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Hands-on Experiments To Test for Acid Mine Drainage

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Science Experiments for Kids Living Where Creeks are Orange, Yellow, or Red

Contents

You may browse the entire document by using the scrolling arrows to the right of the page, or you may go directly to the experiment you are interested in by clicking on the links below. Please read the safety tips below before conducting any of these experiments in or around your stream. We recommend that you read the Introduction before choosing an experiment.

"Thoughts on Pollution": Tell us what you think by adding your comments, ideas, and suggestions.

The experiments in this document should always be done with the proper supervision from a teacher, parent, or other adult. Always use caution and the proper protective equipment when you are in or around a stream (recommendations: waders or boots, gloves, safety glasses). Additional safety tips are listed below. Always make sure you have permission before entering private property, and wear shoes with rubber soles and good traction when in and around a stream.

Safety Tips: Always use the buddy system, and have an adult check the stream flow and the stream bottom for sharp objects before entering a stream. Do not enter the stream if you cannot see the bottom, and do not enter after a hard rain. Wait for several days of dry weather before conducting any outside experiment in or around a stream. Do not go stream collecting without the presense of a responsible adult!

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Dear Kids, Parents, Guardians, Teachers, and all Concerned Citizens,

This is a prototype for a new book we want to write for kids. This is the first draft, and we want kids to help write it. If they do, their names and comments will appear in the book. The deadline for submissions is spring 2001. Right now, we would love to hear your questions. What questions do you have about acid mine drainage, colors in the water, critters in the water, or any other water quality questions? Our addresses are on the front page. Please write or e-mail nrobbins@usgs.gov with your comments or questions.

My sister and I wrote a science book for kids in 1992. (It is now out of print by the federal government and only available from the Colorado School of Mines.) It is called "What's Under Your Feet?" We talked to many scientists while we were writing the book. One fascinating finding was that most scientists find their vocation by age 8 or 9. This means that when they were children, they were making observations about their environment. These observations were so powerful that they formed the basis for understanding of how the world works. Now, not everyone is going to become a scientist. But everyone is going to enter the job market. It is my opinion that environmental cleanup is going to provide many jobs in the future. I think that if we get the kids out and looking and getting dirty now, they will have a body of observational knowledge needed to compete in that future job market.

The kinds of experiments that are laid out here are some of the very things that scientists do when they are trying to understand the natural environment and to help clean up problems left from past activities. The observations that kids will be making will also be helping present day scientists.

These are mine and others' thoughts on why we started putting together these experiments. We are outdoors people, so most of these experiments are for other outdoor lovers. However, many can also be done indoors. Please remember that our objectives are to help you learn about the effects of acid mine drainage on our environment through experimentation and observation. As you try these experiments and invent new ones at school and at home, record your observations, keep in mind the principals of scientific experimentation, and, most importantly, have fun.

Sincerely yours,
Dr. Eleanora (Norrie) Robbins

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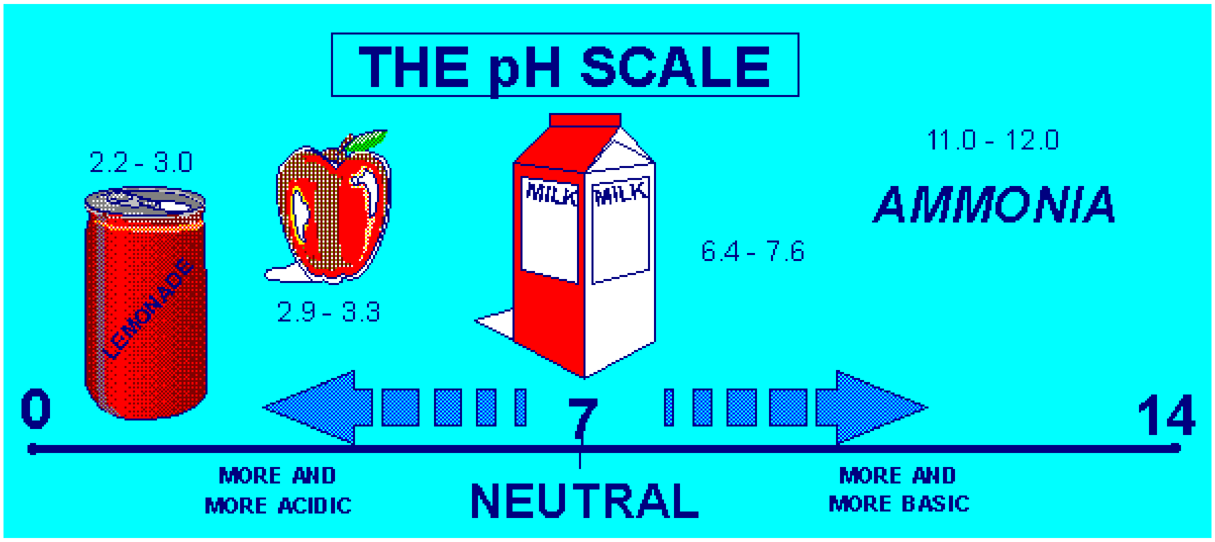
Making your own litmus paper



The pH is a measurement (color change or number) of how acidic or basic (alkaline) a chemical substance may be. As you can see in the above picture, the pH scale ranges from 0 to 14, with 7 being the middle or neutral point. A substance with a pH of less than 7 is acidic, and if it is greater than 7 the substance is basic or alkaline. Each time the pH changes 1 unit there is a tenfold increase or decrease in the strength of the acid or base being measured. Litmus paper is one way to measure the strength of an acid or base. Other ways include electronic pH meters and chemical tests kits that measure the pH by comparing results to a color scale. For more information and definitions, check the websites below.

***Hint**: Lemon juice and vinegar are acids and should turn the paper pink; baking soda is a base and should turn the paper green. If there are no color changes with your test substances, this means that they fall somewhere close to the middle of the pH scale.*

Tools and Things you will need

Red cabbage	Lemon juice	Blender
5 x 8 white card	Vinegar	Strainer
Plastic sheet to contain the mess	Baking soda	Eye dropper

What to do.

- Pull off the cabbage leaves.
- Press them down hard on the white card until the card turns purple (6th grader Peter Cable discovered that the purple in the leaves works the best).
- When you have turned the whole card purple, put a drop of each test substance on the card.

More things to do (You'll need a blender and adult supervision).

- Cut cabbage into chunks.
- Blend the cabbage chunks into a blender until liquid.
- Strain the contents of the blended cabbage with the strainer.

- Mix a drop of this liquid with the substance being tested.

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http://www.encyclopedia.com/articles/00085.html
http:www.chem4kids.com/reations/acidbase.html

What is acid and how do you know it?

Robert Angus Smith, an English chemist, was the first to use the phrase "acid rain" in 1852. He noticed that the bricks in many of the cities buildings were falling apart, and through scientific experimentation he made a connection between London's polluted skies and the pH of its rainfall. Most scientist agree that normal rainfall is slightly acid with a pH of about 5.6. The rain in the atmosphere reacts with carbon dioxide to form a weak carbonic acid that gives the rain its lower pH. Scientist define acid rain as any form of wet precipitation with a pH of less than 5.6. The rain becomes more acid when the water molecules react with different gases in the air such as sulfur dioxide and various nitrogen oxides. These gases occur in the atmosphere naturally. However, their amounts have been increasing for many years due to our many types of industrial processes and the buring of fossil fuels.

Tools and Things you will need

Gloves	Bowl
Measuring cup	Litmus paper
Stirring rod	Miscellaneous substances *

* vinegar, lemon juice, baking soda, chalk, milk of magnesia, cola, coffee, etc. - use only a few drops of each.

What to do.

- Get a cup of water out of your local creek and pour it into a bowl.
- Wash and dry the measuring cup.
- Test the water with litmus paper (acids turn the paper pink).
- Measure out one cup of baking soda.
- If the water is acid, slowly stir baking soda into the bowl.
- Test with new litmus paper periodically until the paper turns blue. (This happens when the acid is neutralized.)
- Repeat with a variety of acids (lemon juice, cola, and coffee) and a variety of bases (milk, milk of magnesia, and chalk).

What did you see?

- How much baking soda was needed to neutralize your creek water, how about cola or lemon juice?
- What happened when you combined two different acids?
- What else did you see?

What do you think?

- Which substance had the highest pH (was the most basic), and which had the lowest pH (the most acidic)?
- What else can you conclude? **Write down what you think.**

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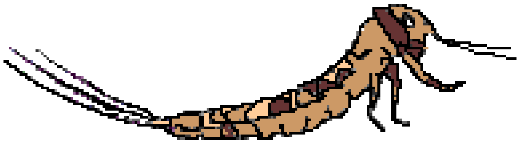
http://antoine.frotburg.edu/chem/senese/101/index.html



If your creek water is clear, is it clean?

Studying aquatic organisms

Each creek has a different chemistry. Some are polluted, others are not. One way to learn your creek's chemistry is to study the aquatic life (macroinvertebrates) that live in the creek. Scientists and others have collected these organisms from many places, and they have found that their presence can help to determine what kind of chemical elements (pollutants) are present in the creek and can give you a good idea of the health of the creek.

Tools and Things you will need

Gloves	Rubber boots	Netting (fine mesh net)
Tweezers (forceps)	Jar to collect organisms	Litmus paper
Reference materials*		

* Reference sheets are available from the web or from your state dvision of environmental protection. The next section also shows some common aquatic organisms that may be found in your creek.

What to do.

- Test the pH of the creek water with litmus paper. Write it down.
- Find a stretch of your creek that has a riffle. A riffle is a shallow rapid where water flows swiftly over small rocks (cobblestones).
- Stretch a net downstream from the riffle.
- Kick and rub the cobblestones to get the organisms to fall off the rocks. Do this for 2 or 3 minutes. (Make sure you rub the rocks upstream from the net.)
- Collect the aquatic organisms caught in the net and place them in a jar.
- Lay out the aquatic organisms and compare them to the pictures found in your reference material.

What did you see?

- How many aquatic organisms came off the cobblestones?
- What kinds of organisms were there?
- What were some other things collected in the net?
- What else did you see?

What do you think?

- What information can you interpret from the different types of aquatic macroinvertebrates present in the creek?
- What are your conclusions? **Write down what you think.**

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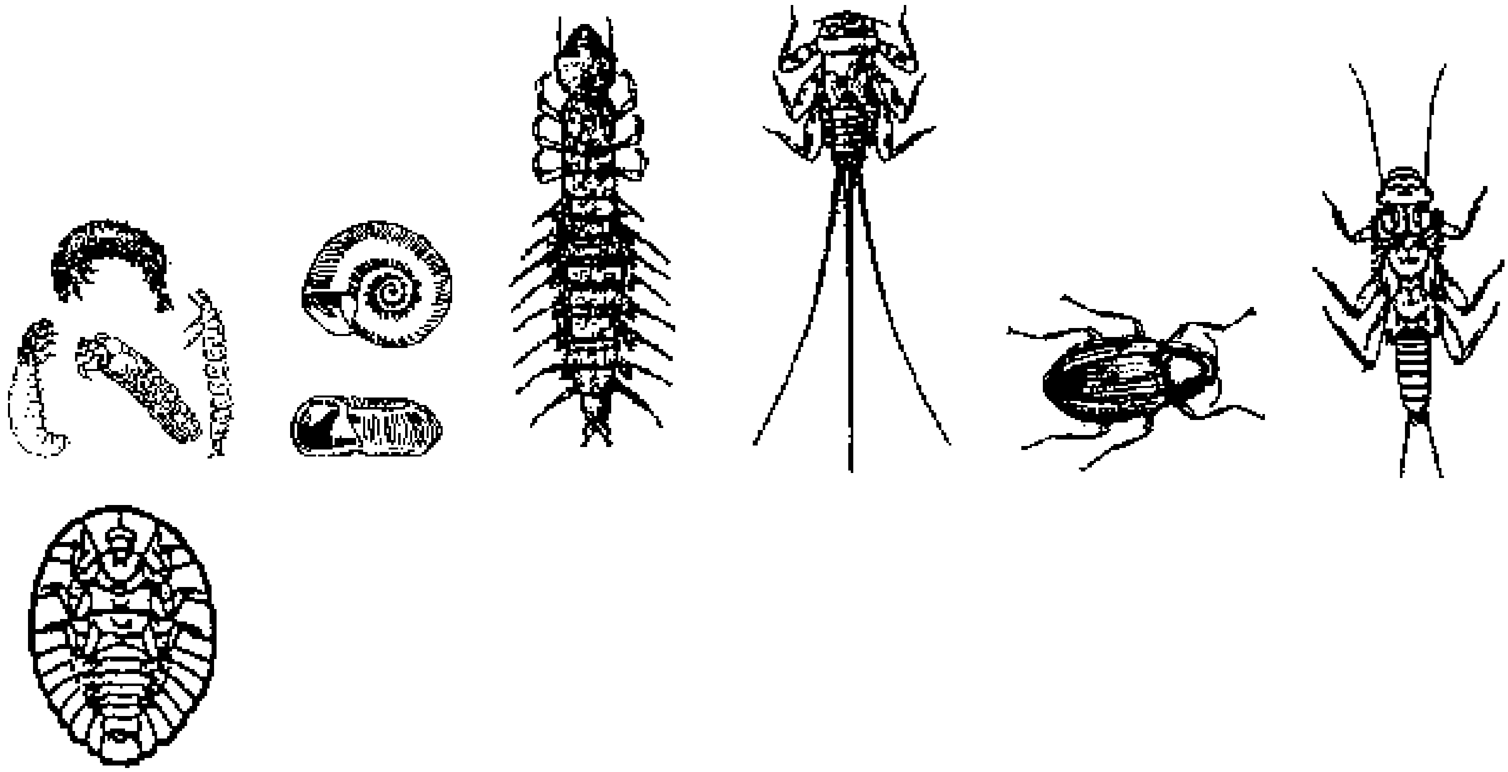
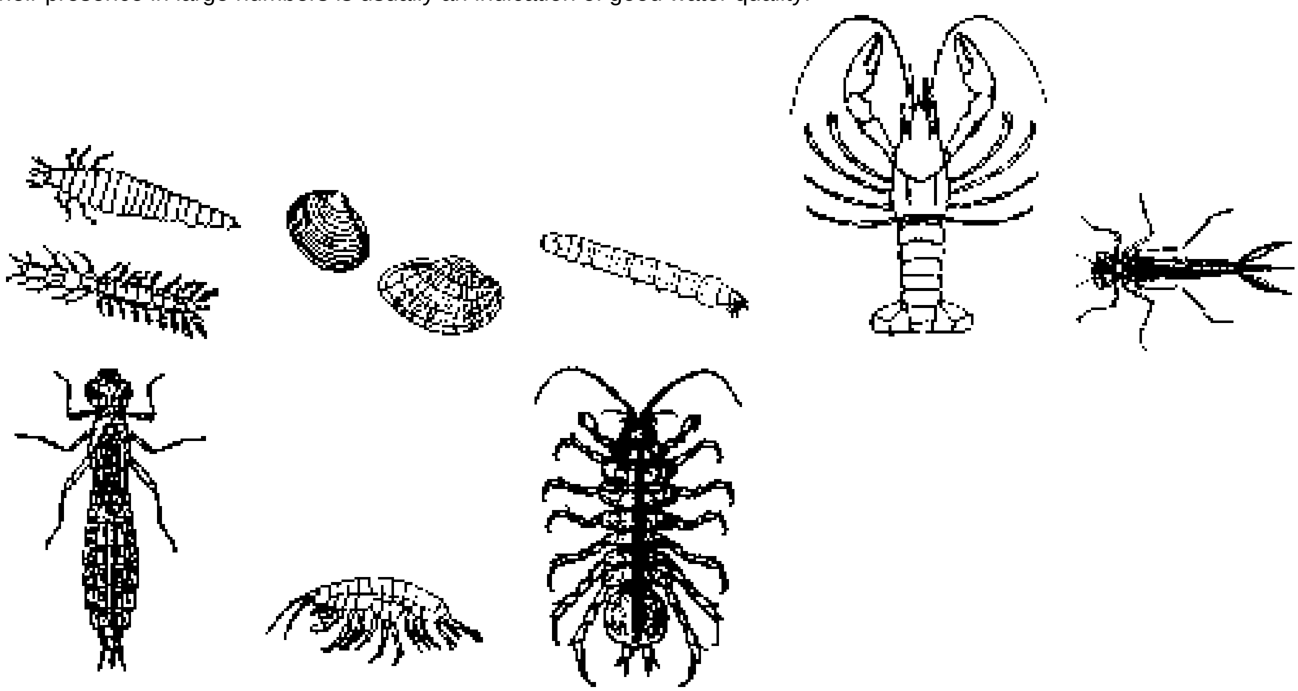
This section contains information to help you identify some of the more common aquatic insects found in streams. For more information visit EPA's Biological Indicators of Watershed Health website at http://www.epa.gov/ceis/atlas/bioindicators/ or Virginia's Save Our Streams website at http://www.sosva.com/.

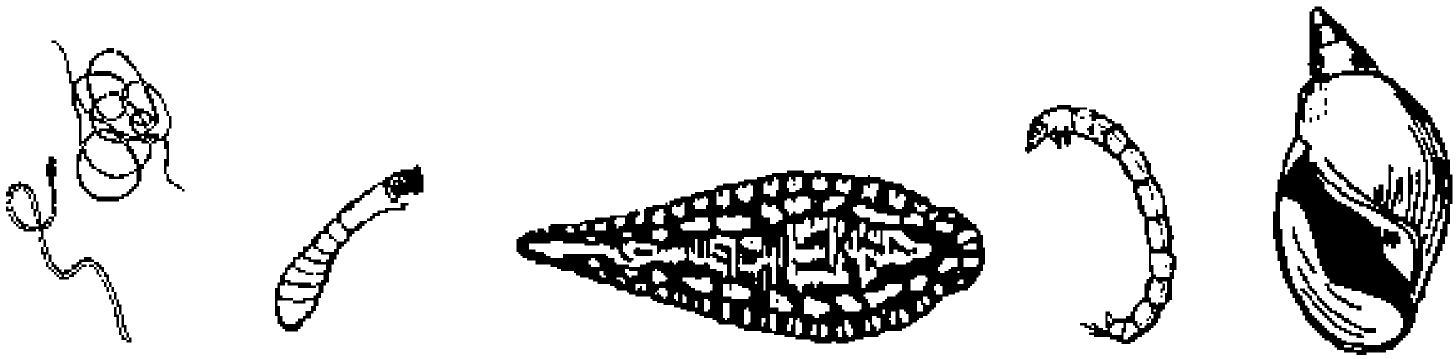
Some common aquatic organisms (macroinvertebrates)



The aquatic organisms above are generally **pollution intolerant**, which means they cannot live in streams that are polluted, even in small amounts. Their presence in large numbers is usually an indication of good water quality.



The aquatic insects above are **pollution sensitive**, which means they can tolerate small amounts of pollutants. Their presence generally indicates moderately good water quality conditions.



The aquatic insects above are generally **pollution tolerant**, which means they can live in streams that have high amounts of pollutants. Their presence in large numbers is usually an indication of poor water quality.

Note: The macroinvertebrates shown above are not to scale, which means they are not rhe actual size as they will be if you find them in your creek.

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Why does acid mine drainage form?

The weathering process

In many areas of the country, acid mine drainage forms naturally when certain materials come into contact with water, air, and bacteria through a process called weathering. The weathering of rocks slowly releases acids, metals, and sulfates into rivers, lakes, streams, wetlands and groundwater. The process may be speeded up and the acid amounts increased (the environment contains more acid than it can clean by natural processes) when industry does not take the proper precautions to protect the environment. When too much of these acids and minerals is released into creeks, creeks can become polluted and will no longer support animals.

Tools and Things you will need

Limestone	Tap water	Small piece of coal
Litmus paper	Metal ores *	Bottles
Other types of rocks or solid materials		

* such as iron, aluminum, or magnesium available at local science and nature stores: http://www.worldofscience.com

What to do.

- Collect solid materials that are found where you live.
- Add tap water to bottles and measure the pH with litmus paper.
- Add one type of solid material to each of the water bottles. To get a good result, break the solid materials into very small (crushed) pieces.
- Put water but no solids in one bottle. (This is called the control.)
- Measure the pH of each bottle over time and write down what you see.

What did you see?

- What materials lowered the pH of the water?
- What materials raised the pH of the water?
- How long did it take for acid to form?
- What else did you see?

What do you think?

- What materials in your areas creek do you think can cause acid mine drainage?

- How could you prevent acid mine drainage from forming?
- What are your conclusions? **Write down what you think.**

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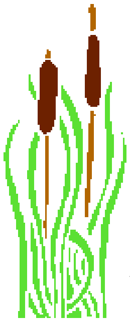
http://cotf.edu/ete/modules/waterq/wqacidmine.html



What type of plants love acid water?

Very few plants like acid conditions in creeks. But some plants such as cattails can help change the chemistry by cleaning up some substances that are carried into the water. These plants work in cooperation with the bacteria in the soil to improve the coditions in the water. Many scientists are testing these plants to learn how they are able to do this. Scientists are also creating new environments, such as wetlands, that can help clean up the acid water (more about this in later experiments).

Tools and Things you will need

Small shovel or dowel	Litmus paper
Rubber boots	Gloves*
Magnifying lens	Camera or drawing pad with pencils

* **Caution**: Some plants have spines or sticky substances that can annoy the skin.

What to do.

- Test the pH of the water with litmus paper. (Is your creek acidic?)
- Collect, **draw,** or take photos of the plants growing along your creek. If you collect the plants, only take one. If you find only one kind of a plant by your creek, do not collect iit. We would prefer that you draw or take pictures of the plants instead.
- Take any plants that you collect and press them in a phone book between sheets of newspaper.
- Identify and make a list of these plants.
- Dig out one or two of the plants to the root, or find their seeds to see if you can get them to grow somewhere else (do not take any plants without permission).
- Take a field trip to a wetland area.

What did you see?

- What types of plants grow along the creek?
- What kind and color of soil did they grow in (hard, soft, squishy, wet, orange, black, or gray)?
- What equipment did you need to keep the plants alive?
- What else did you see?

What do you think?

- What information did the plants give you?
- What are your conclusions? **Write down what you think.**

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http://psybergate.com/wetfix/WetlandFix/WetlandFix4/Part4.htm

Who is very small and living in your creek?

Looking at bacteria and algae

Many plants and animals may not like acid conditions, but certain types of bacteria and algae do. These small one-celled life forms collectively know as microorganims can show a wide variety of colors. The colors are a result of the many different types of chemical processes of which these life forms are capable. For example, iron-oxidizing bacteria are able to "remove" the dissolved iron in the water and form minerals that look like rust. Many types of bacteria and algae use energy from sunlight as a food source (similar to higher plants) in a process called photosynthesis. They can produce brilliant colors such as green, blue, purple, red, yellow, or brown.

Tools and Things you will need

Baby food jar	Eye dropper	Gloves
Magnifying lens	Rubber boots	Litmus paper
Microscope (if possible)		

What to do.

- With an eyedropper, collect in baby food jars the different red, yellow, orange, or brown flocculates in the water. Try filling some of the jars all the way to the top, and leave an air space in some of the other jars.
- Test each jar with litmus paper to check its pH, and write down the results.
- Put the jars on a windowsill. (Put some jars on a south-facing windowsill - gets direct sunlight. Put other jars on a north-facing windowsill - doesn't ever get sunlight). Certain algae will probably develop in the jars receiving the sunlight, and certain bacteria will develop in the jars that do not receive sunlight.
- Observe over 2 or more weeks and take the pH of the water regularly. Take notes of what you see and be sure to include the dates and times of your observations.

What did you see?

- Observe the water sample every other day or so (if possible). Did swimming protozoans hatch out?
- Did any of the iron bacteria colonize (coat) the jar?
- Did any of the iron bacteria form a reddish, oily looking film at the surface between the air and the water?
- Did any of the iron bacteria form a brown ring at the top of the water?
- What else did you see?

What do you think?

- Did you collect acid loving iron oxidizing bacteria or neutral iron bacteria? How can you tell the difference?
- What are your onclusions? **Write down what you think.**

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http://www.uga.edu/srel/Fact_Sheets/microbial_ecology.htm

What is in your creek water?

A creek can carry an amazing amount of chemicals. This is because the activities on the land surrounding the creek (watershed) can affect what is in the creek. Some of these chemicals may change the pH in a creek because they are so abundant. When these chemicals are removed or fall from the water, such as when the water passes through a wetland or over rocks, the water loses some of these chemicals to the sediments. This may cause stains and different colors on the bottom or on the rocks. When these chemicals fall into the sediments by the actions of rocks, bacteria, and *plants, many times the result is a change in the creek's pH.*

Tools and Things you will need

Gloves	Rubber boots
Litmus paper	Access refrigerator and stove
Small jar*	hydrogen peroxide

* Baby food jars, pill bottles, etc.

What to do.

- Fill a small jar or pill bottle full with water from your creek.
- Test the water for its pH with litmus paper. Write it down.
- Pour in one capful of hydrogen peroxide.
- Let the red flocculates settle.
- Test the water again for its pH. Write it down.
- Repeat the experiment with water that has been kept in a refrigerator for 1 hour.
- Repeat the experiment with water left in a warm stove for 1 hour.
- Repeat the experiment with baking soda.

What did you see?

- What happened when you put hydrogen peroxide in the water? What about baking soda?
- What happened to the pH?
- Which reaction (refrigerator, warm stove) occurred faster?
- What else did you see?

What do you think?

- What kind of chemical reaction did you perform?
- Does heat or cold speed up a reaction?
- What are your conclusions? **Write down what you think.**

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http://k12science.stevens-tech.edu/curriculum/waterproj/index.html

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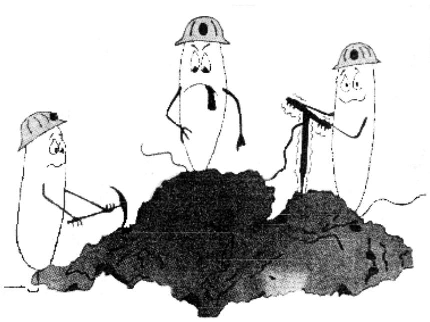
How many colors does iron have?



Iron and the oxidation-reduction process

A common element in Appalachian creeks is iron (Fe). Iron has many different forms and colors, and each tells its own story about the chemistry of the creek where it is found. Iron that occurs naturally in the creeks does not normally cause a problem, but it can be increased by human activities to a point where it becomes harmful to the life in a creek. The color of the iron in a creek will show you what type of chemical reaction is occurring. If the iron is red it is being oxidized, if it is black it is being reduced.

Tools and Things you will need

Gloves	magic marker	Rubber boots
Baby food jars with lids	Shovel	Litmus paper
Eyedropper		

What to do.

- Fill jars with red, yellow, or orange flocculates and water from a creek. These can be found in many different creeks but are more common in those affected by acid mine drainage.
- Dig with a shovel in different places along the creek bed until you find the change from red to black.
- Add some of the black sediment to some of the jars and fill all the way to the top to keep out oxygen.
- Label the jars with the dates of collection.
- Put covered jars on windowsills and observe them over several weeks.

What did you see?

- Make observations as to what happened to the colors. Write down everything you observe.
- At the end of the experiment, uncover the jars and smell them. **Write down what you smell.**
- What else did you see?

What do you think?

- Which of these colors are from iron?
- Which iron was oxidized and which was reduced?
- What are your conclusions? **Write down what you think.**

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http://pubs.usgs.gov/publications/text/Norriemicrobes.html

What is that black stuff on the rocks?

The manganese cycle

Finding metals that coat the rocks is a very old profession. The prospectors of years ago used to scrape off the coatings from rocks and send them to the laboratory for analysis. The information would help them decide if they should look upstream for such metals as gold and silver. The coatings and the colors on the rocks can usually tell you what is the most abundant mineral in the creek. Manganese is almost always the darkest mineral.

Tools and Things you will need

Rubber boots	Gloves	Magic marker
hand lens	Litmus paper	Glass slides
String or small rope	Microscope (if possible)	Miscellaneuos materials*

* cans, bottles, tile, styrofoam, paper, plastic, etc.

What to do.

- This experiment requires that your creek has cobblestones in it that are coated black.
- Tie a string or small rope across your creek. Attach some of the materials listed above to the string, allowing them to dangle into the creek. (You may also attach them to tree roots and wooden stakes.)
- Fill a large jar with creek water collected near the riffles; drop a microscope slide into the jar. Examine this slide at least once a week. Write down what you see and how changes occurred over time.

- Write down what day you started the experiment.
- Examine the items dangling in the creek at least once a week. Write down what you see and how changes occurred over time.
- After about 6 weeks, end the experiment (write down the ending date) and make your final observations and comments.

What did you see?

- What materials became coated with manganese?
- What did you see on the microscope slides?
- Why do you think manganese sticks to many things?
- What else did you see?

What do you think?

- Which materials do manganese oxidizing bacteria like best?
- What are your conclusions? **Write down what you think.**

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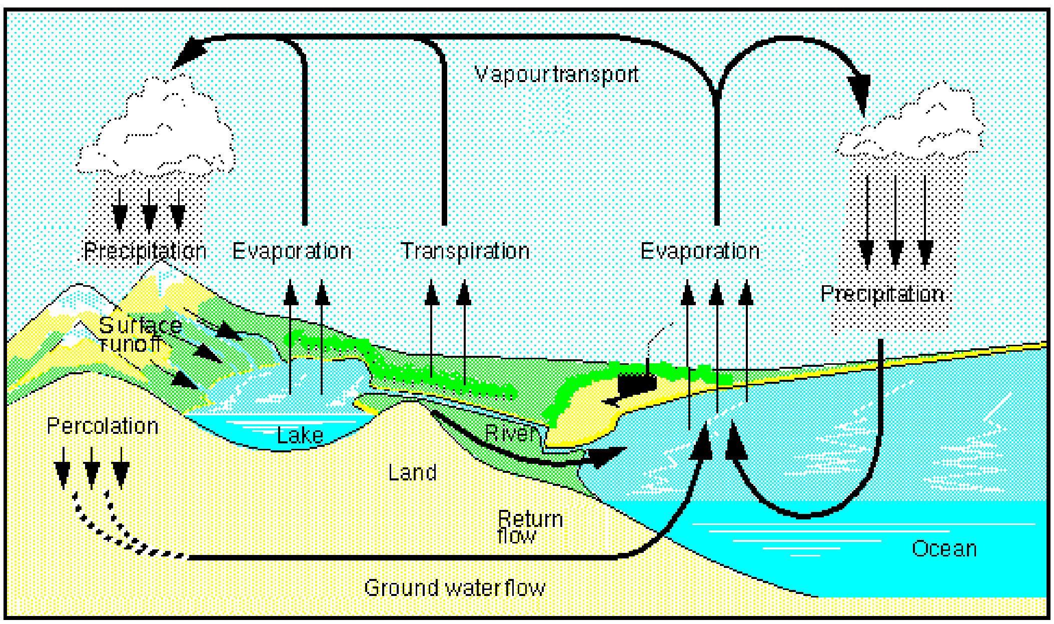
http://energy.er.usgs.gov/products/papers/wvsmdtf/index.htm

Is the groundwater acid also?



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

The surface water, mostly from rain, runs off from the ground into creeks, rivers, lakes and wetlands. A small amount of this surface water does not run off, but instead seeps underground. This underground water is called groundwater. Groundwater fills the spaces that are found in the soils and rocks and eventually flows downhill, just like the creeks do. The place that the groundwater is first observed is called the water table. If you live near creeks that are polluted with acid mine drainage, there is a good chance that the groundwater may also be polluted.

Tools and Things you will need

Shovel	Gloves	Rubber boots	Hollow pipe*

* Short length of PVC, steel, or aluminum pipe.

What to do.

- Test your creek's pH with litmus paper.
- Move away from the stream in a straight-line (transect) and push a pipe down into the sediment, or dig a hole with a shovel.
- Collect the water from the hole and test its pH with litmus paper.
- Test another distance further away from your creek.

What did you see?

- How deep did you have to dig to find water as you moved farther away from the creek? What does this tell you about the water table?
- Was the underground water the same chemistry as the creek?
- What else did you see?

What do you think?

- Would acids leak into the groundwater from the creek or from other underground sources?
- What are your conclusions? **Write down what you think.**

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http://www.groundwater.org/

What is the white stuff in the water?

Both natural processes and pollution cause white colors in creeks. If the white is foam, foam is "a gas (usually oxygen) mixed in a liquid containing some impurity." If the white is aluminum, the pH is slightly acidic. If the white is sulfur, it is from surfur-oxidizing bacteria that live above sulfur-reducing bacteria. Sulfur-reducing bacteria give off hydrogen sulfide, which is the smell of rotten eggs.

Tools and Things you will need

Rubber boots	Gloves
Microscope (if possible)	Litmus paper
Eyedropper	Shovel or stick
Baby food jars with lids	

What to do.

- How can you tell if an impurity is present in the environment?
- Find out if your creek has white foam.
- Collect the white flocculate in a baby food jar with an eyedropper.
- Smell the mud under the white flocculate. What do you smell? A sulfur smell may indicate the presence of sulfur-reducing bacteria.

What did you see?

- Look at the flocculates under a microscope.
- Do you see changes over time?
- What else did you see?

What do you think?

- What types of substances are present in your creek? How can you find out what is in your creek?
- What are your conclusions? **Write down what you think.**

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http://www.science.murdoch.edu.au/teaching/m234/recycle01.htm

How can acid mine drainage be fixed with natural things?

"**Passive Treatment Methods**" **-** The next two experiments provide information about passive treatments.

Acid mine drainage sometimes forms when minerals are exposed during mining. These minerals weather and release the contents into nearby creeks which sometimes causes them to become acidic (lower the pH). Acid drainage effects thousands of miles of streams throughout the U.S. It can affect animals, plants, and small organisms living in or near the stream. At the present time, many industries use chemicals to treat the contaminated waters. However, less expensive methods are also available to help clean up acid mine drainage.

Tools and Things you will need

Compost	Litmus paper	Limestone
Leaves	Pine needles	Cobblestones
Bottles with caps*	Acid water from creek	

* You will need enough bottles, and large enough bottles, for each object that you plan to test.

What to do.

- Find an acid creek and use litmus paper to measure the pH.
- Collect the water in bottles.
- Add one natural material (leaves, pine needles, cobblestones) to each bottle. Measure the initial pH and write it down.
- Every few days for about a 2-week period, measure the pH to see what happens in each bottle. Write down your results.

What did you see?

- What materials decreased the pH of the water?
- What materials increased the pH of the water?
- What materials caused solids to form at the bottom of the bottles?
- What colors were the solids?
- Did one of your experiments change acidic water to neutral?

What do you think?

- What natural materials may be used to treat acid mine drainage?
- Can you create a treatment system using these natural materials?
- What are your conclusions? **Write down what you think.**

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http://www.fetc.doe.gov/coolscience/teacher/lesson-plans/lesson10.html

Using stinky bacteria to treat acid mine drainage

The sulfate-reduction process

Passive Treatment -- continued

As mentioned in the previous experiment, there are many expensive ways to treat acid mine drainage problems. Another alternative is a more passive treatment of constructed and natural wetlands. In the wetland, a combination of the plants, the holding capacity (how long the water will stay in the wetland), the soil, and the bacteria are responsible for treating the acid mine drainage. Many times these areas have a "rotten egg" smell, which is hydrogen sulfide gas being released through biological reactions that take place in the wetlands. This odor's presence is one way to tell if the wetland is helping to treat acid mine drainage.

Tools and Things you will need

Acid water from creek	Collection boxes*	9 bottles with caps**
Litmus paper	Wetland mud	Shovel
Yeast		

* The plastic collection boxes should be large enough for one small shovel full of mud.
** The bottles should be large enough for at least a tablespoon of mud and a half of a tablespoon of yeast.

What to do.

- Collect acid mine drainage in 9 bottles.
- Collect mud that smells like rotten eggs from a wetland.
- Add mud to 6 of the bottles and yeast to 3 of the bottles.
- Measure the pH in the bottles over time, label each bottle, write down its pH, and watch for different colors to form.
- Smell each bottle and write down what you smell (rotten eggs, a yeast smell, or something else).

What did you see?

- What happened in the bottles having no yeast?
- What happened in the bottles having yeast?
- Which bottles really smelled like rotten eggs?
- Which bottles had bacteria activity?
- How did the bacteria affect the smell of the water?
- What color was associated with the strong smell?
- What else did you smell?

What do you think?

- What might affect the ability of the bacteria to treat the water?
- Why do people use compost in constructed wetlands?
- What are your conclusions? **Write down what you think.**

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http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_amd.htm

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Designing your own experiments

To use the Scientific Method you should design an experiment to test your hypothesis. A hypothesis is a question that has been reworded into a form that can be tested by an experiment. Your hypothesis should be based on the background information you gathered. Make a numbered, step-by-step list of what you will do to answer your question. This list is called an "experimental procedure." Your procedure should be detailed enough that someone else could do your experiment without needing to talk to you about it. This procedure should include:

- Any amounts or measures you will be using
- Your one variable and how you will change it
- Your control

- How you are going to measure the change you observe
- Diagrams or drawings so your ideas are clear

Your experiments must be repeated to guarantee what you observe is accurate and to obtain an average result. This process of repeating the same experiment many times is called "repeated trials." Experiments can be more or less complex, depending on how they are set up or designed.

Conduct Experiment, Gather Data, and Record Observations: As you experiment, record all numerical measurements made. Data can be amounts of chemicals used, how long something is, the time something took, etc. If you are not making any measurements, you probably are not doing an experimental science project. Observations can be written descriptions of what you noticed during an experiment or problems encountered. You should be looking for differences between your control group and your experimental group(s).

Two things to be aware of while doing your experiment and making observations.

- First, if you did not observe any differences between the control and experimental groups, then the variable you changed may not affect your experiment.
- Second, if you did not observe a consistent, reproducible trend in your experimental runs, there may be experimental errors affecting your results or something else that you might not have thought about.

If you suspect experimental errors, the first thing to check is how you are making your measurements. Is the measurement method questionable or unreliable? Maybe you are reading a scale incorrectly, or maybe the measuring instrument is not working. If measurements do not seem to be a problem, check to make sure you are following the rest of your procedure carefully from one run to the next. If you determine that experimental errors are influencing your results, carefully rethink the design of your experiments. Review each step of the procedure to find sources of potential errors. If possible, have a teacher review the procedure with you. Sometimes the designer of an experiment can miss something obvious.

Always keep careful notes of everything you do and everything that happens. Observations are valuable when drawing conclusions and useful for locating experimental errors.

For more information on science fair projects, designing experiments, and other closely related information, visit the website http://ipl.lub.lu.se/youth/projectguide/

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Send us a letter or e-mail with your name, address, city, state, and zip code. Describe your experiments, let us know what you think, tell us what you have discovered about our environment, and become an important part of the writing of our book on acid mine drainage. The e-mail and mailing addresses can be found at the beginning of this document.

"Thoughts on Pollution" from Tim Craddock: The quality of a stream is the result of what happens along its banks and in its watershed. A watershed is "all the land surrounding the stream that drains into the stream." In a watershed that has been transformed into shopping centers, factories, mines, homes, highways, and farms, many potential sources of pollution exist. If the sources are not identified and corrected, the stream will no longer be able to provide habitat for all the living things that depend on the stream, including fish, wildlife, and even humans. The goals of these experiments are to help you become more familiar with one of the pollution problems, acid mine drainage. However, the ultimate goals are to encourage you to get outside and develop a better understanding about your environment through observation and experimentation and to help you become more aware of the many sources of pollution that exist in our world today, even in our own backyards.

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http://www.epa.gov/owow/nps/

Resources for more Information

- AIMS Foundation, 1988, Water, precious water: A collection of elementary water activities for grades 2 through 6: PO Box 8120, Fresno, CA

- Costen, J., and Hornberger, M., 1995, Water wizardry: A teachers guide to classroom activities and demonstrations about water pollution and remediation: U.S. Geological Survey, Menlo Park, CA (To order contact: Michelle I. Hornberger, 345 Middlefield Rd., MS 465, Menlo Park, CA 94025.)
- U.S. EPA, 1990, Acid rain: A students first source book: U.S. Environmental Protection Agency (RD-682), 401 M Street, SW. Washington, DC 20460 (Also available on the Internet at: http://www.epa.gov/acidrain/student/student2.html)
- Gartrell, J.E., and others, 1992, Earth - The water planet: National Science Teachers Association. (To order contact: U.S. Geological Survey, MS 950, Reston, VA 20192.)
- McGee, E., 1995, Acid rain and our Nations Capitol: A guide to effects on buildings and monuments: U.S. Geological Survey, Reston, VA (To order contact: U.S. Geological Survey, MS 950, Reston, VA 20192.) (Also available on the Internet at: http://pubs.usgs.gov/gip/acidrain/)
- Robbins, E.I., and Hayes, M., 1997, What's the red in the water? What's the black on the rocks? What's the oil on the surface?: (Available on the Internet at: http://pubs.usgs.gov/publications/text/Norriemicrobes.html)
- Schrock, J.R., 1993, Surface mining of coal: The Kansas School Naturalist, v. 4, no. 1, Emporia State University, 1200 Commercial St., Emporia, KS 66801-5087
- Sly, C., 1990, Water wisdom: A curriculum for grades 4 - 8: Publication of the Alameda County Office of Education. (To order contact: U.S. Geological Survey Library, MS 950, Reston, VA 20192.)
- Zielinski, E.J., 1995, Acid mine drainage in Pennsylvania, K-12 Awareness Activities: Pennsylvania Department of Environmental Resources, Bureau of Land and Water Conservation.

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Internet Links

A Community Water Quality Monitoring Manual: http://www.vic.waterwatch.org.au/manual/
Acid Mine Drainage, the unseen enemy: http://www.valdosta.edu/~tmanning/hon399/wally.htm
Acid Mine Drainage Lessons: http://www.aqd.nps.gov/ard/lessons.html
American Rivers: http://www.amrivers.org/mines.html
Aquatic Macroinvertebrate ID: http://www.net1plus.com/users/tdriskell/macroinvertebrates.html
Bacteria in Groundwater: http://www.ce.vt.edu/enviro2/gwprimer/bacteria/bacteria.html
Biological Time clock Experiments: http://www.cbt.virginia.edu/Olh/
Environmental Education: Internet Resources: http://www.wcupa.edu/library.fhg/recommnd/Environ.htm
Environmental Links: http://www.innovative-solutions.net/links.htm
Explore EE Links on the Internet: http://www.uwsp.edu/acad/wcee/links.htm
Hydrogeology and the Water Cycle:
http://www.arch.cuhk.edu.hk/~patrick/slope/background_information/water_cycle.htm
Learn about Wetlands: http://athena.wednet.edu/curric/land/wetland/index.html
Micro-organisms in Acid Rock Drainage: http://www.enviromine.com/ard/Microorganisms/roleof.htm
Mine Net: http://www.microserve.net/~doug/aciddra.html
NACD Links to Internet Resources: http://www.nacdnet.org/resources/links.htm#EviEd
National Watershed Focus: http://www.ctic.purdue.edu/KYW/Focus/Nov96.html
National Wildlife Federation: http://www.nwf.org/nwf/kids/cool/water2.html
Native American uses for Cattails: http://www.nativetech.org/cattail/cattail.htm
Natural Resource Conservation Service: http://www.nrcs.usda.gov/
Passive Treatment Technologies for Treating AMD: http://www.wvu.edu/~agexten/landrec/passtrt/passtrt.htm
Recycling and Solid Waste Management Resources: http://wayne-health.org/wc_recycling_info.html
Restoration of a Stream Degraded by AMD: http://wwwpah2o.er.usgs.gov/projects/amd/restoration.html

Save-Our-Streams, Stream Doctor Program: http://www.iwla.org/SOS/streamdo.html
Science Made Simple: http://www.sciencemadesimple.com/
The Environmental Education Network: http://www.envirolink.org/enviroed/content.html
The Young Scientist Introduction to Wetlands: http://www.wes.army.mil/el/wetlands/ysi.html
U.S. Environmental Protection Agency: http://www.epa.gov/
U.S. EPA Region 3: Mountain top Mining: http://www.epa.gov/region3/mtntop/
U.S. Fish and Wildlife Service: http://www.fws.gov/
U.S. Geological Survey: Educational Resources: http://water.usgs.gov/education.html
U.S. Geological Survey: Programs in West Virginia: http://water.usgs.gov/wid/html/wv.html
USDA Backyard Conservation: http://www.fb-net.org/Backyard.htm
USDA: Watersheds and Wetlands Division: http://www.ftw.nrcs.usda.gov/programs.html
USGS National Wetlands Research Center: http://www.nwrc.nbs.gov/
USGS: New Techniques to Treat AMD: http://www.usgs.gov/tech-transfer/factsheets/FS-212-96.html
Volunteer Stream Monitoring: http://www.epa.gov/owow/monitoring/volunteer/stream/
Water Quality Modules: http://www.cotf.edu/ete/modules/waterq/wqacidmine.html
Watershed Education Links: http://www.adopt-a-watershed.org/aawlinks.htm
Watershed Education: http://stopnpp.com/educate/educate.htm
West Virginia Geology: http://129.71.2.20/www/geology/geology.htm
West Virginia Wetlands: http://www.geocities.com/Athens/Aegean/8003/wvwet.html
Wetlands and People: http://psybergate.com/wetfix/ShareNet/Sharenet1/Share.htm
WV Division of Environmental Protection: http://www.dep.state.wv.us/
WV Division of Natural Resources: http://www.dnr.state.wv.us/default.htm
WV K-12 Rural Net Project: http://www.wvu.edu/~ruralnet/monitor/monitor.html
WV Nongame and Natural Heritage Program: http://www.dnr.state.wv.us/wvwildlife/nongame/default.htm
WVU: Acid Mine Treatment: http://www.wvu.edu/~research/techbriefs/acidminetechbrief.html

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U.S. Department of Interior, U.S. Geological Survey
URL of this page: http://pubs.usgs.gov/openfile/of00-369/
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