



***Epigenetics, Environmental Justice, and Pollution
Case Studies in North Carolina***

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This curriculum unit is recommended for:
Middle Grades and High School Science
and Social Studies

Keywords: epigenetics, evolution, DNA, gene modification, race, environmental justice, genes, pollution, Warren County, coal ash ponds, PCB, DDT, non-renewable resources

Teaching Standards: See [Appendix 1](#) for teaching standards addressed in this unit.

Synopsis: This curriculum unit includes research and information for the middle school and high school teacher regarding localized pollution issues and includes epigenetics and the effects of environmental factors on long-term health over generations. I teach an integrated 8th grade science class and the curriculum I teach reaches almost all of the science disciplines. This particular curriculum unit is a five-day unit, which one can implement throughout the year, with various units, or saved for a testing review at the end of the year. There are activities and case studies described in detail, along with teaching strategies and methods. All of my activities include inquiry based learning. Vocabulary words are also included along with an annotated bibliography and instructions on how to integrate the teaching standards, with the rationale and research included. I teach a diverse population of students in a high-needs school and I believe this unit will help assist teachers and students to make connections with topics such as chemistry, water quality, non-renewable resources, evolution, DNA modification, and generational effects of pollution on low income and minorities. Also, the topic of environmental justice is defined and explored for interdisciplinary lesson plans between science and social studies.

I plan to teach this unit during the coming year to 110 students in 8th Grade Science teach North Carolina Teaching Standards

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Introduction

I teach at an inner city middle school with a diverse population of 60% African American and 40% Hispanic students. The student body is transient with some living in hotels and extended stay motels. Standardized test scores are low and my school is designated a high-impact school and received an “F” from North Carolina on the school report card in 2018. Any case studies and activities related to the science curriculum need to engage and relate the science standards to everyday life. The North Carolina Science Standards are not readily adaptable to current events. However, this Curriculum Unit (CU) goes along with the NC 8th grade standards and I have three case studies and activities that directly relate to pollution issues in North Carolina.

We must remember that our students do not watch the evening news and are very isolated from the world. They have cellphones and technology, but their primary use is social media. They do not know about current events and local environmental issues per se. Reading levels are sometimes at 4th grade levels. The large majority of students do not read books and despise reading across the board. In my class room they refuse to read any articles even if related to their demographics and lifestyle. Very seldom do you see anyone carrying a personal book or a library book. Even comics and graphic novels are not widely read in my school’s demographics. Anything I can do to keep the students away from their cell phones and relate to everyday life is important in capturing the attention of these high needs students. Athletics, clothes, expensive shoes and music seem to be the only thing they gets their attention. Grades are not important to most and parent support and involvement ranks very low.

This CU focuses on a classroom science teacher with one to five years of experience, who is looking for activities and case studies for their science class related to the NC standards. In this Curriculum Unit I give some elementary background on epigenetics, how DNA switches work in response to stressors such as environmental pollution. Additionally, this CU will explore local environmental issues, and how pollution can affect long-term health of lower income minorities who might be exposed to pollutants and help you, as a teacher and citizen to understand the topic of epigenetics and potential long-term generational effects of environmental stressors on DNA. Included in the CU is research and statistics about people of color living near waste landfills and coal ash ponds in the case studies section. These facts will be helpful when relating coal ash and other pollution to your students. Keep in mind that the material presented is intended for an audience of 8th grade teachers and for the average high needs 8th grade student.

Rationale

As I decided to participate in this seminar, I really did not know the definition of epigenetics. However, as I explored the topic, I realized that I could integrate my research, case studies and activities into just about every unit I teach in eighth grade integrated science. In the North Carolina Science Standards, we cover DNA modification, biotechnology, chemistry, non-renewable energy resources, evolution, and microbiology. Many of the students I teach know relatives and friends affected by the environment we live in. An important part of this CU is the plight of lower socio-economic people and minorities having a larger percentage of health issues caused by pollution because of a higher proximity in living next to industrial and electrical generating plant locations. A national study by the Commission for Racial Justice of the United

Church of Christ, *Toxic Wastes and Race in the United States: A National Report on the Racial and Socioeconomic Characteristics of Communities with Hazardous Waste Sites* confirmed that race and ethnicity were the largest factors in deciding where to place waste facilities and landfills.¹ In 1994, the follow-up report, *Toxic Wastes and Race Revisited*, found that the disproportionate burden placed on communities of color had, grown since the 1987 report. The 1994 report found that “people of color were 47 percent more likely than whites to live near a commercial hazardous waste facility” and that between 1980 and 1993 the population of people of color living in areas with hazardous waste facilities increased 6 percent, from 25 to 31 percent.²

Health disparities, like environmental pollution, are also disproportionately affecting minorities in the United States. "The differences in diabetes risk is clear: For black people in the US, the risk of getting diabetes is 77% higher than for white people in the US. Among Latinos, the risk is 66% higher. Overall, 9% of white people in the US have diabetes, compared to 18% of black people and 20% of Latino people.³ One major reason black and Latino people are exposed to toxic chemicals is also clear: Race is the single biggest indicator in the US of whether you live near toxic waste and pollution. Often that pollution includes endocrine disruptors, including PCBs, certain pesticides. Even air pollution can contain endocrine-disrupting chemicals.

Historically, the people living there did not know what is causing these health issues and how they passed to future generations in hereditary actions through DNA. For example, the pollution around us, such as the prescription drug residue and lead in our drinking water can cause our DNA to modify over time. The concerns in North Carolina with Duke Energy’s Coal Ash is a perfect scenario in how heavy metals in coal ash seeps into our local water supply and effects our health. The environment you live in, the food you eat, the drugs you take, the tobacco you use, the pollution you live in, and the chemicals you are exposed to can eventually cause chemical modifications around the genes (not in genes) and will turn those genes on or off over time. For example, certain diseases such as cancer or Alzheimer’s, genes can be switched an opposite way, away from the normal/healthy condition. In addition, environmental pressures on DNA can make us different from others. The different combinations of genes that are switch on or off by stressors is what makes each one of us different and unique. These changes could be passed down to future generations. We are still learning how much this occurs but studies in other animals suggest it does happen with unknown frequency at this time.

Instructional Implementation

Environmental Justice: Social Studies and Science

In 1982, the state of North Carolina planned to dump 31,000 gallons of the highly-carcinogenic polychlorinated biphenyl (PCB) in a landfill in Warren County, North Carolina with a 75 percent African American population. The citizens objected to the plan, saying that the PCBs would get into their groundwater and contaminate their soil. Local leaders organized the protests and people laid down in front of dump trucks to prevent them from entering the town. The protests drew national attention to the issue of minorities and higher rates of exposure to industrial pollution and kicked off what is now known as the modern environmental justice movement.

According to The Health and Human Services Department of the federal government, Environmental Justice is defined as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” In 1994, President William J. Clinton signed Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The Executive Order required each federal agency to “make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.” Specifically, the Executive Order requires that each agency develop an agency-wide environmental justice strategy specific to the agency’s mission.⁴

What is Epigenetics?

While deciding how to present this college-level material, I realized how difficult it is to reduce the research to a middle school student’s ability to comprehend the concepts. My number one goal is to introduce the concept that our genes are expressed, by way of environmental exposures that might be passed down to future generations. I am presenting a lesson that provides a connection between environmental pressures, particularly exposures to chemicals, on the human biology in a way that is user friendly to middle school and high school teachers. There is evidence that pressures such as pollution, poor nutrition, lack of exercise, and stress related issues on the human body could cause changes in the biological switches that turn genes on and off. Furthermore, there have been indications that some epigenetic changes can be inherited. Our DNA continues to be shaped in a dynamic way by our development. “Epigenetics represents the programming of the genome to express a particular set of genes in specific cells at specific time points during life. Epigenetic patterns are generated during cellular differentiation by a highly programmed and organized process. Nevertheless, they are dynamic and responsive to our environment especially during the important periods of gestation and early life”.⁵

I have attempted to reduce the level of complexity of the research to the level of understanding of 8th grade science by way of a simplified definition; *Epigenetics is the study of the ways biology switches genes on and off. Or how environmental pressures or stressors act as a control for a dimmer switch.* This a highly simplified definition and does not contain all the very technical and complicated actions that occur during the process. Certain circumstances in life can cause genes to be turned off or turned on over time. This process is similar to a light switch being turned on and off or more like a dimmer light switch. In other words, they can become dormant or become active. We have 20,000+ genes, so what will be the implications of the different combinations of genes being turned on or off? The possible changes are mindboggling. In theory, we could map every single cause and effect of the different combinations, and could reverse the gene’s state to keep the good while eliminating the bad stuff. While researching to find proof and data that connects switches being turned and off surrounding our DNA that respond to our environment, I discovered some interesting case studies and research that suggest that behaviors such as smoking tobacco can influence our biology over generations.⁶

Epigenetics vs Evolution

Epigenetics is an emerging field. The concept is changing what we know about evolution, natural selection, and variation. As we learn more about epigenetics, our view of the Theory of Evolution, heredity, and phenotypes is continuing to change. Many factors work together to build traits and DNA by itself does not determine them. Darwin's theory does support the changing of gene switches, but does not see the role of development in producing adaptive traits. Darwin was interested in developing a general hypothesis for how organisms change over time and how species may arise. He had no knowledge of genes, but used some general idea of heredity. Over the following 150 years, biologists have tried to understand the mechanisms, which originally came out of population genetics (DNA centered) but now includes the environment, more specifically with epigenetics. Many factors work together to build traits and DNA by itself does not set them. Human epigenetics is dynamic and modified by our experiences with environmental pressures, nutrition and stressors, moving away from the normal/healthy condition. In addition, epigenetics can make us different from others. The different combinations of genes that are turned on or off is what makes each one of us different and unique.

Results of epigenetics over the past 100 years.

Due to increased nutrition and more effective disease control, humans have grown taller over the past 100 years. I visited a historical home place in the nearby Appalachian Mountains and saw that the doorframes, beds, and chairs from 100 years ago were so small. So is evolution by natural selection the cause of the growth? I had always thought this might be the result of evolution, but now after researching it seems to be epigenetics. But I also knew evolution is time over change. Immense time, not just one century, and not in the sense of actual genetic changes, as one century is not enough time for such changes to occur, according to researchers.

The height gain that occurred within such a short time period "are simply the developmental responses of organisms to changed conditions," such as differences in nutrition, food distribution, health care and hygiene practices, said Stephen Stearns, a professor of ecology and evolutionary biology at Yale University. Stearns also said, "A big take-home point of all current studies of human evolution is that culture, particularly in the form of medicine, but also in the form of urbanization and technological support, clean air and clean water, is changing selection pressures on humans."⁷

From the research I have completed, epigenetics has an effect on how we view the Theory of Evolution. Adding epigenetics in the thought process gives the idea that the environment has two ways to change things. It still picks the individuals that get to breed and thrive, but it also creates trait variation through gene expression and maybe epigenetic change. When you bring this up to the population level, you begin to see how fast variation can occur from environmental changes. New variation does not only come from mutation. Mutations are rare, random, and slow to affect populations.⁸

The Epigenome and Gene Regulation

The epigenome is a group of chemical compounds that tells the *genome* what to do. Of course, we know that DNA holds the instructions for building the proteins that carry out different functions in a cell. In addition, the epigenome is made up of chemical compounds and proteins that can bind to DNA and control actions such as turning genes on or off, and controlling the production of proteins in particular cells. When the small chemical molecules attach to DNA and change its function, they *mark* the genome. These marks do not change the sequence of the DNA. Rather, they change the way cells use the DNA's instructions. The marks are sometimes passed from cell to cell as the cells divide. They can be passed from one generation to the next. How exactly does the epigenome accomplish in its role? A human being has trillions of cells, built specifically for different functions and these many different types of cells and each of these cells carries the same genome in its nucleus. The differences among cells are set by how and when different sets of genes are turned on or off in different kinds of cells. Specific cells in the eyes turn on genes that make proteins that can detect light, while specific cells in red blood cells make proteins that carry oxygen from the air to the rest of the body.

The epigenome controls these changes to the entire genome. Cells express, or turns on only a fraction of its genes. The rest of the genes are turned off. The process of turning genes on and off is known as gene regulation. Gene regulation is an important part of a human's development. Genes are turned on and off in different directions during development to make a brain cell look and act different from a liver cell or a muscle cell, for example. A gene's regulation also allows cells to change quickly to changes in their environments. Although we know that the regulation of genes is crucial for life, the process is not really understood. Gene regulation can happen at any time during gene expression, but mostly occurs at the level of transcription. Signals from the environment or from other cells engage proteins called transcription factors. These proteins bind to regulatory regions of a gene and raise or lower the level of transcription. By controlling the degree of transcription, this process can determine the amount of protein product that is produced by a gene at any selected time.⁹ Click [here](#) for a link that shows an animation demonstrating how the protein MECP2 can act as an on off switch for gene expression.¹⁰

Epigenetics and Pollution

We now know that research suggests that environmental stressors can turn gene switches in the opposite direction. As I mentioned earlier, these switches increase and decrease the expression of genes - as opposed to simply turning genes on and off (dimmer switch analogy). These changes in our genes can affect change in short periods, and can also be handed down to future generations. Studies suggest that our genes can be changed in the short term because of exposure to pollution, and chemical toxins and this can *potentially* effect humans in the short term and potentially be handed down through our genes to our grandchildren.¹¹ DDT exposure has been studied intensely since the early 1970's and this research sheds light on almost fifty years of generational inheritance and its implications.

Teaching Strategies

I believe this CU is the perfect opportunity to educate the average middle school teacher and relate this issue to the 8th grade curriculum. The reader of this unit will need some background information related to the standards and academic level of their students to teach this unit. Key components of this CU will include:

- Why non-renewable resources such as fossil fuels are costly to the environment and human health.
- How low socioeconomic classes and minorities are affected more by pollution.
- How genes are switched off and on due to environmental pressures.
- How these switches are passed to future generations and gene overexpression.
- The process in which we produce electricity.
- The problem with coal ash, PCB's and other toxic substances over generations.
- How evolution is different from epigenetics.
- Epigenetics also suggests that humans are affected by short-term environmental pressures.

This CU provides resources and ideas for classroom inquiry based activities, demonstrations, and case studies. The case studies, hopefully, will motivate and engage students to write analytical sentences, paragraphs, and essays, because they are relatable to everyday life in North Carolina. The teacher should integrate collaboration, problem solving, research, writing, using writing prompts, and sharing information in any lesson plan. Using 21st Century Learning Skills such as communication, collaboration, and media technology skills are necessary in order for students to be able to analyze and complete inquiry-based projects. The ability to analyze and write about the observation is paramount in achieving a higher level of understanding in science. Initially, graphic organizers can assist students in organizing their work in their minds in order to understand it. Video links are included further on in this CU for students who prefer not to read long articles during class. *Playpostit* is an excellent resource for the teacher to watch *YouTube* videos with embedded questions. Chromebooks are invaluable in writing and analyzing work as well as utilizing different writing apps that can be used to quickly grade papers. Any demonstration or hands-on inquiry should be directly related to the applicable standard and should increase standardized test scores in science. I have included I can statements easy to understand for the student.

An assessment should be provided after any demonstration or hands-on activity to provide data about which Essential Questions and standards were or were not mastered. Project-based assessments, such as power-point slideshows, posters, google slide presentations, or iMovie make it easy for the students to demonstrate their knowledge learned. I have included suggested methods and activities in the case studies section.

I want to make it easy for you to design your own lesson with the complexity you want. I am including resources to educate yourself and your students. I am including video links and short case studies for you to expand on (Some students can't or won't read the short articles). I have included many open ended essential questions and activities. I teach at a high impact Title One school with low test scores. I would like for you to give some guided notes from PPT

presentations, discuss the issue of coal ash pollution and its hazards to the population living near the pond and the effects on people of color and poverty. The students can take notes from video with some questions provided from my list before starting the video. You can also use the questions that students should be able to answer on an exit ticket type assessment and quick and easy to grade. Sometimes, I allow my top students to make a Google slide presentation in lieu of taking a multiple-choice formal assessment. Poster boards are also an excellent way to prove evidence of student learning. E-books or folded mini books, also are excellent assessment tools. I have even included three web quests for days you don't feel well and want the students to learn on their own!

Activity and Lesson #1: DDT

Background on DDT

Dichloro-diphenyl-trichloroethane (DDT) was banned in the US in the 1970s, yet its effects on health continue to be shown and studied years later. DDT was developed as a pesticide in the 1940s and was used widely in the United States until banned in 1972. It is very prevalent in the environment and still used in other parts of the world. Michael K. Skinner, PhD, a professor in the School of Biological Sciences at Washington State University looked into this, focusing on a pesticide consumed and used widely by our great grandparents, DDT. Having already shown that DDT exposure can promote the inheritance of obesity, Skinner and his graduate students looked into this further by a wide range of epigenetic changes across an entire genome. When Skinner and his colleagues exposed gestating rats to DDT, they saw no altered rates of obesity in the parent or first generation of offspring. However, obesity developed in more than half the third-generation males and females. The researchers say the insecticide may be affecting how genes are turned on and off in the offspring of an exposed animal, even though its DNA sequences remain unchanged. This study also showed completely different combinations between the generations when compared to control mice, showing that exposure to DDT can affect the mouse epigenetic gene switching.¹²

Activity for DDT Lesson #1

Background Lesson

Objective: Students will understand the potential dangers of DDT on birds and other wildlife and learn about how scientists first discovered these issues. DDT was widely used to kill insects in people's homes, on crops, and in neighborhoods. The health impacts of DDT to humans and wildlife were not known during its early use and was considered a safe pesticide.

Rachel Carson, who is a prominent marine biologist, recorded her observations of the problems of pesticides, mainly DDT, on humans and wildlife in her 1962 book, *Silent Spring*. In this activity, we learn about how steps that we take can either harm us or protect us. It is important for us as educated human beings to weigh the positive and negative impacts of our decisions and learn from mistakes that were made in the past. Bald Eagles in 1782, when America adopted the eagle as its national symbol, was estimated to be around 100,000 eagles.

Before the 1940's, Bald Eagles were declining due to hunting and persecution by collectors and farmers. Congress passed the Bald Eagle Protection Act in 1940 to protect eagles from anyone killing, selling, or capturing the species. Less than 500 pairs of Bald Eagles remained in the lower 48 states from the original population and the Bald Eagle was in danger of extinction.

The ban of DDT in 1972 was the first step in the road to rebuilding the Bald Eagle population. DDT causes eggshell thinning in Bald Eagles (and other birds), and when adult birds sit on their eggs, they easily break in the nest. Because of this condition, Bald Eagles were not able to successfully reproduce.

DDT quickly breaks down into DDE which is still present in the environment. Scientists are still trying to understand the effects of DDE on wildlife and humans. Following the ban of DDT, the U.S. Fish & Wildlife Service in 1978 listed Bald Eagles as endangered depending on the location of the population. This action helped speed up the recovery for Bald Eagles through breeding programs, reintroduction to areas, law enforcement, and nest site protection during the breeding season. In 2007, Bald Eagles were removed from the endangered list but population numbers still remain low on the Channel Islands.

Suggested Activities and Strategies

- Watch *Return Flight* video and take notes on uses, impacts, and facts about DDT that are mentioned in the film.
- Decide if you would like to have your students read the book *Silent Spring* by or research the author and write a short essay about her work.
- Have a list of pesticides ready that are used now or used in the past, which have also been phased out or have been banned.
- Have examples prepared of safer alternatives to toxic chemicals that we use every day.

Materials

- *Return Flight: Restoring the Bald Eagle to the Channel Islands* DVD (23:33 min.)
- Paper and pen or pencil
- Internet
- Copies of *Silent Spring* (optional)

Activity and Lesson #2: Coal Ash

Background on Coal Ash Pollution

One of pollutants I wish to focus on in this CU are some that are in our backyard, in our rivers, and are located in the Southeastern United States. These primarily affect lower income working class citizens. A great amount of news coverage has spent on Duke Energy's Coal Ash dilemma, although many power companies across the US are struggling with implications and methods of cleaning up this potentially dangerous environmental situation. Coal ash has not been regulated until recently.

Coal ash was not regulated by the EPA until recently. However, The EPA has responded to catastrophic failures of coal ash ponds, such as what occurred at TVA's Kingston, Tennessee power plant by adding new requirements for coal ash ponds and landfills. Since The Dan River Spill in North Carolina incidents occurred, a significant increase in state and federal regulation has been implemented. Since these incidents such as these, the EPA has determined poorly constructed or managed coal ash disposal ponds have been linked to cases of harm to surface or ground water or to the air, however state laws covering burned coal waste disposal are usually nonexistent. The result: Millions of tons of coal ash are being stored in ponds, landfills, and abandoned mines right beside our lakes, rivers, and homes. According to a risk assessment done by the EPA, living near a coal ash pond is more dangerous than smoking a pack of cigarettes a day. The toxins found in coal ash are linked to organ disease, cancer, respiratory illness, neurological damage, and developmental problems. People living within one mile of unlined coal ash ponds can have a 1 in 50 risk of cancer—more than 2,000 times higher than what the EPA considers OK.

On February 2, 2014, a drainage pipe ruptured at a coal ash containment pond owned by Duke Energy in Eden, North Carolina, and sent 39,000 tons of coal ash into the Dan River. At the same time 27 million gallons of wastewater from the plant was also released into the river. The broken pipe was left unsealed for almost a week before the draining coal ash was stopped. The ash was deposited up to 70 miles from the site of the spill and contained harmful metals and chemicals. This catastrophe occurred at the site of the Dan River Steam Station, a closed coal power plant which had stopped operations in 2012.

The heavy metals that are contained in coal ash are carcinogenic. Coal ash contains high levels of toxic heavy metals such as arsenic, lead, selenium, and other cancer-causing chemicals. The public health hazards and environmental problems to nearby communities from unsafe coal ash dumping have been known for many years range from increased risk of cancer, learning disabilities, neurological disorders, birth defects, reproductive failure, asthma, and other illnesses. Coal ash contains also mercury, aluminum, barium, boron, and chlorine. All can be toxic. Particularly where there is long-term exposures, these toxins can cause cancer, heart damage, lung disease, respiratory distress, kidney disease, reproductive problems, gastrointestinal illness, birth defects, impaired bone growth in children, and behavioral problems. In short, coal ash toxics have the potential to injure all of the major organ systems in adults (including pregnant women) and children.¹³

Exposure to toxic coal ash can also lower birth rates, cause tissue disease, slow development, and even kill plants and animals, leading to changes in wildlife concentrations and disruptions to entire ecosystems. The toxic pollution from coal ash builds up in exposed animals and plants, causing the pollution to make its way up the food chain when they it is eaten. According to the EPA, 1.54 million children live near coal ash ponds.¹⁴ The NAACP recently released a report, *Coal Blooded*, which documents the “Environmental Justice Performance” of all coal-fired power plants around the country. The report ranks the 378 plants using EPA toxic emissions data and demographic information – race, income and population density. The report shows that the six million Americans living near coal plants have an average income lower than the national average and 39% are people of color – whereas people of color make up 36% of the US population.¹⁵

Lesson and Implementation

For students to fully understand exactly what coal ash ponds are and how they relate to pollution requires some background content relating to coal fired power plants. Most students do not know where their electricity is produced. My students don't know how a coal fired plant produces electricity. Click [here](#) for a link for the animation. My students have never seen coal. They do not know that a nuclear power plant is located just a few miles away on Lake Norman. They didn't know about the dangers of coal ash ponds and health problems for generations to come.

One important concept of creating electricity from coal is the fact that a chemical change takes place in process of burning coal. This chemical reaction creates heat, light, Carbon Dioxide, Carbon Monoxide and is included in the Carbon Cycle. I teach about the differences in chemical vs physical changes. Also, we can use the equation for burning coal to verify a balanced equation and count atoms and elements. The chemical equation is $C + O_2 \rightarrow CO_2$. This equation satisfies the Law of Conservation of Mass and Energy. There are 2 elements (carbon and oxygen) in each side of the equation and 3 atoms on each side. Thus, we can re-loop what we discussed in chemistry during the non-renewable resources energy unit.

The heat released by the burning of coal is an evidence of a chemical reaction. The heat turns water into steam, which a physical change, which turns a generator that creates electricity. The steam vapor (invisible) changes to condensation (water, physical change of state). At that point the water is ran through a water cooling tower to cool to an acceptable level before pumping it back into the river. Water that is too hot, causes low dissolved oxygen in river water, which results in fish kills and accelerated bacteria growth. We can re-loop physical changes in water and issues of water quality into this unit as well. Another important concept is the production of heavy metals from the coal burning process. The definition of *heavy metals* is: any metallic chemical element that has a high density and is toxic at low concentrations. Coal contains many heavy metals, as it is created through compressed organic matter containing virtually every element in the periodic table - mainly carbon, but also heavy metals. Small amounts of some heavy metals are necessary for health, but too much may cause toxicity (poisoning). Many of the heavy metals released in the mining and burning of coal are environmentally toxic elements, such as lead, mercury, nickel, tin, cadmium, antimony, and arsenic.

Electric coal-fired power plants are the largest source of toxic pollutants in the United States, due to coal ash and coal waste, which contain toxins such as heavy metals. Each year, the waste left over from burning coal generates 125 to 130 million tons of coal ash and sludge. About 40% of the coal ash is manufactured as new products, such as gypsum board, called drywall and into our homes. 60% is stored in ponds, which can cause environmental risks if released into ground water-due to unlined ponds or catastrophic situations like flooding due to hurricanes. *The lesson and procedures below would be an excellent Academic Enrichment Case Study or long-term project using the NC 8th grade science Energy Resources Unit regarding the disadvantages of non-renewable energy resources.*

Unit Objective/Students will:

1. Know that coal as a fossil fuel and know how and when coal was formed.
2. Observe the combustibility of coal and recognize it as an important energy fuel.
3. Research and report on the different methods of coal mining.
4. Know the Environmental impacts of mining and use of coal.
5. Compare and contrast the use of coal energy to other energy sources related to health, safety, environmental impacts, and cost versus renewable energy sources.
6. Recognize that coal ash can be recycled into useful products.

Activity 1: Students will review coal as fossil fuel. Students will describe and illustrate how coal is formed.

Materials: ice cream sandwiches, wax paper, construction paper, rolling pin, nonstick spray or oil, forceps, candle, matches

Procedure: Review to determine students' knowledge of coal as a fossil fuel.

-Coal is a major energy resource in the world.

-Coal is used for heating and changing water to vapor to produce electricity

-Coal forms due to the accumulation of plant matter, which has undergone changes due to pressure and heat over millions of years.

-Coal is composed primarily of carbon, hydrogen, oxygen and nitrogen (Can be used to count atoms and elements).

Press ice cream sandwiches together with rolling pin represents coal layers being compressed into a solid mass.)

Activity 2: Coal Combustion and Energy Use

Objective: Observe the combustibility of coal and recognize it as an energy fuel.

Materials small coal samples (1-3 cm. size),

- votive candles with candle holders
- aluminum foil
- matches
- forceps with insulated handles
- goggles
- thermometers
- water
- small beakers

Introduce activity to recognize coal as an energy fuel.

*This lesson can be performed as a teacher demonstration or as a student hands on project.

Have students work with partners to share materials.

Distribute materials, except for matches.

Students put on goggles.

They place candles on foil, place thermometers in bottom of beaker, and fill beaker with just enough water to cover base of thermometer (25-50 ml.).

Students note temperature of water at room temperature.

Teacher lights one candle for each group.

Using forceps, students hold coal pieces in the flame for one minute.

Students observe glowing coal, place coal in beaker and record water temperature immediately. (Coal samples are difficult to keep burning, but the absorbed heat is measurable.)

Discuss observations.

Facilitate class discussion on conclusions of experiment.

Evaluation: Students write procedure, data and conclusions of science lab, and diagram lab set-up.

Procedure: Discuss various renewable and nonrenewable energy resources:

Renewable resources, include hydroelectric, solar, geothermal, biomass and wind power.

Nonrenewable resources, which are limited in quantities, include petroleum, coal, natural gas, and uranium (used in nuclear power plants).

Divide class into groups and assign different energy resources to be researched and compared to coal energy. Students should include topics of safety, efficiency, environmental impacts and cost.

Evaluation/Assessment: Students compare and contrast coal energy to other sources of energy in a report digitally as a PPT Presentation or a debate using a Socratic Seminar.

Teacher Resources

Coal ash questions for students and both the student and teacher should know.

1. Where do we get our electricity?
2. How is electricity produced from coal?
3. How is coal formed?
4. What is contained in a chunk of coal?
5. How is coal transported?
6. What elements from the Periodic Table is found in coal ash?
7. Is burning coal a chemical reaction?
8. What are some evidences of a chemical reaction while burning coal?
9. Are we destroying any matter while burning coal?
10. What are heavy metals?
11. What are the health risks of burning coal?
12. Is coal renewable?
13. What is coal ash pond?
14. Why is it potentially dangerous?
15. What happens when a coal ash pond contents get in drinking water?
16. Can exposure to heavy metals cause long term health affects?
17. Can these changes in gene expression cause problems for our great grandchildren?
18. Why do we need to clean up around a coal-fired power plant?

Web quest <https://tinyurl.com/y829qok2>

Coal Equations

This resource is for counting atoms and naming the elements in a chemical equation.

$C_{137}H_{97}O_9NS$ is the chemical equation for bituminous coal and $C_{240}H_{90}O_4NS$ for high-grade anthracite. Anthracite coal is a dense, hard rock with a jet-black color and a metallic luster. Notice the number of atoms present in each formula indicating a high density energy source. Carbon, Hydrogen, Oxygen, Nitrogen, Sulfur are the elements present in coal.

Activity and Lesson #3: PCBs

Background on PCBs

Because of their long life, PCBs are still in use, mostly overseas, even though their manufacture has been banned in the US since the 1960s, toxicity issues were found. Because of PCBs environmental toxicity and classed as a long lasting pollutant, PCB production was banned by United States federal law in 1978. Polychlorinated biphenyl (PCB) is an organic chlorine compound with the formula $C_{12}H_{10-x}Cl_x$. The number of chlorine atoms and their location in a PCB molecule determine many of its physical and chemical properties. PCBs have no known taste or smell, and range from an oil to a waxy solid. Polychlorinated biphenyls were once used as electrical transformer coolant, carbonless copy paper and in heat transfer fluids. Due to their non-flammability, stability, high boiling point and electrical insulating properties, PCBs were used in many industrial and commercial applications including:

- Transformers and capacitors
- Electrical equipment including voltage regulators, switches, re-closers, bushings, and electromagnets
- Oil used in motors and hydraulic systems
- Old electrical devices or appliances containing PCB capacitors
- Cable insulation
- Thermal insulation material including fiberglass, felt, foam and cork
- Oil-based paint
- Caulking
- Plastics
- Carbonless copy paper
- Floor finish

Today, PCBs can still be released into the environment from:

- Poorly maintained hazardous waste sites that contain PCBs.
- Illegal or improper dumping of PCB wastes.
- Leaks or releases from electrical transformers containing PCBs.
- Disposal of PCB-containing consumer products into municipal or other landfills.
- Burning some wastes in municipal and industrial incinerators.

PCBs studies through decades of animal research have been demonstrated to cause a variety of adverse health effects.¹⁶ Many studies in animals and human populations have been performed to check the potential cancer risks of PCBs. They have been shown to cause cancer in animals as well as a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system and other health effects. While exposure to PCBs, tends to come from food (especially animal fats), there is also evidence that we can be exposed to PCBs through the air, through breathing, and that inhaled PCBs can increase the risk of diabetes, cardiovascular disease, and high blood pressure. PCBs concentrate in fat tissue as the chemical goes up the food chain. This process is called bio-magnification. Animals at the top of the food chain, including humans, have concentrations 100,000 times greater than those organisms at the bottom of the food web. However, it may take years of regularly eating contaminated fish to build up the toxic levels of PCBs in the tissues necessary to cause health or reproductive problems. Click [here](#) for a video about PCBs.

Newborn monkeys exposed to PCBs showed persistent and significant deficits in neurological development, including visual recognition, short-term memory and learning. Some of these studies were conducted using the types of PCBs most commonly found in human breast milk. Reproductive effects of PCBs have been studied in a variety of animal species, including Rhesus monkeys, rats, mice and mink.¹⁷

Lesson and Implementation

Objective: In this activity, students will be introduced to environmental justice by learning about a Warren County, North Carolina case study that involved a hazardous waste landfill and is often cited with launching the environmental justice movement.

This lesson follows the 5E inquiry model, using Engagement, Exploration, Explanation, Elaboration, and Evaluation to promote student learning.

Issues Relating to 8th Grade Science

- Describe how humans affect the quality of water: Point and non-point sources of water pollution in North Carolina.
- Economic trade-offs.
- Local water issues.
- Recognize that the good health of environments and organisms requires: Monitoring of the hydrosphere.
- Water quality standards.
- Methods of water treatment.
- Maintaining safe water quality.
- Stewardship: Understand that both naturally occurring and synthetic substances are chemicals.
- Identify evidence that some chemicals may contribute to human health conditions. Describe risks and benefits of chemicals.

Essential Questions

- What is environmental justice?
- Why should the general public be informed about local hazardous waste sites?
- How does science inform a community's response to an environmental justice issue?
- What federal, state, and local agencies exist to protect the environment and human health?
- What are PCBs?
- Where they found in North Carolina?
- What is the chemical equation for PCBs?
- How many atoms are in the chemical equation?
- How many different elements are in the equation?
- How are people exposed to PCB pollutants in the environment?
- What are some health risks for PCB exposure?
- What is the EPA doing to fix the problem?

Teacher Preparation

To prepare for this lesson, you may choose to read the complete Warren County-Afton, NC case study. You will also want to be prepared to provide a definition of environmental justice (EJ) during the lesson. *The EPA defines EJ as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.”* Citing local examples of recent environmental justice issues can help your students to understand the relevance of this movement to their lives.

Student Preparation

This activity could be preceded by a discussion about chemicals in the environment, including hazardous chemicals and their disposal, routes of human exposure (e.g., via air, water, food) to chemicals, and landfill design to prevent groundwater contamination.

Procedure:

1. **Provide copies or present the following reading** to your class, and ask students if they can find any community concerns that might arise as a result of this scenario.

“Over 30,000 gallons of industrial waste containing the hazardous chemical polychlorinated biphenyl or PCB were dumped along approximately 243 miles of highway shoulders in 14 counties of North Carolina. Because of the quantity of soils involved and the distances to approved landfills, the State has decided to construct a new landfill in order to dispose of this hazardous waste.”

“Let’s imagine that we live in a small town where the population is approximately 1,300. Sixty-nine percent of the residents are nonwhite and twenty percent of the residents have incomes below the federal poverty level. The town is an economically depressed community. A 142-acre tract of land on the east side of town has been identified by the state as the resting place for the 60,000 tons of soil highly contaminated with PCBs. PCBs are a class of chemicals that have been determined to be hazardous to human health and reproduction. This PCB-contaminated soil will be placed into a hazardous waste landfill, as permitted by EPA regulations, which will not be used for the disposal of other wastes. *The EPA eliminated the following requirements in order for the landfill to be built here: requirement for 50 feet between the landfill and groundwater, requirement of an artificial liner, requirement of an under liner collection system.*”

End the class discussion by revealing the problem to be addressed by this activity: *Community leaders are upset about this landfill because they believed that the landfill site was intentionally selected due to its being located in a poor, rural, mostly minority community. They are determined to fight this decision and prevent the landfill from being constructed. Tell the students that now they are going to consider this story from different viewpoints and identify the various groups who are involved in this story and will identify actions each group can take to address this problem and predict how this story might end.*

Exploration: Draw a “T” chart on the board; draw a plus sign in the left hand column of the chart and a minus sign in the right hand column. Ask the class to think about how the community might benefit and or be negatively affected by the location and construction of the PCB Landfill near them. *Students might need to be prompted* to consider the positive and negative effects of the landfill on: The local economy (job opportunities), society/social well-being (living conditions), and public health and overall community infrastructure (schools, roads, emergency services, etc.).

Next, ask the students to identify the different groups involved in this case study and brainstorm actions each key group (see list below) could take to address this problem. Record student answers on the board and conclude by asking the class to predict reasonable solutions to this problem:

- Concerned Citizen Group(s) e.g., those who live near the proposed site
- Media
- Scientists/Public Health Experts
- EPA (Federal Government)
- NC Department of Natural Resources (State Government)
- Town and County officials (Local Government)

Explain: Tell the students that the scenario they just envisioned actually happened in North Carolina and suggest that students to read the summary titled Real People-Real Stories: Seeking Environmental Justice - Afton, NC (Warren County) to find out the outcome of this story and how the many groups responded. <http://avoiceline.org/envirojustice-edu/assets/warrencasestudy.pdf>

Follow up Questions

- What are PCBs used for?
- Describe risks and benefits of hazardous industrial chemicals.
- What was the evidence that PCB-contaminated soil may have impacted human health conditions?
- What were the water quality issues that this community faced as a result of this landfill?
- How was the water quality monitored at the site?
- Was the leaking landfill an example of point or non-point source pollution?
- What features of the PCB landfill resulted in dioxin contamination of groundwater?
- How does this story connect to the larger problem of a growing human population?

Next, revisit the “T” chart on the board; ask the class to reflect on how the community of Afton was both positively and negatively affected by the PCB landfill. Ask students to compare their previous predictions from step 2 with what actually occurred.

Then ask the class to describe the demographics (race/ethnicity, income, age, employment statistics, education level, etc.) of the community affected. Ask the class to discuss the evidence that race and income level were used as criteria for siting the landfill in Afton, NC.

Finally, read EPA's definition of environmental justice (EJ) as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies”.

Resources for the coal ash case study

What exactly is a coal ash pond?

<https://youtu.be/A1wRyDAmxuY>

An excellent power point to teach the locations and hazards of coal ash ponds in NC:

<https://cenrep.ncsu.edu/cenrep/wp-content/uploads/2015/07/Asiseh.pdf>

This link is a short reading about what is contained in coal ash and its dangers:

https://www.sourcewatch.org/index.php/Heavy_metals_and_coal

This link contains a neighbor letter from Duke Energy about Marshall Steam Station, which is located on Lake Norman (Catawba River).

https://www.duke-energy.com/_/media/pdfs/our-company/ash-management/safebasinclosureupdate-neighborletter-marshall-web.pdf?la=en

Below is a link to a recent video from PBS concerning issues from Hurricane Francis and the rupture of a dam holding coal ash near a power plant in Wilmington, NC.

<https://www.pbs.org/newshour/nation/floodwaters-inundate-lake-at-north-carolina-power-plant-raising-alarm>

Below is a link to an elementary detailed video of exactly what coal is.

<https://youtu.be/9Wv2GKaukZU>

The next link is a video about coal ash pollution and the toxins contained within.

<https://youtu.be/C2d70PEhhJw>

Another excellent video about coal ash pollution in NC:

https://youtu.be/OWEEe7O_vUM

Annotated Bibliography

<https://www.greenfacts.org/en/pcbs/1-2/1-polychlorinated-biphenyls.htm>

An easy to understand website about the perils of PCBs and their uses.

<http://www.clearwater.org/news/pcbhealth.html>

Another easy to use and understand website about the problems with PCB pollution and some background on the history of polluted locations.

<http://www.diabetesandenvironment.org/home/contam/pops/pcbs>

A site for the teacher to obtain statistics from studies about PCBs and their relationships with obesity and diabetes.

<https://www.med.navy.mil/sites/nmcphc/Documents/environmental-programs/risk-communication/posters/PCBSML.pdf>

An easy to understand poster that can be used as a model for a student poster project.

<https://www.ewg.org/research/anniston-alabama/monsanto-knew-about-pcb-toxicity-decades#.W56xGOhKjIU>

This site explores the cover up of the dangers of PCBs and the resulting implications of an Alabama town.

<https://www.whatisepigenetics.com/topic/epigenetics-environment/>

A blog for a teacher about epigenetics and many interesting articles about its relationship with environmental pollution.

<https://www.citylab.com/equity/2018/09/mapping-where-environmental-justice-is-most-threatened-in-the-carolinas/570985/>

An excellent site and map showing locations of pollution areas in the Carolinas.

<https://cenrep.ncsu.edu/cenrep/wp-content/uploads/2015/07/Asiseh.pdf>

A case study power point for modeling a student project about coal ash pollution.

https://www.niehs.nih.gov/health/assets/docs_f_o/lesson_nc_ej_508.pdf

<http://www.umich.edu/~snre492/cases.html>

A list of domestic and international environmental justice case studies.

<http://www.ejnet.org/ej/principles.html>

The Principles of Environmental Justice.

https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.cabarrus.k12.nc.us/site/handlers/filedownload.ashx%3Fmoduleinstanceid%3D58728%26dataid%3D111033%26FileName%3DEnergy%2520Webquest%2520.pdf&ved=2ahUKEwiTp_Ov-KTeAhXEnOAKHaoHDioQFjAAegQIAhAB&usg=AOvVaw1xPCv4bRFjvFT3_8r0m0IJ&cshid=1540585651079

Excellent simple energy web quest.

Endnotes

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Appendix 1: Implementing Teaching Standards

North Carolina 8th Grade Essential Standards

The topic of epigenetics as related to environmental pressures from exposures to air and water pollution, poor nutrition, drug use, tobacco use, alcohol use, exposure to chemical toxins and lack of exercise relates to many North Carolina 8th Grade science standards. Below is a short list of topics:

- Evidences of Chemical reactions (Burning of coal)
- Elements, Compounds and molecules (Counting atoms and balanced equations)
- Biotechnology in North Carolina
- Water Quality
- Natural Selection and Evolution
- Renewable vs. Non-renewable Resources
- Cellular Energy