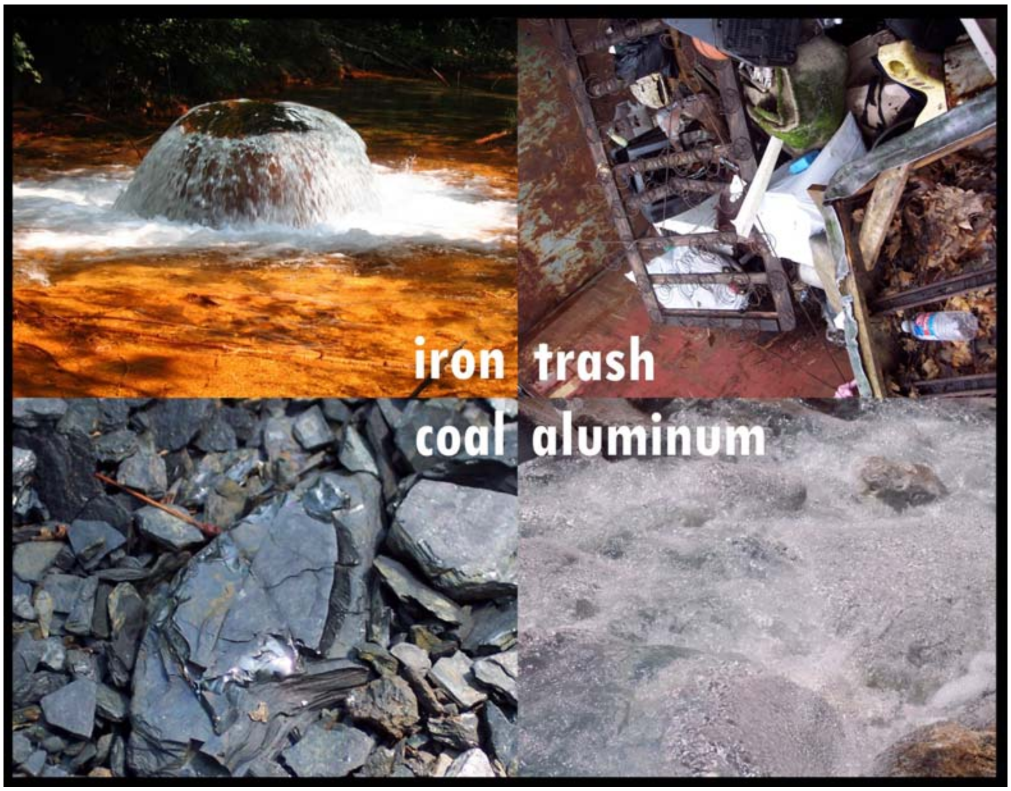
What's in Your Water?

Abandoned Mine Drainage in Local Watersheds

AN EDUCATION MODULE



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www.OrangeWaterNetwork.org
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Type of Program: This is an Interactive discussion with games and hands-on experiments.

Goals: The goal of this lesson is to understand the effects of abandoned mine drainage (AMD) on water chemistry, aquatic life, and human consumption by discussing it in relation to non-point source pollution.

Objectives: The participants will be able to:

1. Define *AMD, watershed, non-point and point source pollution*
2. Discuss the pH scale
3. Connect the health of invertebrates to the health of the stream
4. Connect human activities to their effect on steam life
5. Understand how polluted water influences human activity
6. Discover ways to improve their watershed

Curriculum Standards: *(met in part or whole)*

Pennsylvania Department of Education:
Environment & Ecology: 4.1.4E, 4.1.10E, 4.3.4A,B,C, 4.8.4C, 4.8.7C
Science & Technology: 3.2.4C, 3.4.7A, 3.5.4A
Reading, Writing, Speaking, Listening: 1.6.3A, 1.6.5A, 1.6.8A, 1.6.11A

Virginia Standards of Learning:
1.1, 1.5/ 2.1, 2.5/ 3.1, 3.6, 3.7, 3.9, 310, 3.11/ 4.1, 4.5, 4.8/ 5.5, 5.7/ 6.1, 6.7, 6.8/ LS.7, LS.12/ PS.2, PS.5/ ES.7, ES.9/ BIO.3/ CH.6.

Target Groups: School groups (adapted for kindergarten through 12th grade)

Equipment: Map of local watershed, bag of orange AMD sludge, photos of AMD sites, pH scale, pH testing equipment, water samples (drinking water, orange mine discharge, clear mine discharge), and shirt tie-dyed with AMD.

Evaluation: Review topics covered during program with a quizzing game.

BACKGROUND

Abandoned mine drainage (AMD), a type of non-point source water pollution, exists throughout the world and within our country, especially in Appalachia. Each discharge degrades all water downstream, elevating mine drainage to a watershed level concern. AMD comes from chemical reactions, uncommon in nature, which occur because mining exposes earthen layers to air and water. The orange result exterminates aquatic life. Correcting these discharges requires building a specialized treatment system specific to each site's water chemistry. Many organizations and individuals cooperate to construct these systems. Broadening awareness enlists community support. Community support is the first step to treatment and remains our greatest chance to eliminate this pollution.

To learn about mine drainage we must examine its effect on watersheds: how water obtains pollutants from mines, the effect of one particular pollutant – iron oxide – on aquatic and human life, and options to remove these pollutants from our waterways.

How Abandoned Mine Sites Contaminate Water

Underground mines and surface mines expose rocks and minerals to air and water; consequences accompany this human-made alteration. Pyrite is the most common mineral in coal mines. Physical and chemical weathering of pyrite, the first reaction, takes place within the mine. Here, this mineral bonds with oxygen, producing sulfate and ferrous iron. The reaction generates one unit of ferrous iron for each unit of oxidized pyrite.

(1) $FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$
(1) pyrite + oxygen + water → ferrous iron + sulfate + acidity

When this water exits the mine, it contacts oxygen, causing the second reaction to occur. Ferrous iron oxidizes, forming ferric iron. Certain bacteria can metabolize iron, and increase the rate of the reaction, if in this situation the pH value nears 5. At lower pH values these bacteria do not exist, in which case the process of oxidizing iron slows. Also at this time, sulfur from the first step may evaporate as gaseous sulfate compounds (SO_4^-), or a rotten egg scent. Losing aqueous sulfur sometimes elevates the water's pH. This reaction is the "rate determining step" in the overall acid-generating sequence.

(2) $2\ Fe^{2+} + ½\ O_2 + 2\ H^+ \rightarrow 2\ Fe^{3+} + H_2O$
(2) ferrous iron + oxygen + acidity → ferric iron + water

Hydrolysis of iron transpires as the third reaction, responsible for splitting water molecules. Formation of ferric hydroxide precipitate (when dissolved iron becomes solid, granular sediment clouding the water or settling on the stream channel bottom) depends upon pH. This orange sediment is also called iron oxide, rust, or yellowboy. If the pH is above 3.5, this sediment becomes visible more quickly. If it is below this value, little or no solids will form; instead, these heavy metals will remain dissolved in the water, often unseen.

(3) $Fe^{3+} + 3\ H_2O \rightarrow Fe(OH)_{3\downarrow} + 3\ H^+$
(3) ferric iron + water → ferric hydroxide + acidity

The result of abandoned mine lands' chemical reactions with air and water produce widespread non-point source pollution that is difficult to remediate (*AMD Education Modules*, C1.3.25.3).

Iron Oxide's Effect on Aquatic and Human Life

The layer of iron oxide on creek beds is not toxic to humans, though it is lethal for aquatic life. For humans, this silt-like iron solid is not dangerous to touch or smell, unless the discharge also contains poisonous heavy metals like aluminum. Aquatic macroinvertebrates (underwater insects, insect larvae, and crustaceans without backbones) respond to this iron coating in the same manner as any sediment. They die from buried habitats and clogged gills. Without the presence of these prey species, fish no longer live in affected waterways. Mine drainage in any tributary negatively impacts the biodiversity of all water downstream and the human activities that thrive on that water and its biodiversity.

Remediation for This Pollution

Remedying this orange waste entails cleaning the polluted water near the place it first emerges into the air. Cleaning this water may be accomplished with chemical treatment, wetland ecosystems, or a combination. Remediation techniques are relatively new and develop rapidly. However, two certainties do exist. Treatment must be specific to each site's unique water chemistry, and establishing such a system requires a team of community organizations, government agencies, engineers, scientists, and businesses.

Smaller groups and individuals play essential roles both directly and indirectly in site treatment. Directly, they act as part of the remediation team described above, assist with treatment preparations such as water monitoring, and build vital community support. Outside of direct treatment, educating others about orange water is one of the most important tasks to complete.

Hands-on education projects facilitate connections between people and their local environment. Possible projects for non-point source pollution other than AMD include removing litter, planting trees on a stream bank to control soil sedimentation, or managing large amounts of animal waste. Addressing AMD by repairing other forms non-point source pollution reinforces a watershed view. Employing any of the multiple uses for iron oxide pigment including tie-dye shirts, paints, and chalk, builds awareness in its makers and fashions a market for the compound that will be supplied perpetually.

Remediation in every country, state, and town where this drainage exists is essential. Over 4,000 Pennsylvanian stream miles suffer from this devastation, the state's greatest source of water pollution. While each discharge spurs a long reach of damage, one treatment system cleanses many miles of stream. Restoration continues while communities obtain funding, advance awareness, and organize widespread support.

PROCEDURE

Introduction

Ask the class a question, such as one of those below, and let each student provide their name and an answer.

- What is your favorite sound at a creek?
- Name a plant or animal that lives in a stream.
- What is your favorite thing to do in a creek?
- What color is the creek water where you play?

Watersheds

Local Watershed

- Introduce a map of the local watershed and define the term.
- Choose volunteers to come to the front of the room and point to specific locations on the map that you request such as:
  - their school
  - the creek nearest to their school
  - other land marks they will recognize
- Ask the last volunteer to trace, with a finger, the creek nearest the school. Begin at the school or an upstream location and end in the river to which it travels.
- Ask class to define a watershed.

Larger Watershed

- Show or discuss a map of a regional watershed that includes the local stream and the largest body of water in which it ends, such as an ocean or bay.
    - In what state does this larger watershed begin?
    - In what body of water does it empty?
    - If you threw a paper cup in the creek near your school, could it float all the way to the Chesapeake Bay?

<u>Pollution Sources</u>

- Explain point-source pollution to the students.
    - *(If you are walking down your creek and see a pipe with black goo dripping in to the stream, you know that is point-source pollution because you can point at the exact spot where pollution enters the stream.)*
- Explain non-point source pollution.
    - When it rains, water falls on the ground and travels to the stream.
    - Can the water pick-up objects and take them to the stream? What objects do they carry?
        - *(In floods: cars, people, houses, cows)*
        - *(In average rainstorms: dirt, oil in parking lots, grass clippings, sticks, loose dirt, animal waste)*
    - Can you point to the exact place where this dirt begins? *(No, it comes from too many places and that is why it is called non-point source pollution.)*
- **Suggested Activity:** Stormwater Filter Game

<u>Abandoned Mine Drainage</u>

- Abandoned Mine Drainage (AMD) is another form of non-point source pollution.
    - Show picture of orange creek.
    - Who has seen a creek like this before?
    - Pass around bag of sludge.
- Discuss local mine drainage sites.
    - List a few local creeks that are affected by mine drainage.
    - Show pictures of these.
- Discuss its affects and sources.
    - Where does it come from? *(abandoned coal mines)*
    - What makes it orange?
        - HINT: What happens when your bike is left in the rain? *(rust)*
    - What is rust made of? From which metal does rust come from? *(iron, oxygen)*
    - Discuss local creeks with AMD
        - What does this do to animals that live in the creek? *(impairs gills, destroys habitat)*
        - Is this water toxic or poisonous? Would your finger fall off? *(No, iron does not hurt humans through direct contact. This sediment is toxic to animals. If the water is acidic or contains metals other than iron it can become toxic to humans, and remains lethal to aquatic life.)*
    - Where does the iron enter the water? What rocks are in a mine? *(coal, dirt, pyrite)*
    - Explain how water becomes orange.
        - *(Pyrite is made of iron and sulfur.)*

        - *(Instead of chunks of fool's gold swimming down the river, orange clay enters the water. Acidity of the water dissolves this metal. When the water becomes less acidic, the iron becomes a solid, bonds with oxygen, and coats the stream bottom.)*
- **Suggested Activity:** Mine Drainage Role Play

<u>Acid/Base Discussion</u>

- Give the pH scale handouts to the students to share.
- Who has seen or used a pH scale before?
- Introduce the scale.
    - *(The ph scale begins at 1 and goes to 14. Seven is the middle of the scale and is neutral. Any number less than 7 is an acid and any number higher than 7 is a base.)*
- Ask students for examples of acids, bases, and neutrals.
    - What is the most acidic thing on your handout? The most basic?
- **Suggested Activity:** Limestone Experiment

<u>pH Testing</u>

- Introduce pH test.
    - Explain the three different samples of water that will be tested.
        - orange mine drainage
        - clear mine drainage
        - drinking water
    - Explain how the test works *(compare it to litmus paper or testing pool water)*
        - show equipment
        - drop indicator into water *(color changes)*
        - compare the color to the color wheel to determine pH
    - Make predictions.
        - Consider each water sample one at a time. Ask the class to guess if each sample will be basic, acidic, or neutral. Record their guesses on the chart.

	GUESS	**ACTUAL**	**ACID, BASE, OR NEUTRAL?**
Orange Mine Drainage			
Clear Mine Drainage			
Drinking Water			

    - Choose volunteers
        - *(For younger children, have two volunteers test one water sample, present results, and then call two more volunteers to test the next sample. Let one test happen at a time.)*
        - *(For older youth, have three volunteers come to the front together. Let each student test one sample, all three tests occur at the same time.)*
        - *(For smaller groups, divide class into 3 groups, if age appropriate supervision is available, and let each group test a sample together and write their answer on the blackboard.)*

- Evaluate tests
  - Let the class look at the completed chart. Ask if each pH is acidic, basic, or neutral and write the answer beside its pH value on the chart.
  - Which water sample is the most acidic? Why?
  - Is the pH of the tap water what we expected?
  - If the pH of the most acidic water sample is raised, what dissolved metal would precipitate?

Evaluation

- What can you do to prevent or clean AMD?
  - *(Students usually struggle to find an answer. It takes special treatment systems to clean orange water, but AMD is just one type of non-point source pollution.)*
  - How can you clean or prevent other types of pollution?
    - *(pick up litter or dump sites)*
    - *(only use what you need of lights and cars, so excess pollution is not made)*
    - *(wear a tie-dye shirt, so your friends will ask you about it. The most important thing you can do is to help other people learn about this so there will be more hands helping to clean and prevent.)*
  - For what can this sludge be used?
    - *(Pigment for stains, paints, or dyes)*
    - *(Tie-dye shirts. Show example.)*
- **Suggested Activity:** AMD Jeopardy

ACTIVITIES

Stormwater Filter Game

Materials: none.

This is a game that is similar to a less mobile version of tag and demonstrates how plants reduce or eliminate non-point source pollution. There are three scenarios: rainwater on a paved parking lot, rainwater on a grassy hill, and rainwater in a wetland.

1. **For each round, choose several students to be the plants and place them in a row facing the class. "Plants" should stand so that their outstretched arms do not touch each other.**
2. **Choose several more students to be rain. Those students should line up shoulder-to-shoulder facing the line of "plants."**
3. **On your mark, the rain students run through the wall of plant students.**
4. **Those tagged by the "plants" become plants immediately and beginning tagging other "rain" still nearby. The "rain" not tagged by "plants" have escaped.**

Part I – Parking Lot

The "plants" are those little pieces of grass that grow in the pavement cracks. Space these plant volunteers farther apart than the other scenarios. They have roots and cannot move their feet from their spot in line. Their arms must stay at their sides. Rain may only be tagged by bending towards them with head or shoulders.

Usually all of the rain escapes this grass. In nature, a paved parking lot does not absorb any rain. All of the oil residue and litter is picked up by the stormwater, carried through stormwater drains, and directly deposited into streams , or waste water treatment facilities, receiving these drains.

Part II – Grassy Hill

This time the "plants" in this round continue to be grass, not moving their feet or arms. "Rain" may only be tagged by bending. However, there will be more plant volunteers and they will be placed a little closer to each other.

Less than half of the rain is usually tagged in this scenario. While a grassy hill slows stormwater a little and absorbs some direct pollution, many pollutants still reach receiving streams and facilities.

Part III – Wetlands

In a wetland the "plants" will be plentiful and placed closer together than the other two rounds. While these plants continue to have roots that do not let them stray from their line, they now have branches and may also use their arms to tag "rain."

Only the most wily "rain" will escape the wetland. Wetlands are sponges for stormwater, collecting and holding a great volume for a longer amount of time than most other ecosystems. This allows the soil to absorb the stormwater where it is purified while percolating through the lithosphere. This is necessary to recharge springs and groundwater sources.

Limestone Experiment

Materials: bowl, limestone, hydrochloric acid (HCl), a dropper.

Have you ever mixed baking soda and vinegar? The fizzing that results evidences the acid and the base neutralizing. In this demonstration the presenter will place a few drops of HCL, a strong acid, onto the limestone. If the limestone is a base it will begin to fizz. If it is an acid, nothing will happen.

1. **Do you think limestone is an acid or base? Take a vote.**
2. **Have students crowd around you to watch this demonstration.**
3. **Place a few drops of HCl onto the limestone. It fizzes.**
4. **Here are some evaluation questions to ask the students.**
    a. **Is the limestone an acid or a base?** (A base.)
    b. **Why was there fizz?** (It was the result of neutralization.)
    c. **Was there more of the base or the acid in this demonstration?** (Base.)
    d. **Which was neutralized, the acid or the base?** (The acid.)

Mine Drainage Role Play

Materials: a piece of coal, a piece of pyrite, an orange blanket.

Guide students through acting Part I, then briefly discuss what they demonstrated. Follow the same pattern for Part II.

Part I – Water enters the mine and dissolves pyrite.

1. **Choose four volunteers: coal, pyrite, oxygen, and water.**
2. **Hand a piece of coal to the student representing coal.**
3. **Give the piece of pyrite to the student representing pyrite.**
4. **The student playing oxygen jumps and twirl around others.**
5. **On your count, the student being water rushes onto the scene and steals pyrite away.**

Part II – Water becomes orange when iron is exposed to oxygen and becomes rust.

1. **Choose four volunteers: iron, two hydrogen, oxygen.**
2. **Iron stands on the scene.**
3. **The hydrogen and oxygen link arms to become water and march around iron.**
4. **Freeze the scene and rearrange the volunteers. One hydrogen stands alone and the other three (iron, oxygen, and one hydrogen) join arms creating rust (iron hydroxide).**
5. **Unfreeze the scene and have the new molecule fall to the ground. Throw an orange blanket over them.**

AMD Jeopardy

Materials: index cards with a question on one side and a monetary value on the other.

1. Setup the game on a chalk board by writing the topic, which is AMD, and question values: 100, 200, 300, 400, and 500. The goal is for the class to answer each question correctly.
2. **Students raise their hands to choose a question and then answer it.**
3. **If a student cannot answer a question he/she may phone a friend or poll the audience.** Phoning a friend lets the student answering the question choose one person to answer the question in his/her place. Polling the audience lets the student ask the entire class for their suggestions and then choose the one he/she likes best.
4. **The class wins the points, if the question is answered correctly.**
5. **Play this game until the class period ends, or until all questions are answered.**

VOCABULARY

Abandoned Mine Drainage (AMD): Exposure of rocks and minerals to air and water and the pollution created by the chemical reactions that occur.

Coal: A sedimentary rock created with decaying plant material and geologic pressure.

Erosion: This occurs when sediment (soil, gravel, sand, etc) moves by water or air. This is a problem when large amounts are washed by water into streams.

Non-Point Source Pollution: Pollution whose source comes from many tiny, widespread places.

pH: A way to classify the acidic and basic qualities of liquid materials.

Point Source Pollution: Pollution with one, certain origin.

Pyrite: This inexpensive mineral made of iron and sulfur is also known as Fool's Gold. It is commonly found with coal deposits.

Stormwater: Refers to the water that reaches the earth's surface during a rain event.

Treatment System: These are designed and built to remove non-point source pollutants associated with mining from water.

Watershed: An area of land and the network of streams to which all of its water drains.

Wetland: This is an ecosystem of water-loving plants, animals, and soil that holds a large amount of water.

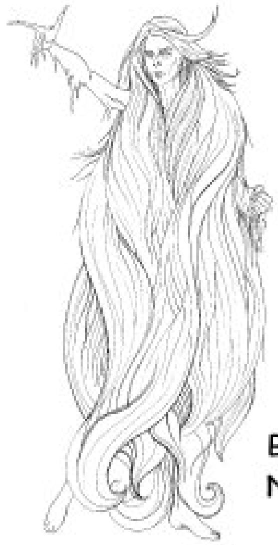
RESOURCES

Environmental Concern, Inc. and The Watercourse. 2003. *WOW!: The Wonders of Wetlands*. Published through a partnership of Environmental Concern, Inc., St. Michael's, MD. and The Watercourse, Bozeman, MT.

Environmental Concern, Inc., The Watercourse, and Project WET. 1995. *Project WET: Curriculum and Activity Guide*. This program is sponsored by the Department of Education Office of Curriculum & Academic Services, 333 Market Street, Harrisburg, PA 17126. http://pixel.cs.vt.edu/sol.html .

Saint Vincent College Environmental Education Center. *AMD Education Modules*. 300 Fraser Purchase Road, Latrobe, PA 15650. 724-532-6600. http://facweb.stvincent.edu/eec/Lessons.htm .

The pH Scale



Color the boxes below with the color that is mentioned above it. When you are done you will see what color pH testing paper will turn when it is dipped in the substances represented by the pictures below.