Optical Brighteners and Water Quality

Virginia SOL

- *Science* BIO.9
- *Language arts* 10.1, 10.7, 10.11
- *Technology* C/T12.2

Objectives

- Make plans to test local water sites for presence of OBs
- Test local water sites for presence of OBs
- Compile OB data from multiple sites in local area
- Relate presence of OBs in water to the presence of laundry effluent
- Use OB information to identify possible sources of water pollution
- Present conclusions from OB testing

Materials

- Untreated cotton pads
- Black "Sharpie" brand permanent marker pen
- Wire or string
- PVC pipe
- Strong rubber bands or metal plumbing-type clasp
- Blacklight fluorescent bulb (Available from Home Depot for $24)

Safety & Regulations

See Planning a Safe Trip in the Introduction section of this packet and Safety at the Stream at the end of this lesson. Adult chaperones will be needed for visits to the water site.

Follow proper safety precautions when using the fluorescent lamp.

Time Needed

Class time is needed for planning the project and afterwards for groups to work on conclusions. Time is also needed in the field, and this activity is ideally suited for carrying out as a class project.

Does testing for optical brighteners give any evidence of wastewater in local streams?

This lesson relates to the tenth grade biology SOL BIO.9, concerning dynamic equilibria within populations, communities, and ecosystems. More specifically, the lesson relates to human influences on ecosystems, and students are involved in an analysis of the local ecosystem. Students also gain practice in planning and conducting experiments, and analyzing and communicating experimental information.

The activity described in the lesson involves an interesting and simple test procedure for the presence of optical brighteners in water. To carry out the test, students will leave cotton pads held in traps in various stream locations for seven days, then retrieve the pads and observe them for the presence of optical brighteners. Students can also monitor well water for optical brighteners by placing a cotton pad inside a toilet tank for seven days. Optical brighteners are dyes present

in most laundry detergents sold in the United States. They are added to detergent to make cotton clothes look whiter and brighter. They are not harmful themselves, but their presence is an indicator of the presence in the water of laundry effluent. This is turn can indicate untreated or inadequately treated wastewater reaching the stream or water supply. The cotton pads that are used for this procedure need to be specially obtained so as to guarantee against any prior contact of the cotton with detergents and optical brighteners.

Choosing the appropriate watershed area for students to study for optical brighteners is an important decision to be made. The area chosen should be relatively small, and should ideally include a local water study site that is the location of other activities or projects. It would be useful to include in the testing area any stream that is known to have elevated levels of fecal coliform bacteria or *E. coli.* See the box on this page for information on how you can learn if elevated levels of fecal coliform or *E. coli* have been found in your local streams. These fecal indicator bacteria can come from both humans and animals. The optical brightener monitoring (OBM) procedure can provide a clue as to whether elevated levels of bacteria are likely to be due to presence of human sewage.

One beauty of the OBM method is that it is not just a "grab sample." Since cotton test pads are left in the water for a period of seven days, a composite sample is collected, picking up data across that whole time period. In theory, then, the longer you are able to leave the optical brightener test trap in the field, the more information you will pick up. However, it is important that the traps not be left in the field during storms, and even if the traps have not been out for as long as

Finding data about fecal coliform bacteria in your local waters

Every two years (with some exceptions), Virginia's Department of Environmental Quality compiles water quality monitoring data, and writes a report that lists the impaired (polluted) water bodies in the state. This report is called the Impaired Waters 303(d) Report, as it meets the requirements of section 303(d) of the Clean Water Act. A part of this report will be helpful to you to find if your local streams, lakes, or estuary waters have been found to have elevated levels of fecal coliform. To access the table of contents for this report on the Internet, go to *www.deq.state.va.us/water/303d.html.*

In the report's Appendix, there are fact sheets for each of Virginia's major watersheds. Select the fact sheet for your watershed, and then scroll through the pages looking for your county. Since the fact sheets can be very large documents, you will probably want to print just the pages that interest you.

Also, the Virginia Water Monitoring Council's web site (*www.vwrrc.vt.edu/vwmc*) lists citizen organizations that conduct water quality monitoring programs, some of which analyze water samples for the presence of fecal coliform or *E. coli*. By contacting these groups, you may obtain additional data to help you select sites for your optical brightener monitoring.

seven days, they should still be retrieved if stormy weather threatens. The reason for this is the possibility of atypical wet-weather pathways for wastewater in stormy conditions.

Dr. Tom Aley, the founder of The Ozark Underground Laboratory, first pioneered OBM in the Karst region of the Ozarks in Missouri. Various materials describing OBM procedures in detail, including a free handbook “Groundwater Tracing Handbook,” are available from The Ozark Underground Laboratory (see Resources at the end of this lesson). Samples testing positive for optical brighteners can also be sent to The Ozark Underground Laboratory for more precise analysis if desired. Donald Waye, Senior Water Resources Planner for the Northern Virginia Regional Commission, used OBM in Northern Virginia as a tool for tracing human sewage in water bodies (Waye, 2000). That investigation led to the discovery that two industrial-sized washing machines were discharging into a storm drain within Four Mile Run’s Long Branch tributary in Fairfax County.

LESSON INTRODUCTION

Making plans to test local water sites for presence of optical brighteners...

Students will need to carry out some background reading on the OBM method of testing water. Students can be given readings from the information sources cited at the end of this lesson. Students should focus their attention on dangers posed by untreated or inadequately treated sewage wastewater in a water supply. Human sewage, containing fecal matter rich in nitrogen, contributes to stream eutrophication. Its bacteria load also poses a direct threat to people using contaminated waters for recreational purposes such as fishing and swimming. The OBM procedure provides a low-cost survey to pinpoint instances where wastewater is reaching our water supplies without first receiving adequate treatment.

If an OBM project is to be carried out, a local watershed area should be selected, and a systematic plan formed for setting optical brightener test traps over that area. When deciding where to place test traps, storm drain outfalls are a logical choice. Traps can be placed in creeks or streams below these outfalls. When Waye used the OBM technique in the urban Four Mile Run watershed in Northern Virginia, every known storm drain outfall in the 19.7 square mile watershed was screened – nearly 300 outfalls in all (Waye, 2000). As part of the planning process, field observations can be carried out, and these observations might indicate the presence of specific pollution sources, such as drainage ditches or unexpected pipes, where test traps might then be placed. As mentioned above, well water can also be screened by placing test traps in household toilet tanks.

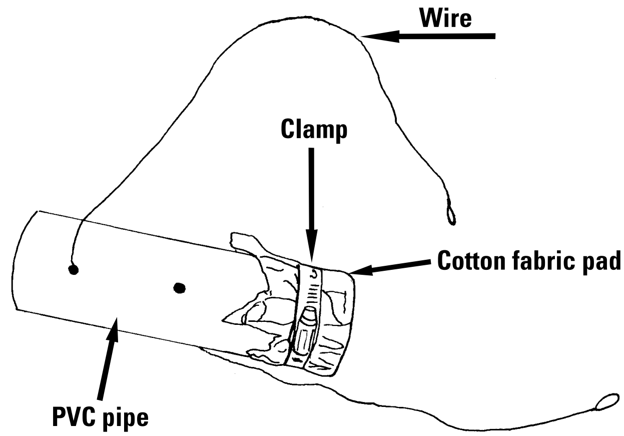
You may choose to use this activity as the basis of a long-term project for a class or for individual students. If so, you may refer to the Designing an Experiment chapter later in this curriculum packet.

ACTIVITY PROCEDURES

Testing local water sites for presence of optical brighteners...

To carry out the optical brightener monitoring, you will need to build simple traps holding a cotton pad to place in the water. The best way to do this is to stretch a cotton pad over one end of a wide section of PVC pipe. You should buy 2-inch diameter PVC pipe from a hardware store. Then cut the pipe into sections 6–8 inches long and drill 4 small holes in each section to run malleable wire through. This wire will secure the trap in place at its testing site, wrapping around tree roots, rocks, or anything handy at the site. The essence of the optical brightener test is having water run over a swatch of untreated cotton fabric. Suitable pads of untreated cotton, with no previous exposure to laundry detergents, can be obtained from The Ozark Underground Laboratory (contact information at the end of this lesson). Be careful when handling the pads. You should not have had direct contact with laundry soaps and detergents for 24 hours prior to handling the pads. The cotton pad can be stretched tight over one end of the pipe section, either with thick rubber bands or better with a cheap but sturdy metal, plumbing-type clasp. The trap will then be suspended in the water at the test site, with the cotton-covered end pointing upstream against the direction of flow, and left there for a period of seven days. When traps are removed from the water, the cotton pad can be separated from the trap and placed in a Ziploc bag with an identification label for transportation back to school for viewing. (Black "Sharpie" brand permanent markers will not fluoresce and affect the test result.) Used wire and rubber bands can be discarded after each test is completed.

When the trap has been recovered from the water after the test period is over, the cotton pad will be removed from the trap and examined for presence of optical brighteners. This can be done conveniently using a blacklight fluorescent bulb to view the pad. (These bulbs are cheaply available from hardware stores such as Home Depot.) Hot incandescent UV bulbs (party bulbs) also work but not as well. It is possible that the cotton pad might sometimes collect clay sediments or other detritus from the water during the test period. Laundry dyes can still reach the cotton fibers, but materials sticking to the outside of the cotton fibers may mask this. In this case, the area of the cotton covered up by the holding rubber bands or metal clasp will need to be examined under the lamp.



Some care should be used when placing test traps. The following cautions were listed by Dates (1999).

- Keep the traps out of direct sunlight, since optical brighteners gradually degrade when exposed to direct sunlight. Traps should be in the shade between 11 a.m. and 4 p.m.
- Suspend the traps away from sediments on the water bottom. Sediments can coat the cotton pads.
- Keep the traps away from iron. Iron, either in the water or in bacteria, can coat the pads.
- Avoid highly colored waters, since waters with tannins and lignins contain naturally fluorescing materials.
- Avoid waters with lots of coarse organic matter, since as leaves break down they form naturally fluorescing materials.

Since the OBM test is so simple and qualitative, each test site should be tested a second time to help safeguard against false negative or false positive test results. There are some naturally occurring fluorescent substances (such as humic and fulvic acids) that can cause false positives. False negatives can be caused by the coating of cotton pads by such things as clay particles or algae. Optical brighteners are slowly broken down by sunlight, so this could also lead to false negative test results. When positive test results are consistently obtained, they should then be confirmed by more precise analysis as described below.

Compiling optical brightener data...

Students should be encouraged to keep project journals throughout the project to record all their work. When testing is completed, students can use databases and spreadsheets and integrated applications to organize their data (Computer/Technology SOL C/T12.2). Refer to the Analyzing Experimental Data chapter in this curriculum packet for some suggestions on helping students with organizing and analyzing data.

Using optical brightener data to identify possible sources of water pollution...

Help students relate the presence of optical brighteners in water to the presence of laundry effluent. Since laundry effluent is a major component of the wastewater from our homes, the presence of optical brighteners in groundwater or surface water indicates ineffective sewage treatment.

Comparing optical brightener test results from various sites can lead to location of possible sources of water pollution. For example, if you find optical brighteners in storm drain runoff water upstream of treatment plant outfall, it is an indication that some wastewater is bypassing treatment. Untreated water may be bypassing the treatment plant either by faulty sewage pipe connections or by leaky sewer pipes. According to Dates (1999 in The Volunteer Monitor), optical brighteners are theoretically removed from wastewater by the treatment process in wastewater treatment plants. However, OB may still be detected below a properly functioning plant, so this cannot be automatically taken as an indicator of plant failure or contaminated water. In such a case, the water should probably be tested further to see if bacteria levels are also high. The presence of optical brighteners in surface water in an area with septic systems can be a fairly reliable indicator of the septic systems failing. Optical brighteners are removed from wastewater by adsorption – the binding of molecules to soil and organic particles. Since adsorption of wastes to soil particles is one of the processes that make septic leach fields work, a properly functioning septic system should remove optical brighteners. (See Dates, 1999 for the full information on this.)

The OBM test is a simple qualitative procedure, and so positive test results should be confirmed by more precise analysis. Sample cotton pads can be sent to The Ozark Underground Laboratory for analysis by spectrophotometer at a cost of around $25 per sample.

According to Waye in Northern Virginia (2000), there are some limitations to using OBM as a method for screening storm drain outfalls for sewage. The method is not guaranteed to detect every case of poorly treated wastewater in the water supply. "It is not likely to detect sewage from most commercial buildings, which often lack laundry facilities. Also, centralized laundry rooms common to most multi-unit residential buildings add a complicating factor – for instance plumbing errors that do not involve laundry rooms may avoid being detected by OBM."

Presenting conclusions from optical brightener testing...

As students work on analyzing and communicating their experimental findings, activities can be designed to reinforce English SOL 10.1 (small-group learning activities), 10.7 (writing), and 10.11 (collecting, evaluating, organizing, and presenting information).

Students should first summarize their OBM test results using appropriate data tables and graphs, then work in small groups to write conclusion paragraphs. A suggested format for writing a structured conclusion paragraph is included in the Analyzing Experimental Data chapter of this curriculum packet. Students should have class time for group discussion as they work on their conclusions. Small groups can be asked to present their conclusions in class. The class might then work together to prepare a group presentation of the project results for communication in their school or community and to interested local and state agencies. This presentation might be in the form of posters, web pages, or written reports.

QUESTIONS

- What are optical brighteners and why are they added to laundry detergents?
- What precautions did you need to take to help guarantee accurate test data?
- What were the key findings from the OBM project?
- How would you summarize the differences in test results, comparing the different sites that were tested?

- How can local or state agencies make good use of our test results?
- What steps would you suggest to reduce occurrences of untreated wastewater as indicated by high levels of optical brighteners?
- What are likely sources of untreated wastewater causing high levels of optical brighteners?

ASSESSMENTS

- Project journals.
- Data tables and graphical displays of test results.
- Small-group presentations.
- Class posters, web pages, or written reports.

EXTENSIONS

- This type of activity lends itself to individual students carrying out investigative research studies, which can then be reported at various science fairs, Junior Academy of Science meetings, etc.
- Coordinate your work with that of colleges or universities or local and state agencies, including Soil & Water Conservation Districts, Extension offices, and State offices. Optical brightener monitoring performed by your students might be linked with bacteria level measurements collected by agencies with capability for accurate bacteria testing.

RESOURCES

For the teacher...

- *A New Tool for Tracing Human Sewage in Waterbodies: Optical Brightener Monitoring.* Waye, D. (2000). Available at *www.novaregion.org/pdf/OBM_Abstract2.pdf*

  Abstract on OBM for Virginia Water Resources Research Symposium, November 2000. (Additional information on the Northern Virginia project available at *www.novaregion.org/4MileRun/obm.html.*)

- *An Optical Brightener Handbook.* Sargent, D., & Castonguay, W. (1998). Available at *www.thecompass.com/8TB*

  This handbook, available online, provides extremely detailed step-by-step directions for carrying out OBM testing. It is full of useful information but many of the procedures can be carried out more simply as described in the other resources listed here.

- Monitoring Optical Brighteners. Dates, G. (1999). *The Volunteer Monitor, 11*(2), 21–23.
- Optical Brightener Sampling: A Reconnaissance Tool for Detecting Sewage in Karst Groundwater. Aley, T. (1985). *Hydrological Science and Technology: Short Papers, 1* (1), 45-48.
- *The Ozark Underground Laboratory, Inc.* 1572 Aley Lane, Protem, MO 65733. Phone: 417-785-4289 or E-mail: *oul@tri-lakes.net*

- *The Ozark Underground Laboratory's Groundwater Tracing Handbook.* Aley, T. (1999). Single copies available free from The Ozark Underground Laboratory, 1572 Aley Lane, Protem, MO 65733. Phone: 417-785-4289 or E-mail: *oul@tri-lakes.net*

Obtaining materials for optical brightener testing...

Cotton pads can be ordered from The Ozark Underground Laboratory (cost around $1 per pad for bulk orders).
Phone: 417-785-4289
Email: *oul@tri-lakes.net*

Blacklight fluorescent bulbs with built-in base housing and cord can be obtained from many hardware stores, including Home Depot where they cost around $24.

BACTERIA AND PATHOGENS

To learn more about bacteria and pathogens, see the Healthy Water, Healthy People web site:

www.healthywater.org/testmanlinks.html#bacteria

SAFETY AT THE STREAM

(SOME OF THESE IDEAS FROM THE "STREAM SENSE" ACTIVITY BY PROJECT WET.)

For the teacher...

- Make sure the stream site is safe for students. Check the stream depth, velocity, and temperature. Also, check for walking conditions, litter, potentially dangerous wildlife, and poisonous plants.
- Bring a first aid kit on the trip.
- Define the boundaries for your visit. Make sure students understand that staying within these boundaries protects both them and wildlife.
- Locate a place where students can wash hands after the visit.

For the students...

- Stay with group members at all times.
- Wear old shoes or boots because they will likely get wet and muddy. Keep shoes on at all times to protect feet from harm.
- Stay in the designated area, and do not go near or into the water except to place and retrieve the monitoring equipment.
- Do not touch any wildlife that you find or taste any water or plants.
- Learn what poison ivy and poison oak look like, and avoid these plants.
- Do not eat any food without first carefully washing your hands.