How Acid Mine Drainage Has Affected the Greater Susquehanna Valley Region Local Story: Shamokin Creek, Northumberland County PA

Figure 1: An example of acid mine drainage flowing into Shamokin Creek. Notice the red-orange color of the water.

Acid mine drainage can be defined as the overflow of acidic water from abandoned mines (Websters Dictionary). It can be a byproduct from mining practices used to extract coal, copper, gold, silver, zinc, lead, and uranium (Center for Educational Technologies). In this lesson, the main focus will be on how local coal mining has contributed to the acid mine drainage problem in this area. Acid mine drainage is a form of sulfide weathering from extracting materials from below the water table (Reclamation Research Group). The main chemical reaction occurring is the oxidization of pyrite, which is also known as iron disulfide (FeS_2). The main products formed in acid mine drainage reactions are: ferrous iron and sulfuric acid, and ferric iron, which eventually turns into iron hydroxide. Sulfuric acid is the cause of the distinct smell that acid mine drainage produces. Ferric iron is mainly responsible for loss of habitat for aquatic species, while iron hydroxide is what makes the water source turn the red-orange color that is shown in the picture of Shamokin Creek above.

There are three main reactions that occur in acid mine drainage. For the sake of this lesson, the equations below that illustrate these reactions are simplified non-quantitative:

The first reaction that occurs in acid mine drainage is:

$$\mathbf{FeS_2 + O_2 + H_2O \rightarrow Fe^{+2} + H_2SO_4}$$

or (pyrite + dissolved oxygen + water) -> (ferrous iron+ sulfuric acid)

In this reaction pyrite is being oxidized and while also reacting with water from the stream. This reaction produces ferrous or soluble iron and sulfuric acid, which is the distinct smell that can be associated with acid mine drainage. Ferrous or soluble iron is the first pollutant associated with acid mine drainage as it starts to make streams too acidic to support aquatic life

The second reaction that occurs is:

$$Fe^{+2} + O_2 + H^{+} \rightarrow Fe^{+3} + H_2O$$

or (ferrous iron + oxygen +hydronium) -> (ferric iron + water)

In this reaction, oxidation of ferrous iron is occurring and this produces ferric or insoluble iron. This is the reaction that begins to coat the stream floor and damage the aquatic habitat and cause detrimental effects on the environment.

The third reaction that occurs continues this process:

$$Fe^{+3} + H_2O \rightarrow Fe(OH)_3 + H^{+}$$

or (ferric iron + water) -> (iron hydroxide + hydronium)

This final reaction is the precipitation of the ferric or insoluble iron. This is the reaction that is visible to the human eye because streams affected by this pollutant exhibit a red-orange color, as is seen in Shamokin Creek. This reaction can only occur if the pH of the stream is around 3.5 and this is extremely low for supporting aquatic life (Carl Kirby).

(all reaction equations adapted from http://www.facstaff.bucknell.edu/kirby/AMDPrimer.html)

The average pH of fresh water is about 7, which is neutral. Studies have found that streams affected by acid mine drainage can have a pH as acidic as 2.5 (Pennsylvania USGS website). This can severely impact fish populations and all aspects of aquatic ecosystems (Reclamation Research Group). If fish living in these aquatic ecosystems are directly exposed to hydronium ions, respiration through their gills can be difficult and this can eventually lead to death of entire fish populations (Reclamation Research Group). Aquatic ecosystem health is important to overall ecosystem health and biodiversity, which is why acid mine drainage is such a problematic environmental issue.

There are two ways to treat acid mine drainage: active and passive treatment. An example of passive treatment is to build a wetland next to the affected stream in order to filter out the acidity without using any direct chemical additives to the water source (Reclamation Research Group). These wetlands usually consist of limestone gravel and are covered with soil and sometimes plastic. The limestone neutralizes the acidity from the hydronium ions which makes the streams more livable for aquatic life (Carl Kirby). Even though these are considered passive systems, they are still producing active chemical reactions. Active water treatment programs use direct chemical treatments or additives to neutralize the acidity of water affected by acid mine drainage. Popular forms of active treatment are limestone or carbonate neutralization and they can be highly effective when utilized properly.

Coal Extraction in Central Pennsylvania and Acid Mine Drainage

During the late 18th and early 19th centuries, the Susquehanna Valley region was a major source for anthracite coal. Due to intrusive coal mining methods half of the land in the valley has been negatively affected (Marsh, 1987) Because of the rapid boom and bust cycle of anthracite coal mining in the valley environmental precautions were not always taken. Thus the effects are still seen today in areas like Shamokin. Acid mine drainage from abandoned coal mines has contaminated more than 3,000 miles of streams in Pennsylvania and it is the most extensive water-pollution problem affecting watersheds in Pennsylvania (Pennsylvania USGS website). The estimated cost for restoring the damaged watersheds is from $5 billion to $15 billion (Pennsylvania USGS website) because of how extensive the damage is throughout most of the state.

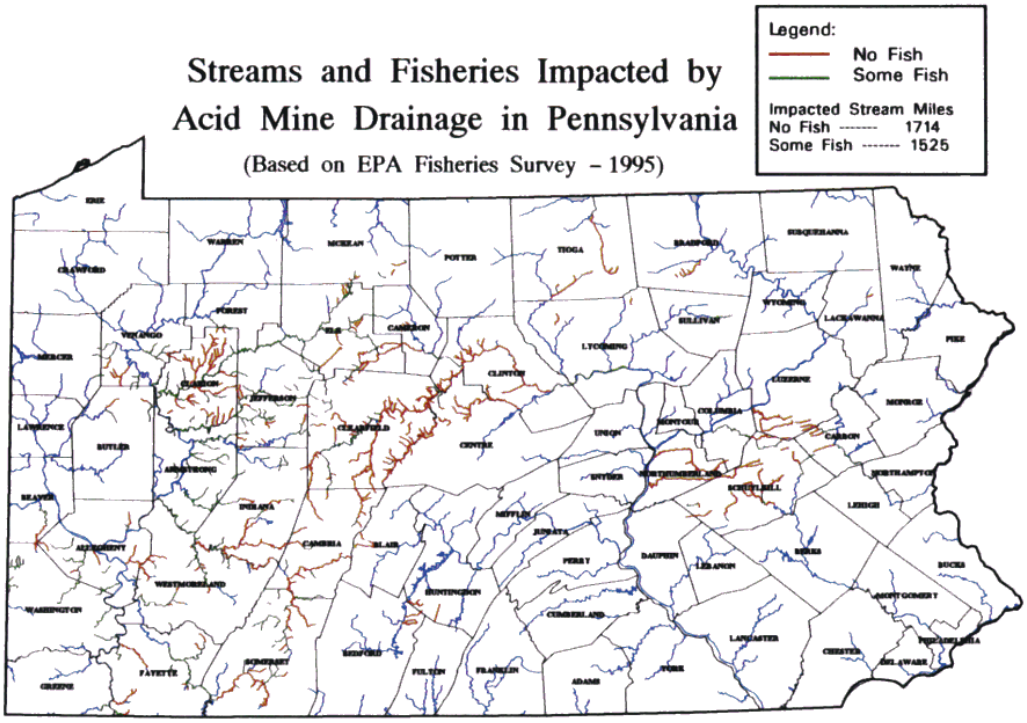

Figure 2: A map of Pennsylvania showing the streams affected by acid mine drainage. Blue streams are affected, but still have some aquatic life and orange streams have no aquatic life. Shamokin Creek is located in the area where there is a lot of orange streams in the Eastern part of the state.

Because acid mine drainage is not limited to local watersheds, there are a few regional coalitions that are fighting the effects of acid mine drainage on a large scale. The first regional coalition that was founded was the Western Pennsylvania Coalition for Abandoned Mine Reclamation or (WPCAMR). It started in 1982 and currently works with volunteers, technical experts, and government agencies to try to reclaim mines and streams polluted by coal mining. It encompasses twenty-four counties in Western Pennsylvania and focuses on education and reclamation at the local level (WPCAMP website). The other regional coalition that was established is the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation or (EPACMR). It started in 1995 and is a coalition of watershed organizations and reclamation partners focused in Eastern

Pennsylvania counties. This organization includes Northumberland County, which is where part of the Shamokin Creek watershed is located. Their main projects and initiatives include: mapping abandoned mines, GIS development, and acid mine remediation (EPCAMR website). These two coalitions are two major examples of initiatives that are being taken to neutralize acid mine drainage and restore aquatic ecosystems in the state of Pennsylvania.

Shamokin Creek

Acid mine drainage is a problem that occurs at coal mining sites globally, but a local example of its effects is Shamokin Creek located in Northumberland County, Pennsylvania. Shamokin Creek is an example of a stream that has been severely impacted. Due to the large amount of abandoned anthracite coal mines along Shamokin Creek there is high volume of acid mine drainage in this watershed area. Shamokin Creek is red-orange and is even devoid of aquatic life in some places. This is especially dangerous for overall aquatic ecosystem health because Shamokin Creek eventually flows into the Susquehanna River, which flows to the Chesapeake Bay and eventually the Atlantic Ocean. However, these effects can be minimized if initiatives are taken on the local scale and this is shown in the map below. There are four main treatment sites in the area, which are all examples of passive treatment sites.

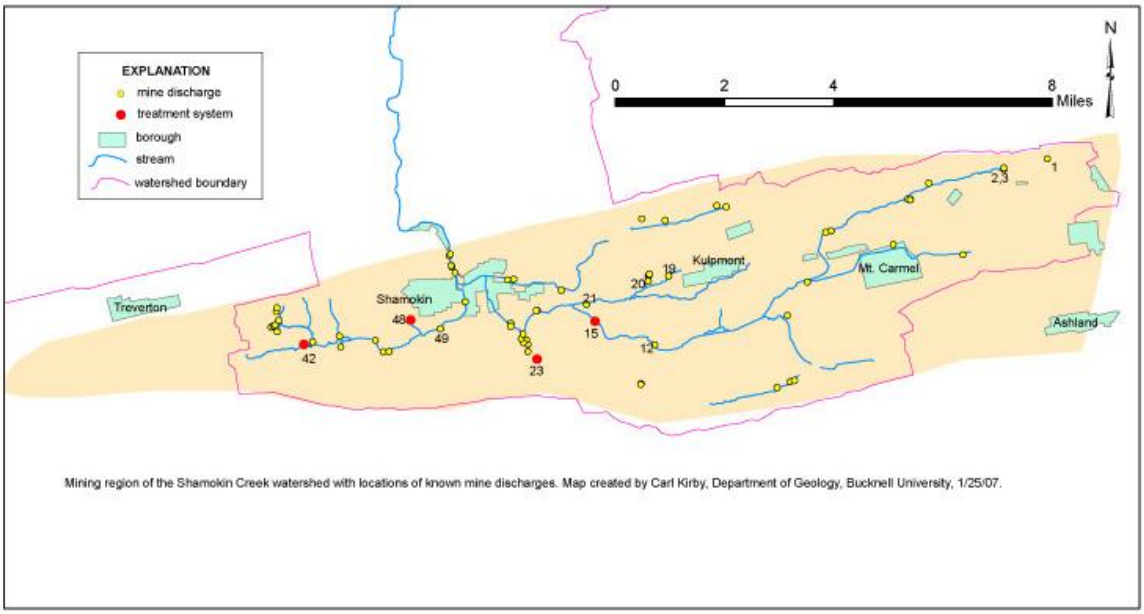

Figure 3: A map of the Shamokin Creek and its watershed. The four treatment systems, represented by the red dots, are all located close to Shamokin, but there are still multiple drainage sites that have not been treated.

These four projects were started by a local group that was established to fight the environmental effects of acid mine drainage in the Shamokin Creek. This particular group is the Shamokin Creek Restoration Alliance or (SCRA) which started in 1996 by local individuals who wanted to restore the Shamokin Creek back to its original state. They emphasize the importance of local knowledge of the mining industry for treating its environmental effects, while also admitting to its downfalls for some local ecosystems (SCRA website). They have made some strides in the past years in order to effectively

combat the effects of acid mine drainage, but there is still much to do in order to restore the aquatic ecosystem health of Shamokin Creek.

Conclusion

Acid mine drainage is a water quality issue that is typically associated with abandoned coal mines. There are three main chemical reactions that can take place when acid mine drainage is affecting a stream. The main reaction occurring is the oxidization of pyrite (iron disulfide). This reaction produces ferrous or soluble iron, and sulfuric acid. The second reaction is the further oxidization of ferrous iron and this produces ferric or insoluble iron which is responsible for extreme aquatic habitat loss. Ferric or insoluble iron is precipitated even more over time to produce ferric hydroxide which creates the red-orange color typically associated with acid mine drainage. These reactions can take place over long periods of time which is why acid mine drainage is still a problem today, if it is not treated. There are many regional and local programs that have been established in order to fight the ecosystem effects that have been caused by acid mine drainage. Locally, Shamokin Creek is an example of a watershed that has been damaged by acid mine drainage, but steps are being taken to restore it by the Shamokin Creek Restoration Alliance, which is an example of a local resource for environmental problems.

By Ashley Urban

Pennsylvania Curriculum Standards Met

Academic Standards for Environment and Ecology

Pennsylvania Department of Education

XI. INTRODUCTION

This document includes Environment and Ecology standards that describe what students should know and be able to do in these areas:

- 4.1. Watersheds and Wetlands
- 4.2. Renewable and Nonrenewable Resources
- 4.3. Environmental Health
- 4.4. Agriculture and Society
- 4.5. Integrated Pest Management
- 4.6. Ecosystems and their Interactions
- 4.7. Threatened, Endangered and Extinct Species
- 4.8. Humans and the Environment
- 4.9. Environmental Laws and Regulations

The Declaration of Rights, Article I of the Pennsylvania Constitution states in Section 27: "The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people." To this end it is our responsibility to develop a citizenry that is aware of and concerned about the total environment and has the knowledge and skills to work toward solutions to current problems and the prevention of new ones.

Environment and Ecology is grounded in the complexity of the world we live in and our impact on its sustainability. The human interactions with the ecosystem and the results of human decisions are the main components of this academic area. Environment and Ecology examines the world with respect to the economic, cultural, political and social structure as well as natural processes and systems. This integration across systems is what sets this academic area apart from all others.

Environment and Ecology places its main emphasis in the real world. It allows students to understand, through a sound academic content base, how their everyday lives evolve around their use of the natural world and the resources it provides. As we move into a more technologically driven society, it is crucial for every student to be aware of his/her dependence on a healthy environment. The 21st century will demand a more sophisticated citizen capable of making sound decisions that will impact our natural systems forever.

4.2. Renewable and Nonrenewable Resources

4.2.4. GRADE 4	4.2.7. GRADE 7	4.2.10. GRADE 10	4.2.12. GRADE 12
Pennsylvania's public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to:			
A. Identify needs of people. • Identify plants, animals, water, air, minerals and fossil fuels as natural resources. • Explain air, water and nutrient cycles. • Identify how the environment provides for the needs of people.	A. Know that raw materials come from natural resources. • Identify resources used to provide humans with energy, food, housing and water. • Explain how plants and animals may be classified as natural resources. • Compare means of growing or acquiring food. • Identify fiber and other raw materials used in clothing and shelter production. • Identify types of minerals and fossil fuels used by humans.	A. Explain that renewable and nonrenewable resources supply energy and materials. • Identify alternative sources of energy. • Identify and compare fuels used in industrial and agricultural societies. • Compare and contrast the cycles of various natural resources. • Explain food and fiber as renewable resources.	A. Analyze the use of renewable and nonrenewable resources. • Explain the effects on the environment and sustainability through the use of nonrenewable resources. • Evaluate the advantages and disadvantages of reusing our natural resources.
B. Identify products derived from natural resources. • Identify products made from trees. • Identify by-products of plants and animals. • Identify the sources of manmade products (e.g., plastics, metal, aluminum, fabrics, paper, cardboard).	B. Examine the renewability of resources. • Identify renewable resources and describe their uses. • Identify nonrenewable resources and describe their uses. • Compare finished products to their original raw material. • Identify the waste derived from the use of renewable and nonrenewable resources. • Determine how consumption may impact the availability of resources. • Compare the time spans of renewability for fossil fuels and	B. Evaluate factors affecting availability of natural resources. • Describe natural occurrences that may affect the natural resources. • Analyze technologies that affect the use of our natural resources. • Evaluate the effect of consumer desires on various natural resources.	B. Analyze factors affecting the availability of renewable and nonrenewable resources. • Evaluate the use of natural resources and offer approaches for using them while diminishing waste. • Compare the economics of different areas based on the availability and accessibility of the natural resources.

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C. Know that some natural resources have limited life spans. • Identify renewable and nonrenewable resources used in the local community. • Identify various means of conserving natural resources. • Know that natural resources have varying life spans.	alternative fuels. C. Explain natural resource distribution. • Distinguish between readily available and less accessible resources. • Identify the locations of different concentrations of fossil fuels and mineral resources. • Analyze the effects of management practices on air, land and water in forestry, agriculture, fisheries, wildlife, mining and food and fiber production that is unique to different climates.	C. Analyze how man-made systems have impacted the management and distribution of natural resources. • Explain the complete cycle of a natural resource, from extraction to disposal, detailing its uses and effects on the environment. • Analyze energy uses and energy conservation in different regions. • Examine conservation practices in different countries. • Analyze the costs and benefits of different man-made systems and how they use renewable and nonrenewable natural resources. • Analyze the impact of information systems on management and distribution of natural resources.	C. Analyze factors that influence the availability of natural resources. • Compare the use of natural resources in different countries. • Determine how delivery systems influence the availability of resources at the local, regional and national level.
D. Identify by-products and their use of natural resources. • Understand the waste stream. • Identify those items that can be recycled and those that can not. • Identify use of reusable products. • Identify the use of compost, landfills and incinerators.	D. Describe the role of recycling and waste management. • Identify materials that can be recycled in the community. • Explain the process of closing the loop in recycling. • Compare the decomposition rates of different organic materials. • Describe methods that could be used to reuse materials for new products. • Evaluate the costs and benefits of disposable products.	D. Explain different management alternatives involved in recycling and solid waste management. • Analyze the manufacturing process (before, during and after) with consideration for resource recovery. • Compare various methods dealing with solid waste (e.g., incineration, compost, land application). • Differentiate between pre/post-consumer and raw materials. • Illustrate how one natural resource can be managed through reduction, recycling, reuse or use.	D. Evaluate solid waste management practices. • Examine and explain the path of a recyclable material from collection to waste, reuse or recycling identifying the market forces. • Understand current regulations concerning recycling and solid waste. • Research new technologies in the use, reuse or recycling of materials.

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4.3. Environmental Health			
4.3.4. GRADE 4	4.3.7. GRADE 7	4.3.10. GRADE 10	4.3.12. GRADE 12
Pennsylvania's public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to:			
A. Know that plants, animals and humans are dependent on air and water. • Know that all living things need air and water to survive. • Describe potentially dangerous pest controls used in the home. • Identify things that cause sickness when put into the air, water or soil. • Identify different areas where health can be affected by air, water or land pollution. • Identify actions that can prevent or reduce waste pollution.	A. Identify environmental health issues. • Identify various examples of long-term pollution and explain their effects on environmental health. • Identify diseases that have been associated with poor environmental quality. • Describe different types of pest controls and their effects on the environment. • Identify alternative products that can be used in life to reduce pollution.	A. Describe environmental health issues. • Identify the effects on human health of air, water and soil pollution and the possible economic costs to society. • Describe how indoor pollution may affect human health (e.g., dust mites, fumes, cat dandruff). • Explain the costs and benefits of cleaning up contaminants. • Explain how common household cleaning products are manufactured and how to dispose of their by-products after use.	A. Analyze the complexity of environmental health issues. • Identify environmental health issues and explain how they have been addressed on a worldwide level. • Analyze efforts to prevent, control and/or reduce pollution through cost and benefit analysis and risk management. • Describe the impact of occupational exposures as they relate to environmental health issues. • Identify invisible pollutants and explain their effects on human health. • Explain the relationship between wind direction and velocity as it relates to dispersal and occurrence of pollutants. • Explain the different disposal methods used for toxic and hazardous waste.
B. Identify how human actions affect environmental health. • Identify pollutants. • Identify sources of pollution. • Identify litter and its effect on the environment. • Describe how people can reduce	B. Describe how human actions affect the health of the environment. • Identify land use practices and their relation to environmental health. • Explain how natural disasters affect environmental health.	B. Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices. • Explain how human practices affect the quality of the water and soil.	B. Analyze the local, regional and national impacts of environmental health. • Analyze the cost of natural disasters in both dollars and loss of natural habitat. • Research and analyze the local, state and national laws that deal with

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pollution. C. Understand that the elements of natural systems are interdependent. • Identify some of the organisms that live together in an ecosystem. • Understand that the components of a system all play a part in a healthy natural system. • Identify the effects of a healthy environment on the ecosystem.	• Identify residential and industrial sources of pollution and their effects on environmental health. • Explain the difference between point and nonpoint source pollution. • Explain how nonpoint source pollution can affect the water supply and air quality. • Explain how acid deposition can affect water, soil and air quality. • Explain the relationship between resource use, reuse, recycling and environmental health. C. Explain biological diversity. • Explain the complex, interactive relationships among members of an ecosystem. • Explain how diversity affects ecological integrity of the natural resources.	• Identify evidence of natural events around the world and their effects on environmental health (e.g., Yellowstone National Park fires). • Identify local and state environmental regulations and their impact on environmental health. • Analyze data and explain how point source pollution can be detected and eliminated. • Identify and explain ways of detecting pollution by using state-of-the-art technologies. C. Explain biological diversity as an indicator of a healthy environment. • Explain species diversity. • Analyze the effects of species extinction on the health of an ecosystem.	point and nonpoint source pollution; evaluate the costs and benefits of these laws. • Explain mitigation and its role in environmental health. • Explain industry's initiatives to meet state and federal mandates on clean air and water. • Describe the impacts of point and nonpoint source pollution on the Chesapeake Bay. • Identify and evaluate the costs and benefits of laws regulating air and water quality and waste disposal. C. Analyze the need for a healthy environment. • Research the relationship of some chronic diseases to an environmental pollutant. • Explain how man-made systems may affect the environment.

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• underground. B. Understand the concept of cycles. • Explain the water cycle. • Explain the carbon dioxide/oxygen cycle (photosynthesis). C. Identify how ecosystems change over time.	biomes and their characteristics. • Identify the relationship of abiotic and biotic components and explain their interaction in an ecosystem. • Explain how different soil types determine the characteristics of ecosystems. B. Explain the concepts of cycles. • Identify and explain cycles within an ecosystem. • Analyze the role of different cycles within an ecosystem. C. Explain how ecosystems change over time. • Explain how ecosystems change. • Identify the succession stages of a given ecosystem. • Explain how specific organisms may change an ecosystem. • Explain a change in an ecosystem that relates to humans.	environments to sustain their needs. • Assess the effects of latitude and altitude on biomes. • Interpret possible causes of population fluctuations. • Explain how erosion and sedimentation have changed the quality of soil related habitats. B. Explain how cycles affect the balance in an ecosystem. • Describe an element cycle and its role in an ecosystem. • Explain the consequences of interrupting natural cycles. C. Analyze how ecosystems change over time. • Identify and explain the succession stages in an ecosystem. • Identify causes of succession. • Analyze consequences of interrupting natural cycles.	B. Analyze the impact of cycles on the ecosystem. • Evaluate the materials necessary for natural cycles. • Explain the processes involved in the natural cycles. C. Analyze how human action and natural changes affect the balance within an ecosystem. • Analyze the effects of substances that move through natural cycles. • Analyze the effects of natural occurrences and their effects on ecosystems. • Analyze effects of human action on an ecosystem. • Compare the stages of succession and how they influence the cycles existing in an ecosystem.

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4.8. Humans and the Environment			
4.8.4. GRADE 4	4.8.7. GRADE 7	4.8.10. GRADE 10	4.8.12. GRADE 12
Pennsylvania's public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to:			
A. Identify the biological requirements of humans. • Explain how a dynamically changing environment provides for sustainability of living systems. • Identify several ways that people use natural resources.	A. Describe how the development of civilization relates to the environment. • Explain how people use natural resources in their environment. • Locate and identify natural resources in different parts of the world. • Compare and contrast how people use natural resources throughout the world.	A. Analyze how society's needs relate to the sustainability of natural resources. • Explain why some societies have been unable to meet their natural resource needs. • Compare and contrast the use of natural resources and the environmental conditions in several countries. • Describe how uses of natural resources impact sustainability.	A. Explain how technology has influenced the sustainability of natural resources over time. • Describe how technology has changed the use of natural resources by business and industry. • Analyze the effect of natural resource conservation on a product over time (e.g., automobile manufacturing, aluminum can recycling, paper products).
B. Know that environmental conditions influence where and how people live. • Identify how regional natural resources influence what people use. • Explain the influence of climate on how and where people live.	B. Explain how people use natural resources. • Describe how natural resources are used for survival. • Explain how natural resources and technological changes have affected the development of civilizations. • Explain how climate and extreme weather events (e.g., drought, flood) influence people's lives.	B. Analyze the relationship between the use of natural resources and sustaining our society. • Explain the role of natural resources in sustaining society. • Analyze the effects of a natural resource's availability on a community or region.	B. Analyze technology's role on natural resource sustainability. • Explain how technology has decreased the use of raw natural resources. • Explain how technology has impacted the efficiency of the use of natural resources. • Analyze the role of technology in the reduction of pollution.

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C. Explain how human activities may change the environment. • Identify everyday human activities and how they affect the environment. • Identify examples of how human activities within a community affect the natural environment.	C. Explain how human activities may affect local, regional and national environments. • Describe what effect consumption and related generation of wastes have on the environment. • Explain how a particular human activity has changed the local area over the years.	C. Analyze how human activities may cause changes in an ecosystem. • Analyze and evaluate changes in the environment that are the result of human activities. • Compare and contrast the environmental effects of different industrial strategies (e.g., energy generation, transportation, logging, mining, agriculture).	C. Analyze how pollution has changed in quality, variety and toxicity as the United States developed its industrial base. • Analyze historical pollution trends and project them for the future. • Compare and contrast historical and current pollution levels at a given location.
D. Know the importance of natural resources in daily life. • Identify items used in daily life that come from natural resources. • Identify ways to conserve our natural resources. • Identify major land uses in the community.	D. Explain the importance of maintaining the natural resources at the local, state and national levels. • Explain how human activities and natural events have affected ecosystems. • Explain how conservation practices have influenced ecosystems. • Define the roles of Pennsylvania agencies that deal with natural resources.	D. Explain how the concept of supply and demand affects the environment. • Identify natural resources for which societal demands have been increasing. • Identify specific resources for which human consumption has resulted in scarcity of supply (e.g., buffalo, lobsters). • Describe the relationship between population density and resource use and management.	D. Analyze the international implications of environmental occurrences. • Identify natural occurrences that have international impact (e.g., El Nino, volcano eruptions, earthquakes). • Analyze environmental issues and their international implications.

Further Classroom Activities Relating to Acid Mine Drainage

http://www.cotf.edu/ete/modules/waterq3/WQmain.html

- This activity provides for an overall understanding of water quality as an environmental issue and it includes all of the different kinds of water pollution in the lesson.

http://serc.carleton.edu/NAGTWorkshops/geochemistry/activities/9082.html

- This field lab activity teaches students how to take water samples and gives them experience in the field. This is useful because it allows them to interact with an acid mine drainage site firsthand.

Further Local Resources for Treating Acid Mine Drainage

http://www.facstaff.bucknell.edu/kirby/AMDtrmt.html

- A resource about all aspects of acid mine drainage treatment including: chemical reactions, images, and examples of local treatment facilities.

http://www.facstaff.bucknell.edu/kirby/0SCRAnewHome/SCRAhome.htm

- The Shamokin Creek Restoration Alliance (SCRA) website is a helpful resource for information about acid mine drainage, their projects, and links to other local resources.

Sources

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http://www.dep.state.pa.us/dep/deputate/minres/districts/AMDPostMortem.html
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http://www.facstaff.bucknell.edu/kirby/AMDPrimer.html

Figures (in order of appearance)

Figure 1: http://farm4.staticflickr.com/3591/3502701636_db54cf068f_z.jpg
Figure 2: http://pa.water.usgs.gov/projects/energy/amd/images/amdmap.gif
Figure 3: http://www.facstaff.bucknell.edu/kirby/WshedMap.html