SCWIBLES an NSF GK-12 Project | Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences

Filtering Out Pollution

Lowering Turbidity to Increase Water Quality

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Field-tested with: 10th-11th grade students in the Natural Resources Course, ESNR Academy, Watsonville High School, Watsonville, CA (Fall, 2010)

Concepts: turbidity, water quality, pollution, erosion, eutrophication, NTUs, habitat modification, contamination, run-off

Skills: quantitative comparisons, measuring turbidity, experimental design, constructing a filter, creating and applying a solution to a real world problem.

Module Type: lab activity and discussion

Duration: One 2-h class session and one 1-h class session (or 1 ½ two-hour class sessions)

Key materials:

- 1200 ml construction site water
- 1200 ml river water
- Lab Quest Pro Turbidity Sensors
- Filtration materials: Cheesecloth, t-shirt, aquarium rocks, paper towels, toilet paper
- 25 and/or 50 ml beakers
- Funnels
- Introductory starter questions
- Lab packet copies

Science Education Standards:

National: Science As Inquiry; Science and Technology; Science in Personal and Social Perspectives
California: Biology-Life Sciences: 6. Ecology (ecosystem changes); Investigation and Experimentation

Overview: Students learn what turbidity is and how to measure it using a turbidity sensor connected to a data logger. Students will then use an array of readily available materials to investigate how to build a water filter that efficiently reduces turbidity.

This project is an opportunity for students to learn:

- How human activities such as construction can cause run-off and reduce water quality
- How run-off can cause eutrophication and negatively affect environmental health
- How to observe changes in water quality and quantify changes in the turbidity of water
- How to develop and apply simple technological solutions to reduce the turbidity of water
- How difficult it is to find a true solution to some human-caused environmental problems, such as making polluted water drinkable

Background for Teachers

Filtering Out Pollution: a solution to reduce turbidity

Human activity negatively affects environmental health in many ways, from habitat loss to global warming. One result of human activity that negatively affects both human and ecosystem health is the increase of water pollution. This module teaches students not only about how human activity can increase the turbidity of water, but also how to use scientific instruments and methods to create a solution to this environmental problem. Specifically, students will learn how sediment run-off decreases both the habitat quality of and the drinkability of water. This is a hands-on, inquiry-based module that allows students to be creative while learning about a major environmental issue.

Science Education Standards Addressed

This module focuses on how increased turbidity affects water quality and building a filter to reduce turbidity, and addresses NSES standards A. Science As Inquiry (p.175-176); E. Science and Technology (p.192-193); F. Science in Personal and Social Perspectives (p.198-199), as well as the following SCSCPS content standards:

Biology-Life Sciences**,** 6. Ecology: Stability in an ecosystem is a balance between competing effects.

b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size (p. 54).

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

d. Formulate explanations by using logic and evidence.

j. Recognize the issues of statistical variability and the need for controlled tests.

k. Recognize the cumulative nature of scientific evidence.

m. Investigate a science-based societal issue by analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California (p.61).

NSES (http://www.nap.edu/catalog/4962.html)
SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf);

What Is Turbidity?

Turbidity is the cloudiness of a fluid caused by individual particles that are sometimes invisible to the naked eye (USGS, 2002). The measurement of turbidity is a key test of water quality.

Turbidity in open water may be caused by human activities. Human activities that disturb land, such as construction, can lead to large amounts of soil and other particles entering water bodies through storm-water runoff. This makes the water turbid.

Urbanized areas contribute large amounts of turbidity to nearby waters, through storm-water pollution from paved surfaces such as roads, bridges, and parking lots. Certain industries such as quarrying, mining and coal recovery can generate very high levels of turbidity from broken rock particles.

Turbidity may also be caused by overgrowth of algae, usually because human activities cause nutrients (e.g., agricultural fertilizers), to runoff into the water. When farmer use nitrogen and phosphorous fertilizers on crops, the fertilizers can be washed with rain into open bodies of water. Those fertilizers then allow algae to grow uncontrollably; this is called an algal bloom. This process of creating excessively high levels of nutrients in bodies of water is called **eutrophication**. This is what you see when lakes and ponds are covered in green algae. When the algae die, they decompose and this results in even more particles in the water, which further increases turbidity.

In drinking water, the higher levels of turbidity are associated with a higher risk that people may develop water-borne diseases caused by viruses and bacteria attached to the suspended particles. This is especially dangerous for immune-compromised people. The suspended particles can act as shields for the virus and bacteria and interfere with standard approaches to water disinfection with chlorine or ultraviolet (UV) light.

In water bodies such as lakes and reservoirs, high turbidity levels can reduce the amount of light that reaches lower depths, which can kill submerged aquatic plants, fish, and shellfish. This phenomenon has been regularly observed throughout the Chesapeake Bay in the eastern United States (Chesapeake Bay Program 2002).

Turbidity is measured using **Nephelometric Turbidity Units (NTU).** NTU's are a measure of how much light scatters when it is shined into a clear tube of water (University of Minnesota, 2008). If the light scatters a lot, that means it is hitting many particles and the turbidity, or NTU, of the water sample is higher. A healthy river has readings of 0-25 NTU units and an unhealthy river will have 25 and above (EPA, 1986). Drinking water should measure between 0-5 NTU units (EPA, 1986).

Common Student Misconceptions

It is important that this module is placed in real world context, such as with the construction scenario. It is easy for students to get into the lab and procedural side of things in this lesson, but the main idea is that they understand how turbidity can affect environmental health. One way to address this issue is to spend time before and after the module clearly explaining the effect of turbidity on water quality, such as with the background information above. Another way is to embed this module into a larger unit on water quality. Finally, having the students actually collect the water to test at a nearby river and/or polluted water source directly puts a real world component on this module.

Project Description

Materials

- Large container of construction site water
  -can be obtained from any water source near development, or created with 25g soil into 1200 ml water
- Large container of river water
  -can be obtained from any nearby clear river or created using 1200 ml tap water
- Turbidity Sensors (at least 4 for a class of ~30)
  -This is a small device that comes with a clear vial in which to put water samples. It shines light through the water in the vial and measures the turbidity of the sample. Instructions to calibrate sensors are included. They can be purchased online for $112.00 each from Vernier: http://www.vernier.com/probes/trb-bta.html
- Lab Quest Pro (at least 4, or one for each sensor)
  -This is a sensor interface that is connected to the turbidity sensor to actually read and display the turbidity level of the water sample. This interface can be used with a variety of sensors and use for many environmental labs. They can be purchased online for $329.00 each from Vernier: http://www.vernier.com/probes/trb-bta.html
- Filtration set up materials
  -Cheesecloth
  -T-shirt
  -Aquarium Rocks
  -Toilet paper
  -Brown paper towels
  -25-ml beakers, two for each group of 3-4 students

- 50-ml beakers, two for each group of 3-4 students
- Funnels, one for each group of 3-4 students
- Introductory starter questions (see below under "Procedure: starting point for inquiry")
- Lab packet copies (see below, "Filtering Out Pollution" worksheet)

Timeline

10 minutes	Introductory lecture -Introductory starter questions -Definition of turbidity and why it is important -Read lab introduction -Intro to lab problem
5 minutes	Break into groups of 3-4 students
10 minutes	Initial Observations
20 minutes	Test for turbidity
5 minutes	Introduction to filtration material options
15 minutes	Design 3 filtration systems on paper
20 minutes	Create one filtration system
20 minutes	Test water prior to filtering
10 minutes	Filter
20 minutes	Test water after filtering
25 minutes	Answer questions
10 minutes	Post lab discussion

Preparation

Calibrate turbidity sensors. This is something you can do in advance or have the students do. The instructions to calibrate the sensors are included with the sensor manual and it is very straightforward.

Make copies of the lab packet (see below), one for each student.

Purchase materials for filter creation. See the materials list for ideas.

Collect or create water samples. Again, this is something you can do in advance or have the students do as part of the unit.

Set out filter materials, funnels, beakers, and sensors before the lab starts. If sensors must be shared among groups, set up sensor stations where students can use the sensors when ready.

Procedure

1. Introductory lecture

Have a jar of "dirty" water, recently shaken, as well as a jar of clean water in front of you. Begin by asking the whole class some introductory discussion questions, such as:

- Which jar of water would you drink? Why?
- What does it mean to have high water quality?
- What does it mean to have low water quality?
- Do you know how we measure how dirty water is?

Then give the definition of turbidity and explain why it is important. At this point, pass out the worksheet and give the introductory lecture. You can come up with your own lecture or read the background material presented above (also on the student's worksheet). You could also have the students read the background information on turbidity to themselves or aloud, with each student taking a section.

2. Starting Point for Inquiry

Next, introduce the lab problem by introducing where the water sources came from, if the students did not collect the samples themselves. Explain that the dirty water is from a nearby construction site and the clean water is from a nearby river that is in a park or surrounded by a forested area, for instance. Then, give the students the inquiry prompt (also on their lab packet):

"Your job today has two parts. First, it is to evaluate the water quality of two local water resources. The first site is from a freshwater resource that is believed to be a healthy river and the second is a water resource that is being affected by a local construction project. The second part of your job is to find a solution to improve the quality of the water, or lower the turbidity. To do this, your group should design and create a filtration system using the provided materials. The goal is for your filter to clarify the contaminated water resource by lowering its turbidity value. Lastly, your group will discuss how turbidity impacts local ecosystems and humanity."

3. Starting and Guiding Hands-on Activities

1. Break the students up into groups of 3-4 students each.
2. Have them read through the entire worksheet on their own or go through it as a class.
3. Have one person from each group come to gather water samples in the provided 50-ml beakers.
4. Instruct students to begin the lab by making general observations of the water samples and writing those down on the worksheet.

5. Let them begin measuring the initial turbidity of the samples, following the instructions on the worksheet. At this time, teachers should float to the different groups, answering questions as well as clarifying how to use the turbidity sensors if there is confusion.
6. Introduce the available filter building materials
7. Float as students begin drawing out different potential filter designs. As they decide on their favorite, they will raise their hand to show you and you should provide guidance and approval on their filters. You may also choose to write ideas on the board.
8. Let students create their filters, providing help along the way and then filter their samples as they are ready and them measure the turbidity of the filtered water samples.
9. You may want to put the turbidity measurements on the board and make it a competition with the students trying to get the lowest turbidity value of the class with their filter. This may cause students to want to experiment more with the filter options, so allow time for this if desired.
10. Guide students in answering the worksheet questions
11. Have a whole class discussion about their results and experience creating the filter. Include a discussion that relates this activity to real world solutions to water pollution and environmental health issues.

4. Guiding Thoughtful Question-Generation, Design, and Testing:

To get students to think about how to reduce turbidity in the water samples, teachers can give hints to designing an effective filter. For example, you can encourage students to think about the size of the particles. Are they visible with the naked eye? Do they think there are particles they can't see in the water? How would they filter out the large particles? How would they filter out the small particles? You could suggest a filter with multiple layers to filter out all of the particles in the water. For example, students might find that cheesecloth blocks the large particles, but tissue blocks the small particles.

5. Assessment Methods

Recommended approaches to assessment include:

- Review data collect by students on worksheet
- Review group work and discussions
- Review answers to worksheet questions
- Assess learning of the main idea from class discussions

Lab Packet: Filtering Out Pollution

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First, it is to evaluate the water quality of two local water resources. The first site is from a freshwater resource that is believed to be a healthy river and the second is a water resource that is being affected by a local construction project. **The second part of your job is to find a solution to improve the quality of the water, or lower the turbidity.** To do this, your group should design and create a filtration system using the provided materials. The goal is for your filter to clarify the contaminated water resource by lowering its turbidity value. Lastly, your group will discuss how turbidity impacts local ecosystems and humanity.

Initial observations

1. Compare both samples by gathering a 25ml beaker full of solution.
2. Which environment do you believe is more turbid (unclear)?

3. Why?

Testing for turbidity: procedures.

1. Power on the labquest unit. Make sure that the turbidity sensor is attached to the labquest unit using the provided cable.
2. Follow the next steps to measure the turbidity of your healthy river water.
3. Fill a sample vial with the first solution up to the line so that the curve of the meniscus is at the top of the line.
4. Wipe the vial with a cloth/tee shirt.
5. Hold the black cap of the vial and place it inside the turbidity reader; lining up the arrows.
6. Keep the turbidity reader on a flat surface and do not touch the table.
7. Let the sensor read your sample for 4 minutes and record the value.
8. Repeat steps 3-7 for two new samples of the river water from your beaker.

Sample #	Turbidity reading in NTU
1	
2	
3	
Average:	

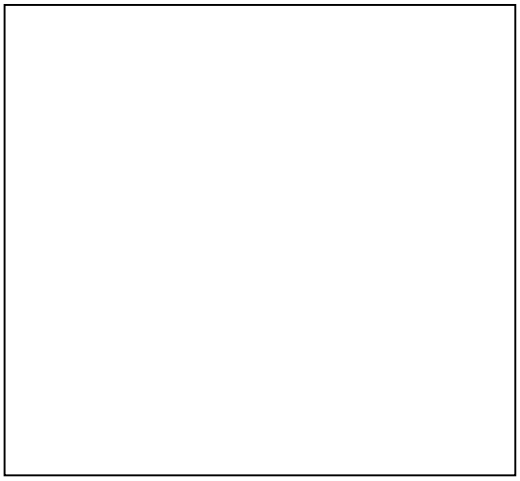
9. Now, measure the turbidity of the construction site water sample by repeating steps 3-8 for the construction sites water.

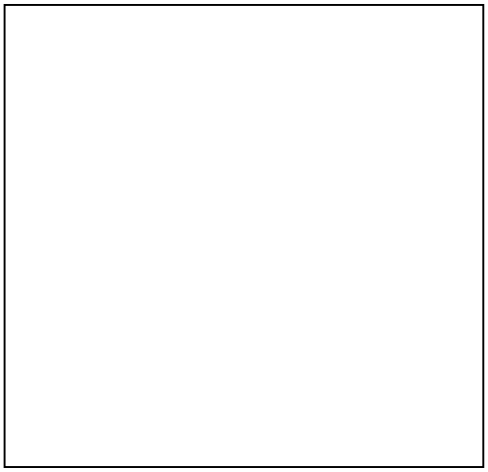
   Data before filtration:

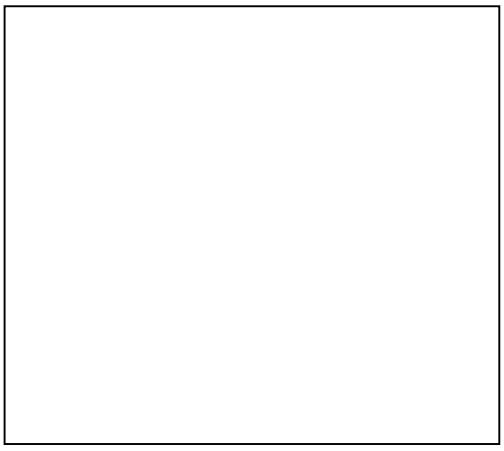
Sample #	Turbidity reading in NTU
1	
2	
3	
Average:	

Create a filtration system

1. Review the provided filtration set up materials (cheesecloth, t-shirt, rocks, brown paper towels, funnel, beakers)
2. Diagram 3 possible filter setups







3. As a group, choose one filtration system to test. Explain the system and why you believe this system will work best. Before you begin building your filter, raise your hand and show the teacher your model and explanation.

Design an experiment to test how well your filtration system works.

a. Create a hypothesis: fill in the sentence below to state how you will know your filter system improves water quality.

Hypothesis: If_____
_____, then we know the water quality improved.

4. Now, measure the turbidity of the filtered construction site water sample by repeating steps 3-8 above for the filtered construction site water.
   a. Data after filtering:

Sample #	**Turbidity reading in NTU**
1	
2	
3	
Average:	

Before filtration average (from above): _____ NTU

After filtration average: _____ NTU

b. Results and Discussion

i. Did your filter work?

ii. Why do you think your filter worked or did not work?

iii. Is this healthy river water?

iv. Can you drink this water?

v. Why might the construction project have increased the turbidity of the water?

vi. The construction project created large amounts of sediment, contaminating the surrounding water. How could you use your new knowledge to prevent the damage caused by the construction?

2. Reference List

Quality Criteria for Water. 1986. Environmental Protection Agency (EPA). Washington, DC. Document No. EPA-440/5-86-001. http://www.epa.gov/waterscience/criteria/goldbook.pdf

Chesapeake Bay Program (2002). Habitats. Accessed August 10, 2010 from http://www.chesapeakebay.net/habitats.htm.

"Understanding Turbidity." United States Geological Survey (USGS). Accessed August 10, 2010 from http://ga2.er.usgs.gov/bacteria/helpturbidity.cfm

Water on the Web (2008). University of Minnesota, Duluth and Lake Superior College. Accessed on August 11, 2010 from http://www.waterontheweb.org/under/waterquality/turbidity.html