Yale National Initiative
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Curriculum Units by Fellows of the National Initiative
2009 Volume V: Green Chemistry

The Science of Environmental Justice: Can Green Chemistry Change Our World?

Curriculum Unit 09.05.10, published September 2009

by Catherine Salvin

Teaching Context: The Need for Chemistry in an Inner-City Continuation School

I teach at an inner-city continuation school in San Francisco where every student has a history of academic struggle. They are assigned to us by the district when failing grades and severe truancy place them at risk of dropping out. The fact that all of my students are students of color is representative of the achievement gap within our district. While San Francisco Unified School District (SFUSD) high school students are, on average, 21% Latino and 12% African American, our site is typically 40% Latino and 35% African American, [1] evidence that these students have been disproportionately underserved. While students have a wide range of critical thinking ability, most struggle with basic academic proficiencies; it is not uncommon for me to have zero students during a semester who both read and write at grade level. Many students also lack academic confidence; after years of facing low expectations in school, they do not trust in their intelligence or abilities, resulting in severe underachievement. In this context, it is my responsibility to both re-engage students in their education and to offer the structured rigor they need to begin catching up on academic skills.

Because our school is often the last formal educational experience many of our students will have, I believe it is imperative to offer a rigorous academic curriculum that enables students to move through the world as knowledgeable and informed people. This unit represents the first time in my fifteen years at Downtown High School (DHS) that chemistry has been offered to our students. Hard sciences such as chemistry are gateway subjects that can provide opportunities to students but, in the SFUSD, only two years of science are required for graduation. Because chemistry is often placed last in comprehensive high school science sequences—typically the realm of students on college preparatory trajectories—very few of my students have ever taken a chemistry course, and most do not view themselves as capable of learning higher-level science. While this unit does not take a traditional approach to chemistry, it will allow my students to explore and practice a subject they may have previously viewed as beyond their capabilities. By integrating chemistry and social justice issues, chemistry is made accessible to students in that it is placed within a context that connects directly to their own lives. The content and skills embedded in this unit have the potential to be very important in helping students navigate the realities in which they live. It is my job as the teacher to utilize strategies that will help all of my students access the curriculum.

This unit will be taught within an interdisciplinary environmental studies program called the Wilderness Arts and Literacy Collaborative (WALC). WALC uses environmental themes and corresponding core science as a center around which multiple subject areas are integrated. "The Science of Environmental Justice" will be an eight-week unit within an eighteen-week semester themed "Struggling for Sustainability: Preservation, Restoration, and Environmental Justice." It will take place in the second quarter of the fall semester, beginning in November and concluding in January.

Rationale: Placing Environmental Justice at the Center

Fundamentally, environmental justice can be defined as the right of all people—regardless of race or class—to live, work, play, and learn in healthy, safe environments wherein they have equal access to quality resources that support their basic needs: heath care, jobs, education, food, housing, recreation, clean air, water, and soil. Environmental justice is a goal, borne of a movement that grew in response to environmental injustice; statistically, people of color and poor people—in industrialized nations like the United States and developing countries alike—are far more likely to live in communities that bear disproportionate burdens of toxic emissions, toxic waste, and other environmental hazards. A 2007 study by the University of California at Santa Cruz determined that, in the San Francisco Bay Area, while whites are twice as likely to live more than 2.5 miles from a Toxics Release Inventory facility (TRI) than they are to live within one mile of a TRI, African Americans are three times more likely and Latinos 2.5 times more likely to live within one mile of a TRI than they are to live more than 2.5 miles from one. [2] Further, the percentage of residents living in poverty is half as much when more than 2.5 miles away from TRI sites as it is when within one mile. [3] Of 200 TRI sites counted on a map of the Bay Area, more than 70% are located in neighborhood where more than 61% of residents are people of color. [4] Fewer than 5% are found in neighborhoods where people of color number fewer than 34%. [5] This correlation between race, class and toxic environments has been consistently evident in numerous studies since the 1980's.

Despite the disproportionate toxic burden shouldered by communities of color, their right to protection is enforced in a similarly inequitable manner. Fines paid for violating hazardous waste laws are 500% higher when the offense is committed in predominantly white communities, compared to fines enacted in communities with high percentages of people of color. [6] Even to simply be listed on the Environmental Protection Agency's National Priorities List takes communities of color with serious hazardous waste issues 20% longer than it does for an abandoned site in a white community to be listed, then as much as 42% longer to clean up after listing. [7] This pervasive lack of corporate and government accountability for the disproportionate contamination of low-income neighborhoods of color cannot be divorced from the serious health issues faced by such communities. For example, African Americans are three times more likely to dies from asthma than whites, and African American children five times more likely to have lead poisoning than white children. [8] As the correlation between health and environment becomes increasingly evident, the injustice of disproportionate toxic burdens increases.

Bayview Hunters Point (BVHP), the neighborhood in southeast San Francisco where the largest percentage of my students live, is a case study in environmental injustice. The neighborhood is home to 34,800 residents, 90% of whom are people of color: approximately half African American, a quarter Asian and Pacific Islander, the rest mostly Latino. [9] In BVHP, 40% of the residents live below the poverty line, earning less than $ 15,000 per year in a city that consistently ranks among the top 10 most expensive cities to live in within the United States. [10] The unemployment rate is almost 15%, more than double the rest of San Francisco. [11] There are close to 1,000 units of public housing. [12] The leading cause of death for African American males is homicide; the second is AIDS. [12] There are no grocery stores or hospitals, and only one pediatrician in private practice for the community with the highest density of children in all of San Francisco. [13] BVHP is San Francisco's "roughest," most disenfranchised community.

At just three square miles, BVHP comprises less than 6% of the city's total area, inhabited by less than 4% of its population, yet more than half of the neighborhood is zoned for industrial use, housing over 50% of San Francisco's industry in the form of 500+ industrial, commercial, and retail establishments. [14] Industrialization leaves a toxic imprint on the impoverished BVHP community. BVHP houses at least one-third of San Francisco's hazardous waste sites, and the neighborhood's residents live surrounded by no fewer than 325 toxic sites. [15] There are 100 brownfield sites (abandoned or underused industrial or commercial facilities where contamination inhibits redevelopment) and 187 leaking underground fuel tanks, as well as at least 124 hazardous waste handlers. [16] Per capita, compared with the rest of San Francisco, there are ten times the number of contaminated water sites, five times as many acutely hazardous materials storage facilities, four times the polluted air dischargers, three times more underground storage tanks, and four times the number of contaminated industrial sites. [17] The BVHP sewage treatment plant processes 80% of the city's sewage and, from 1929-2006, the state's oldest and dirtiest power plant operated in BVHP, where two-thirds of the 1,100 homes within a one-mile radius were public housing units. [18] The Hunters Point Naval Shipyard, a Superfund site named by the Environmental Protection Agency as one of the ten most toxic federal sites in the United States, occupies nearly 500 acres of BVHP. [19] There are an estimated 1.5 million tons of toxic and radioactive waste still buried in the shipyard despite extensive clean-up operations for the purposes of developing the land. [20] The shipyard houses the former Naval Radiological Defense Laboratory, the military's largest applied nuclear research facility from 1947-1969, where scientists tested the effects of radiation on animals; [21] waste that was not dumped in the bay or ocean lies in a 146-acre landfill 800 feet away from a public housing project. [22] Other major polluters include a rendering plant, the Potrero Hill power plant less than one mile away, a non-stick pan coating factory, and two freeways that border the neighborhood. [23] All told, the toxic outputs in BVHP contribute more than 20 tons of particulate matter to the air per year, [24] and well over 200 toxic chemicals to the community [25] , including 109 radioactive substances recently disclosed by the Navy as being present at the Shipyard. [26] The quantity of ambient air pollution in BVHP is four times greater than all other San Francisco neighborhoods, emissions of nitrogen dioxide, sulfur dioxide, and particulate matter are the highest on the city, and chromium is found at levels thirteen times higher than what is considered safe. [27] BVHP ranks in the 80th percentile for high levels of particulates, carbon monoxide, nitrogen oxides and volatile organic compounds and in the 90th percentile for sulfur dioxide. [28] Soil and water in BVHP contain particulates, pesticides, petrochemicals, heavy metals, asbestos, and radioactive materials. [29]

The health outlook of the BVHP community is correspondingly stark. At 12 deaths per 1,000 live births (15 per 1,000 for African American women), the rate of infant mortality in the BVHP zip code is 2.5 times higher than any other San Francisco neighborhood, and the highest in the state of California. [30] More than 50% of infant deaths in San Francisco occur in BVHP and the adjacent neighborhood of Potrero Hill, [31] where there are nearly 500 public housing units and the city's last remaining power plant still operates. There are 44.3 birth defects per 1,000 births, compared with 33.1 per 1,000 in the rest of San Francisco. [32] Asthma is another persistent health issue: Upwards of 10% of BVHP residents have asthma, compared to 5.6% nationwide. [33] For children, the incidence of asthma is close to 20%, [34] and as high as 25% at some schools. [35] In BVHP, hospitalizations for asthma run four time the state's rate. [36] In addition, cervical and breast cancer are twice as common as the rest of Bay Area, [37] which already has the highest breast cancer rates of any metropolitan area in the world. [38] Hospitalization rates for congestive heart failure, hypertension, diabetes, and emphysema are more than three times the statewide average. [39] Clearly, the health of the BVHP community is highly compromised. While some of these incidences can certainly be attributed to the dearth of health care services in the community, there are many correlations between health issues and toxic environments. Asthma, for example, can be caused or aggravated by air pollution and a major cause of breast cancer is known to be ionizing radiation. [40]

While BVHP can be considered one of the most extreme examples of environmental injustice in the nation, it is not the only neighborhood in the southeast sector of San Francisco where nearly all of my students reside that faces such issues. Potrero Hill, the neighborhood where our school is located, is home to San Francisco's last fossil fuel burning power plant. Emissions from its smokestack rise up into the Potrero Hill housing projects on the hillside that overlooks the plant. South of Potrero Hill in Visitacion Valley, a low-income and working class neighborhood, another superfund site is located only a few blocks away from the Sunnydale public housing projects, San Francisco's largest public housing complex with nearly 800 units. At the Midway Village public housing projects that are just across the city and county line from Sunnydale, waste from a decommissioned PG&E gas plant was used as landfill that has contaminated the ground directly beneath the housing. [41] Despite several attempts at soil removal, residents there suffer from a multitude of health issues and have spent years fighting for relocation and compensation for chronic and severe illness. [42] Next to Visitacion Valley is the Excelsior neighborhood where I live alongside many of my students. A recent study reports that the Excelsior, with one of the lowest per capita incomes in the city and among the highest percentages of both children and elderly residents, has had the highest overall number of people hospitalized for asthma for six years in a row. [43] This health issue is attributed to the close proximity of a major freeway and the truck routes that pass through the neighborhood into other parts of San Francisco. [44]

Objectives

It is within this context of environmental injustice that I will be teaching my students chemistry, including green chemistry. BVHP is the community in which many of my students live, bordering the neighborhoods of most students who do not live there; it is clear that a study of environmental justice and injustice is, therefore, extremely relevant to the students I teach. Integrating chemistry into this unit can lend relevance to a subject that many of my students perceive as academically out of reach for them. Within this unit, chemistry is presented in a real-world framework that makes the content more accessible. My goal is to integrate chemistry in two substantive ways.

The Chemistry of Toxicity

First, my students will learn the chemistry necessary to understand toxicity. While BVHP is rife with toxic substances, the concept of toxicity is often abstract. Even as we name toxic substances, we may not understand the characteristics that cause their toxicity. I want my students to have a chemistry-based understanding of why certain chemicals are toxic based on their atomic and/or molecular structures and how a substance's atomic and/or molecular structure can cause it to be toxic. To this end, I have chosen to categorize BVHP's toxic array into four main categories based on their atomic or molecular composition: reactivity, solubility, radioactivity, and volatility. Through an examination of these chemical characteristics, students will gain a chemical understanding of toxicity while necessarily learning several related fundamental concepts of chemistry: atomic structure, electron configuration, ionic and covalent bonds, polarity, ions and isotopes, atomic and molecular mass. An ability to analyze the structure of toxicity will also enable students to better comprehend how that same structure influences its toxic interactions with the atmosphere and within the body—the mechanisms of toxicity and the resulting effects of specific toxins on human health.

In addition to learning the fundamental concepts in chemistry that facilitate understanding of the nature of a chemical's toxicity, students will also examine case studies of specific substances found in BVHP that exhibit toxicity of each nature. Because of the extremely high incidence of respiratory ailments among BVHP residents and among my students, these case studies will focus on airborne pollutants and the effects of compromised air quality. Within each case study, we will examine the source of the toxin and analyze its impact on human health in the BVHP community. Chemistry will become a tool to help students deepen their understanding of environmental justice issues, as they will be able to identify what makes a toxin toxic and what kinds of chemicals pose threats to the community. This study of chemistry can empower students and their communities with concrete scientific knowledge about environmental injustice.

In examining unsustainable practices within local industries, students can learn to identify specific processes, substances, and waste products that pose issues of toxicity, threatening human health and the environment. They will know why it is bad to have a freeway in their neighborhood, whether the sewage treatment plant simply smells bad or if it presents a health hazard, and how far away you have to be from radioactive waste before you are safe. My students should be able to identify substances that put their communities at risk when emitted into the air they breathe, the water they drink, or the soil in which they play, and to understand why those substances are dangerous. This knowledge can enable them to identify and combat environmental injustices. I will also provide examples of critical campaigns against environmental injustice in which a community's ability to gather data and provide evidence of toxicity—in air, water, or soil—has led to an environmental justice victory. In one specific case, a neighborhood called "Cancer Alley" in Louisiana, residents affected by toxins identified and tested for specific toxic chemicals affecting air quality. They presented undeniable findings to the polluting corporation, elected officials, and even the United Nations, eventually winning relocation for the residents. The utilization of science can, in this manner, serve as an important tool for communities fighting to secure environmental justice.

Within this study of chemical composition and toxicity, green chemistry will be integrated as well. With its emphasis on understanding and evaluating risks and hazards, green chemistry can add to our discourse around the damage each type of toxin we study can potentially cause the BVHP community. I plan to introduce two concepts presented in Green Chemistry by Paul T. Anastas and John C. Warner: the formula Risk=f(hazard, exposure), [45] as well as the method of assessment for toxicity being based upon analysis of potency, severity, and reversibility. [46] Using these methodologies, students can begin to evaluate the risks posed by the toxins they face, potentially identifying which substances are most dangerous to the community.

Intersecting Principles: Green Chemistry and Environmental Justice

The second way I will integrate chemistry into this unit, focusing specifically on green chemistry, is by having students examine the principles and practice of green chemistry as a means of discovering possible methods of remediating or preventing the types of toxicity that exist in BVHP. Students, for example, can explore whether or not there is a greener way to treat sewage or if it is chemically possible to burn fuel in cars or in power plants without emitting pollutants. More specifically, I want students to evaluate whether or not there are current innovations in green chemistry that make it possible to power our cars and homes without also contributing to the alarming rates of asthma, breast cancer, and chronic bronchitis in the low-income communities like BVHP where power plants and freeways have been built. When communities demand relief from the toxins that plague them, knowledge of viable alternatives can aid in their efforts. Since green chemistry calls for the creation of products that "preserve the efficacy of function while reducing toxicity," [47] it is conceivable, then, that understanding green chemistry can mean understanding how to create safer, healthier communities.

This process of exploring green chemistry will take place in two stages. First, students will read and analyze the twelve principles of green chemistry, examining case studies of those most applicable. While many of the principles are very technical and specific to areas of chemistry we will not be studying, students can gain a general comprehension of the ideology and the ways the field of chemistry will have to change in order to become more sustainable. Earlier in the semester, students will have learned the seventeen principles of environmental justice. After they examine the principles of green chemistry, I will ask them to identify any ways they see that the two sets of principles align. The first green chemistry principle, "It is better to prevent waste than to treat or clean up waste after it is formed," [48] for example, aligns closely to the sixth principle of environmental justice, "Environmental Justice demands the cessation of the production of all toxins, hazardous wastes, and radioactive materials, and that all past and current producers be held strictly accountable to the people for detoxification and the containment at the point of production," [49] because both principles call for preventing toxic materials from being produced and clean up is a less desirable option. Similarly, the tenth principle of green chemistry, "Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment," [50] aligns with the fourth principle of environmental justice, "Environmental Justice calls for universal protection from nuclear testing, extraction, production and disposal of toxic/hazardous wastes and poisons and nuclear testing that threaten the fundamental right to clean air, land, water, and food" [51] in that toxic substances must not be allowed to enter the environment. Using the principles of green chemistry, students will generalize the goals of the field and analyze how those goals might apply to efforts to achieve environmental justice.

In the second stage, each student will choose a source of toxicity in BVHP or Southeast San Francisco and research any green developments, based on the principles of green chemistry, which can help reduce or eliminate the toxins. For example, a student investigating contamination of soil by chemical waste products might discover bioremediation efforts involving fungi or bacteria based on the principal that "A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable." [52] While this principle was certainly not articulated with bioremediation in mind, the idea of renewable materials can lead a student, in their research, to bioremediation. This same principle might lead to a study of freeway pollution illustrating the need for cars running on alternative fuels or the power plant being replaced with a solar array or wind turbines. To launch their discovery of alternatives to toxic practices and products affecting BVHP, students will identify which green chemistry principles could be enacted and, therefore, what innovations—or, conceivably, lack thereof—currently exist. As a conclusion, students will also identify the environmental justice principles best supported by the solutions they discover to the toxic problems they have chosen to address. It is not, however, my intention to paint green chemistry as the panacea for all that is toxic in the world. Rather, I want my students to analyze the potential and limitations offered by green chemistry, and honestly evaluate the extent to which green chemistry can contribute to achieving both greater sustainability and increased environmental justice. While pharmaceuticals, plastics, energy, and fuel are areas of significant research and development, students might be hard pressed to find an alternative to traditional meat rendering plant processes that can reduce VOC emissions or a way to eliminate radiation in landfills. The purpose of this process is to acquaint students with the world of sustainable science in order to foster a sense of agency around the feasibility of making BVHP and Southeast San Francisco safer and more just for the communities within them.

By incorporating chemistry into our study of environmental justice, students can achieve the objectives of using chemistry to understand the nature of the toxicity they face on atomic and molecular levels, as well as examining the viability of green chemistry and its principles in working for greater environmental justice. In doing so, this unit achieves two larger objectives: First, it demystifies hard science by placing it in a relevant context that makes chemistry accessible. Second, it enables students to use science to generate a greater sense of agency in addressing the issues that plague their community. Students can become both scholars and as scientists.

Background Information: A Foundation in Chemistry

Reactivity

The first category of toxicity students will learn about is reactivity, meaning chemicals that are toxic because they are highly reactive. Understanding reactivity will require students to learn basic atomic structure because that structure determines the tendency of each element to bond or not. Students will first learn that an atom consists of protons and neutrons in the nucleus at the center of an atom, the number of protons being constant in every atom of an element and determining the atomic number of each element. We will then explore electron configuration. Students will learn that electrons orbit the nucleus in orbitals at specific energy levels, which are called electron shells. In every atom, each electron shell is capable of holding a particular number of electrons. For example, the first electron shell always holds two electrons; the second shell always holds eight. Even though each energy level has a different number of orbitals (or subshells), after the first electron shell with just two electrons, the outermost shell most often houses eight electrons, called valence electrons. If this outermost shell, also called the valence level, is not full because it is holding fewer than eight valence electrons, then the atom is more reactive because it has a tendency to fill its valence level through bonding with other atoms. This is called the octet rule; atoms seek to acquire stable octets in their outer shells by bonding with other atoms. The electron configuration of every atom can be diagrammed to predict its reactivity, or tendency to bond, by observing the number of electrons in the outermost shell. An atom that has more "space" available in its valence shell can be said to have a high electron affinity: the ability of an atom to accept electrons from other atoms. This electron affinity contributes to making an atom reactive.

Students can look at a model of any molecule to predict electron affinity and reactivity. A model of carbon, as an example of high levels of reactivity or electron affinity, indicates that it is very likely to bond because it has only four valence electrons, allowing for four more. Conversely, a model of neon would show students that, with eight valence electrons, neon is essentially un-reactive; with a full valence shell, there is no reason for neon to bond. Comprehension of atomic structure and the relationship of electron configuration to chemical bonding will lead us into a study of covalent and ionic bonds, both of which are driven by an atom's tendency to complete its octet. Covalent bonds occur when two atoms share an electron. For example, water (H_2O) is the result of one oxygen atom covalently bonded with two hydrogen atoms. Hydrogen has just one valence electron in the first electron shell, instead of a filled shell of two. Oxygen has six valence electrons in its second shell instead of a complete octet. Therefore, when hydrogen shares an electron with oxygen, its valence level is complete with two electrons: one of its own and one from sharing with oxygen. If oxygen were to share just one electron with hydrogen, it would then have seven valence electrons. Since eight is the ideal number, oxygen then bonds with a second atom of hydrogen to complete its valence level: six of its own electrons, and two from sharing with two atoms of hydrogen. Ionic bonds occur when atoms are joined by opposite electrical charges. While atoms are most often neutral because they contain the same number of positively charged protons as negatively charged electrons, they can gain or lose electrons to other atoms, creating a positive or negative charge. Charged atoms are called ions; cations are positively charged and anions are negatively charged. Atoms gain and lose electrons for the same reason as they form covalent bonds: the tendency toward a complete valence shell. One common ionic bond is sodium chloride (NaCl), or table salt. Sodium has just one valence electron; it can either gain seven or lose one to achieve a complete octet, and losing one is "easier" than gaining seven. Chlorine has seven valence electrons; it needs just one more. When sodium loses its valence electron, it gains a positive charge. Chlorine is happy to accept a free electron but, in doing so, it gains a negative charge. The positively charged sodium cation and the negatively charged chlorine anion then are electrically attracted to one another, forming an ionic bond. While water and salt have different types of bonds, both bonds occur for the same reason; they involve atoms that are reactive because they have incomplete octets in their valence energy levels. Once students understand this concept, they will understand the basis for chemical bonding as well as the nature of reactivity.

Our case study for reactive toxins will be nitrogen oxides. Nitrogen oxides are one of the six main pollutants the EPA tracks that have significant concentrations in BVHP (80 th percentile), and one cause of the area's non-attainment of state and federal air quality standards. [53] Before the PG&E power plant closed, it emitted approximately 321 tons of nitrogen oxides per year. [54] Since the plant's closure, the largest emitter of nitrogen oxides is the sewage treatment plant, releasing close to 16 tons of nitrogen oxides per year. [55] Nitrogen oxides are also emitted by burning fossil fuels such as at the Potrero Hill power plant, in motor vehicle exhaust, as from the two highways running through BVHP, and during industrial processes such as welding and electroplating, [56] both of which take place in BVHP. At low levels, nitrogen oxides can irritate the eyes, nose, throat, and lungs, causing coughing, shortness of breath, nausea, fatigue, or fluid build-up in the lungs. [57] High levels can cause the swelling of throat and respiratory tract tissues, reduced oxygenation of body tissues, fluid build-up in lungs, spasms, burning when in direct contact with skin, and even death. [58] In laboratory experiments of animals, birth defects and genetic mutations resulted from nitrogen oxide exposure. [59] Nitrogen oxides can also exacerbate or increase susceptibility to respiratory infections and asthma, damaging lungs, destroying lung tissue and, over time, leading to chronic lung disease such as emphysema. [60] Students can apply their understanding of reactivity in atoms to reactivity in molecules, creating models of nitrogen oxides to identify the chemical nature of their reactivity. Even when bonded as a molecule, nitrogen dioxide (NO_2), for example, has three available electrons for other atoms or molecules to bond with. Students can extrapolate that NO_2 can then react with molecules in the body, often to toxic effect.

Solubility

The second category of toxicity we will study is solubility, or the chemicals that are harmful because they dissolve easily. Understanding solubility will require students to learn specifically about polarity in molecules. Polar molecules are molecules that have an "uneven" electrical charge because one atom has a higher electronegativity than the others. Every atom has a different electronegativity value from 0.7 to 4.0, which is the strength an atom has to attract electrons to itself. Learning about polarity, electronegativity and the electronegativity values for different atoms is a logical progression from the study of reactivity that included atomic structure, covalent bonds, and ionic bonds. Students will already understand charge in atoms and the relationship of electron and proton charges to ionic bonds. Electronegativity can add an understanding of why some bonds are covalent and some are ionic; an atom with high electronegativity is more likely to attract an electron from one with low electronegativity, rather than share. These ionic bonds take place when the difference in electronegativity is greater than 1.5. In sodium chloride, a good example of an ionic bond, sodium has an electronegativity of 0.9, while chlorine's is 3.0. This enables chlorine to attract an electron from sodium to fill its octet, precipitating the ionic bond. In studying polarity, students can then learn that these varying values of electronegativity in atoms can also cause electrons to be shared unequally among atoms in what are called polar covalent bonds; polar molecules are the molecules in which covalently bonded atoms have an unequal sharing of electrons. Polar molecules occur when the difference in electronegativities is between 0.3 and 1.4.

The relationship between solubility and polarity is attributed to the fact that water (H_2O) is a polar molecule. Because oxygen has a higher electronegativity than hydrogen, the electrons that the oxygen atom shares with the two hydrogen atoms spend more time around the oxygen than the hydrogen. This gives the hydrogen atoms slightly positive charges and the oxygen atom a slightly negative charge. Having a positive end and a negative end make water molecules dipole molecules that attract other polar molecules. Dissolution then follows polarity; like dissolves like, so polar molecules dissolve other polar molecules. Water then becomes the solvent that dissolves polar solutes such as alcohols and even ionic compounds like salts. Students can build models of molecules and, referencing the electronegativity values of the atoms present, they can determine whether the molecules are polar or non-polar. They can then identify which molecules would have high solubility in water.

We will focus our case study of solubility on sulfur dioxide, one of the most prevalent soluble chemicals in BVHP (90th percentile) tracked by the EPA. The PG&E power plant previously emitted 12 tons of sulfur dioxide per year, and the wastewater treatment plant continues to emit 4 tons per year. [61] Sulfur dioxide is a emitted by fossil fuel burning power plants such as the nearby Potrero Hill power plant, as well as by copper smelting plants and the manufacture of products such as sulfuric acid, paper, food preservatives, or fertilizers. While even short-term exposure to high levels of sulfur dioxide can be fatal or extremely harmful, long-term exposure to lower levels can result in reduced lung function and breathing ability, inflammation or infection of airways, and aggravated asthma. [62] Recent studies seek to determine the extent to which sulfur dioxide poses a risk to fetuses. [63] When students create models of sulfur dioxide that include electronegativity and an assessment of polarity, they can ascertain the relationship between solubility and toxicity. Since sulfur dioxide is a polar molecule that is highly soluble is water, it directly affects moist mucous membranes of the eyes, nose, throat, and upper respiratory tract. [64] Breathing air containing sulfur dioxide may cause its absorption into the body through nose and lung, where it can easily and rapidly enter the bloodstream through your lungs. [65]

Radioactivity

Students will examine radioactivity as a third classification of toxicity by understanding the nature of radioactive elements. Unlike reactivity and solubility, which are driven by electron configuration, radioactivity lies within the "configuration" of the nucleus, which will provide students with an opportunity to review and expand their understanding of atomic structure. Radioactivity is caused when the nucleus of an atom is unstable. Generally speaking, the larger the atom, the more unstable it is because all of the positively charged protons in the nucleus are repelling each other. "Nuclear glue," which is also called nuclear force or strong force, holds most nuclei together, keeping their protons and neutrons in place. However, nuclear force can only hold so much, and all elements with 84 or more protons are unstable. Slightly smaller atoms that are "neutron rich" or have an imbalanced proton to neutron ratio are likewise unstable; the nuclear glue is not strong enough to keep the nucleus intact and the nucleus breaks apart. The process of a nucleus breaking apart with a corresponding release of energy is called radioactive decay. Atoms that decay are considered radioactive and are called radionuclides. When an atom decays, it can emit protons and/or neutrons in order to alleviate the strain of too many atomic particles in the nucleus. Elements decay, typically into smaller elements, until they become stable. There are three main forms of radioactive decay: alpha, beta, and gamma emissions. Alpha particle emissions release two protons and two neutrons, essentially a helium cation without electrons that can quickly pick up free electrons in order to become a neutral helium atom. Beta particle emissions release an electron from the nucleus when a neutron breaks down into a proton and an electron. The electron is released but the proton stays in the nucleus, increasing the atom's atomic number by one. Gamma radiation emissions occur when a nucleus emits a high-energy photon. This can take place in conjunction with alpha and beta emissions. All three types of radioactive decay give rise to forms of ionizing radiation, a release of atomic particles and energy that can cause neutral atoms to become reactive ions. In summation, radionuclides have unstable nuclei caused by a high number of protons and/or neutrons, causing them to change into more stable atoms of other elements by releasing nuclear particles and energy as ionizing radiation in the form of alpha, beta or gamma emissions.

Our case study in radioactive toxins will focus on several radioactive isotopes found in the Hunters Point Naval Shipyard. The United States Navy has disclosed 109 different radioactive chemicals contaminating the site, primarily Cesium-137, Radium-226, and Strontium-90. [66] We will examine these isotopes, as well as radioactive elements such as uranium and plutonium, also found in the shipyard. [67] Even after students learn that larger atoms with more nuclear particles are unstable, they must also learn about isotopes in order to properly understand the radionuclides affecting BVHP. While all atoms of the same element have the same number of protons in their nuclei, the number of neutrons can vary. This is why the atomic number of every element is based on the number of protons in an atom of that element. Electrons can be lost or gained, but an elements remains in its form if the number of protons remains constant. If an atom loses or gains a proton, it becomes a different element. The atomic mass of an element represents the sum of its atomic number (protons) and an average of the number of neutrons an atom of that element contains. Atoms of the same element can have different numbers of neutrons; these different versions of the same element are called isotopes. Cesium, for example, has an average atomic weight of 133. Cesium-137 has more neutrons than an average atom of cesium. This imbalance causes Cesium-137 to be a radioactive isotope.

All of these radionuclides are toxic because the ionizing radiation they release as they decay can produce reactive ions in materials including our flesh. Reactive ions can damage cells, including DNA, hinder production of hemoglobin, cause severe anemia, mutations, birth defects, cancer, and death. [68] While alpha particles have a low penetrating power, they can enter the body through ingestion and cause major damage to exposed tissue. Beta particles are more penetrating than alpha particles, and can penetrate skin and membranes. Gamma radiation in the form of high-energy wavelengths can penetrate our bodies most easily. By examining models of radioactive atoms, students will understand the process of radioactive decay and the cause of radiation.

Volatility

Volatility is the final category of toxicity students will focus on, studying volatile organic compounds (VOCs) that evaporate easily. In order to understand volatility, students must understand molecular mass. VOCs typically have low molecular mass, meaning the atomic mass of all of the atoms in the compounds is relatively low. Many VOCs are short hydrocarbon chains, wherein the atomic mass of hydrogen (1) and the atomic mass of carbon (12) form compounds that are still able to evaporate. Other VOCs are organohalides. Calculating atomic mass will offer students a means of reviewing atomic structure. Protons and neutrons in the nucleus determine the atomic mass of each element in a compound, and electron configurations will illustrate why hydrogen and carbon bond so well into hydrocarbon chains, as well the reasons halogens are common in compounds. The lower the molecular mass of a compound, the higher its volatility, and the more likely it is to be emitted out of liquids or solids as a gas. VOCs can evaporate from water or soil and disperse into the air; they vaporize easily into a gaseous state that enters the atmosphere. By identifying these characteristics of VOCs, students will be able to understand the nature of their toxicity. While humans may be exposed to VOCs through contact with solid or liquid forms, they are most likely to be encountered in gaseous form as they affect the quality of the air we breathe. Their volatile behavior also creates many challenges in managing VOC emissions.

There are many sources of volatile organic compounds (VOCs) in BVHP. Like nitrogen oxides and sulfur dioxide, VOCs are tracked by the EPA [69] and BVHP ranks in the 80th percentile for VOC prevalence. [70] Darling International, a rendering facility in the neighborhood, emits more than 47 tons of VOCs per year; Pan-Glo Services, Inc., an industrial baking pan coating factory, emits 29 tons of VOCs per year, and the sewage treatment plant emits around 8 tons of VOCs annually. [71] Prior to its closure, the PG&E power plant emitted 13 tons of VOCs each year. [72] VOC emissions from motor vehicles travelling on the two freeways in BVHP are also a concern. While the data sets for VOCs in BVHP are not disaggregated into specific compounds, there are several common VOCs we can examine by calculating their molecular mass and/or carbon chain structure: benzene, formaldehyde, methylene chloride, and perchloroethylene. Illustrating the volatility of VOCs will also enable students to conceptualize the reasons they present health issues; we absorb VOCs by breathing the air into which they have evaporated. Inhalation of VOCs, as well as absorption through skin, can have many impacts on health: eye, nose, and throat irritation or discomfort, nosebleeds, difficulty breathing, headaches, fatigue, dizziness, loss of coordination, impaired memory, allergic skin reactions, nausea or vomiting, damage to liver, kidney, and central nervous system, and cancer. [73] Some hydrocarbon solvents can dissolve lipid coverings around nerve fibers when inhaled, which results in a condition called peripheral neuropathy. [74]

Strategies: Access through Engagement

DHS has developed a unique structure wherein every teacher works with a partner to develop thematic, interdisciplinary, project-based curricula. We call these teams and the curriculum they offer "projects." Students choose one project per semester and each project teaches the same students all day, every day, for a semester at a time. Within each project, the two teachers are responsible for integrating English, science, social studies, math, and one elective. This is feasible because continuation school teachers in California are permitted to teach outside of their credential areas. We created this structure in order to offer students a more holistic learning experience with a built-in community of learners. Every project also incorporates hands-on and experiential learning and community partnerships in order to better engage our students. Because California continuation schools are not ranked by standardized testing in the same manner as other schools, our teachers have the freedom to develop curriculum that focuses on depth over breadth and performance standards over content standards. Our school upholds six "Core Tenets of Project-Based Curriculum" that guide our practice and function as instructional strategies. Four of them are particularly applicable to this unit.

Integration

The project I have developed with my partner is called the Wilderness Arts and Literacy Collaborative (WALC). WALC uses environmental studies concepts as the central, unifying themes with which we integrate science, art, English, social studies, and math. We have developed four distinct semesters of curriculum, each organized around a different environmental theme and the science that best illustrates it: Our sense of place unit centers on geology, the interconnections semester focuses on watersheds, dynamic balance is demonstrated by evolution, and sustainability is explored within forests.

Integration allows us to connect the environment to multiple subjects, thereby giving us many avenues through which we can engage students. For example, many students are drawn to WALC because there is an art component; the art students learn and do in WALC is then utilized as a means of expressing what they learn about the environment. Other students are interested in history; we thematically connect the historical experiences of our students' communities with our environmental themes. Our motto in WALC is, "Everything we teach you about the environment, you can apply to yourselves," whether that means personal, community, or historical experiences.

The semester for which I am developing this unit is themed "Struggling for Sustainability: Preservation Restoration, and Environmental Justice." The preservation unit explores old growth redwood forests as models of sustainability in nature that must be preserved for ecological, practical, and even ethical reasons. Our study of restoration takes place in local natural areas where we do habitat restoration regularly. In the past, our examination of environmental justice (and injustice) has been primarily socio-political. Integrating chemistry offers WALC an opportunity to stay true to our model of science at the center of the curriculum. At the same time, many students find chemistry to be an intimidating subject; integrating chemistry into the social science of local environmental justice issues makes it both more accessible and more meaningful to our students, enhancing interest and offering greater motivation for studying a complex field.

Real World Focus

This unit, based in a local neighborhood, clearly has a strong real world focus. This strategy is essential to student buy-in. Environmental issues are often abstract to students who live in urban areas; they see the environment as only "nature." The study of environmental justice redefines the environment as where we live, work, play, and learn, thereby including communities who have not historically experienced the wilderness. The environmental justice issues we are studying in this unit are immediate, observable, and undeniably connected to students' lives. In this context, students have greater impetus to learn, and protecting the environment becomes a way to protect their own communities.

Real world focus also means collaborating with community-based organizations. WALC has a partnership with an organization called Literacy for Environmental Justice (LEJ), which is based in BVHP. LEJ conducts a "Toxic Tour" of BVHP that points out several sources of toxicity. LEJ educators also visit the school twice, once before the tour to introduce the issues in BVHP, and once after the tour to have students apply their learning to the greater, global struggle for environmental justice. In between the tour and the concluding classroom visit, we also take students to participate in habitat restoration at Heron's Head Park, a restored wetland in BVHP that LEJ stewards. This service learning opportunity enables students to have an immediate, positive impact on the community and promote environmental justice by contributing to the health of a "green" recreation site in the neighborhood that can also improve water quality as plants filter toxins and improve air quality as they photosynthesize and release oxygen.

Our partnership with LEJ is an important strategy for engaging students for two main reasons. First, it demonstrates that addressing environmental issues does is not only an academic pursuit, nor is it the concern only of the teacher. The staff at LEJ is young, diverse, and dynamic. They provide positive role models for our students as people who have dedicated themselves to the community and as activists who are able to make a career out of working for change. It is important for students to experience diversity among environmentalists, as many students have preconceptions of environmentalists as "white hippie tree huggers." Working with LEJ dispels that myth and offers our diverse student population a model for engaging with the environment, allowing students to deeper and more meaningful engagement with the curriculum. Second, working with LEJ provides students with an automatic outlet for their feelings of anger, frustration, and indignation when they learn of the environmental injustices so prevalent in BVHP. The question of "What are we supposed to do about all of this?" has an immediate answer; students can join LEJ by participating in their programs, volunteering, or even seeking employment. Several WALC students have gotten involved or gained employment with LEJ as a result of our partnership. The feeling of helplessness students have in the face of such a tremendous environmental burden is mitigated by the opportunity to take action.

Experiential Study

If students can see, feel, and experience their subject matter, they will be more confident in their scientific explorations, more engaged in their learning, and more willing to accept academic challenges. Every unit of curriculum in WALC is place-based, explicitly designed around those environmental subjects most applicable to the region in which we live. Place-based learning ensures that field experiences are a priority that allows me to enhance and build upon classroom instruction within the many natural and wilderness areas near our urban home. Hiking, camping, and habitat restoration are interwoven with classroom coursework to provide an experiential and conceptual foundation for a challenging academic curriculum. Each field experience is truly a field study—having class outside, not getting out of class. This strategy is foremost because it gives students so many tools with which to process subject matter: environments and physical processes that can be experienced and felt, memorable firsthand interactions with the course content, integration of kinesthetic learning, hands-on lessons and activities, and sensory stimulation through opportunities to look at, touch, and even smell the subject matter. Field studies provide students with an alternative to traditional sources of information.

For this unit in particular, experiential study will happen when we take the Toxic Tour of BVHP. Students will be able to use their own firsthand observations to identify sources of toxicity and the degree of exposure the community faces for each source. For example, students can observe buildings with no windows in the Naval Shipyard and hypothesize as to their past usage. They can then walk from the Naval Shipyard to the closest housing projects and estimate the distance. They can observe how the power plant's smokestack spews gray smoke and sits below housing projects so that, when the wind blows, the smoke blows up into the complex. When we compare their observations and hypotheses to formal findings, students will have an experiential context for understanding the data. Experiential learning gives them a foundation for understanding complex subject matter; their experiences become the conceptual edge they need in order to be successful academically. When we begin to study potential solutions to the toxicity in BVHP, the habitat restoration work we do at Heron's Head Park will offer students an experiential means of understanding the science of how wetlands can be a form of bioremediation, filtering toxins in water and providing fresh air.

Another important form of experiential study is hands-on learning. I will be using hands-on activities in order to demonstrate atomic structure as it relates to reactivity, bonding, and radioactivity. Students will build models of atoms that represent atomic structure: protons and neutrons in the nucleus, energy levels, and valence electrons. They can then reference their models when learning reactivity due to unfilled valence shells and radioactivity due to unstable nuclei. These models will not only allow students to engage as kinesthetic learners, but also as visual and spatial learners because they have a model to see and manipulate. The same strategy will apply when we create models of specific molecules in order to study ionic and covalent bonds, atomic weight, polarity, and solubility. Having created models hands-on, that can then be manipulated to enact various molecular concepts, will enable students to visualize and better comprehend the subject matter. The experiential nature of the activity bolsters students' understanding.

Applied Learning

Applied learning can be loosely defined as giving students a means of connecting classroom content to further study, projects, real world scenarios, or themselves. In science, scientific inquiry is an extremely effective form of applied learning. In this structure of inquiry, students apply prior knowledge to their observations in order to form hypotheses that they then support by applying evidence they gather. Regardless of the quantity of prior knowledge each individual possesses, an investigation makes learning more relevant and helps students conceptualize the answers to challenging questions. Field based, experiential inquiries can be particularly effective because, while many of my students hesitate to answer the question, "What do you think?" all of them can answer, "What do you see?" When inquiry is based on field observations and evidence can be collected during the course of a field study, students are more confident in "being scientists." Scientific inquiry also encourages curiosity and forces students to become involved in a lesson—critical in increasing academic achievement—as they make their own observations, generate their own hypotheses, and formulate their own conclusions.

There will be two main inquiries in this unit. The first will be the experiential toxicity assessment during the BVHP toxic tour. Students will use their observations of the neighborhoods to hypothesize as to the sources of pollution and their effects on the community. They will support their hypotheses using observable evidence, then test them against toxicity data in order to draw conclusions. After students gain confidence with methods of inquiry during the experiential exercise, the second inquiry will be a culminating assignment involving application of the principles of green chemistry to BVHP. Students will choose one toxin in BVHP from a category of toxicity we have studied in class. The toxin must have an identifiable source. For example, a student may choose VOCs emitted from the sewage treatment plant or carbon monoxide from freeway emissions. Based on their understanding of the principles of green chemistry and the various forms of toxicity in BVHP, students must hypothesize as to which principles hold potential solutions or remediations for the toxins they have chosen, and what those solutions might be. A student who has chosen radionuclides at the Naval Shipyard, for example, might hypothesize that the solution lies in abiding by the green chemistry principle that "chemical products should be designed so that, at the end of their function they do not persist in the environment and break down into innocuous degradation product." While that principle was not created with nuclear testing in mind and it is not currently the realm of green chemistry to identify ways to reduce existing toxicity in the environment, this green chemistry principle emphasizes designing materials to ensure that persistent toxins are not introduced into the environment. The same basic goal applies. The student might then hypothesize that the solution to radioactive waste is to use less persistent radioactive materials with shorter half-lives. Research may determine that this is impossible and a student can conclude that there is no safe way to test the effects of radiation. What is most important is the process of inquiry: students will apply prior knowledge of toxicity and principles of green chemistry to a problem in order to hypothesize about solutions, then use researched evidence to evaluate their hypotheses and form conclusions. Students who reason out the relationship between toxins borne of environmental injustice and green chemistry will gain a better grasp of a complex topic. The investigation works to facilitate students' synthesis of the content. As a part of the conclusion to their inquires, students must also apply the principles of environmental justice to their research by identifying which principles must be upheld in order to address the toxicity in a just way.

Another form of applied learning that is important at our school is project-based learning. At the end of every semester, students must utilize what they have learned in order to complete a final project they then present to the entire student body during our school-wide exhibition. The project for this semester is for students to use art in order to launch a campaign about an environmental issue related to preservation, restoration, or environmental justice. Students will design political cartoons and persuasive posters to educate the public and persuade them to take action. While not every student will choose an environmental justice issue, an example of such a campaign could be a student who chooses the power plant, educating people about alternatives to burning fossil fuels and promoting a letter writing campaign to the mayor about investing in solar energy. In this case, applying learning to an action project gives students a venue to address the injustices they face rather than allowing what they have learned to discourage them.

Activities

Inquiry-Based Toxic Tour of Bayview Hunters Point

A toxic tour of BVHP will be one of our first activities in this "Science of Environmental Justice" unit, so that students can use the inquiry process to identify sources of toxicity in the community and their impacts on the residents. This activity is a field study involving multiple van stops and some walking through the neighborhood.

Students will first be introduced to the neighborhood and its environmental justice issues via a map of all the toxic sites in BVHP. This map utilizes a key with each different type of toxicity represented by a colored shape. It is immediately evident that BVHP is overwhelmed by toxic sites. In groups, students will identify what each symbol in the key represents, count each type of toxic site, generate a total number of toxic sites, and answer an application question about how the map applies to environmental justice or injustice. Each group will share its findings. I will then introduce the inquiry activity by explaining to students that the purpose of the field study is to tour the area in order to identify sources of toxins and hypothesize as to their possible effects on human health. At each stop, students will divide a page in their field notebooks into three sections: observations of the site, hypothesis of sources of toxicity supported by specific observations, and hypothesis of effects on human health supported by specific observations. Observations in every category can include multiple senses: sight, sound, smell, taste, and touch.

Our first stop will be near the sewage treatment plant. Students will be able to smell the sewage and see the open separation tanks, as well as note the close proximity of housing on the very same block. The second stop will be near the rendering plant and a factory that coats non-stick pans. The rendering plant also has a distinct and unpleasant odor while the factory is full of the noise of industrial activity. Both are close to a busy street where pedestrians are a constant. The third stop will be on a hill where the Potrero Hill power plant and junction of two freeways are in view. The freeways and power plants are both downhill from the Potrero Hill public housing projects and power plant's smoke is clearly and visibly blowing toward the complex. Our last stop will be the Naval Shipyard, where we will have to peer through the fences to observe construction in progress, then walk up a few yards to a dilapidated park and the nearest housing projects. Our last stop will be at Heron's Head Park, where we will be able to see a recycling center, the remains of the now-dismantled power plant, and the park itself. This will pose an interesting contrast as a preview for our next visit to BVHP, when we will be doing habitat restoration at the park.

At the end of each stop, students will share their observations and hypotheses, taking note of observed evidence generated by their classmates that might also work to support their own hypotheses. This debriefing process will help students be increasingly attentive and analytical at each stop as they gain insights from one another regarding the correlation between observations and hypotheses. The conclusion of the field trip will be an assignment in which students must predict the toxicity of BVHP on a scale of one to ten, citing specific observations to support their assessments. After each student has written their evaluation, students will be grouped with classmates who had similar ratings (a 1-2 group, 3-4 group, etc.) and each group will prepare a statement with which to debate the others. We will have a debate with opening statements, rebuttals, and closing statements for each group, then vote at the end for a final rating.

This inquiry will continue at school as students read a summary of BVHP's "State of the Environment" report. Students will compare the findings of that report, and its data, to their own hypotheses and observations from the field study. They will then write final conclusions in which they confirm or revise their own studies.

Modeling the Nature of Toxicity

Students will create models to represent each form of toxicity we study: reactivity, solubility, volatility, and radioactivity. Creating models will help students visualize the chemistry concepts they must learn in order to answer the question, "What makes a toxin toxic?" As previously discussed, in order to understand the reactivity of elements and molecules, students must understand atomic structure, especially electron configuration. To create models of atoms and assess their electron affinity, we will use large red beads to represent protons, large beige beads to represent neutrons, small blue beads to represent electrons, and wire to represent electron shells, onto which we can thread the electrons. Protons and neutrons will be collected in some kind of container, and the wire electron shells will be attached in concentric circles to that container. In pairs, students will use these materials to construct atomic models of the first twenty elements because the orbitals of those twenty are very straightforward and do not overlap across different energy levels. Each element will be presented, including an assessment of its reactivity based on valence electrons and the octet rule. Each atom/pair of students must then find at least one other atom with which they think they can bond. These pairings will also be based on the octet rule, so students should seek out atoms with valence levels complementary to their own. As each pair presents itself, the class will identify which molecules will be stable and which might remain reactive. Molecules that have filled valence shells are stable, those that have unfilled valence shells and are reactive.

Later, when studying the relationship between polarity and solubility, students will utilize the same models. Taking any two atoms, groups of four students will use a periodic table to determine the electronegativity of each. Based on electronegativity values, each group will then identify whether the atoms would form an ionic bond, a polar covalent bond, or a non-polar covalent bond. The models will provide visual clues in that atoms of similar sizes tend to form non-polar bonds, while big-small pairs will result in ionic or polar covalent bonds. Once the type of bond is chosen, students must then attach their atoms to one another in a way that demonstrates the type of bond. For example, an ionic bond would require students to remove one electron from an atom and relocate it on another. A polar covalent bond would require students to shift the electrons toward the atom of highest electronegativity.

While our models for reactive and soluble chemicals will focus on the first twenty elements, the models that demonstrate radioactivity will focus on the last ten. For these radioactive elements, we will use the same materials to represent atomic structure. However, when students build these atoms, the large number of protons and neutrons will be difficult to enclose within the container that represents the nucleus. Any spillover, especially when the teacher jostles the table, will demonstrate an unstable atom. After demonstrating the basic instability of large atoms, we will then create models of several isotopes to analyze the imbalance of protons and neutrons. The last step of this modeling process will be to enact alpha and beta emissions by removing protons and neutrons to see if the stability of the nucleus increases.

The final set of models will also utilize traditional molecule-making sets. In groups, students will build models of three different molecules, and then calculate the molecular mass of each using a periodic table. Each group must then determine which molecule is most volatile, based on the molecular mass. Once the VOCs are identified, the structure of each VOC will be examined and categorized. We will then refer back to our atomic models to identify why the bonded elements have bonded, focusing on the electron configurations of hydrogen and carbon.

After studying the structure and behavior of each type of toxin, students will predict how atoms and molecules in each category might interact with the atmosphere or within a body. These predictions will be used to predict ways and reasons each type of substance is toxic to humans. We will discuss these predictions, then the answers will be revealed in a reading that also reinforces the earlier lessons about the atomic and molecular structure.

Integrating the Principles of Environmental Justice and the Principles of Green Chemistry

In this activity, students will first be presented with summaries of simple case studies that demonstrate a few of the most pertinent principles of green chemistry. In small groups, students will read the case studies and work together to analyze why the chemistry represented is more sustainable than traditional chemistry. Through this analysis, students will be identifying some of the principles of green chemistry. As each group shares, the class will work to identify what principle is at work in the case study. After the class as a whole has recorded their interpretation of the principles, we will read the actual principles that correspond. Students will be paired up to translate each principle into their own words and share it with the class.

Students will individually examine some of the sources of toxicity in BVHP: the power plant, the sewage treatment plant, the rendering plant, and the shipyard. They will be asked to identify which principles of green chemistry are being violated in the process of also disregarding the principles of environmental justice. As each student shares an analysis, the class will identify which specific environmental justice principles seem to best correspond with specific green chemistry principles. The conclusion of the activity will be for students to write a summary of which two or three green chemistry principles they feel best support the principles of environmental justice, why, and how.

Bibliography

Anastas, Paul T., and John C. Warner. Green Chemistry: Theory and Practice. New York: Oxford University Press, USA, 2000. This is the most authoritative explanation of Green Chemistry, as Anastas as considered a founder in the field.

Cann, Michael C. Real-World Cases in Green Chemistry. Washington, DC: American Chemical Society, 2000. Offers case studies of innovations in green chemistry.

Manahan, Stanley E.. Green Chemistry and the Ten Commandments of Sustainability, 2nd ed. Columbia, Missouri: Chemchar Research Inc, 2005. This text offers a very accessible explanation of green chemistry for non-chemists.

Moore, John T.. Chemistry for Dummies. New York: For Dummies, 2003. Provides a good foundation in basic chemistry concepts.

Endnotes

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1. "San Francisco Unified School District." http://portal.sfusd.edu/template/default.cfm (accessed August 13, 2009).
2. Pastor, Manuel, James Sadd, Rachel Morello-Frosch. "Still Toxic After All These Years: Air Quality and Environmental Justice in the San Francisco Bay Area (2007)." cjtc.ucsc.edu/docs/bay_final.pdf. (accessed August 13, 2009).
3. Ibid.
4. Ibid.
5. Ibid.
6. Weintraub, Irwin. "Fighting Environmental Racism: A Selected Annotated Bibliography." Electronic Green Journal. http://www.mapcruzin.com/ejigc.html (accessed August 13, 2009).
7. Ibid.
8. "NBEJN EJ Fact Sheet." Welcome to the Environmental Justice Resource Center Clark Atlanta University. http://www.ejrc.cau.edu/NBEJNEJFS.html (accessed August 13, 2009).
9. Bayview Hunters Point Mothers Environmental Health & Justice Committee, Huntersview Tenants Association, Greenaction for Health & Environmental Justice, "Pollution, Health, Environmental Racism and Injustice: A Toxic Inventory of Bayview Hunters Point, San Francisco, www.greenaction.org/hunterspoint/.../TheStateoftheEnvironment090204Final.pdf. (accessed August 13, 2009).
10. Ibid.
11. Ibid.
12. "SFHA Developments." San Francisco Housing Authority. http://www.sfha.org/about/developments/index.htm (accessed August 13, 2009).
13. "Silent Violence of Environmental Racism." Welcome to Greenhomebuilders.com. http://www.greenhomebuilders.com/environmentalracism.htm (accessed August 13, 2009).
14. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
15. Ibid.
16. Ibid.
17. Ibid.
18. Ibid.
19. "Articles." San Franciscans For Our City's Health. http://www.hunterspointnavalshipyard.org/articles.html (accessed August 13, 2009).

20. Phelan, Sarah. "Going Nuclear." San Francisco Bay Guardian. www.sfbg.com/entry.php?entry_id=8471 (accessed August 13, 2009).
21. "Articles." San Franciscans For Our City's Health.
22. "ATSDR - Health Consultation - Hunter's Point Naval Shipyard (a/k/a Treasure Island Naval Station-Hunter's Point Annex), San Francisco, San Francisco County, California." ATSDR Home. http://www.atsdr.cdc.gov/HAC/PHA/hunterspoint/hun_p1.html (accessed August 13, 2009).
23. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
24. Ibid.
25. Ibid.
26. D'Andrea, Niki. "San Francisco News - Fallout: The Past Is Present - page 6." San Francisco News, Events, Restaurants, Music. http://www.sfweekly.com/2002-07-31/news/fallout-the-past-is-present/6 (accessed August 13, 2009).
27. Glanville, Sarah. "Environmental Justice in Bayview Hunters Point." Urban Studies 515 - Race, Poverty, and the Environment. bss.sfsu.edu/raquelrp/projects/515.../SF_Bayview_Hunters_Point.ppt (accessed August 13, 2009).
28. Porter Sumchai, M.D., Ahimsa. "The Chicken or the Egg?." San Francisco Bay View. http://www.sfbayview.com/2009/the-chicken-or-the-egg (accessed August 13, 2009).
29. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
30. McCormick, Erin, and Reynolds Holding. "TOO YOUNG TO DIE / Part One: Life's Toll." San Francisco Bay Area — News, Sports, Business, Entertainment, Classifieds: SFGate. http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2004/10/03/MNINFANTMO.DTL (accessed August 13, 2009).
31. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
32. Ibid.
33. Ibid.
34. "About Us." LEJ HOME. http://lejyouth.org/aboutus/about.html (accessed August 13, 2009).
35. Lelchuk, Ilene. "BAYVIEW-HUNTERS POINT / S.F.'s invisible majority / Area with highest density of children is most underserved." San Francisco Bay Area — News, Sports, Business, Entertainment, Classifieds: SFGate. http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2006/05/31/BAG3UJ4MK71.DTL (accessed August 13, 2009).
36. Ibid.
37. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
38. "Articles." San Franciscans For Our City's Health.
39. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
40. "Articles." San Franciscans For Our City's Health.
41. Brown, Todd. "Midway Village Riles Peninsula Green Activists, San Mateo County Times." Greenaction. http://www.greenaction.org/midway/press/smt061206.shtml (accessed August 14, 2009).
42. Ibid.
43. Sciammas, Charlie, Tom Rivard, Megan Wier, Edmund Seto, and Rajiv Bhatia. "Traffic Causes Death and Disease in San Francisco Neighborhood | Urban Habitat." Welcome to Urban Habitat | Urban Habitat. http://www.urbanhabitat.org/node/2814 (accessed August 14, 2009).
44. Ibid.
45. Anastas, Paul T. Green Chemistry: Theory and Practice.
46. Ibid.
47. Ibid.
48. Ibid.
49. "Principles of Environmental Justice." EJnet.org: Web Resources for Environmental Justice Activists. http://www.ejnet.org/ej/principles.html (accessed August 14, 2009).
50. Anastas, Paul T. Green Chemistry: Theory and Practice.
51. "Principles of Environmental Justice." EJnet.org.

52. Anastas, Paul T. Green Chemistry: Theory and Practice.
53. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
54. Ibid.
55. Ibid.
56. "ATSDR - ToxFAQs™: Hazardous Substance Fact Sheets." ATSDR Home. http://www.atsdr.cdc.gov/toxfaq.html#bookmark05 (accessed August 14, 2009).
57. Ibid.
58. Ibid.
59. Ibid.
60. Ibid.
61. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
62. "ATSDR - ToxFAQs™: Hazardous Substance Fact Sheets." ATSDR Home.
63. Ibid.
64. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
65. "ATSDR - ToxFAQs™: Hazardous Substance Fact Sheets." ATSDR Home.
66. "Radiation at Hunters Point Shipyard - Community Window on the Hunters Point Shipyard." Community Window on the Hunters Point Shipyard. http://www.communitywindowontheshipyard.org/toxics_radiation/radiation.htm (accessed August 14, 2009).
67. Ibid.
68. Manahan, Stanley E. Green Chemistry and the Ten Commandments of Sustainability.
69. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
70. Glanville, Sarah. "Environmental Justice in Bayview Hunters Point."
71. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
72. Bayview Hunters Point Mothers Environmental Health, "Pollution, Health, Environmental Racism and Injustice."
73. "Radionuclides (including Radon, Radium and Uranium) | Technology Transfer Network Air Toxics Web site | US EPA." U.S. Environmental Protection Agency. http://www.epa.gov/ttnatw01/hlthef/radionuc.html (accessed August 14, 2009).
74. Manahan, Stanley E. Green Chemistry and the Ten Commandments of Sustainability.
