50	3/13/2007 12:50	16.85	77.06	W	200703	8/3/2007
3/13/2007 12:50	3/20/2007 12:50	3.8	232.79	W	200703	8/3/2007
3/20/2007 12:50	3/27/2007 12:50	5.28	208.79	W	200703	8/3/2007
3/27/2007 12:50	4/3/2007 12:50	—	—	W	200703	8/3/2007
4/3/2007 12:50	4/10/2007 12:50	8.23	175.59	W	200704	8/3/2007
4/10/2007 12:50	4/17/2007 12:50	4.66	505.8	W	200704	8/3/2007
4/17/2007 12:50	4/24/2007 12:25	17.91	13.65	W	200704	4/17/2008
4/24/2007 12:25	5/1/2007 12:50	16.45	622.64	W	200704	4/17/2008
5/1/2007 12:50	5/8/2007 12:50	—	0	D	200705	4/17/2008
5/8/2007 12:50	5/15/2007 12:50	18.26	171.66	W	200705	4/17/2008
5/15/2007 12:50	5/22/2007 12:50	40.52	648.49	W	200705	4/17/2008
5/22/2007 12:50	5/29/2007 12:50	23.52	191.18	W	200705	4/17/2008
5/29/2007 12:50	6/5/2007 12:50	7.35	263.34	W	200706	4/17/2008
6/5/2007 12:50	6/12/2007 13:00	15.41	78.29	W	200706	4/17/2008
6/12/2007 13:00	6/19/2007 12:50	27.06	116.88	W	200706	4/17/2008
6/19/2007 12:50	6/26/2007 12:50	10.22	366.66	W	200706	4/17/2008
6/26/2007 12:50	7/3/2007 21:15	9.88	190.87	W	200706	4/17/2008
7/3/2007 21:15	7/10/2007 12:50	10.83	401.87	W	200707	4/17/2008
7/10/2007 12:50	7/17/2007 11:50	25.95	250.52	W	200707	4/17/2008
7/17/2007 11:50	7/24/2007 12:50	13.82	530.35	W	200707	4/17/2008
7/24/2007 12:50	7/31/2007 13:10	23.1	181.93	W	200707	4/17/2008
7/31/2007 13:10	8/7/2007 13:05	19.88	85.84	W	200708	4/17/2008
8/7/2007 13:05	8/14/2007 13:15	14.36	264.29	W	200708	4/17/2008
8/14/2007 13:15	8/21/2007 15:55	12.69	718.78	W	200708	4/17/2008

8/21/2007 15:55	8/28/2007 13:15	6.86	148.28	W	200708	4/17/2008

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